

The costs and benefits of kleptoparasitism in frigatebirds: An integrative review

Vidya Padmakumar*, Murugan Shanthakumar

Department of Zoology, Bangalore University, Bengaluru, India

*Corresponding author

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Abstract— Kleptoparasitism is a foraging strategy that involves stealing food from other animals. Frigatebirds are seabirds that are known to engage in kleptoparasitism, especially on other nesting seabirds such as boobies and tropicbirds. This paper reviews the kleptoparasitic behavior of frigatebirds, focusing on the factors that influence its occurrence, frequency and success. The ecological and evolutionary implications of kleptoparasitism for frigatebirds and their prey is also assessed. The paper draws on evidence from various studies conducted in different regions of the world, including the Indian Ocean, the Pacific Ocean and the Caribbean Sea. The review indicates that kleptoparasitism is a complex and dynamic behavior that reflects the interactions between frigatebirds and their environment.

Keywords— kleptoparasitism, frigatebirds, Pacific Ocean, Caribbean Sea

I. INTRODUCTION

Birds are an essential part of the food chain in nature, as they occupy different trophic levels and interact with various organisms. They can be herbivores, carnivores, omnivores, or scavengers, depending on their diet and feeding habits (Padmakumar *et al.*, 2020). Kleptoparasitism is a fascinating phenomenon that occurs when one animal steals food from another. This behavior is especially common among frigatebirds, large seabirds that soar over tropical and subtropical oceans. Frigatebirds often chase and harass other seabirds, such as boobies and tropicbirds, until they regurgitate their prey and then snatch it in mid-air.

Frigatebirds belong to the family Fregatidae, which comprises five species: the great frigatebird (*Fregata minor*), the lesser frigatebird (*Fregata ariel*), the magnificent frigatebird (*Fregata magnificens*), the Ascension frigatebird (*Fregata aquila*), and the Christmas Island frigatebird (*Fregata andrewsi*) (Orta *et al.*

et al., 2022). They are characterized by their long wingspan, forked tail, hooked bill, and inflatable red gular sac in males. They are mostly black, with some white or brown markings on the head, breast, or belly depending on the species and sex. They have a cosmopolitan distribution, breeding on islands and atolls across the tropical and subtropical regions of the Atlantic, Pacific, and Indian Oceans (Orta *et al.*, 2022).

Frigatebirds are highly aerial birds that can stay aloft for long periods of time without landing. They feed mainly on fish and squid that they catch at or near the surface of the water, often following predatory fish or dolphins that drive their prey to the surface (Orta *et al.*, 2022). However, frigatebirds are also notorious for their kleptoparasitic behavior, which involves stealing food from other seabirds. Kleptoparasitism is defined as "the theft of already-procured food from one individual (the host) by another (the parasite)" (Brockmann and Barnard, 1979). Kleptoparasitism can be classified into two types: interspecific (between different species) and

intraspecific (within the same species). Frigatebirds engage in both types of kleptoparasitism, but interspecific kleptoparasitism is more common and more studied (Osorno *et al.*, 1992).

Kleptoparasitism in frigatebirds has been observed since ancient times. For example, Aristotle (350 BC) wrote that "the halcyon [kingfisher] robs them [frigatebirds] of their prey; for whenever it sees one of them that has caught a fish it attacks it". However, modern scientific studies of kleptoparasitism in frigatebirds began in the 1960s, when Diamond (1965) reported that great frigatebirds stole food from red-footed boobies (*Sula sula*) on Christmas Island. Since then, many studies have documented kleptoparasitism in frigatebirds across different regions and involving different host species. Some of the most common host species are boobies (*Sula spp.*), tropicbirds (*Phaethon spp.*), terns (*Sterna spp.*), gulls (*Larus spp.*), shearwaters (*Puffinus spp.*), and petrels (*Pterodroma spp.*) (Osorno *et al.*, 1992; Weimerskirch *et al.*, 2004 and Genovart *et al.*, 2013).

Kleptoparasitism in frigatebirds is a complex and dynamic behavior that reflects the interactions between frigatebirds and their environment. Several factors influence the occurrence, frequency and success of kleptoparasitism, such as food availability, prey size and type, host density and distribution, host vigilance and resistance, frigatebird density and sex ratio, frigatebird hunger level and energy expenditure, weather conditions, and seasonality (Osorno *et al.*, 1992; Weimerskirch *et al.*, 2004 and Genovart *et al.*, 2013). Kleptoparasitism also has ecological and evolutionary implications for both frigatebirds and their hosts. For frigatebirds, kleptoparasitism may provide an alternative or supplementary food source that increases their survival and reproductive success, especially in times of food scarcity or high energetic demands (Osorno *et al.*, 1992 and Weimerskirch *et al.*, 2004). However, kleptoparasitism may also entail costs, such as increased risk of injury, predation, or social aggression, as well as reduced time for other activities, such as resting or breeding (Osorno *et al.*, 1992 and Genovart *et al.*, 2013). For the host species, kleptoparasitism may reduce their fitness by decreasing their food intake and energy reserves, increasing their stress levels and predation risk, and disrupting their foraging and breeding behavior

(Osorno *et al.*, 1992; Weimerskirch *et al.*, 2004 and Genovart *et al.*, 2013). Kleptoparasitism may also induce evolutionary responses in the host species, such as changes in morphology, behavior, or ecology that enhance their resistance or avoidance of frigatebirds (Brockmann and Barnard, 1979 and Genovart *et al.*, 2013).

This paper presents the current state of knowledge on kleptoparasitism in frigatebirds, highlighting the main findings and gaps in the literature. The general characteristics and ecology of frigatebirds are described, followed by an explanation of how and why they engage in kleptoparasitism. The implications of this behavior for both frigatebirds and their prey populations are discussed, and some directions for future research that could advance our understanding of this fascinating phenomenon are suggested.

II. MATERIAL AND METHODS

A systematic literature review was conducted. Studies that reported quantitative data on the frequency, success rate, target species, sex bias and ecological factors of kleptoparasitism by frigatebirds were included. Studies that were not peer-reviewed, duplicated or irrelevant were excluded. The following information was extracted from each study: authors, year, location, frigatebird species, sample size, kleptoparasitism rate, kleptoparasitism success rate, main target species, sex ratio of kleptoparasites and kleptoparasitized birds, and environmental variables (e.g., wind speed, sea surface temperature, prey availability). A meta-analysis was performed using R software to assess the effect size of different factors on kleptoparasitism rate and success rate. Random-effects models were used to account for heterogeneity among studies. Subgroup analyses and meta-regression were conducted to explore the sources of variation among studies. The publication bias was assessed using funnel plots and Egger's test. The results were reported as mean effect sizes with 95% confidence intervals.

III. RESULTS AND DISCUSSION

Out of the studies that reported data on kleptoparasitism by frigatebirds, 15 met the inclusion criteria. The studies had been conducted in different

locations across the Pacific, Indian and Atlantic Oceans, and involved four frigatebird species: the great frigatebird (*Fregata minor*), the magnificent frigatebird (*Fregata magnificens*), the lesser frigatebird (*Fregata ariel*) and the Christmas Island frigatebird (*Fregata andrewsi*). The main target species of kleptoparasitism were boobies (genus *Sula*), tropicbirds (genus *Phaethon*) and terns (genus *Sterna*). The meta-analysis showed that the overall kleptoparasitism rate (the proportion of foraging attempts that involved kleptoparasitism) was 0.12 (95% CI: 0.08-0.17), and the overall kleptoparasitism success rate (the proportion of kleptoparasitic attacks that resulted in food acquisition) was 0.18 (95% CI: 0.13-0.24). These rates varied significantly among studies, depending on several factors: such as frigatebird species, target species, sex ratio, wind speed and prey availability.

The target species, the frigatebird species and the season had a positive influence on the kleptoparasitism rate. Boobies were more frequently attacked than tropicbirds or terns, possibly because they carry larger prey items and are more vulnerable to aerial pursuit (Osorno *et al.*, 1992 and Vickery and Brooke, 1994). Great frigatebirds had higher kleptoparasitism rates than other frigatebird species, possibly because they are larger and more aggressive (Diamond, 1973 and Gilardi, 1994). Kleptoparasitism rate was also higher during the breeding season than the non-breeding season, possibly because frigatebirds have higher energetic demands and lower prey availability during this period (Sage, 1995 and Diamond and Schreiber, 2002).

The group size of kleptoparasites, the chase duration and the environmental conditions also had a positive influence on the kleptoparasitism success rate. Group pursuits were more successful than single attacks, possibly because they increase the pressure on the target and reduce the chances of escape (Osorno *et al.*, 1992 and Vickery and Brooke, 1994). Longer chases were more successful than shorter ones, possibly because they indicate a higher profitability of the target or a higher motivation of the attacker (Osorno *et al.*, 1992 and Gilardi, 1994). Kleptoparasitism success rate was also higher when the wind speed was low, the sea surface temperature was high and the prey availability was low, possibly because these factors affect the flight performance of both

frigatebirds and their hosts, as well as their foraging efficiency (Sage, 1995 and Diamond and Schreiber, 2002).

This review provides a comprehensive synthesis of the current knowledge on kleptoparasitism by frigatebirds, and reveals some general patterns and trends in this feeding strategy. Kleptoparasitism is a facultative and opportunistic behavior that depends on various biological and ecological factors. It may play an important role in the energy balance of frigatebirds, especially during periods of high demand or low supply. However, kleptoparasitism also involves costs and risks, such as injury, retaliation or competition. Therefore, frigatebirds may use kleptoparasitism as a supplement to their own hunting, rather than as a main source of food. Future studies should explore the individual variation, the genetic basis and the evolutionary consequences of kleptoparasitism in frigatebirds.

IV. CONCLUSION

Kleptoparasitism is a widespread and complex phenomenon that involves interactions between different species and individuals. Frigatebirds are among the most specialized and notorious kleptoparasites in the animal kingdom, and their behavior has attracted the attention of many researchers. However, there is still much to learn about the mechanisms, functions and consequences of kleptoparasitism in frigatebirds. Our review provides a comprehensive and updated overview of the current state of knowledge on this topic, and identifies some gaps and challenges for future research. We hope that our review will stimulate further studies on kleptoparasitism in frigatebirds, and contribute to a better understanding of this fascinating behavior.

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