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A Review of the Literature on the Effects of Parasites on Zoo Birds in Captivity

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ABSTRACT
Large populations of captive wild birds are exposed to many parasitic diseases, infectious diseases which are a major concern in conservation of endangered species as well as of public health concern. They can lead to mortality, dramatic population declines, and even contribute to local extinction events in the place of conservation. It would be of great benefit if more studies are channeled at this area to provide more insight and guide on how to manage such a challenge. The endoparasite load preference was highest incarnivorous and herbivorous birds, while the ectoparasites load was very high in omnivorebirds. The predilection site highly infested by ectoparasites was the head region, while the intestine was mostly infected by endoparasites. Seaonality influences the composition and distribution of parasites. Therefore, the likelihood of the occurrence of disease outbreak for birds in captivity is predictable. Hence, the current knowledge of the impact of parasites in captive birds rather than in wild birds was reviewed based on their biology and load in birds in relation to feeding guilds, predilection sites and seasonality that may help in effective management practices.

KEYWORDS
Captive birds, Parasites, Feeding guilds, Predilection sites, Seasonality.

1. Introduction

Birds kept in captivity are sometimes released into the wild, when there is sufficient natural habitat to support new individuals or when the species in the wild suffer less threat or bought by individuals [2]. Captive breeding allows for a controlled environment within welldefined settings that facilitate biodiversity and may save species from extinction [3]. Captive breeding is employed by modern conservationists, and has saved a wide variety of species from extinction; the Pink Pigeon (Nesoenasmayeri) is one of such success stories, [2]. Captive birds are prone to attack by parasites which causes serious threats to birds. These might be so serious for growth, reproduction and long term survival. This is a major concern in conservation of endangered species as they can lead to mortality, dramatic population declines, and even contribute to local extinction events [4-

7]. These parasites are found on both wild and captive bird species which causes various diseases such as avian malaria, ornithosis or psittacosis and bird flu [8]. A parasite can either be an ectoparasite or endoparasite. Ectoparasitesinclude ticks, flies, mites[9]whereas endoparasites such as nematodes, trematodes, cestodes, acanthocephalans and protozoans were recorded by Rahimangaet al. (2002) [10]. Parasitic diseases often represent a major concern in zoo animals due to the poor maintenance of confined cages leading to high level of environmental contamination as well as a possible zoonotic potential [11,12].

Hence, the current knowledge of the impact of parasites in captive birds rather than in wild birds was reviewed based on their biology and load in birds in relation to feeding guilds, predilection sites and seasonality that may help in effective management practices.

Captive Birds and Parasites

Almost all species of captive birds suffer from parasite infestation [13]. Large populations of captive birds are exposed to many parasitic diseases. This may include feather chewing lice (Ischnocera, Amblycea) which destroy feathers to helminthic infections which may lead to death [14]. Ascardiagalliis the largest nematode of birds residing in the small intestine. It is the most prevalent and pathogenic parasite of domestic fowl. Parasite infestation can also be observed in other species of birds which causes anorexia, weight loss, hemorrhages in the intestinal mucosa and obstruction in intestinal lumen [15]. Parasitic infections are among the most common sanitary problems affecting captive birds, especially in high density populations due to an increased risk of exposure.

Ectoparasites

Birds may harbor a great variety of ectoparasites[16]. These parasites have been noted to be responsible for restlessness, skin damage, restricted growth, loss of weights in birds, as a result of their bites [17]. Parasites show morphological and physiological adaptations to enhance their living and existence on their host [18]. Most ectoparasites possess tarsal claws at tips of their leg that enable them to hold grip on their hosts hairs and feathers. The shape and size of ectoparasites are also modified; some are microscopic (mites) while some are not microscopic for example ticks and lice [19]. Ectoparasites affect the health and productivity of many captive bird species [20]. Parasitic arthropods, including ticks, mites, flies, mallophages and fleas are often found on the skin or feathers of their hosts.

Ectoparasites such as: lice, fleas, ticks and mites have been reported by Balaet al. (2011) [21] to show morphological and physiological adaptations to enhance their living and existence on their host. This include piercing and sucking mouth parts, characteristics stylets enclosed in a sac beneath the head, as found in lice, mouth parts are also armed with barbs which may not allow forceful withdrawal from host flesh as found in ticks. Lice also possess longer jaw adapted for biting and fleas are laterally compressed, possessing comb that helps to retain them amongst the fur of their host [18]. Most ectoparasites also possess claws at tips of their leg that enable them to hold grip on their hosts hairs and feathers. The shape and size of ectoparasites are also modified. They are mostly small, some so small that they require microscopic observation like mites. Others can however be seen with naked eyes since they are large enough like ticks and lice [19].

Bacterial and fungal infections caused by ectoparasites can occur in wounds, and many ectoparasites are vectors. Philips [22, 23, 24] reviewed the parasitic mites of raptors and the author maintains an online checklist of raptor hosts and their mite ectoparasites. Ectoparasites cause illness and sometimes death in many species, a few adult ticks feeding on a chick of the domestic fowl can cause anaemia, reduced growth, weight loss, and contribute to a depressed state of health [25, 26]. Fatal paralysis from bites of tick has been reported in numerous species of small birds [20, 27]. Recently, parasitic diseases have been increasing in incidence in captive birds, this is as a consequence of increased levels of exposure to the parasite as a consequence of increased contamination of the aviary by the parents. A large ectoparasites infestation on a bird is typically a

sign of the bird being ill for other reasons, as any fit bird will usually control its own parasites rather than just treating the parasite it's also important to deal with the root cause [20].

Effect of Ectoparasites on Bird Host

Ectoparasites affect the host in different ways. They cause damage to birds feathers and impair a host of physiological comfort [28]. Chewing lice (Ischnocera, Ambblycea) are permanent ectoparasites primarily of bird species and they feed on feathers and skin scales. These lice can be harmful to both captive and wild hosts as they deteriorate the quality of the plumage, provoke small holes on feathers (which diminishes the thermoregulatory capacity as well as increase feather breakage [29].

Lice

Lice are also a common ectoparasite of birds. Lice feed on skin debris and feathers, they do not however survive outside the host for long,they do not suckblood but they feed on feathers. It is difficult to spot them as they can easily vanish under feathers [30].

Lice of the genus Struthiolipeurus can cause intense pruritis, feather damage and feather loss. Both lice and mites can be found by examining the skin and feathers, especially around the vent, legs, wings and neck. Night time examination of birds may detect parasites that feed at night, but specific identification of the parasite requires microscopic examination [31]. Chewing (biting) lice (feather lice, ostrich lice), Struthiolipeurusstruthionis cause skin and feather damage (which diminish thermoregulatory capacity), and increase feather breakage [32]. The lice and eggs can be seen in feathers close to the skin around the vent, legs, wings and neck [33, 34]. They are narrow bodied lice with large heads, not sucking blood but feeding on feathers [34]. It is difficult to spot them as they can easily vanish under feathers.
Struthiolipeurus eggs are deposited on feather barbs on both sides along the shaft [31]. Price et al. (2003) [35] provided a list of global avian lice, their hosts, and identification keys to genera by host. Chewing lice usually are transferred by direct contact and, less frequently, by louse flies. Their feeding can damage feathers, and scratching in response to infestation can cause additional damage [34, 36, 37, 38].

Mites

Mites are members of the spider family. They spend their entire life cycle on a bird. Mites spread from bird to bird as flock members make body contact. They are about 0.5 μm long [34]. Mites of the family Pterolichidae are known to infest ostriches. The feather (quill, shaft) mites Gabuciniabicaudata(Pterolichusbicaudatus) of ostriches live in the vein in the ventral groove of the feather shaft and feed on blood and gelatinous contents of feather sheath. They can be visualized as small, reddish, dust-like, elongated particles in the feather vent [33,34,39,40]. As ostriches molt continuously, there are always immature feathers for them to feed on, although when their population grows out of control they also attack the skin [39]. These microscopic mites live within the shaft of the feather. Damage is done to the feather when the mites pass through the quills during their life cycle [41].

Skin or tissue-eating mites reported on raptors include Pneumophagus in the lungs and air sacs, Ereynetidae in the nasal cavity, Turbinoptidae in the outer nares, Hypoderatidae under thigh and underbody skin, Syringophilidae in quills, and Analgidae, Cheyletiellidae, Epidermoptidae, Harpirhynchidae, Knemidocoptidae, and Trombiculidae (chiggers) on or in the skin. Cheyletiellid mites also feed on blood, and, as with epidermoptid and harpirhynchid mites, can cause edema, hyperkeratosis, and feather loss, with secondary infections in skin lesions. Knemidocoptes can cause development of scaly-face and scaly-leg encrustations. Females of Strelkoviacarus and Microlichus are phoretic on louse flies, whereas Myialges females lay their eggs on these flies. Hypoderatid mites reproduce in nests, but their adults are non-feeding and shortlived. Chiggers, often a cause of dermatitis, are larval mites whose nymphal and adult forms are soil

predators. Many mites live on feathers where they scavenge fungi, lipids, bacteria, and feather fragments. A few live in the rachis and quill and eat medulla tissue. Feather and quill mites are most abundant on wing feathers. Feather mites can be collected by ruffling feathers dusted with insecticides [34, 37, 41]. Thus, Barbosa et al. (2002) [42] reported that the activity by such parasite have effect on the behavior of their host.

Ticks

Adult ticks all suck blood, often from different hosts. Individuals remain attached to hosts for as long as two days [43]. They feed for very brief period of time, spending most of their time in secluded areas. Eyelids and the bases of beaks are usual feeding sites. Most ticks are ambush parasites found in litter and soil that latch on to passing hosts. Just a few adult ticks feeding on a small bird can cause anemia, reduced growth, weight loss and contribute in other ways to a depressed state of health [44]. Avian soft ticks (Argasidaeargas and Ornithodoros) and some hard ticks (Ixodidae, Ixodes) live in nests and burrows. Ticks transmit avian spirochetosis and Lyme disease, and are vectors for Babesiaspecies, an anemia causing protozoan known to occur in Prairie Falcons [45]. They also transmit viruses and tularemia bacteria to birds. Some species produce a toxin in their saliva that induces paralysis. Ticks have killed nestling Prairie Falcons [46,47] and Peregrine Falcons F. peregrinus [48], and tick paralysis killed an adult Powerful Boobook (Ninoxstrenua) [49] in Australia. Paralysis of birds voluntary muscles is a result of the argasidae species bites. Tick paralysis in songbirds has been associated with the bite of the hard bodied tick Ixodesbrunneus [50]. Ticks of various species and different life stages infest ostriches and high infestation is associated with areas of high rainfall and dense vegetation [33,51, 52]. The most common site of attack for ticks (80%) is the head and neck. A preferred site of attachment is under the chin [31].

Flies (Diptera)

Flies that parasitize birds externally include biting midges, blackflies, louse flies and mosquitoes.

Biting midges

Biting midges (Ceratopogonidae) which are often called “no-see-ums,” transmit filarial nematodes, blood protozoans Haemoproteus and Leucocytozoon, and the Thimiriarbo virus to birds [53]. Flies spending all or most of their adult life within the furor among the feathers of their hosts [54].

Blackflies (Simuliidae)

Crosskey and Howard (1997) [55] provided an inventory of the blackflies of the world. Blackflies are the main vectors of Leucocytozoon in birds, and also transmit Trypanosoma and filarial nematodes [56]. Adler et al. (2004) [57] listed North American blackfly species, their raptor and other hosts, and the species of Leucocytozoon they transmit. Blackflies have killed nestling Red-tailed Hawks B. jamaicensis [58, 59], nestling MerlinsFalco columbariu [60], and have weakened nestling Cape Vultures Gyps coprotheres [61]. Blackflies tend to feed on the crown, back, and shoulders of raptors. Biting occurs during the day in the open.

Louse Flies (Hippoboscidae)

Maa (1963) [62] listed the louse flies of the world and provides genera and species group identification keys. Avian louse flies, often called flat flies, tend to remain on their host unless disturbed, and they sometimes bite humans that handle infested birds. Larvae develop in the female and pupate in birds nests and roosts immediately when born. Louse flies transmit the blood protozoans, Haemoproteus and Trypanosoma, through biting, and carry lice and the ectoparasitic skin mites, Strelkoviacarus, MicrolichusandMyialges on their exterior to new bird hosts [63,64]. Louse flies have tested positive for West Nile virus, but their role as

vectors of this and other viruses is unconfirmed. Infestation of several dozen louse flies does not seem to harm raptors, but when levels exceed 80, raptors become emaciated and too weak to hunt [65].

Mosquitoes (Culicidae)

Mosquitoes transmit many viruses to birds, including encephalomyelitis viruses, West Nile virus, and poxvirus [66]. They are also vectors of avian malaria (Plasmodium) and filarial nematodes. After a blood meal, female mosquitoes lay eggs on water or wet surfaces under floating vegetation or in the walls of wet tree holes [67]. Mosquitoes (Diptera: Culicidae): Aedesspecies and Culex species of mosquitoes have been involved in the transmission of fowl pox caused by avian poxvirus [68]. Mosquitoes can harbor and transmit the virus for a month or longer after feeding on infected birds or by direct contact with infected birds [69]. Other insects, such as stable flies have also shown the capability of transmitting the poxvirus [69]. Mosquitoes are vectors of avian malaria (Plasmodium) and filarial nematodes [70].

General Control Measures for Ectoparasites

Sanitation and cleanliness are the keys to ectoparasite control in captive birds. Sanitation includes cleaning and disinfecting bird cages, facilities and equipments. Eliminating the contact between flocks and wild birds can reduce the potential transfer of external parasites a wide spectrum insecticide not harmful to birds containing 0.09% tetrametrin and 0.45 piperronyl is highly favored in use to pulverize on the feather or the predilection sites [71]. Since the life cycle of lice and mites is approximately 2 weeks, treatments should be repeated every 2 weeks as needed [72].

Endoparasites

Endoparasites such as single celled protozoa, worms (helminths), invade nearly all organs of their host. Endoparasitism is one of the major health problems in the companion birds and is on the top of the list of clinical problems considered for differential diagnosis, especially in newly acquired birds and in large aviary collections [22]. Greve (1996) [73] reported that gastro-intestinal parasitism ranked as the most frequent and important one in caged and aviary birds. Ramiszet al. (2014) [74] determined the parasitic species composition, prevalence and intensity of infection in selected parrots. Lee et al. (2005) [75] conducted a prevalence study of gastrointestinal parasites in Psittacine birds which while in groups were found to have a significant higher percentage of parasites than birds that are kept individually.

Effect of endoparasites on the host

Parasitic diseases caused by endoparasites generally constitute major impediments on husbandry, productivity and welfare of captives birds particularly poultry. Extensive studies have been conducted on the endoparasites of captive birds. This disease conditions limit their production through retardation in growth, poor health conditions, reduced egg production, lowered and overall sustainability. Endoparasitism causes loss of appetite, changes in vocalization, ruffled plumage, breathing difficulties, weight loss, bloody diarrhea, and inability to survive [22,23].

Common Endoparasites Reported to infest Captive Birds Avian trichomoniasis

Trichomonasgallinae is a protozoan parasite known to infect the upper digestive tract and various organs of several avian groups, including Columbiformes (i.e. pigeons and doves). The genome of parasites can be bigger than those of the free living parasite relatives and in some cases, bigger than those of the hosts they occupy [76].

Trichomoniasis is caused by a group of one celled protozoa and regularly affects many bird species. One strain of the parasite infects pigeons and doves and also, their predators, such as raptors. In some strains of the disease, birds develop sores in their mouths, throats or gastro-intestinal tract and upper respiratory tract of birds. Birds can be affected with Trichomonasgallinae by consuming contaminated food which has dropped by infected birds. Symptoms includes: reduce appetite, or a physical inability to eat, inability to swallow,vomiting, dehydration , weight loss, depression, weakness, diarrhea and respiratory distress which makes it hard for the birds to breathe. Liver damage can occur if the liver is invaded byTrichomonasorganisms, resulting in green biliverdinemia [30, 36, 77].

Coccidiosis

Coccidiosis is a disease caused by Coccidia which are a group of protozoan parasites that are extremely common. Coccidia live in the intestinal tract and if they proliferate, or at times of stress, will also cause chronic bloody stools.An infection may be mild enough to go unnoticed while a large infective dose of coccidia may produce severe lesions that can cause death. Coccidians survive for long periods outside the bird's body, so infection can occur simply by keeping a bird in a contaminated cage or aviary. It is difficult, if not impossible, to prevent coccidiosis by sanitation alone. It is best prevented by addition of a drug (coccidiostat) to the feed that controls the growth of coccidia in the digestive tract [78].

Avian malaria

Avian malaria parasites of the taxa Plasmodium and Parahaemoproteus (order: Haemosporida) are ubiquitous parasites that may co-circulate with zoonotic pathogens for which birds are reservoir hosts[79]. These parasites have complex lifecycles that involve asexual reproduction in an avian host and sexual reproduction in a dipteran vector. Parahaemoproteus is vectored by Culicoides midges (Ceratopogonidae), whereas Plasmodium parasites are vectored by mosquitoes (Culicidae), including those of the genus Culex [80,81].

Avian Giardiasis

Giardiasis is a gastrointestinal parasite that can cause a number of problems in a bird's stomach and intestines, but affects the normal functions of other organs. Giardia is a singled celled microbe (protozoa) found in the intestines. Giardiasis generally affects cockatiels, budgerigars [82], lovebirds, and other birds of the parrot family, like macaws, parrots, and cockatoos [83].

Aspergillosis

Aspergillosis is a fungal infection caused by the Aspergillus fungus, which can be found in damp or wet seed mixtures, in birds' nesting materials, or in landfills. Spores inhaled into the lungs and air sacs of birds eventually cause pneumonia and bronchitis. Sick birds experience labored breathing, weakness, and diarrhea, but will continue to take food at feeding stations until they die [84].

Roundworms

These are the largest and most significant group of endoparasites. The group includes the Syngamus trachea and Serratospiculumspp. which affect the wind pipe and air sacs respectively. Both will cause respiratory signs in infected birds, however in both cases it is particularly important that the diagnosis is made prior to treatment being given. In the case of Syngamus even after the worms are killed they will remain in the airways for up to six weeks slowly rotting away causing respiratory signs and occasionally pneumonia in the meantime [85].

General Control Measures for Endoparasites

Contact with wild birds should be avoided because it increases the chances of attracting parasitic diseases. Parasitic diseases are difficult to avoid in totality, but may be controlled by the use of management and treatment strategies. Cleaning and disinfection procedures should be improved. Routine deworming programmes are usually advised. Each treatment with a drug will increase the selection pressure in the helminth population for development of anthelmintic resistance [86], and therefore parasitic control programmes should reduce the number of treatments to a minimum and rather increase other control measures. Nevertheless, some kinds of routine anthelmintic treatments are relevant in the control of nematodes in most management systems [87].

Class I anthelmintics: Benzimidazoles and probenzimidazoles should be administered. These drugs exert their action on the intracellular polymerization of the tubulin molecules to microtubules. As the cellular functions are disrupted, the worms die. Brands such as albendazole, thiabendazole, fenbendazole, parbendazole, flubendazole, febantel, and thiophanate are generally effective against helminthic infections. Regular vaccination against viral infections are also recommended as well as anticoccidial drugs [88].

Parasitic Load in Captive Birds in Relation to Feeding Guilds and Predilection Sites

(a) Ectoparasitic Load

Studies by Omuduet al. (2011) [89] and Njilaet al. (2018) [90] on captive birds in the Makurdi Zoological Garden in Benue State and Jos Museum Zoological Garden respectively showed that the omnivores had the highest abundance of parasitized bird group with heavy ectoparasites load, followed by carnivores, while low infestation rate in frugivores [73, 91] as shown in Table 1.

Table 1. Ecto-and-endoparasitic loads in captive birds in relation to feeding guilds

Feeding guild	Ectoparasite Load	Endoparasite Load
Carnivores	++	+++
Frugivores	+	++
Omnivores	+++	+
Herbivores		+++

Table 2. Ectoparasites load in relation to predilection sites

Species	Head	Crown	Wing	Leg	Tail	Feather	Eyelid	Beaks	Chin	Neck	Vent	Thigh	Body (Breast/ Stomach)	Trunk	Perenium	Feet
Tick	+++	-	-	+	-	++	+	++	++	+++	-	-	-	-	-	-
Mite	+++	++	-	-	-	-	++	+	-	-	+++	-	-	-	-	+++
Lice	-	-	++	++	-	++	-	-	-	++	-	+	+++	++	+	-
Fleas	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
% of Preference Mean	50	12.5	31.25	18.75	0	37.5	18.75	18.75	12. 5	37.5	25	6.25	25	12.5	6.25	25

Table 3. Endoparasites preference in relation to predilection sites

Parasite	Blood	Intestine	Liver	Lung	Air sac	Throat	Crop

Trichomonas	-	-	-	-	-	+++	++
Coccidia	-	+ ++	-	-	-	-	-
Giardia	-	+ ++	-	-	-	-	-
Aspergillus	-	-	-	+++	+++	-	-
Plasmodium and *Haemoproteus*spp.	+++						
Preference Mean (%)	**20**	**40**	**0**	**20**	**20**	**20**	**10**

Ticks predominantly preferred the head and neck regions. Mites preferred the head, vent and feet regions. Lice preferred feather, body (breast/stomach) region while fleas were heavily loaded in wing region (Table 2).

(b) Endoparasitic load

The carnivores and herbivores were mostly infected as described by Santos et al. (2011) [92] in faecal specimens andas well as their blood specimens [81] respectively (Table 1).

The intestine was the most preferred predilection site by endoparasites[77, 92, 93,94,95] and then in blood [81]. But, the liver was not a site of attachment for endoparasites (Table 3).

The site most preferred by Trichomonaswas throat; both Coccidia and Giardia was intestine; Aspergilluswas lung/air sac [96]; and Plasmodium and Haemoproteus species was the blood [81].

Composition and abundance of parasites in captive birds in relation to seasonality

Numerous factors drive seasonalcomposition and abundance of parasites in captive birds. One of the major factor being climate [97]. An understanding of these processes increases our ability to predict when outbreaks are likely to occur and in what abundance [98,99]. Some drivers of seasonal infection involve vector behavior and population dynamics. Seasonal shifts in vector utilization of hosts for blood meals have been demonstrated in numerous mosquito species and populations, and these shifts may influence the incidence of vector-borne infectious disease [100]. Pest abundance and activity are associated with infection risk and are influenced by seasonal climate variation [101].Climate also influences seasonal changes in host behavior and physiology that affect pathogen transmission. Host reproduction is often seasonal and correlated with resource availability, which in turn may vary with weather and climate. Energetically expensive breeding activities may leave adults more susceptible to infection [102]. Most birds reproduce during the wet season when food is abundant in which their young immunologically naive juveniles increases the proportion of susceptible individuals in a population and promotes disease transmission [103].

Avian Plasmodium infections within hosts can be highly dynamic. Studies have revealed seasonal patterns in haemosporidian prevalence especially in temperate regions where variation in the annual climate cycle influences host and vector demography[104]. A classic model of temperate avian malaria infection posits an age-structured bimodal peak in the seasonal Plasmodium prevalence among hosts [105]. The model suggests that malaria prevalence drops in winter as infection causes mortality in some hosts while others clear infections from the blood stream through host defense mechanism. Stress associated with reproduction drives a recrudescence of dormant infections among adult birds, elevating the prevalence [105].

Cosgrove et al.(1971) [106] showed that the expected seasonal pattern of malaria infection among blue tits (Cyanistescaeruleus) in Oxford shire, United Kingdom, was absent in Plasmodium relictum and present only in hatch-year hosts for Plasmodium circumflexum.

The dry season period in tropical region is characterized by dry environment which have shown

lessectoparasites activities owing to poor resource availability and environmental conditions [107].

2. Conclusion

Large populations of captive wild birds are exposed to many parasitic diseases, infectious diseases which are a major concern in conservation of endangered species as well as of public health concern. They can lead to mortality, dramatic population declines, and even contribute to local extinction events in the place of conservation. It would be of great benefit if more studies are channeled at this area to provide more insight and guide on how to manage such a challenge. The endoparasite load preference was highest incarnivorous and herbivorous birds, while the ectoparasites load was very high in omnivorebirds. The predilection site highly infested by ectoparasites was the head region, while the intestine was mostly infected by endoparasites.Seaonality influences the composition and distribution of parasites. Therefore, the likelihood of the occurrence of disease outbreak for birds in captivity is predictable.

It would be of great conservation benefit and more economical if captive bird managers improve management and maintenance of the various captive birds and there environment, particularly in the area of sanitation condition.

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