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Factors Associated with Malaria Occurrence in Narok Town Ward, Narok County, Kenya

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Abstract: Despite malaria being a life threating but preventable disease, it is the foremost cause of disease and death in Kenya; over 25 million individuals are at risk with estimated 6.7 million new clinical cases and 4,000 deaths each year. It is approximated to cause 20% of all deaths in children under the age of five. This study was aimed at identifying factors associated with malaria occurrence in Narok Town Ward, Narok County, Kenya, so as to generate evidence to be used to enhance efforts for focused malaria control in Narok Town and similar urban areas in Kenya. The data was collected by administering structured questionnaire to household heads of the 480 randomly selected households and capturing mosquitoes in 36 randomly selected households. There were 2010 inhabitants in the 480 selected household, majority of the residents were aged 1-14 (34.1%) and 25-44 (34.6%); the proportion of females was 58.8% (1182). Pregnant females were 2.9% (58/2010). The literacy rate was 93.9%. Majority of the households (79.0%) reported having a monthly income of Kshs. 20,000 and above. About 97.92 % (470/480) of the total responders recognized that malaria was spread by mosquitos. Fever, vomiting, headache and chills were reported by majority of the respondents 99.56% (478/480) as the main symptoms of malaria. 68.33% (328/480) of respondents rated malaria as an ordinary disease while 24.58% (118/480) rated malaria as a deadly disease; 86.0% (413/480) reported to have sought malaria treatment in public hospitals while 74.4% (367/480) of the responders reported purchasing drug over the counter. The study revealed 1.04% (21/2010) prevalence rate of malaria disease. The most frequent mosquito breeding site was water held in garbage 85.4% (410/480) and stagnant dirty water 81.0% (389/480). 31.7% reported to have been clearing stagnant water and 67.1% (322/480) covered water holding containers to prevent mosquito breeding. The most reported mosquito bite time was at night 100% (480/480) and morning 53.3% (246/480). 91.0% (437/480) of responders reported to have been using mosquito net in their beds. Most people 96.5% (463/480) indicated that they had learned about malaria on TV and radio advertisements. Out of the total 2257 mosquitoes that were collected, *Anopheles* mosquitoes (malaria vector) were 8.4% (190/2257), 4.7% (9/190) of anopheline mosquitoes tested positive for *Plasmodium* sporozoites. Regardless of high level of literacy, knowledge on malaria cycle, and presence of *plasmodium* infected anopheline species. a significant gaps relating to diagnosis, treatment and control was evident. There were high percentage (74.4%) of people preferring to purchase drugs without a prescription and failure by community members to carry out outdoor vector control and prevention measures. This study presents proof that point to the need by the relevant agencies to establish regular public health awareness and trainings, cultivate community based environmental hygiene, maintain regular mass LLITN distribution, regular training of health care workers and CHV and establishment of the county based mosquito surveillance and research center in order to keep track of the mosquito borne pathogens.

Keywords: Malaria, Human, Entomological, Ecological, Narok

INTRODUCTION

Malaria is an infectious and life threatening illness spread to humans through the bite by infected female *Anopheles* mosquitoes. Once an individual is infected with malaria, the resultant disease leads to fever, chills, nausea, sweats, muscle pain, vomiting and headache. Malaria disease may cause injury to the kidney, nervous system and liver and it can speedily lead to death if infected individual is not treated on time (CDC, 2015). Though malaria is curable and preventable, the burden is enormous. According to World Health Organization (2015), there was an approximated 215 million fresh malaria infections among 3.3 billion people at risk in 2015 which led to 439, 000 malaria deaths globally. 90% of these fatalities occurred in Africa, trailed by the South-East Asia 7% and the Eastern Mediterranean Region 2%. In Kenya, Malaria is the foremost cause of sickness and deaths; 25 million persons are at risk and estimated 6.7 million fresh infections and 4,000 deaths occur each year (CDC, 2015); According to Kenya Medical Research Institute (2016), Malaria is responsible for 30% to 50% of total outpatient appearances and 20% of all admittances to medical health facilities in Kenya and it is approximated to cause 20% of total demises in children under the age of five years.

According to the National Malaria Control Programme of Kenya (NMCP, 2016), Kenya is divided into four malaria epidemiological areas. They comprise: Endemic zones: Where malaria is regularly present in these areas mainly found around Lake Victoria in Nyanza and western Kenya and in the coast zones. Favourable temperatures, rainfall and moisture are the causes of regular spread of malaria as they provide suitable ground for mosquito breeding. Periodic transmission regions: These regions are found in the dry and semi-arid parts of northern and south-eastern part of Kenya, these areas encounter short phases of high malaria transmission during the rainy seasons. Epidemic regions, these are areas around Western uplands of Kenya where malaria transmission is seasonal, with significant difference from year to year. High transmission rate occurs during the rainy season when lowest temperatures increases to 18 ^{0}C. Low risk zones: These are areas within uplands of Central and Nairobi counties. Some regions such as Nakuru and Nyeri do not experience any malaria transmission risks. Narok county is as low malaria risk zone but increased movement of people from high malaria risk areas such as Nyanza regions to the Narok County has led to rise of malaria infected persons in the recent years (MOH, 2021).

The occurrence of malaria disease consists of *Plasmodium* species (agent), a susceptible human (host) and an environment that gets the host and agent together. Presence of female A*nopheles* mosquitoes, mosquito breeding sites, favorable temperature, moisture and socioeconomic factors such as crowding, sanitation, and the availability of health services influence occurrence and distribution of malaria in a population (CDC, 2023).

Not all species of mosquitoes are responsible for the transmission of malaria. Only female mosquitoes of some subgenera in the genus *Anopheles* are known to be host of *Plasmodium* species, which are; *P. falciparum*, *P. vivax*, *P. malariae*, and *P. ovale*. Some studies on *Plasmodium* vectors have been done in some regions in western Kenya (Minakawa *et al.*, 2002) as well as other malaria prone regions such as Baringo, Kilifi, Rabai and North Eastern (Lutomiah *et al.*, 2013). Currently, there is no documented research on the extent of entomological, ecological and human risk factors associated with malaria occurrence in Narok Town Ward, Narok County, Kenya. This study was aimed at generating evidence that would be useful to researchers and policy makers in enhancing efforts for focused malaria control in Narok Town and similar urban areas in Kenya.

Statement of the Problem

Narok town is a transit centre for persons moving between Nairobi and Maasai Mara, Trans Mara, Bomet, Kisii and Migori Counties; Movement of people may lead to transfer of malaria to and from Narok town through movement of infected individuals or infective vectors from malaria endemic zones of Nyanza thereby causing a serious threat to the people and businesses. Malaria can be a threat to the economy of Narok as it mainly depends on tourism and pastoralism; fear of being infected with malaria may discourage tourism, this leads to low bed occupancy at hotels and other tourist facilities thus threatening the Narok County's leading source of revenue (Sabot *et al.* 2010; Hanafi *et al.* 2011).

Narok town ward has no adequate piped sewerage systems and is prone to frequent flooding and stagnant waters which provides suitable breeding grounds for mosquitoes. Due to poverty, many people have a habit of self-treatment with cheap and locally available herbs (Oliver *et al.* 2009); Most people in Narok are from Maasai community and they traditionally wear little clothing and reside in poorly constructed mud houses which are surrounded by mosquito bleeding sites such as garbage and stagnant waters which increases the risk of contracting malaria (Fana *et al.*, 2015; Somi *et al.* 2007).

According to Kenya Ministry of Health, Narok County had 15,807 malaria cases (per 100,000 people) and malaria test positivity rate of 17%, close to the national average of 22.6%. Malaria is the fifth killer disease in the County after diarrhea, pneumonia, HIV/AIDS and tuberculosis. The most affected areas were Ongata Barakoi, Ngararu and Transmara West Sub County (MOH, 2020).

Currently, there is no documented evidence on the extent of entomological, ecological and human risk factors associated with malaria occurrence in Narok Town Ward, Narok County, Kenya. it is therefore imperative to carry out this study with a view of generating evidence to be used to enhance efforts for focused malaria control in Narok Town ward and similar urban areas in Kenya.

Purpose of the Study

This research will supplement to the understanding on Entomological, Ecological and Human risk factors associated with occurrence of malaria in Narok Town Ward, Narok County, Kenya. The extent of risk of the respective variables will be established in order to generate evidence to be utilized to enhance efforts for focused malaria control interventions in Narok Town Ward and similar urban areas in Kenya.

Major Objective

To identify factors associated with Malaria occurrence in Narok Town Ward, Narok County, Kenya.

Specific Objectives

1. To establish human risks factors affecting the occurrence of malaria disease in Narok Town Ward, Narok County, Kenya.
2. To establish the prevalence of malaria disease in Narok Town Ward, Narok County, Kenya.
3. To establish the ecological risk factors associated with occurrence of malaria disease in Narok Town Ward, Narok County, Kenya.
4. To establish the proportion of *Anopheles* mosquitoes infected by *plasmodium* sporozoites in Narok Town Ward, Narok County, Kenya.

Research Questions

1. What are human risk factors affecting the occurrence of malaria disease in Narok Town Ward, Narok County, Kenya?
2. What is the prevalence of malaria disease in Narok Town Ward, Narok County, Kenya?
3. What are the ecological risk factors associated occurrence of malaria disease in Narok Town Ward, Narok County, Kenya?
4. What is the proportion of *Anopheles* mosquitoes infected by *plasmodium* sporozoites in Narok Town Ward, Narok County, Kenya?

Justification

Although Malaria is the fifth killer disease in the Narok County after diarrhea, pneumonia, HIV/AIDS and tuberculosis, there is no documented evidence on entomological, ecological and human risk factors that influences malaria occurrence in Narok Town Ward, Narok County, Kenya. This study will generate evidence based information on entomological, ecological and human risk factors associated with malaria occurrence in Narok Town Ward. This evidence will be useful to researchers and policy makers in enhancing efforts for focused malaria control in Narok Town ward and similar urban areas in Kenya.

Scope of the Study

This research was done by collecting ecological and human demographic data using a structured questionnaire in the 480 randomly selected households and by capturing mosquito samples in 36 households. Mosquitoes were later classified and testing of *Plasmodium* sporozoites in *Anopheles* mosquitoes was done. The collected data was later analyzed to establish the entomological, ecological and human factors associated with Malaria occurrence in Narok Town Ward, Narok County, Kenya. The data was collected in the following villages within the Narok Town Ward: Olpopong', Narok Town center, Majengo, London, Lenana and Total (Areas around Maasai Mara University). The data and samples were collected during the month of January and February 2020.

Study Limitations

Although malaria occurrence was present throughout the country. The study outcome only gives a representation of Narok County. The study relied on information provided by the household heads in a structured questionnaire. Some respondents were not comfortable in giving out some information correctly especially age, pregnancy status and level of education. Variation in weather condition especially absence of rainfall during the month of January and February 2020 could have affected the study outcomes particularly on the population of mosquitoes.

Delimitations

This study focused on people residing in Narok Town Ward because this town had all socioeconomic classes of the population in Narok County. Random sampling was applied to give opportunity to any household irrespective of the socio-economic status of the residents. To guarantee the accuracy of collected information, questionnaires were administered in the evening as from 7.00 PM to 12.00 midnight to ensure that household heads were already in their homes, where there was no household head or a representative adult, the next household was chosen or a notice given for a research assistant to visit the household in the following evening. Mosquitoes were also collected at night as from 7.00 PM to 12.00 midnight, this enabled to capture as many mosquitoes as possible considering that most mosquitoes are usually more active at night than during the day.

Assumptions

Assumptions to this study was that household heads would provide accurate information that would be beyond any questionable doubt. That there was occurrence of malaria in Narok town ward and data collected would provide a standard reference for further studies to be done on same or similar topic.

Operational Definition of Key Terms

Entomology: Study of insects.

Ecology: Study of organisms and how they interact with environment around them.

Human factors: Basic demographic factors of a human in relation to malaria occurrence and transmission

Household: A housing unit comprising of a one nuclear or extended family.

Household head: The person who leads the household

LITERATURE REVIEW

Mosquito Genera of Public Health Importance: The main mosquitoes responsible for spreading diseases to humans belong to four genres, namely: *Anopheles, Aedes, Culex and Mansonia* (CDC, 2023)

Aedes includes about 950 species characteristically recognized by dark and white body color, they prefer reproducing in exposed water vessels, and they like feeding during the day particularly morning and evening (Bravo *et al.*, 2014). *Aedes* are main carriers of arboviruses, for instance, *Aedes aegypti* and *A. albopictus* of African and Asian origins respectively, are internationally recognized for their aggressive characteristic and responsibility in spreading pathogens that cause yellow fever, dengue fever, chikungunya and zika viruses among other diseases of medical importance (Kraemer *et al., 2015*).

Anopheles encompasses mosquito species generally recognized by elongated palps, dark-brown body coloring, distinct black and white scales placed at the wings and a specific resting position (stomach area pointing upwards) (CDC, 2015) Over 460 anopheline species have been documented, about 7% are known to spread *Plasmodium* parasites (Harbach, 2007). The chief vectors of malaria parasites include *Anopheles gambiae, Anopheles arabiensis, Anopheles funestus* and *Anopheles nili* (Scott *et al.,* 2015).

Culex encompasses about one thousand species with a fairly feeble flying behavior and normally present in all geographical zones stretching from the tropics to cool temperate areas (Ciota *et al.,* 2013). They are usually known as common house mosquitoes due to their tendency to stay near human houses. They have high preference on blood food from birds that feed at morning and evening and are worldwide identified as vectors of human, birds, and animal pathogens such as lymphatic filariasis (Burkett *et al.,* 2014).

The *Mansonia* mosquito species are usually recognized by having a big body size and uneven wing scale structure with shiny on their wing veins and appendages. They display some similarity with *Culex* and *Aedes,* mosquito but the easiness of their tarsal claws in structure and a truncated abdomen in females make the different (Harbach, 2008). *Mansonia* usually breed in stagnant waters with water foliage where larvae can burrow into the decaying floras at the foot or hold on growing aquatic plants roots (Islam *et al.,* 2011). They are known vectors of lymphatic filariasis, Rift valley fever and Zika virus amongst additional illnesses (Epelboin *et al.* 2017).

Malaria Vectors: Malaria is spread to human by female *Anopheles* mosquitoes which are cyclical hosts of *P. falciparum, P. vivax, P. malariae, P. ovale* and *P. Knowlesi.* Malaria vectors that are generally found in Kenya include: *Anopheles gambiae s.s, An. arabiensis* and *An. merus*. *Anopheles gambiae s.s* is adapted to cool and moisturized areas; it is highly plentiful in raining periods. *Anopheles arabiensis* is adjusted to dry regions. It increases during the dry periods since it like reproducing in long-lasting stagnant water. *Anopheles merus* reproduce in saline environment and is largely present on the coastline areas adjacent to the Indian Ocean ((Burkett *et al.,* 2014).

Life Cycle of Mosquitoes: Knowing all the life stages of mosquitoes helps an individual to control and prevent mosquitoes around their homes, this is done by choosing the most effective and efficient preventive and eradication method that is suitable for each stage of the life cycle (Kraemer *et al., 2015*). Similar to all other insects, mosquito species undergo through the four discrete phases through their growth cycle: the female lays eggs near stagnant water, the eggs have adhesive substance that enable them to stick to the surfaces until when they hatch into larvae upon being submerged in water, the eggs are resistant to tough weather conditions such as sunlight and drying, they achieve this by remaining in dormant state for few days to several months awaiting favorable condition for hatching (Bravo *et al.,* 2014).

When the larvae develop from mosquito egg it feeds on microorganisms in the water and molt three time to become a pupa; Pupae then develops to become an adult flying mosquito that emerges from the pupal skin and leaves the water. After adult mosquitoes develop: male mosquitoes depend on nectar from flowers for food while female mosquitoes feed on humans and other mammals blood in order to be able to lay eggs. After feeding, female mosquitoes lay eggs near stagnant water. The first three stages of mosquito that is eggs, larvae and pupae occurs in water, but the adult is an active flying insect (Islam *et al.,* 2011). When the adult female mosquito obtains a blood by sucking humans and other mammals it lays the eggs directly on or near water, soil and at the base of some plants in wet places that may fill with water. The eggs incubation period depends on water temperature, food and species of mosquito. The life cycle usually occurs in two weeks, but depending on prevailing temperature, rainfall and relative humidity, it can happen in a period of four days to 30 days (MOH, 2021; CDC, 2017).

Life Cycle of *Plasmodium* Parasite: The *Plasmodium* parasite lifecycle cycle occurs in mosquito and human hosts, when the *Plasmodium* infected female *Anopheles* Mosquito sucks blood from human, it injects sporozoites to the human blood stream. Injected malaria parasite invades the liver cells and develop into schizonts which break and discharges merozoites. Some malaria parasite such as in *P. vivax* and *P. ovale* may develop into a latent state called hypnozoites which is capable of staying in the liver if an individual is not treated or as a result of under dose treatment and cause relapses of malaria by infecting the red bold cells again after weeks, or even years in future (Françoise *et al.,* 2015).

After replication in the liver, the merozoites infects the red blood cells where it undergoes asexual multiplication to form the ring stage trophozoites which matures into schizonts. Shizonts later bursts to release additional merozoites. Some parasites differentiate into sexual erythrocytic stages (micro and macro gametocyte). Blood stage *Plasmodium* parasite are responsible for the clinical symptoms of the malaria disease. As the female *Anopheles* mosquito sucks blood from humans, it ingests the male and female gametocytes. While in the gut of mosquito, the male gamete fuse with the female gamete to form a zygote. The zygote develops to motile and elongated ookinete which migrate into the midgut wall of the mosquito where they develop into oocysts. The oocysts mature and rupture to release sporozoites, the sporozoites then moves to the mosquito's salivary glands. As the mosquito sucks blood in human, they inject sporozoites into the human host and continues the malaria life cycle (CDC, 2017).

Human Risk Factors Affecting the Occurrence of Malaria

Biological Characteristics: Biological characteristics like sickle cell trait have been proven to protect individuals against *P. falciparum* malaria (Gilles *et al.,* 2018). People with negative Duffy blood group are able to resist from being infected by *P. vivax.* For example, *P. vivax* is uncommon in Africa south of the Sahara, mainly West Africa because most Africans are Duffy negative (Françoise *et al.,* 2015; Miller *et al.,* 1976).

Acquired Immunity: Developed disease immunity by human beings may influence the rate of infectious disease spreads within a population. People who have suffered repeated malaria infection tend to develop partial defensive immunity. When such get infected with malaria parasites they are not likely to develop severe illness and some time they fail to develop noticeable malaria symptoms. Regions in Africa with high rate of *P. Falciparum* have their newborns protected at early months after birth due to maternal antibodies transferred to them during pregnancy (Modiano *et al.,* 1998).

Pregnancy: People who have been infected by malaria disease repeatedly throughout their lifetimes may develop moderate resistance for symptomatic or deadly malaria. But due to the variations in the expectant mother's immune systems during gestation period and the occurrence of extra organ (the placenta) that provide additional spaces for infectious agent to infect, expectant mothers tend to lose some of their resistance to malaria infection (David, 2010). Malaria disease during pregnancy leads to increased dangerous effects on both mother and fetus, including anemia, fetal death, premature birth, retardation of intrauterine development, and delivery of underweight infants (Agomo *et al.,* 2009).

Compromised Immune System: People who have compromised immune system such as HIV and AIDS, diabetes and cancer patients are more likely to have adverse effects of malaria infections (Edwards *et al.,* 2019). HIV leads to high risk of clinical and strong infection and vice versa. Most people suffering from cancer and HIV are not able to engage laborious income generating activities thus end suffering from lack essential basic needs including inability to provide quality health care services and diet for themselves and their families (Abu-Raddad *et al.,* 2006).

Gender: Gender customs and standards impact separation of work, recreation undertakings, and sleeping schedules. This leads to dissimilar forms of contact to mosquitoes for men and women (Lampietti *et al.,* 2000). Gender dimensions' influence accessibility to management and malaria medication, as well as preventative measures, resource provision and financial authority within households (WHO, 2021). Persons belonging to one family usually suffer due to poverty in different ways, subject on influences like sex, age and marriage status. In most African communities, females are mainly underprivileged. The UNDP approximates that women constitute 70% of poor people in the world. In addition, females lag after males in most social and economic pointer of welfare thus making them more vulnerable to attack by infectious diseases (Allison *et al.,* 2020).

Education: Lack of education leads to inadequate information on infectious diseases to the affected individual, education level affects the person's perception and sensitivity to the disease, this is a significant aspect for shaping the individual's acceptance of utilizing available disease control and prevention tools (WHO, 2021). Educated Individuals are able to secure better paying jobs that provides better employment terms such as medical cover, housing, annual leave and retirement benefit. Contrary, people with lower education are more likely to work in high-risk jobs with limited or no health benefits (Baum *et al.,* 2013). Better paying job result to higher income which has a major effect on health of workers. Persons earning better salary can comfortably buy nutritive foods,

have the funds for medical care needs, transportation and education for their children and also get time to work out regularly. In addition, the job uncertainty, small salary, and absence of resources linked to low education can cause people and children to become more susceptible to social and economic suffering during tough economic period which can lead to low quality diet, poorly constructed houses, and un attainable medical bills thus predisposing the them to higher risk of acquiring and transmitting infectious diseases (Montez *et al.*, 2014).

Age: There are constant disparities in distribution of malaria disease and the age of persons infected. Children below 5 years are the most affected during the season of high rate of malaria transmission, Young children especially those with limited parental care such as orphans and from poor families are also heavily affected by malaria disease (Modiano *et al.*, 1998). While most elderly people have good health and body functionality in old age, the process of ageing leads to an increase in chances of the body losing strength and immunity. Age is one of the leading determining factor of good health and wellbeing of an individual. Old individuals above 65 years have higher medical care requirements than people of young age groups but most older people face most difficulties in accessing suitable, inexpensive and quality health care services (WHO, 2021). Biological changes induced by old age plus accrued results of the person's exposure to induced risks, such as alcoholism, smoking, poor nutrition and social variations such as loneliness and death of close relatives and friends' affects individual health thus making older people more vulnerable to both communicable and non-communicable diseases (UN, 2015).

Social and Economic Activity: Social and economic activities affect human behavior which in turn affects the rate of disease spread. Low income earners in malaria-endemic cannot afford good houses, clothes and treated mosquito nets to protect them against mosquitoes. Inadequate resources to enable early malaria detection and timely treatment increases the risk of transmission (KEMRI, 2015). Poverty and cultural beliefs result in use of traditional herbs which most cases are ineffective; Breeding sites created by humans such as ditches and clogged water gutters causes increase of mosquito population; human activities such security provision by night guards, pastoralism and trade increases contact with mosquitoes; keeping livestock near homes offer alternative source of blood meals for *Anopheles* mosquitoes thus reduce risk of transmission**;** other activities such as night trade and migration may expose persons to an area with high risk of spreading malaria.

Human Behavior: Human behavior is usually dictated by social economic influences, person's behaviors lead to a rise in the risk of acquiring infectious disease such as malaria by individuals and communities. For example, some people are often reluctant to adopt to governments malaria control strategies such us use of LLITN due to their cultural believes, some claim that it leads to headache while others claim that it causes bad dreams thus exposing themselves to mosquito bites (WHO, 2021; Barnett *et al.*, 2006). Most people such as Maasai and Turkana communities wear little clothing and reside in poorly constructed mud houses which are surrounded by mosquito bleeding sites such as garbage and stagnant waters, this increases the risk of contracting malaria due to unrestricted exposure (Somi *et al.* 2007). Risky behaviors such as alcoholism, smoking and other drug abuses impacts on an individual's health and immunity and may make someone vulnerable to acquiring an infectious disease.

Prevalence of Malaria: According to World Health Organization (2015), there has been an increase in trend of malaria occurrence in world. Globally there was an approximated 215 million fresh malaria infections among 3.3 billion people at risk in 2015 which led to 439, 000 malaria deaths globally. 90% of these fatalities happened in Africa, trailed by the South-East Asia 7% and the Eastern Mediterranean Region 2%. In Kenya, Malaria is the foremost source of disease and deaths; 25 million persons are at risk and estimated 6.7 million fresh infections and 4,000 deaths occur each year (CDC, 2015). Malaria accounts for 30% to 50% of total outpatient appearance and 20% of all admittances to medical amenities (KEMRI, 2015). Infection by malaria is approximated to cause 20% of total demises in children below five years of age, pregnant women and children under 5 years remain the utmost affected (MOH, 2006).

Diagnosis and Treatment of Malaria: It is necessary to diagnose and treat malaria quickly using the Ministry of Health approved antimalarial drugs in order to stop the disease from progressing to critical condition and to stop further spread of the disease in the community. Malaria medical indications are similar to symptoms of many other diseases, it is therefore important to carry out laboratory confirmation either by microscopy or rapid diagnostic tests in order to make a definitive diagnosis and avoid miss use of antimalarial drugs (MOH, 2021).

Ecological risk factors associated with occurrence of malaria

Ecological risk factors are features related to the relationship between a living organisms to one another and to their physical surrounding.

Availability of Breeding Sites: Availability of stagnant water held in containers, unused tires, neglected pools, blocked rain troughs, tree crevices and in garbage, in catch basins in urban areas and in septic leakage and other waste water sources provide breeding site for mosquitoes. Garbage and rainfall leads to rise in availability of stagnant waters and bushes which provide suitable breeding sites for mosquitoes (Hay *et al.*, 2002). Quality of water affects mosquito population as some species prefer clean while others prefer dirty water (Rapuoda *et al.*, 1996). For example, *An. gambiae* (*s.l.*) reproduce in small, exposed, sun-drenched, fresh aquatic sites, *An. funestus* usually reproduce in a water environment that has plants like swamps and rice fields. *Culex quinquefasciatus* reproduce in contaminated water environments like pit latrines, soak pits, drains and exposed sewerage and waste structures (Imam *et al*., 2014).

Temperature: Research has shown that changes in environmental condition affects the distribution and population of mosquitoes. The effect of temperature on saprogenic duration and mosquito survival is important in hastening malaria transmission. When temperature is less than 18°C, transmission decline due to presence of limited mature mosquitoes which endure the 56 days necessary for sporogenic phase and reduced mosquito population due to prolonged larval period. Extrinsic cycle cannot be completed below a temperature of 15°C for *Plasmodium vivax* and 20°C for *P. falciparum* thus under such environmental condition malaria will not be transmitted (Haddaw, 1943). This elucidates why malaria spread is high in warm areas of the world.

Rainfall: Increase in rainfall leads to increase stagnant waters and clogging of drainage pipes and tunnels, this provide adequate ground for mosquito breeding thus leading to increase in mosquito populations. In Periodic transmission areas that are found in the dry and semi-arid parts of northern and south-eastern part of Kenya usually encounter short phases of high malaria transmission during the rainy seasons.

Distance from the Breeding Site: Distance from breeding sites affects the strengths of risk, short distance from the breeding site to homes leads to higher exposure to mosquito vector while long distance lead to decline in the risk of exposure to mosquito bite (Clarke *et al.,* 2002).

Overcrowding: Research has proven that overcrowding increases the threat of malaria since mosquitoes tend to be lured by increased accumulation of carbon dioxide and other substances in overcrowded households (Alton *et al.,* 2004). Poor build mud and grass homes allow mosquitoes to enter much easily than properly build houses with lockable doors and glass windows, thus leads to high mosquito interaction (Lindsay, 2003). Overcrowding also result to increase in waste accumulation, clogging of drainage tunnels and septic tanks therefor increasing mosquito breeding sites near residential homes (Nyarko *et al.*, 2014).

Lack of Control and Prevention Measures: Lack of consistent and suitable control and prevention methods both by specific houses and at communal level increases the risk of malaria epidemic (Bravo *et al.,* 2011). Deterrent methods like use of ITN, clearing of bushes, removing stagnant waters in drainage tunnels, swamps and containers, timely identification and treatment of infected individual and spraying with long lasting sprays have been proven to be strongly effective in reducing spread of malaria in many regions (Reddy *et al.,* 2011).

***Anopheles* Mosquitoes Infected by Plasmodium Sporozoites:** *Plasmodium* parasites take the help of the obligate blood feeding behavior of the mosquito to enter their human host. Development of the *plasmodium* in the mosquito is influenced by presence of favorable temperature and humidity. As the female *Anopheles* mosquito sucks blood from humans, it ingests the male and female gametocytes. The male gamete fuse with the female gamete to form a zygote in the mosquito gut. The zygote develops to motile and elongated ookinete which migrate into the midgut wall of the mosquito where they develop into oocysts. The oocysts mature and rupture to release sporozoites which moves mosquito's salivary glands. As the mosquito sucks blood in human, they inject sporozoites into the human host and continues the malaria life cycle (CDC, 2017). Mosquitoes infection by *Plasmodium* is different to that human as they do not suffer noticeably from the infection (CDC, 2015) Commonly found mosquito vectors in Kenya include: *Anopheles gambiae s.s*, *An. arabiensis* and *An. merus*. *Anopheles gambiae s.s* (Minakawa *et al.,* 2002).

Mosquito Control and Prevention Strategies

Most mosquitoes are harmful as they spread deadly pathogens not only to humans but also to other wild and domestic animals. Several methods are used to kill mosquito larvae and adults while other methods are used to prevent breeding and prevent human from being exposed to adult mosquitoes.

These includes: Use of larvicides- A larvicides is a type of insecticide used to control mosquitoes indoors and outdoors around residential homes, a larvicides can be chemical or biological based; use of adulticides- this are insecticides used to kill adult mosquitoes, they can be long lasting sprays that keep killing mosquitoes when they get into contact; eradication of breeding sites- regular clearing of bushes and removing stagnant water in tunnels, gutters, dust bins other containers helps to prevent mosquito breeding near residential homes, covering water tanks, septic tanks and pit latrines also prevent mosquito breeding; Use of Long Lasting Insecticide Treated Nets (LLITN)- use of mosquito net in beds help to prevent mosquito contact with human while in beds (MOH, 2021; Chanda *et al*., 2011).

Theoretical Framework

Descriptive Epidemiologic Triad: The epidemiologic triad for malaria disease consists of plasmodium species (agent), a susceptible human (host) and an environment that gets the host and agent together. The risk of malaria disease depends on the contact between the agent and the susceptible host in an environment that facilitate transmission (Ferguson *et al.*, 2010). As shown in the figure 2.1 below, presence of female *anopheles* mosquitoes, mosquito breeding sites, favorable temperature and moisture and socioeconomic factors such as crowding, sanitation, and the availability of health services influence occurrence and distribution of malaria in a population. These factors were studied with a view to recommending appropriate measures to reduce malaria transmission and prevalence in Narok Town ward, Narok County (CDC, 2015).

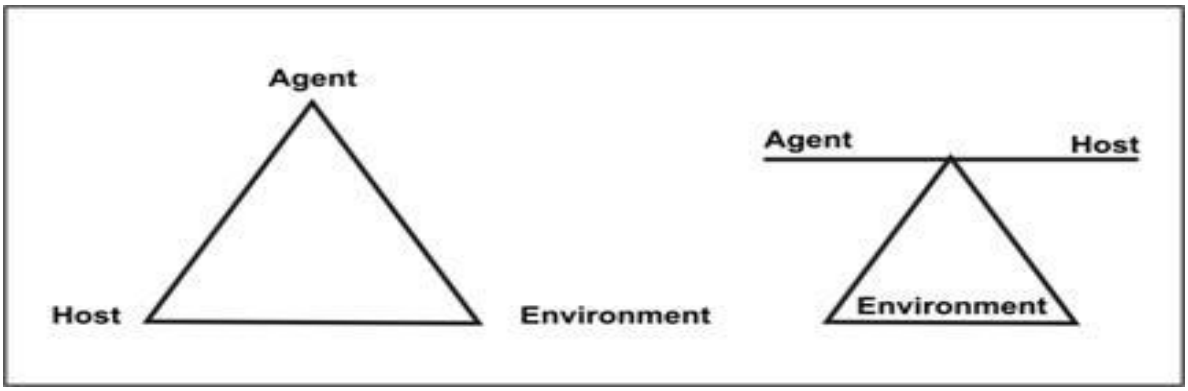

Figure 2. 1 Epidemiological Triad

Source: CDC, 2015

Analytic Epidemiologic Triad: The interaction between the host exposure to the plasmodium parasite and mosquito vector affects the occurrence of malaria disease. Malaria disease result from the interaction between the agent and susceptible humans in an environment that support transmission of the *Plasmodium* parasite from the source to the host. The risk of malaria disease depends on the contact between the agent and the susceptible host in an environment that facilitate transmission.

Conceptual Framework

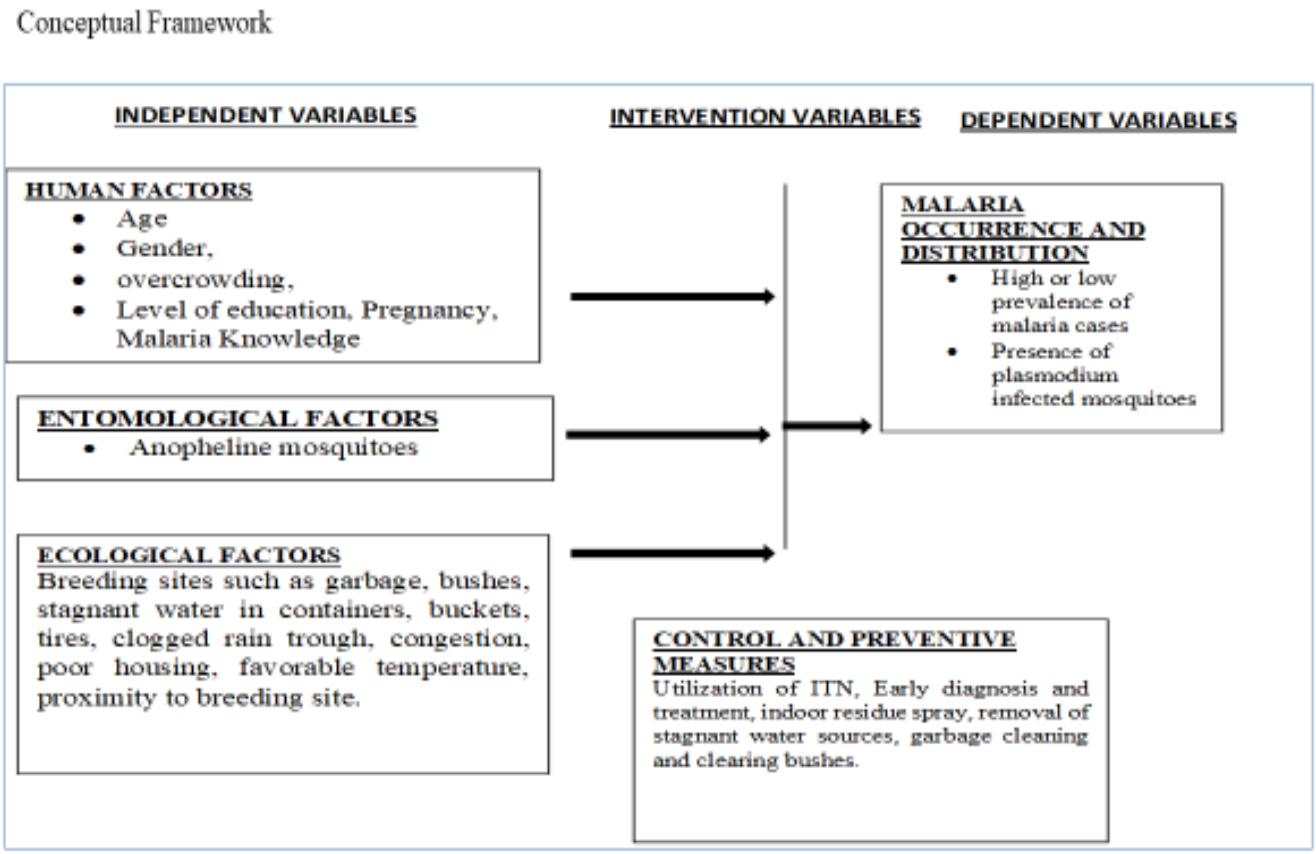

Figure 2. 2 Conceptual Framework

Source: Researcher, 2021

MATERIALS AND METHODS

Research Methodology: Field study method was embraced to gather the needed data relative to the established independent, intervening and dependent variables. Mosquito samples were collected and identified morphologically using taxonomic keys (Harbach, 2007), Anopheles mosquitoes were tested for *Plasmodium* sporozoites by microscopy method. Structured questionnaire was used in the collection of established variables in relation to ecological and human risk factors for malaria transmission.

Study Design: This study embraced a cross sectional and analytical study design. This is because it would provide a picture of human risk factors affecting the occurrence of malaria, prevalence of malaria disease, ecological risk factors for malaria disease and proportions *Anopheles* mosquitoes infected by plasmodium sporozoites in Narok Town ward, Narok County, Kenya.

Study Area: The study was conducted in Narok Town Ward, Narok North Constituency, Narok County, Kenya. Narok town lies between Coordinates: 01°05′S 35°52′E. Narok town was recently conferred the status of municipality having attained a population of 250,000 (KNBS, 2019) and met other requirement as set out in Urban Areas and Cities Act, 2019. Narok town is home the Maasai Mara University, Narok County Referral Hospital and several other public and private health facilities and schools. The approximated area of Narok County is 17,845 square kilometres with population of 1,158,000 (KNBS, 2019). Annual temperature ranges between 12 to 28^{0}C and the average annual rainfall ranges between of 500 to 1,800 mm. Narok town is transit centre for people travelling from Nairobi to Maasai Mara, Bomet, Kisii and Nyanza regions. Tourism is the major source of revenue to both the Narok County Government and private investors. Most residents are small scale traders, farmers and pastoralists. Narok Town is the headquarter of the Narok County and positions as the most

important business hub in the county and rift valley region (NCG, 2015). Narok town has a cosmopolitan population consisting communities from all parts of Kenya. Figures 2.3, 3.1 and 3.2 below, demonstrate the location of Narok town in the republic of Kenya.

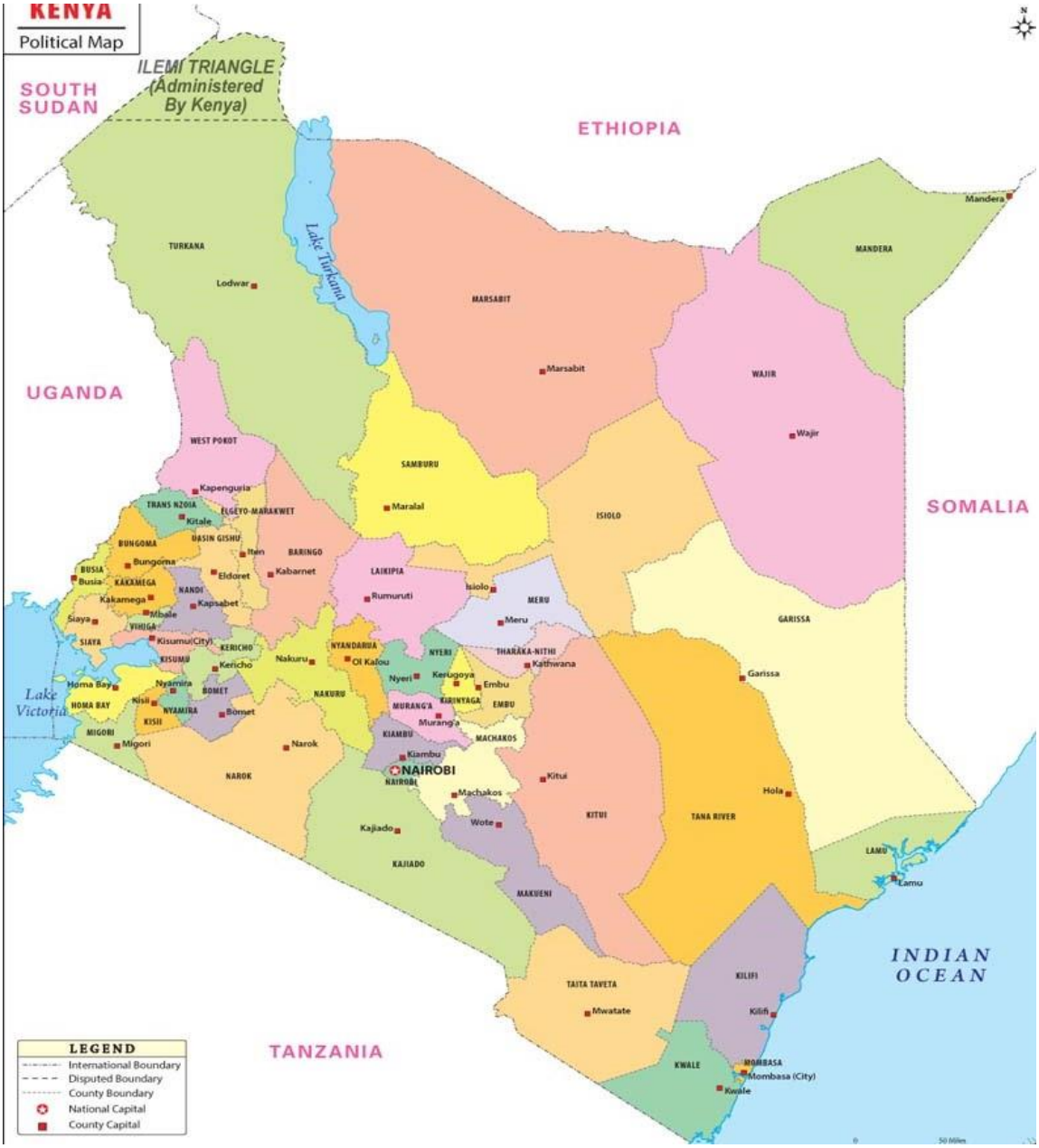

Figure 2. 3 Map of Kenya

Source: www.mapsoftworld.com

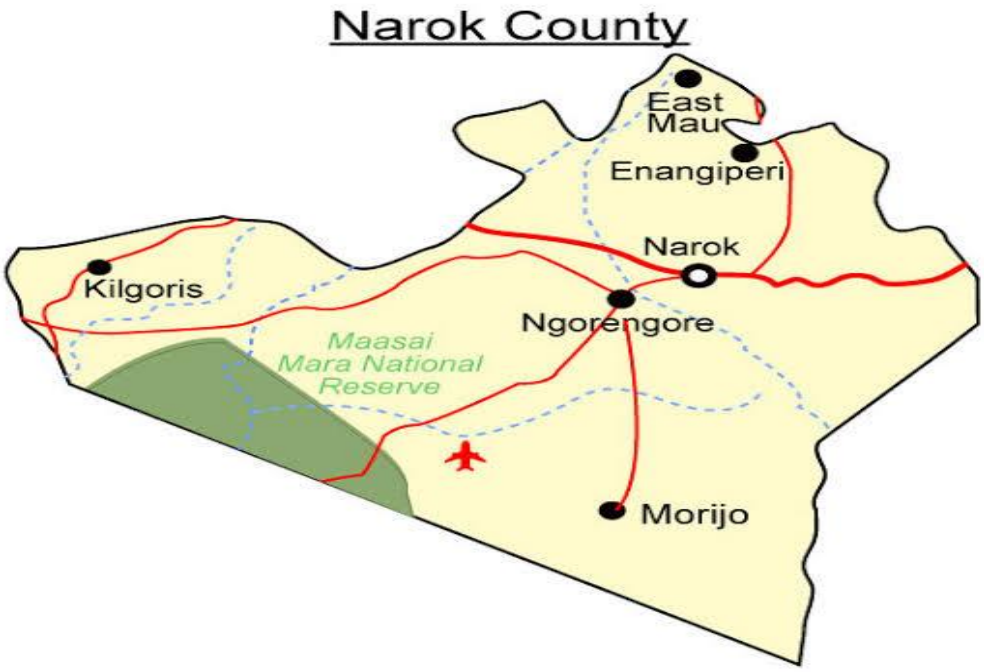

Figure 3. 1 Map of Narok County

Source: learn@e-Limu.org

Figure 3. 2 Map of Narok Town ward

Source: Google Map

Study Population: The study targeted to interview household heads who answered all the questions in regards to themselves and other family members in 480 households within the 6 settlements, namely: Narok town center, Olpopong', Majengo, London, Lenana and Total. At each of 6 study site, 80 households were randomly selected then permission for administering of detailed questionnaire was sought before data collection was done. For entomological data collection, 6 households were selected in each of six study sites, the mosquito samples were collected four times, once in every week for one month.

Sample size Determination: The sample size of 384 respondents + 25% for non-respondents (about 480 respondents) was attained by the use of the Fisher's *et al* formula (1998).

Where: n: sample size when the population is ›10,000;

Z^2 : Standard normal deviation at 1.96 which corresponds to a confidence level of 95%;

p: the proportion of the population with the desired characteristics

q: 1 - p, the proportion of the population without the desired characteristics

d^2 : degree of precision required in general 0.05.

$n = (1.96)^2 \times [(0.5 \times 0.5) \div (0.05^2)] = 384$

Inclusion Criteria: All family members who were residing in the randomly selected 80 households in each of the following study sites: Olpopong', Narok town centre, Majengo, London, Lenana and Total (MMU area) at least for the past one year. The questionnaire was administered to the household heads who answered questions in regards to themselves and those of the other family members.

All captured mosquitoes in the selected study sites.

Exclusion Criteria: Households whose heads were not willing to freely take part in the study and give consent.

Family members who were not residing in the selected study sites

Collection of Data on Malaria cases, Basic and Social Demographic Data: To identify the important risk variables affecting malaria transmission, a structured questionnaire was used to gather information on malaria cases and basic and social demographic data in (480) households; (80) households in each of the (6) study sites around Narok Town ward namely: Olpopong', Narok town centre, Majengo, London, Lenana and Total (Areas around Maasai Mara University). Respondents were asked questions about themselves and their family members in regards to their demographic variables such as age, gender, pregnancy, income, education level, knowledge and perception about malaria, malaria infection status and treatment measures.

The structured questionnaires were only administered after the respondents had read, understood and signed the consent form with the help of research assistant. The consent form had explained details on permission, autonomy of participants, risks, and confidentiality among other details.

Collection of Ecological Data: All ecological data were collected by use of a questionnaire in (480) households; (80) randomly selected households in each of (6) study sites around Narok Town ward namely: Olpopong', Narok town centre, Majengo, London, Lenana and Total (MMU area). Ecological information such as breeding sites, frequent mosquito bite time; modes of preventing mosquito bites; eradication of mosquito breeding sites; how respondents were learning about malaria transmission, symptoms and treatment were collected and recorded in the questionnaire form.

Mosquito Collection: At each study site, namely: Narok town center, Olpopong', Majengo, London, Lenana and Total. Six (6) houses were randomly and systematically selected. Permission for entomological collection was sought before collection was done. Collection was carried out once per week for four (4) times during the month of January and February 2020. Human landing catches method was applied in collecting mosquitoes both indoors and outdoors from 6pm (1800h) to Midnight (2400h) using mouth aspirators. Resting collection was also done in

the selected houses. CDC light traps were laid out to trap outdoor mosquitoes. The morning after the catch mosquitoes were sorted and identified. The mosquitoes were stored in vials with 70% ethanol.

Captured mosquitoes were recorded in a structured form and identified morphologically using taxonomic keys (Harbach, 2007) thereafter.

Identification of *Plasmodium* Infection in *Anopheles* Mosquitoes: *Plasmodium* infection status in Anopheles mosquitoes was determined by simple microscopy. Mosquito specimen were crushed and spread on microscopic slide, each mosquito per slide. Stained with Giemsa stain and examined in microscope 100X oil immersion objective.

Testing for Validity and Reliability

The research tools, that is detailed questionnaire, CDC light trap and mouth aspirators, were submitted to experts and resource persons in field of epidemiology of infectious diseases in order to ascertain their usefulness in relation to the research questions and objectives of the study.

A pilot study was carried out before starting the main study. It included 8 households in each of the six zones. This was 10% of the whole sample size and was omitted in the main research. Pilot survey was conducted to establish the efficacy and practicability of the questionnaires and other tools that were being used. The tools were modified to improve where hitches which were detected. The reliability of research tools was justified by the compliance of the results of the pilot survey.

Data Analysis: Both the ecological and human data were physically checked to confirm the completeness of the answers, mosquitoes were physically examined and identified. the data were then entered into Microsoft Excel Worksheet 2016. Frequency, percentage, histograms were made from univariate analysis. Chi-square and correlation analysis were calculated to determine the association and correlation between different variables. Significance was established at $p < 0.05$ (significance level 95%).

Ethical Consideration: An ethical approval was sought from Mount Kenya University, research license was sought from National Commission for Science, Technology and Innovation (NACOSTI). Clearance to correct data was also sought from the Narok County Commissioner, the Narok County Director of Education and the Narok County Government. Authorization letters were issued by all the aforementioned agencies. Consent to interview respondents and collect data was sought from household heads before commencing the exercise. Respondents consented by signing the consent form. All information collected was handled with ultimate privacy and respect; participants were not required to give their names.

RESULTS AND DISCUSSION

Coverage of Study Populations and Response Rate: The achieved response rate was 100% of the sample size in each study area, to achieve this, steps mentioned in the methodology were consistently used. In case the household head or responsible adult was absent in the selected household, Researcher and Research Assistants chose the next household and so on, until 100.0% of the sample size per study area was totally achieved. Tables 4.1 and 4.2 below show the coverage and response rate in all study sites.

Table 4. 1: **Coverage in the Study of Ecological and Human Factors**

S/No	Settlement	Sample size per settlement	Sample covered	Coverage
1	Olpopong'	80	80	100.0%
2	Narok Town center	80	80	100.0%
3	Majengo	80	80	100.0%
4	London	80	80	100.0%
5	Lenana Total	80	80	100.0%
6	Total (Maasai Mara University area)	80	80	100.0%
	Total	480	480	100.0%

Source: Researcher

Table 4. 2: **Coverage of Mosquitoes Samples Collection**

S/No	Settlement	Sample size per settlement	Sample covered	Coverage
1	Olpopong'	6	6	100.0%
2	Narok Town center	6	6	100.0%
3	Majengo	6	6	100.0%
4	London	6	6	100.0%
5	Lenana Total	6	6	100.0%
6	Total (Maasai Mara University area)	6	6	100.0%
	Total	36	36	100.0%

Source: Researcher

Characteristic of the Respondents

As shown in the Table 4.3 below, out of 480 respondents who represented their households, majority were females 72.1% (346/480) with an average age of 39.3 years and males were 27.9% (134/480) with an average age of 51.6 years. Both male and female had a combined average age of 42.7 years.

Table 4. 3: **Characteristics of the Respondents**

Gender	Number	Average age
Male	134 (27.9%)	51.6
Female	346 (72.1%)	39.3
Total	480	42.7

Source: Researcher

Characteristics of the Mosquito Samples

The collected mosquito samples were identified morphologically using taxonomic keys (Harbach, 2007) and grouped into their respective genus as shown in the Table 4.4 below. A total of 2,257 mosquitoes belonging to four genera were collected during the month of January and February 2020. All of them are known vectors of various pathogens in the world. In overall, the most profuse genus was *Aedes* Species 39.5% (891/2257) followed by *Culex* species 31.1% (701/2257); *Mansonia* and *Anopheles* species accounted for 17.3% (390/2257) and 8.4% (190/2257) respectively. Majority of mosquitoes were captured through light trap collection 64.4% (1453/2257) followed by human landing catches 18.0% (407/2257) and resting collection 17.6% (397/2257). 3.8% (85/2257) were not identifiable due to distortion of their morphological characteristic during the handling process.

Table 4. 4: **Analysis of Mosquito Genus Present in Narok Town Ward**

Genus	HLC	Resting Collection	Light trap Collection	Total	Percentage (%)
Aedes spp.	154	139	598	891	39.5
Anopheles spp.	33	29	128	190	8.4
Culex spp.	121	107	473	701	31.1
Mansonia spp.	81	108	201	390	17.3
Un Identified	18	14	53	85	3.8
Total	407	397	1453	2257	100.0
Percentage (%)	18.0	17.6	64.4	100.0	

Source: Researcher

Human Risk Factors Affecting Malaria Occurrence in Narok Town Ward

Social Demographic Characteristics of the Household Members: As shown in the Table 4.5 and 4.6 below, the study captured the data for 2,010 persons from 480 households in Narok Town ward, Narok County Kenya. Majority of the household members were aged 1-14 (34.1%) and 25-44 (34.6%); The mean age of the members was 26.96 years; 58.8% were females; the literate level was at 93.9%, that is persons who had attained primary education and above; 1.7% (8/480), 2.5% (12/480) and 16.9% (81/480) of the households had a monthly income of 5000-9,999, 10,000- 14.999 and 15,000-19,999 respectively; majority of the households (79.0%) had a monthly income of Kshs. 20,000 and above; there were 58 (2.9%) expectant females.

Table 4. 5: **Social Demographic Characteristics of the Household Members**

Characteristics		**Frequency**			**Percentage (%)**
Age		Male	Female	Total	
	1-14 Male	378	308	686	**34.1**
	15-24 Male	54	253	307	**15.3**
	25-44 Male	220	477	697	**34.6**
	45-64 Male	100	115	215	**10.7**
	65 and above Male	76	29	105	**5.3**
	Total	828	1182	2010	**100%**
Pregnant Females			58		**2.9**
Education					
Persons not having formal education	1 to 14		123		6.1
	15-24		0		0.0
	25-44		1		0.0
	45-64		0		0.0
	65 and above		0		0.0
Sub Total			**124**		**6.2**
Primary	1 to 14		540		26.9
	15-24		120		6.0
	25-44		0		0.0
	45-64		48		2.4
	65 and above		1		0.0
Sub Total			**709**		**35.3**
Secondary	1 to 14		0		0.0
	15-24		147		7.3
	25-44		249		12.4
	45-64		71		3.5

	65 and above	77	3.8
Sub Total		**544**	**27.1**
Post-Secondary Education	1 to 14	0	0.0
	15-24	72	3.6
	25-44	438	21.8
	45-64	95	4.7
	65 and above	28	1.4
Sub Total		**633**	**31.5**

Source: Researcher

Table 4. 6: **Monthly Income of the Households**

Monthly Income	**Frequency**	**Percentage**
Below 4,999	0	0.0
5000- 9,999	8	1.7
10,000- 14,999	12	2.5
15,000- 19,999	81	16.9
20,000 & above	379	79.0
Total	480	100.0

Source: Researcher

Knowledge on Malaria Transmission, Symptoms and Treatment

Four indicators were used to assess respondent's knowledge on malaria, namely: whether respondents knew how malaria is transmitted, whether they knew the symptoms of malaria, how they usually access malaria treatment and how they rate Malaria as a disease. As shown in Table 4.7 below: 97.92 % (470/480) knew malaria was transmitted through mosquito bite; 99.56% (478/480) said they knew the symptoms of malaria; 74.4% (367/480) purchased drug over the counter; 86.0% (413/480) through public hospitals and dispensaries; 75.6% (363/480) through private hospitals while 10.4% (50/480) would also prefer to use other modes of treatment.

Table 4. 7: **Respondents Level of Knowledge on Malaria**

Knowledge Question	Responses	Frequency	Percentage (%)
How is Malaria transmitted (Mosquito Bite)?	Yes	470	97.92
	No	10	2.08
What are the Symptoms of Malaria? (Fever, Chills, nausea, sweats, muscle pain, vomiting & headaches)	Yes	478	99.58
	No	2	0.42
How do you usually access malaria treatment?	Purchase drug over the counter	357	74.38
	Public hospital/dispensary	413	86.04
	Private Hospital/Clinic	363	75.63
	Other treatments	50	10.42
How do you rate malaria as a disease?	An ordinary disease	328	68.33
	A deadly disease	118	24.58
	No Idea	34	7.08
Total		480	100.0%

Source: Researcher

A composite measure of the respondent's knowledge on malaria transmission, symptoms and treatment was developed from the four indicators. The level of knowledge was rated from 0 to 3, where 0 = Very poor (no knowledge on the for indicators), 1 = Poor (knowledge on any one indicator), 2 = Good (knowledge on any 2 or 3 indicators) 3 = Very good (knowledge on all 4 indicators). As indicated in the Table 4.8 below, 0.42% (2/480) had very poor knowledge, 7.08% (34/480) were rated poor, 67.92% (326/480) were rated to have good knowledge and 24.58% (118/480) had very good knowledge on malaria.

Table 4. 8: **Respondents Level of Knowledge on Malaria Based on Composite Score**

Level of Knowledge	Frequency	Percentage (%)
Very poor	2	0.42%
Poor	34	7.08%
Good	326	67.92%
Very good	118	24.58%
Total	480	100%

Source: Researcher

Bivariate analysis of Human Risk Factors Affecting the occurrence of Malaria in Narok Town Ward, Narok County, Kenya

As shown in the Table 4.9 below, five of the variables (age, pregnancy, education, income and knowledge on malaria) were associated with malaria occurrence while one variable (gender) was not associated. Malaria occurrence was associated with age (p = 0.01); persons who were 65 years and above were the most affected. Malaria occurrence was not associated with gender (p = 0.772); the risk of malaria occurrence was higher in pregnant women (p = 0.002) than non-pregnant women; malaria occurrence was associated with education (p = 0.026); households whose heads had a post-secondary education were least affected. Malaria occurrence was associated with monthly income (p = 0.004) and Knowledge on malaria transmission, symptoms and treatment (p = 0.049), households whose head had a higher income (Kshs. 20,000 and above) and very good knowledge on malaria were least affected.

Table 4. 9: **Cross Tabulation of Demographic Characteristics and Malaria Transmission**

Characteristic		**Malaria Occurrence**			**Total**	**Chi-square**	**Df**	**P- value**
		Positive	% Positive	Negative				
Age	1 to 14	0	0	686	686	126.99	4	0.01
	15-24	1	0.33	306	307			
	25-44	0	0	697	697			
	45-64	9	4.19	206	215			
	65 and Above	11	10.48	94	105			
	Total	21	1.04	1989	2010			
Gender	Male	8	0.97	820	828	0.084	1	0.772
	Female	13	1.1	1169	1182			
	Total	21	1.04	1989	2010			
Pregnancy	Pregnant women	3	5.17	55	58	9.3	1	0.002
	Women not pregnant	10	0.9	1114	1124			
	Total	13	1.1	1169	1182			
Education	No formal education	0	0	124	124	9.25	3	0.026
	Primary	5	0.71	704	709			
	Secondary	12	2.21	532	544			

	Post-Secondary	6	0.95	627	633			
	Total	21	1.04	1989	2010			
Monthly Income	Below 4,999	0	0	0	0	13.23	4	0.004
	5000-9,999	1	12.5	7	8			
	10,000-14,999	1	8.33	11	12			
	15,000-19,999	9	11.11	72	81			
	20,000 & above	10	2.63	369	379			
	Total	21	4.38	459	480			
Knowledge on Malaria	Very poor	0	0	2	2	7.86	3	0.049
	Poor	2	5.88	32	34			
	Good	13	3.99	313	326			
	Very good	6	5.08	112	118			
	Total	21	4.38	459	480			

Source: Researcher

Prevalence of Malaria Disease in Narok Town Ward, Narok County, Kenya.

Reported malaria cases were recorded to determine the prevalence of malaria in Narok Town ward, as indicated in the Table 4.10 below, there were (21/81) laboratory confirmed cases resulting to malaria prevalence rate of 1.04%. The most affected age group was 45-64 and 65 and above accounting for 42.86% (9/21) and 52.38 (11/21) of the total cases respectively. There were 3/58 pregnant women who had malaria and 10/1124 non pregnant women who had malaria.

Table 4. 10: Distribution of malaria Cases Against Various Demographic Characteristics

Characteristic		Malaria Occurrence			Total
		Positive	% Positive	Negative	
Age	1 to 14	0	0	686	686
	15-24	1	0.33	306	307
	25-44	0	0	697	697
	45-64	9	4.19	206	215
	65 and Above	11	10.48	94	105
	Total	21	1.04	1989	2010
Gender	Male	8	0.97	820	828
	Female	13	1.1	1169	1182
	Total	21	1.04	1989	2010
Pregnancy	Pregnant women	3	5.17	55	58
	Women not pregnant	10	0.9	1114	1124
	Total	13	1.1	1169	1182
Education	No formal education	0	0	124	124
	Primary	5	0.71	704	709
	Secondary	12	2.21	532	544
	Post-Secondary	6	0.95	627	633
	Total	21	1.04	1989	2010
Monthly Income	Below 4,999	0	0	0	0
	5000-9,999	1	12.5	7	8
	10,000-14,999	1	8.33	11	12
	15,000-19,999	9	11.11	72	81

	20,000 & above	10	2.63	369	379
	Total	21	4.38	459	480
Knowledge on Malaria	Very poor	0	0	2	2
	Poor	2	5.88	32	34
	Good	13	3.99	313	326
	Very good	6	5.08	112	118
	Total	21	4.38	459	480

Source: Researcher

Ecological Risk Factors Associated with Occurrence of Malaria in Narok Town Ward

Five indicators were analyzed to determine ecological risk factors associated with malaria occurrence in Narok Town ward, namely: presence of mosquito breeding sites, most frequent mosquito bite time, method used to prevent mosquito bites, mode of eradicating mosquito breeding sites and how the respondents got information on malaria transmission, symptoms and prevention. As shown in the Table 4.11 below, the most abundant mosquito breeding site was garbage/trash 85.4% (410/480) and standing dirty water 81.0% (389/480); stagnant water was mostly found in clogged road drainage tunnels as shown in picture 1.0 below. The most frequent mosquito bite time was at night 100% (480/480); majority of the respondents 91.0% (437/480) used mosquito net to prevent mosquito bite; 67.1% (322/480) covered water holding containers to eradicated mosquito breeding site; 96.5% (463/480) of the respondents got information on malaria transmission and symptoms on TV and advertisements.

Table 4. 11: **Analysis of Ecological Risk Factors for Malaria in Narok Town Ward**

Question	Response	Frequency	Percentage (%)
What is the common mosquito breeding site you have seen?	(i) Running dirty water	343/480	71.5
	(ii) Running clean water	83/480	17.3
	(iii) Garbage/Trash	410/480	85.4
	(iv) Standing clean water	317/480	66.0
	(v) Standing dirty water	389/480	81.0
	(vi) Plants/vegetation	342/480	71.3
	(vii) No Idea	4/480	0.8
What is the most frequent mosquito bite time?	(i) Sunrise/Dawn	4/480	0.8
	(ii) Sunset/Dusk	173/480	36.0
	(iii) Morning	246/480	51.3
	(iv) Night	480/480	100.0
	(v) Noon	0/480	0.0
	(vi) No idea	0/480	0.0
What do you use to prevent mosquito bites?	(i) Use of smoke to drive away mosquitoes	34/480	7.1
	(ii) Mosquito mat, coil, liquid vaporizer,	383/480	79.8
	(iii) Covering body with clothes	358/480	74.6
	(iv) Use of Fan	116/480	24.2
	(v) Mosquito Net	437/480	91.0
	(vi) Cleaning House	227/480	47.3
	(vii) No Idea	0/480	0.0
How do you eradicate Mosquito breeding sites?	(i) Prevent water stagnation	152/480	31.7
	(ii) Covering water storage containers	322/480	67.1

	(iii) Changing water in storage containers	236/480	49.2
	(iv) Others	11/480	2.3
	(v) No idea	5/480	1.0
How do you get information on malaria transmission, Symptoms and prevention?	(i) Health Professional	272/480	56.7
	(ii) Magazine, Newspaper, Banners	350/480	73.0
	(iii) TV, Advertisements	463/480	96.3
	(iv) Schools, Colleges, University	354/480	73.8
	(v) Relatives, Friends, Family	303/480	63.1
	(vi) Internet	214/480	44.6
	(vii) Any other	0/480	0.0

Source: Researcher

Plate 1.0: Picture of stagnant water under culvert at Lenana Estate in Narok Town Ward**.**

Source: Researcher

Bivariate analysis of Ecological Factors Associated with Malaria Occurrence in Narok Township Ward, Narok County, Kenya

As described in Table 4.12 below, there was no evidence that abundance of mosquito breeding sites (p = 0.183), mosquito density (p = 0.460), proportion of *Plasmodium* infected mosquitoes (p = 0.596) and malaria prevalence (p = 0.055) were associated with the specific locations in Narok Town Ward; that is Narok CBD, Olpopong, Majengo, London, Lenana, Total (MMU).

Table 4. 12: **Cross Tabulation of Ecological Factors and Risk of Malaria Transmission**

Site	Observed breeding site	Expected breeding sites	Chi-Square	Df	P- value
Narok CBD	295	314.67			
Olpopong	333	314.67			
Majengo	312	314.67	7.54	5	0.183
London	313	314.67			
Lenana	289	314.67			
Total (MMU)	346	314.67			
Total	1888	1888			

Site	Observed mosquitoes	Expected	Chi-square	df	P- value
Narok CBD	35	31.67			
Olpopong	33	31.67			
Majengo	37	31.67			
London	22	31.67	4.65	5	0.460
Lenana	34	31.67			
Total (MMU)	29	31.67			
Total	190	190			

Site	*Plasmodium* positive *An. spp.*	*Plasmodium* negative *An. spp.*	Total	Chi Square	Df	P- value
Narok CBD	2	33	35			
Olpopong	1	32	33			
Majengo	2	35	37	3.68	5	0.596
London	0	22	22			
Lenana	1	33	34			
Total (MMU)	3	26	29			
Total	9	181	190			

Site	Persons infected by malaria	Persons not infected	Total	Chi Square	Df	P- value
Narok CBD	4	369	373			
Olpopong	4	310	314			
Majengo	4	360	364			
London	1	354	355	10.82	5	0.055
Lenana	1	342	343			
Total (MMU)	7	254	261			
Total	21	1989	2010			

Source: Researcher

Correlation analysis of Ecological Factors and Outcome Variables

There were 7 variables cross tabulated against the number of persons infected by malaria. As shown in the Table 4.13 below, the seven variables were significant: Density of mosquito breeding site (positive correlation = 0.715**); Mosquito biting time (negative correlation = -0.510**); prevention of mosquito bites (negative correlation = -0.745**); eradication of mosquito breeding sites (negative correlation -0.438**); access to information on malaria (negative correlation -0.557**); number of *Anopheles* mosquitoes (positive correlation = 0.228*); proportion of Anopheles mosquito infected by *plasmodium* (positive correlation 0.887**)

Table 4. 13: **Correlation of Ecological Risk Factors and Outcome Variables**

	Number of mosquito breeding sites	Frequent mosquito bite time.	Prevention of mosquito bite	Eradication of mosquito breeding sites	Access to information on Malaria	Number of Anopheles mosquitoes captured	*Plasmodium* infected mosquitoes	Persons infected by malaria disease
Number of mosquito breeding sites	1							
Frequent mosquito bite time.	-0.239*	1						
Prevention of mosquito bite	-0.429**	0.911**	1					
Eradication of mosquito breeding sites	-0.360*	0.777**	0.858**	1				
Access to information on Malaria	0.314*	-0.162**	-0.131*	0.288*	1			
Number of Anopheles mosquitoes	-0.309*	-0.399**	-0.315*	-0.165*	0.475*	1		
Plasmodium infected mosquitoes	0.368*	-0.610**	-0.731**	-0.296**	0.664**	0.457**	1	
Persons infected by malaria	0.715**	-0.510**	-0.745**	-0.438**	-0.557**	0.228*	0.887**	1

Source: Researcher, 2021

Proportion of *Anopheles* Mosquitoes Infected by *Plasmodium* Sporozoites

To determine the proportion of *Anopheline* mosquitoes infected by *Plasmodium* sporozoites, mosquitoes were first identified and grouped in their respective genus. As shown in the Table 4.14 below, a total of 2,257 mosquitoes belonging to four genera were collected during the month of January and February 2020. All of them are known vectors of various pathogens in the world. In overall, the most profuse genus was *Aedes* Species 39.5% (891/2257) followed by *Culex* species 31.1% (701/2257); *Mansonia* and *Anopheles* species accounted for 17.3% (390/2257) and 8.4% (190/2257) respectively. Majority of mosquitoes were captured through light trap collection 64.4% (1453/2257) followed by human landing catches 18.0% (407/2257) and resting collection 17.6% (397/2257).

Table 4. 14: **Analysis of mosquito genus present in Narok Town Ward**

Genus	HLC	Resting Collection	Light trap Collection	Total	Percentage (%)
Aedes spp.	154	139	598	891	39.5
Anopheles spp.	33	29	128	190	8.4
Culex spp.	121	107	473	701	31.1
Mansonia spp.	81	108	201	390	17.3
Un Identified	18	14	53	85	3.8
Total	407	397	1453	2257	100.0
Percentage (%)	18.0	17.6	64.4	100.0	

Source: Researcher

As shown in the Table 4.14 above and Table 4.15 below, a total of 190 *Anopheles* mosquitoes were collected by the following methods. 67.3% (128/190) mosquitoes were collected by CDC light trap, 17.4% (33/190) by HLC and 15.3% (29/190) by resting collection. 9 mosquitoes tested positive for malaria parasite in microscopy. Therefore, the proportion of *Anopheles* mosquitoes that were infected by *Plasmodium* sporozoites was 4.7%.

Table 4. 15: **Proportion of *Anopheles* mosquitoes infected by plasmodium sporozoites**

	HLC	Resting Collection	Light trap Collection	Total	Percentage (%)
Positive	2	1	6	9	4.7
Negative	31	26	121	178	93.7
Total	33	29	128	190	100.0
Percentage (%)	17.4	15.3	67.3	100	

Source: Researcher

DISCUSSION

This research provides in depth analysis on the entomological, ecological and human risk factors associated with malaria occurrence in Narok Town ward, Narok County, Kenya. The study focused on collecting and analysis of data during the month of January and February 2020. The purpose of the study was to generate evidence to be used to enhance efforts for focused malaria control in Narok Town and similar urban areas in Kenya.

The study captured social, economic and basic demographic characteristic information of 2010 persons in 480 randomly selected households. Characteristic to many urban areas, majority of the population in Narok Town were children aged 1-14 (34.1%); and 25-44 (34.6%); the proportion of females was 58.8% (1182). this finding could have been as a result of presence of many primary schools and colleges thus attracting large number of parents who preferred settling their families in Narok Town in order to enable their children access primary and college education (Adam et al., 2008). The study also captured the data for 2257 mosquitoes that were captured during the month of January and February 2020, there were 190/2257 (8.4%) *Anopheles* mosquitoes out of which 9/190 (4.7%) were positive for *Plasmodium* infection.

The study revealed 1.04% (21/2010) proportion of individuals who had suffered from malaria in the last one month; The most affected age group was 45-64 and 65 and above accounting for 42.86% (9/21) and 52.38% (11/21) of the total cases respectively, pregnant women accounted for 3/21 (14.28%) of the total malaria cases. Malaria occurrence was not associated with gender ($p = 0.772$), however other studies have proven that high proportion of children and females affects malaria occurrence as age and gender customs and standards impact separation of work, recreation undertakings, and sleeping arrangements and patterns leading to differences in exposure to mosquitoes for men and women (Lampietti *et al.,* 2000). Gender dimensions' can also impact accessibility to management and malaria medication, as well as preventative measures, choice of preventive measures, resource provision and financial authority within households (WHO, 2021). The UNDP approximates that women constitute 70% of poor people in the world. In addition, females lag after males in most social and economic pointer of welfare thus making them more vulnerable to attack by infectious diseases (Alton *et al.,* 2004).

Malaria occurrence was associated with pregnancy ($p = 0.002$). Other studies have proven that people who have been infected by malaria disease repeatedly throughout their lifetimes may develop moderate resistance for symptomatic or deadly malaria. But due to the variations in the expectant mother's immune systems during gestation period and the occurrence of extra organ (the placenta) that provide additional spaces for infectious agent to infect, expectant mothers tend to lose some of their resistance to malaria infection (David, 2010). Malaria disease during pregnancy leads to increased dangerous effects on both mother and fetus, including anemia, fetal death, premature birth, retardation of intrauterine development, and delivery of underweight infants (Agomo *et al.,* 2009).

Malaria was associated with age (p = 0.01). Previous studies have shown that there are constant disparities in distribution of malaria disease and the age of persons infected. Children below 5 years are usually the most affected during the season of high rate of malaria transmission; young children especially those with limited parental care such as orphans and from poor families are also heavily affected by malaria disease (Walldorf *et al.,* 2015; Modiano *et al.,* 1998). While most elderly people have good health and body functionality in old age, the process of ageing leads to an increase in chances of the body losing strength and immunity; Age is one of the leading determining factor of good health and wellbeing of an individual. Old individuals above 65 years have higher medical care requirements than people of young age groups but most older people face most difficulties in accessing suitable, inexpensive and quality health care services (WHO, 2021). Biological changes induced by old age plus accrued results of the person's exposure to induced risks, such as alcoholism, smoking, poor nutrition and social variations such as loneliness and death of close relatives and friends' affects individual health thus making older people more vulnerable to both communicable and non-communicable diseases (UN, 2015).

Malaria occurrence was also associated with education (p = 0.026, income (p = 0.004) and knowledge on malaria (p = 0.049). Narok Town ward is an urban center and the head quarter of Narok County and home to many other public and private institutions, it is also home to many public and private learning institution including the Maasai Mara University. This explains the report findings of high literate level where 93.9% of the population had attained primary education and above and high proportions of households (79.0%) that had a monthly income of Kshs. 20,000 and above, these are proven features of urban centers (Williams and Jones, 2004). Previous studies have shown that less educated persons are usually more affected by infectious diseases (Bravo *et al.,* 2011; Berkman *et al.,* 2011; Edwards *et al.,* 2019). Lack of education leads to inadequate information on infectious diseases; information and sensitivity of disease is a significant aspect for shaping acceptance and utilization disease control and prevention tools by communities (WHO, 2021). Educated Individuals are able to secure better paying jobs that provides health-promoting benefits such as health insurance, paid leave, and retirement. Equally, people with less education are more likely to work in high-risk occupations with few health benefits (Baum *et al.,* 2013). Better paying job result to higher income which has a major effect on health of workers. Persons earning better salary can comfortably buy nutritive foods, have the funds for medical care needs, transportation and education for their children and also get time to work out regularly. In addition, the job uncertainty, small salary, and absence of resources linked to low education can cause people and children to become more susceptible to social and economic suffering during tough economic period which can lead to low quality diet, poorly constructed houses, and un attainable medical bills thus predisposing the them to higher risk of acquiring and transmitting infectious diseases (Montez *et al.,* 2014).

Poverty may predispose household members to the high risk of acquiring infectious disease due to inability to acquire preventive tools such as long lasting insecticide treated nets and insecticide sprays, good health care services, well-constructed houses and clothes. They are also not able to feed on nutritious diet thereby compromising their immunity (Koenker *et al.,* 2014; Abu-Raddad *et al.,* 2006). High household income guarantees a population's ability to adjust and contribute positively toward the Government's malaria prevention and control strategies. Failure to timely detect and seek malaria treatment increases the risk of transmission within the community (KEMRI, 2021). Poverty and cultural beliefs result in use of traditional herbs which most cases are ineffective. Some residents in Narok town areas such as Majengo and Olpopong' had people living in overcrowded and poorly constructed mud houses thereby increasing the risk of exposure to mosquito bite. Overcrowding of humans in slums leads to poor sewerage and drainage, consequently increasing mosquito breeding sites (WHO, 2021).

Comparable to other studies, it was good to find out that majority of the household heads, about 97.92 % (470/480) of the total respondents knew that malaria was spread to human by mosquitoes. In regards to malaria symptoms, fever, vomiting, headache and chills were recognized by the majority of the respondents 99.56% (478/480) as the main characteristics identified in individuals infected by malaria. Ability to know how malaria is transmitted and its symptoms could be credited to the presence of high literacy level and high percentage of youthful population, Knowledge on malaria transmission, symptoms and treatment enables timely identification and treatment of infected individual, this has been established to be strongly effective in decreasing the spread of malaria in the community (Forero *et al.,* 2015; Reddy *et al.,* 2011; Adam et al., 2008). Several other research findings have also demonstrated that infectious disease knowledge was considerably higher in areas with higher

education level mainly urban centers and contributed positively to the disease control and prevention strategies (Pallas *et al.,* 2013; Rodriguez *et al.,* 2003).

About 68.33% (328/480) of respondents rated malaria as an ordinary disease while 24.58% (118/480) rated malaria as a deadly disease. Majority 86.0% (413/480) reported to have sought malaria treatment in public hospitals and dispensaries and 75.6% (363/480) reported to have sought treatment in private hospitals This was constant with other studies that has proven that people with a good knowledge of the causative agent, signs and severity of the sickness tend seek prompt medication recognized health facilities (Hlongwana *et al*., 2009). However, it was disturbing to find out that 74.4% (367/480) of the responders reported to have purchased drug over the counter without recommendation by the health professional and about 10.4% (50/480) reported to have used medicinal herbs. Various studies have proven that self-treatment leads to disease complications and potential development of medication resistance of infectious diseases (Yeneneh *at al.,* 2003).

The most reported mosquito breeding site was garbage 85.4% (410/480) and standing dirty water 81.0% (389/480), despite this findings, only 31.7% reported to have been clearing stagnant waters in gutters and tunnels near their homes, these could be attributed to lack of awareness on the need of citizen being personally responsible on their health wellbeing (Peters et al., 2012). 67.1% (322/480) covered water holding containers to prevent contamination. Presence of breeding site and lack of individual commitment to eradicate breeding sites may lead to increase of malaria vector population consequently amplifying malaria distribution in the community (Abilio *et al.,* 2011; Clarke *et al.,* 2002). The most reported mosquito bite time was at night 100% (480/480) and this explains high percentage of responders 91.0% (437/480) who used mosquito net during sleeping time. Most people 96.5% (463/480) indicated that they had learned about malaria on TV and radio advertisements. Various research has indicated that high level of education and increased access to information has a direct correlation with best malaria practices, people who have adequate information on infectious disease transmission and treatment are able to use effective prevention and control mechanisms based on the information they possess (Hanafi *et al.,* 2011).

The proportion of *Anopheles* mosquitoes (malaria vector) was found to be 8.4% (190/2257) this was comparatively fewer compared to other mosquito genera. The leading genus was *Aedes* species 39.5% (891/2257) followed by *Culex* species 31.1% (701/2257) and *Mansonia* 17.3% (390/2257). All of them are globally known vectors of many pathogens. (Kraemer *et al.,* 2015), (Mouchet *et al.,* 2001), (Scott *et al.,* 2015). The available breeding environments could have led to these findings. Other researchers found that Quality of water affects mosquito population as some species prefer clean while others prefer dirty water (Rapuoda *et al.,* 1996). For example, *An. gambiae* (*s.l.*) reproduce in small, exposed, sun-drenched, fresh water sites, *An. funestus* usually reproduce in water environments with emergent plants like swamps and rice fields, therefor absence of swamps and rice fields in Narok Town ward could have led to low Anopheles mosquito population. *Culex quinquefasciatus* reproduce in contaminated water environments like pit latrines, soak pits, drains and exposed sewerage and waste structures (Imam *et al*., 2014).

The proportion of *Anopheles* mosquitoes infected by *plasmodium* sporozoites was found to be 4.7%. These findings were consistent to most studies conducted in Bangladesh and Kenya (Alam *et al.,* 2010), (Lutomiah *et al.,* 2013), (Minakawa *et al.,* 2002).

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Conclusion: The study was carried out appropriately as per the plan, the members of the public were receptive and supportive. There were no challenges in securing relevant ethical clearances and approval from relevant agencies. However, there was difficulties experienced in terms of cost and securing laboratory services in major research institutions.

The study captured data for 2010 persons from the 480 randomly selected households in Narok Town Ward, majority of the population were children and youth; there was high literacy level and most people had good knowledge on malaria transmission, symptoms treatment and prevention. There was considerable proportion of people (1.04%) who had malaria an indicative there was existence of malaria disease in Narok Town Ward. Majority households reported using of ITN to prevent mosquito bite at night, most abundant mosquito breeding

site was stagnant dirty water near homes, this resulted from clogged waste water tunnels and overflow of septic tanks and pit latrines.

Although there was presence of people who had been infected by malaria and *Anopheline* species infected by *Plasmodium*. a significant gaps relating to diagnosis, treatment and control of mosquito breeding sites was evident. There were substantial percentage of people preferring to purchase drugs without a prescription; many people did no appreciate the need to clear stagnant waters and garbage. This study presents evidence that point to the need to develop community based education and awareness activities specific to Narok Town ward based on the specific gaps found in this study.

Recommendations

Recommendations for Policy, Programme/Practice: The Government need to create awareness on the presence of malaria in Narok Town ward and educate members of the public on control and prevention measures and also enlighten them on harmful effects of using drugs purchased over the counter without prescription by a qualified health worker.

The Narok Town Municipality needs to establish and inculcate a community based accountability in town cleaning services by educating members of the public on the need to clear bushes and stagnant waters around their homes, proper waste disposal, proper septic tanks and toilets construction, proper sewerage disposal and proper waste water disposal mechanisms.

The Narok County Government- Department of Health need to establish a regular mass distribution of long lasting insecticide treated mosquito net and carry out annual monitoring and evaluation assessments to ensure that the nets being used by the members of the public are of good condition and are being used properly and consistently. The Department of Health needs also to train the Community Health Volunteers (CHV) on malaria prevention, diagnosis and treatments options who in return will serve as community resource persons at the community level.

Regular training of private health care workers in private pharmacies and clinics on harmful effect of prescribing antimalarial drugs without laboratory confirmation and regular market surveillances carried out by relevant authorities to prevent the same and avert possible drug resistance in the community.

It was difficult to secure laboratory services from reputable institutions, it is therefore important for the Mount Kenya University to establish an Insect based research laboratory for offering services at subsidized rate to its students and other local researchers.

Recommendations for Further Research in this Field of Study: It is reasonably evident that the malaria and mosquito burden in Kenya cannot be underestimated, with the current global warming and climate change, it poses a potential mosquito-borne disease outbreaks thus adding damage to the already overstrained health systems by malaria disease, therefore, a regular and structured mosquito surveillance and research in the country need to be undertaken so as keep track on the individual species present and ascertain their mosquito borne pathogens infection status.

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