The COVID-19 pandemic “anthropause” decreased plastic ingestion in Neotropic cormorants *Nannopterum brasilianus* in Lima, Peru (#88207)

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The COVID-19 pandemic "anthropause" decreased plastic ingestion in Neotropic cormorants *Nannopterum brasilianus* in Lima, Peru

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Background. The anthropause during the recent COVID-19 pandemic provided a unique opportunity to test an effects of human disturbance on seabirds. Lockdowns in Peru prevented people from visiting coastal areas and disposing garbage on beaches and this may have temporarily decreased plastic pollution. We tested this idea in inshore-feeding Neotropic Cormorants (*Nannopterum brasilianus*) along a 12.7 km highway (Costa Verde) on a coastal strip of the city of Lima, Peru (~ 11 million people). **Methods.** Fresh pellets were collected in the median of the highway before (11 months) and during the pandemic lockdowns (8 months). **Results.** There was a significant reduction in the occurrence of plastic in pellets during the pandemic (% Oc = 2.47, n = 647 pellets) compared to pre-pandemic conditions (% Oc = 7.25, n = 800 pellets). The commonest debris item in the pellets was user threadlike plastic of different colors. This study demonstrates that plastic marine pollution is substantially increased by the millions of people visiting the Costa Verde annually. Imported garbage from nearby river mouths and coastal dumps may also be involved in plastic pollution on the Costa Verde.

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Abstract

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1.Introduction

During the COVID-19 pandemic, the new term, "anthropause" was coined to describe a reduction in human activity on a global scale. This reduction was characterized as being unusual, temporary, and having a significant impact on the environment (Rutz, 2022). The substantial reduction in human mobility on the planet as a result of the anthropause brought about by COVID-19 provided an opportunity to study how fauna responds to such a decline in human activity (Bíl et al., 2021; Coll et al., 2021; Madhok & Gulati, 2022), taking into account that it is an unusual and unique event (Markard & Rosenbloom, 2020).

The lockdowns and curfews implemented during 2020-2021 provided an opportunity to study the effects of human activity on the environment by comparing conditions before, during, and after the pandemic in sites with varying levels of social mobility restrictions (Rutz et al., 2020). This unique opportunity allowed detailed analysis of the various interactions between humans and wildlife, which is crucial for the development of conservation policies (Bates et al., 2021). The diversity of studies on the effects of the anthropause on animals has increased due to the lockdowns worldwide, indicating that this period was crucial for many species affected by human activity (Manenti et al., 2020; Perkins et al., 2021; Schrimpf et al., 2021).

As a result of the anthropause, changes in animal behavior have been reported worldwide. The use of roads, airports, and recreational areas for resting and breeding by various animal taxa was commonly observed in ce locations (Manenti et al., 2020; Schrimpf et al., 2021). The behavior responses varied depending on the species, type of human mobility, and time scale. For instance, birds which typically fed in residential gardens were seen less frequently because homeowners were more frequently using their backyards for recreation during lockdowns. Conversely, opportunistic species such as corvids, gulls, and buzzards, as well as resident and rare species, were commonly observed in urban areas (Madhok & Gulati, 2022; Warrington et al., 2022).

Furthermore, the number of wildlife-vehicle collisions involving small mammals crossing main roads decreased by over 40% during lockdowns on highways in Estonia, Spain, Israel, and the Czech Republic (Bíl et al., 2021). In some areas of Poland, the mortality rate of hedgehog populations on asphalt roads was reduced by 50% during lockdowns (Łopucki et al., 2021). The occupancy of beaches by wildlife was also affected during lockdowns. Crabs, endangered sea turtles, iguanas, and various species of seabirds had the opportunity to occupy areas that are frequently visited by tourists (Soto et al., 2021). However, the absence of control, surveillance,

and management led to increased threats to native wildlife, due to the invasion of non-native species and illegal hunting (Manenti et al., 2020).

Among the groups of birds that have benefited from the anthropause are seabirds (Hentati-Sundberg et al., 2021; Schrimpf et al., 2021). For example, magnificent frigatebirds (*Fregata magnificens*), laughing gulls (*Leucophaeus atricilla*), and cormorants (*Phalacrocorax* sp.) were commonly observed on urban beaches (Soto et al., 2021). However, other species were affected by the absence of human activity in tourist areas. A reduction in reproductive success in common murres (*Uria aalge*) was reported due to disturbance from white-tailed eagles (*Haliaeetus albicilla*) when tourists were not present in the murres' breeding areas (Hentati-Sundberg et al., 2021). Nonetheless, while studies of the effects of the anthropause have been conducted on some beaches in Latin America (Soto et al., 2021), there is a lack of information in Peru. On 16 March 2020, Peruvian authorities imposed the first mandatory COVID-19 lockdown, which persisted for several months. Lima is a coastal city with over 11 million inhabitants (INEI, 2022) and high levels of marine pollution (Ayala et al., 2007; Purca & Henostroza 2017; Tapia et al., 2018; Gambini et al., 2019). One of the most visited beaches in Lima is the Costa Verde, which receives millions of visitors during the summer. The beaches in this area are also contaminated by high levels of plastic (Blondet et al., 2023). Along a 13 km stretch of the coastline, Costa Verde offers areas for recreation, education, sports, and vehicle transit (Majluf, 2014). Despite high levels of human disturbance, a group of 460 Neotropic Cormorants are common residents along the Costa Verde, perching on public lighting poles and telephone cables in close proximity to the shore (Lozano-Sanllehi & Zavalaga, 2021). This species is susceptible to indirect ingestion of plastic from its prey (Azzarello & Vleet, 1987), making it an indicator species for measuring the effect of the anthropause on plastic pollution in marine environments. By analyzing regurgitated pellets containing indigestible elements (Barrett et al., 2007), important information on the incidence of plastic in the diet of Neotropic Cormorants can be obtained (Barrett et al., 2007). The objective of this study was to compare the presence of plastics in the pellets of Neotropic Cormorants in Costa Verde before and during the COVID-19 pandemic.

2. Materials & Methods

2.1 Study area

The Costa Verde is a 16-km narrow coastal strip located in Lima, Peru, that experiences high traffic of vehicles and people throughout the year. The main characteristics of the Costa Verde include beaches, parks, sports centers, restaurants, clubs, parking areas located adjacent to the

beaches, and infrastructure for pedestrian and vehicular traffic. The highway has two to three lanes designated for vehicular traffic in both directions. The median contains public lighting poles and telephone cables that serve as perching and pelle[illegible]ilding-up sites for Neotropic Cormorants at four main locations along the highway (Lozano-Sanllehi & Zavalaga, 2021). A total of 1,447 Neotropic Cormorant pellets were collected from a specific section of this highway (12° 12'19'' S, 7[illegible]4' 45'' W, Fig. 1) in the district of Miraflores between October 27, 2019, and February 28, 2021.

Figure 1. Map of the study area depicting the Circuito de Playas Costa Verde (CPCV highway) and the district of Miraflores. The inset illustrates the specific section of the CPCV where the Neotropic Cormorant (*Nannopterum brasilianus*) pellets were collected.

2.2 Definition of the pandemic phases

We examined the contents of the pellets to identify plastic and other debris before (pre-pandemic) and during (pandemic) the COVID-19 lockdowns in Lima, Peru.

2.2.1 Pre-pandemic phase

This period refers to the time before March 16, 2020, when human activities in Peru and the Costa Verde were not restricted. Throughout the year, people frequented the beaches for leisure, with the highest number of visitors during the austral summer (December-March). Despite the high influx of vehicles and people, Neotropic Cormorants are regularly seen perching on the light poles and telephone lines (Majluf, 2014; Lozano-Sanllehi & Zavalaga, 2021).

2.2.2 Pandemic Phase

During the pandemic phase, access to the Costa Verde highway and nearby beaches was either completely prohibited (full lockdown) or restricted (partial lockdown) for people and vehicles (Table 1). Beaches were entirely off-limits to the public from March 16 to October 22, 2022. However, they were partially accessible from October 23, 2020, until February 28, 2021.

Table 1. List of restriction measures on the Costa Verde highway and beaches during the Covid-19 pandemic phase in Peru.

2.3 Collection and analysis of pellets

During the pre-pandemic phase (July 2018 - February 2020), 11 of 20 monthly visits to the study area (Figure 1) were undertaken to collect pellets (11 - 138 pellets per sampling) as part of another project related to the monitoring of the Neotropic Cormorant diet. These pellets were stored in a freezer (-40°C) for subsequent analysis.

During the pandemic phase (July 2020 - February 2021), pellets (11 - 77 per sampling) were collected in 20 of 32 weekly visits to the study area. All pellets were collected during the morning hours to obtain a greater quantity of fresh pellets, which were then individually packaged in 5 x 32 cm paper bags and frozen. Twenty-four hours before analysis, the pellets were soaked in water and placed on individual plates. All solid components (such as fish otoliths, vertebrae, shells, plastic, and others) were sorted and allowed to dry at room temperature. If required, a stereoscope (10X magnification) was employed to classify specific user plastic subcategories, as described by Franeker et al. (2011):

- Sheetlike: Sheets derived from plastic bags.
- Threadlike: Filaments like ropes, threads, and fibers.
- Fragment: Pieces of plastic objects such as bottles, boxes, toys, and tools.

All macroplastic pieces were measured with a digital caliper (Mitutoyo 150 mm, accuracy 0.1 mm). Finally, plastics and other anthropogenic items were grouped, counted, and separated according to their characteristics. Non-plastic anthropogenic items (wood, glass, metal, etc.) were classified as rubbish.

2.4 Data analysis

During each sampling phase, the frequency of occurrence (%FO) of plastic was determined by dividing the count of pellets containing plastic debris by the total number of pellets collected, and then multiplying by 100. To test for differences in plastic intake by cormorants before and during the pandemic, a 2x2 chi-square contingency table was used. Furthermore, the proportion of plastic items within each pellet (%N) was utilized to quantify the extent of plastic ingestion. This was calculated by dividing the count of plastic debris items in a pellet by the total count of debris items in a pellet (otoliths and other prey items were excluded) and then multiplying by 100 (Silva-Costa & Bugoni, 2013).

3.Results

3.1 Pellet composition

Debris (user plastic + rubbish) was found in 109 out of 1447 pellets analyzed (%FO = 7.53). The total number of debris items identified were 176, of which 147 was classified as user plastic. Threadlike items were the commonest user plastic category compared to sheetlike and fragment items (Table 2, Figure 2).

Table 2. Size (mm), percentage of occurrence (%FO), and percentage by number (%N) of the types of user plastic found in 1447 analyzed pellets of Neotropic Cormorant, *N. brasilianus*, on the Costa Verde, Lima, Perú.

Figure 2. Types of user plastic found in the pellets (N = 1447) of Neotropic Cormorants *N. brasilianus* on the Costa Verde, Lima, Perú.

In addition to plastic, various other types of anthropogenic materials found in 23 out of 1447 pellets were identified and classified as rubbish. The most encountered category was threadlike, followed by metal, glass, wood, paint chip and balloon (Table 3, Figure 3).

Table 3. Size (mm) and frequency of occurrence (%FO) of the types of non-plastic rubbish material found in 1,447 pellets of Neotropic Cormorants *N. brasilianus* on the Costa Verde, Lima, Perú.

Figure 3. Types of non-plastic rubbish material found in pellets (N = 1447) of Neotropic Cormorants *N. brasilianus* on the Costa Verde, Lima-Perú.

3.2 Phases of COVID-19 and the presence of anthropogenic materials

During the pre-pandemic phase, 58 pellets (%FO = 7.25, N = 800) contained user plastic, and the contents of 5 pellets (%FO = 0.63, N = 800) were identified as rubbish. In the pandemic phase, 16 pellets (%FO = 2.47, N = 647) contained user plastic, and no pellets contained rubbish. The occurrence of user plastic in pellets collected in the pandemic phase was significantly lower than in the pre- pandemic phase (Chi-squared = 15.85, df = 1, p-value < 0.0001, Figure 4).

During the full lockdown period from March to July 2020, no pellets were collected due to COVID-19 restrictions, thus no data on plastic ingestion by cormorants was available (Figure 4). However, during the strict partial lockdown phase from July to October 2020, no plastic was found in any of the pellets collected (Figure 4). By the end of this phase, on 25 October, there was an increase in the frequency of occurrence of plastic in the pellets, reaching 3.03% FO (Figure 4).

During the subsequent partial lockdown phase on 8 November, the %FO of plastic in the pellets dropped to zero (Figure 4). However, as the partial lockdown phase progressed, there was an increase in user plastic found in the pellets, with the frequency of occurrence reaching 6.98% on 6 December (Figure 4). By the end of the partial lockdown phase and the start of the strict partial lockdown, the %FO of plastic in the pellets returned to zero once again (Figure 4). However, on 24 January 2021, the %FO of plastic waste in the pellets peaked at 16.67% (Figure 4).

Finally, there was a decline in the presence of plastic on 14 February 2021, reaching 0% FO, followed by an increase in the amount of plastic up to 6.67% FO days before the end of the beach restrictions (Figure 4).

Figure 4. Percentage of occurrence of plastic in the pellets of *N. brasilianus* during the pre-pandemic and pandemic phases of COVID-19 on the Costa Verde, Lima, Perú. The top legend describes the restrictions imposed by government authorities during the pandemic.

4. Discussion

The results of this study indicate that the COVID-19 lockdowns in Peru reduced plastic ingestion by Neotropic Cormorants from 7.25 % to 2.47% in one of the most frequented coastal areas in Lima. Restrictions to the access of beaches led to less plastic leaking into the sea, which was

reflected by the absence or low occurrence of user plastic and rubbish in cormorant pellets during the pandemic compared to pre-pandemic conditions. It is important to highlight that despite lockdown restrictions user plastic was still found in cormorant pellets, probably because of access to the beach and surrounding areas during the partial lockdowns.

Lockdowns have contributed to a reduction in plastic pollution in coastal environments as reported in several beaches in Kenya (Okuku et al., 2021), as well as Acapulco (Mexico), Barcelona (Spain), Salinas and Galapagos (Ecuador) (Orzama-González et al., 2021). Most of these changes were attributed to the absence of tourists (Zambrano-Monserrate et al., 2020). A reduced influx of tourists in Latin American countries led to a decrease in beach litter abundance indexes from 2.7 (pre-lockdown) to 1.5 (during lockdown) (Soto et al., 2021).

The ingestion of plastic by Neotropic Cormorants on the Costa Verde is not surprising as high concentrations of plastic fragments and microplastics has been found on sandy beaches in Lima and surrounding areas (Purca & Henostroza, 2017; De-la-Torre et al., 2020) and also on the Costa Verde (Blondet et al., 2023). On the Costa Verde, plastic could be transferred from the land to sea by erosion of the coastline, which contains area wastelands polluted with solid garbage including plastic (Majluf, 2014). Likewise, surface currents and eddies generated by local winds, play a significant role in the accumulation and dispersion of anthropogenic materials such as plastic, as described in studies on floa s debris in the world's oceans (Lebreton et al., 2012; Eriksen et al., 2014). Neotropic Cormorants have a precedent of plastic interactions as they are considerably affected by entanglement in ghost nylon nets and the use of plastic for their nests (Ayala et al., 2023). Furthermore, plastic has already entered the marine trophic web in Peru, being reported in fish (De-la-Torre et al., 2019, Fernández & Anastasopoulou, 2019), seabirds (Thiel et al., 2018, Díaz Santibañez et al., 2023) and marine mammals (Perez-Venegas et al., 2020, Santillán et al., 2020). The most abundant type of plastic found in our study was threadlike (fiber), which is the type of plastic commonly found in marine sediment (Cisneros et al., 2021). Neotropic Cormorants are typically benthic divers (Quintana et al. 2004), and ingest benthic and mesopelagic fish (Galarza, 19 Casaux et al., 2009; Petracci et al., 2009; Muñoz-Gil et al., 2012), and therefore, they likely consume threadlike plastic through trophic transfer from their prey. These results agree with those obtained by Franco et al. (2019) who reported that the most frequent category of user plastic found among 7 species of seabirds was threadlike.

Overall, plastic items were found in 7.25% of Neotropic Cormorant pellets during the pre-pandemic phase. These results are within the range reported in other cormorant species (Robards et al., 1995; Acampora et al., 2017b; O´Hanlon et al., 2017; Brookson et al., 2019; Franco et al., 2019; Baak et al., 2020). For instance, on Macquarie Island, 8% of pellets of Macquarie Cormorants (*Leucocarbo purpurascens*) contained plastic (Slip et al., 1990). Likewise,

3.2% of Great Cormorant (*Phalacrocorax carbo*) pellets on the Irish coast contained plastic litter (Acampora et al., 2017a), whereas the occurrence of plastic in European Shag (*Gulosus aristotelis*) pellets in the Iberian Peninsula wa% (Álvarez et al., 2018). Additionally, microplastic was present in 7% of Guanay Cormorant (*Leucocarbo bougainvilliorum*) pellets on the Peruvian coast (Díaz-Santibañez et al. 2023).

5. Conclusions

This study demonstrates that a significant reduction of human presence leads to a decrease in marine plastic pollution, indicating that this type of pollution may be partially reversible through changes in people behavior and adequate solid waste disposal management. Furthermore, Neotropic Cormorant pellets can be used as an effective non-invasive procedure to detect plastic pollution at sea. Future research should focus on the assessment of the occurrence of plastic in cormorant pellets after the pandemic, to determine the polymer type ingested using Fourier-transform Infrared spectroscopy and examine any gastrointestinal damage in fresh carcasses.

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527

Table 1(on next page)

List of restriction measures on the Costa Verde highway and beaches during the COVID-19 pandemic phase in Peru.

COVID-19 measure	Related decree	Dates	Restrictions on the Costa Verde
1. Full lockdown	044-2020-PCM	16 Mar. - 1 Jul. 2020	No access for people and vehicles to the beachand the highway.
2. Strict partial lockdown	116-2020-PCM	2 Jul. - 22 Oct. 2020	Access was limited to weekdays only, with noaccess permitted on weekends. Pedestrians were allowed access to the highway on weekends, but not to the beaches, except for non-contact watersports (e.g. surfing, swimming).
3. Partial lockdown	170-2020-PCM and 184-2020-PCM	23 Oct - 31 Dec. 2020	Pedestrians were allowed partial access to the beach from Monday to Thursday. The highway and beaches were closed over the weekend. However, the beaches were open for non-contact water sports activities during weekdays. *25 Nov. - 23 Dec.: The highway was also openon Sundays ** 24, 25, and 31 Dec.: No public access to the highway and beaches
4. Strict partial lockdown	202-2020-PCM, 002-2021-PCM, and 008-2021-PCM	1 Jan. - 24 Feb. 2021	Access to the beaches only for non-contact watersports. The highway was only closed on Sundays from 5 am to 12.30 pm. *Second wave of COVID-19 in Perú.
5. End of lockdown	208-2020-PCM	25 Feb. 2021	Entrance to the beaches and the highway was permitted.

1

Table 2(on next page)

Size (mm), percentage of occurrence (%FO), and percentage by number (%N) of the types of user plastic found in 1447 analyzed pellets of Neotropic Cormorant, *N. brasilianus,* on the Costa Verde, Lima, Perú.

1

Plastic categories	Average size ± SD (mm)	Plastic Items (n)	Pellets with plastic items (n)	%FO From the total number of pellets	%N From the total number of items
Sheetlike	8.14 ± 7.14	24	21	1.45	1.58
Threadlike	20.08 ± 26.13	96	35	2.42	6.32
Fragments	7.67 ± 5.66	23	22	1.52	1.51

2

Table 3(on next page)

Size (mm) and frequency of occurrence (%FO) of the types of non-plastic rubbish material found in 1,447 pellets of Neotropic Cormorants *N. brasilianus* on the Costa Verde, Lima, Perú.

1

Categories of non-plastic rubbish	Average size ± SD (mm)	Non-plastic rubbish items (n)	Pellets with non-plastic rubbish items (n)	%FO from the total number of pellets
Glass	8.01 ± 3.35	3	3	0.21
Wood	13.36 ± 3.99	3	3	0.21
Metal	12.08 ± 6.62	4	4	0.28
Thread	22.46 ± 16.71	10	10	0.69
Balloon	9.71 ± 0	1	1	0.07
Paint chip	2.15 ± 0.76	2	2	0.14

2

Figure 1

Map of the study area depicting the Circuito de Playas Costa Verde (CPCV highway) and the district of Miraflores. The inset illustrates the specific section of the CPCV where the Neotropic Cormorant pellets were collected.

The inset illustrates the specific section of the CPCV where the Neotropic Cormorant pellets were collected.

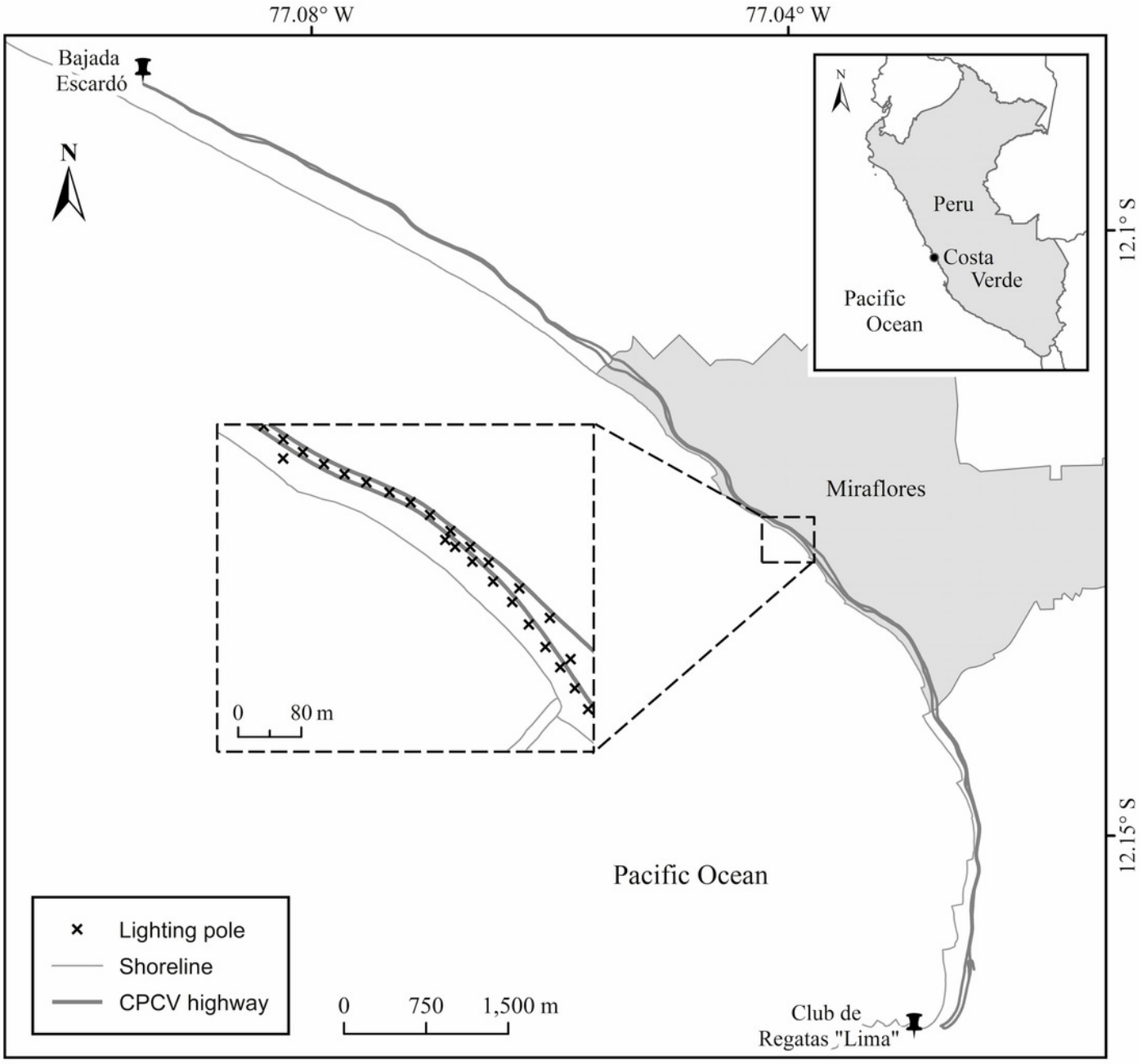
77.08° W
77.04° W
12.1° S
12.15° S
Bajada Escardó
N
Peru
Costa Verde
Pacific Ocean
Miraflores
0 80 m
Pacific Ocean
Lighting pole
Shoreline
CPCV highway
0 750 1,500 m
Club de Regatas "Lima"

Figure 2

Types of user plastic found in the pellets (N = 1447) of Neotropic Cormorants *N. brasilianus* on the Costa Verde, Lima, Perú.

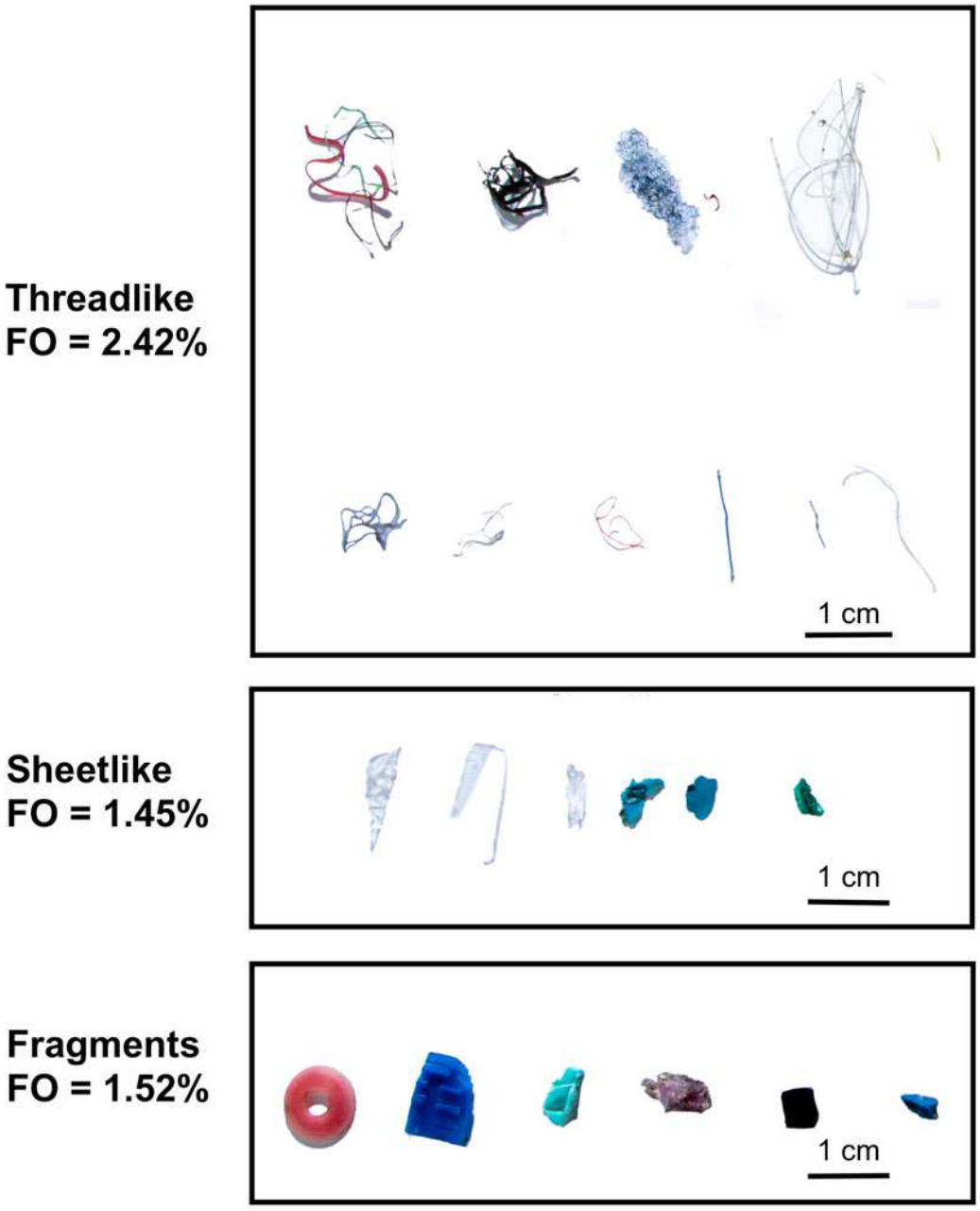

Figure 3

Types of non-plastic rubbish material found in pellets (N = 1447) of Neotropic Cormorants *N. brasilianus* on the Costa Verde, Lima-Perú

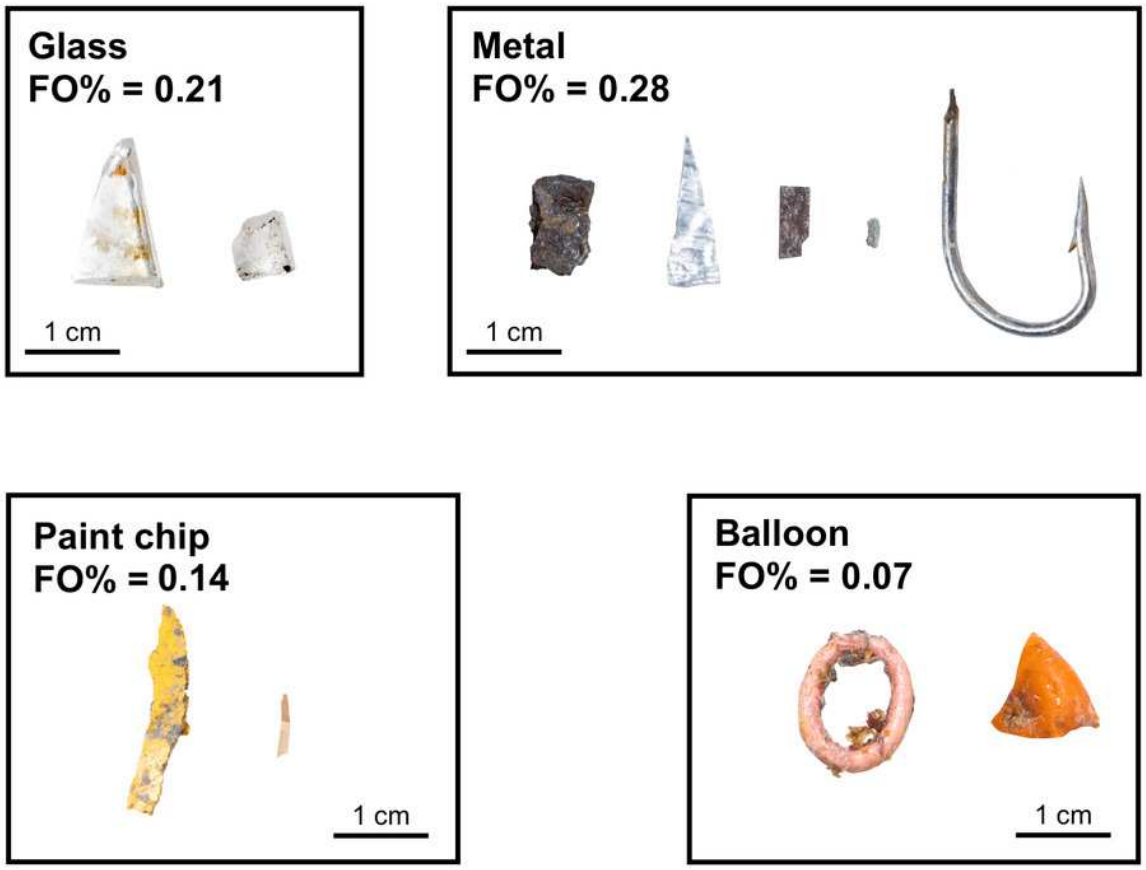

Figure 4

Percentage of occurrence of plastic in the pellets of Neotropic cormorants, *N. brasiluanus*, during the COVID-19 pre-pandemic and pandemic phases on the Costa Verde, Lima, Perú.

The top legend describes the restrictions imposed by Peruvian government authorities during the pandemic.