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FIRST GPS RECORD OF A RED-LEGGED CORMORANT OFF THE COAST OF PERU SUGGESTS PELAGIC FORAGING BEHAVIOR

Primer registro GPS de un Cormorán de Patas Rojas en la costa del Perú

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ABSTRACT: Red-legged Cormorants (*Poikilocarbo gaimardi*) are distributed along the Pacific coast of South America, from Peru to Chile, and restricted to southernmost Argentina along the Atlantic coast. Population monitoring of this species in the Pacific is scarce and research on their ecology has been limited to Argentina, where it has been considered a rocky bottom feeder, travelling distances of ~3 km away from the nest. We deployed and retrieved a GPS device on one adult Red-legged Cormorant at Punta Atico, Arequipa, Peru, in June 2018. Foraging trips of the tracked individual were on average ~6 km away from the nest and reached a maximum of 10 km. More than 50% of trips occurred in pelagic habitats and were widely dispersed around the nest. Based on the observation of this individual we suggest that in the productive Peruvian Humboldt Current System, Red-legged Cormorants may be pelagic foragers rather than benthic specialists. These results have important implications for conservation strategies aimed to protect this seabird species along the Peruvian coast.

KEYWORDS: *foraging ecology, foraging habitat, Peruvian Humboldt Current System, Red-legged Cormorant, seabird movements*

RESUMEN: Los cormoranes de patas rojas (*Poikilocarbo gaimardi*) se distribuyen a lo largo de la costa del Pacífico de América del Sur, desde Perú hasta Chile, y están restringidos a la región más austral de Argentina en la costa atlántica. Los estudios de las poblaciones de esta especie en el Pacífico son escasos y la investigación sobre su ecología se ha limitado a Argentina, donde se ha considerado que se alimenta en fondos rocosos, recorriendo distancias de aproximadamente 3 km desde el nido En junio de 2018, equipamos y recuperamos un dispositivo GPS en un cormorán de patas rojas adulto en Punta Atico, Arequipa, Perú. Los viajes de forrajeo del individuo rastreado fueron, en promedio, de aproximadamente 6 km desde el nido, alcanzando un máximo de 10 km. Más del 50% de los viajes ocurrieron en hábitats pelágicos y estuvieron ampliamente dispersos alrededor del nido. Basados en la observación de este individuo sugerimos que, en el productivo Sistema de la Corriente Peruana del Humboldt, los cormoranes de patas rojas pueden ser forrajeadores pelágicos en lugar de ser especialistas bentónicos. Estos resultados tienen importantes implicaciones para las estrategias de conservación dirigidas a proteger esta especie de aves marina en la costa peruana.

PALABRAS CLAVE: *Cormorán Patas Rojas, ecología de forrajeo, hábitat de forrajeo, movimientos de aves marinas, Sistema de la Corriente Peruana de Humboldt*

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Red-legged Cormorants *Poikilocarbo gaimardi* (Lesson & Garnot 1828) are dispersed in small numbers along much of the southern coast of South America, with a disjunct distribution from northern Peru (5°12'44.34"S, 81°12'0.95"W) to southern Chile (46°44'41.00"S, 75°10'54.24"W) in the Pacific, and from northern Argentina (45° 5'14.11"S, 65°34'21.10"W) to southern Argentina in the Atlantic (52°16'48.04"S, 68°25'30.17"W) (Frere & Millones 2021). They breed on rocky inaccessible cliffs along coastlines and are usually considered as rocky bottom feeders (Gandini et al. 2005) and short distance fliers, with a mean flight distance of ~1.9 kms from the nesting site and a maximum of 4.1 kms (Gandini et al. 2005; Frere et al. 2008).

Extensive research on Red-legged Cormorants has taken place mainly in Ría Deseado, Argentina, where birds exploited the resources inside Ría Deseado and near their colony (Gandini et al. 2005; Frere et al. 2008). More recent evidence indicates they prey almost exclusively on pelagic prey, with a diet including Patagonian sprat (*Sprattus fuegensis*), a small high-energy-content pelagic forage fish, and Patagonian squid (*Doryteuthis gahi*), a demersal - pelagic invertebrate (Morgenthaler et al. 2016, 2025).

There has been little published on the ecology and behaviour of Reg-legged Cormorants along the Pacific coast of South America. Most information about the species has focused on distribution and population sizes (Zavalaga et al. 2002; Barros et al. 2014), breeding biology (Vilina & Gonzalez 1995), and nest descriptions (Garcia-Cegarra et al. 2020; Meza-Chuquizuta et al. 2024), even though the distribution of Red-legged Cormorants off the Peruvian coast encompasses about seven times the stretch they inhabit along the Atlantic coast (Zavalaga et al. 2002; Frere & Millones 2021). Given their disjunct distribution, ecology, adaptations to resources, potential environmental changes, as well as human and natural disturbances that could vary significantly, there is an urgent need for more research on this species. Additionally, the Peruvian Humboldt Current Upwelling System sustains an abundance of Peruvian anchovy (*Engraulis ringens*) (Crawford & Jahncke 1999; Jahncke et al. 2004; Frere et al. 2004), a common and high-quality prey for many seabirds (Crawford & Jahncke 1999; Jahncke et al. 2004). Because this species forages mostly on pelagic prey in the Atlantic (Morgenthaler et al. 2016, 2025), it is likely that Red-legged Cormorants in the Pacific also exploit such prey, and would forage into more pelagic habitats. Given that previous studies relied on radio telemetry, using GPS loggers would provide a more comprehensive understanding of this species' movements, capturing trips that extend beyond the detection range and lower resolution of radio telemetry.

METHODS

We captured one egg-brooding Red-legged Cormorant on 12 February 2018 and two chick-rearing adults on 20 June 2018 at Punta Atico, Peru (16.233°S, 73.696°W) and fitted them with GPS devices (i-gotU GT-120B GPS, MobileAction, ~20g with attachments) set to record locations at 1-minute intervals. The first bird did not return to the nest after deployment. The two other birds returned to their nest shortly after deployment. All birds were captured with a pole and noose at accessible nests, and the location allowed us to be concealed from the view of the birds to facilitate capture. On 22 June 2018 we recaptured one bird and retrieved the GPS device. The third bird proved difficult to recapture, so we decided not to disturb it further and allow it to successfully brood the hatchlings.

After retrieval, GPS data of the one individual were downloaded and processed using R (R Core Team 2024). We calculated the distance between each GPS fix using the *distance* function from the package terra (Hijmans et al. 2023). We also calculated speed and interval between fixes to detect any time gaps between GPS fixes. After careful examination of the raw tracks, we defined a trip as all movement away from the nest for more than 0.6 km (producing a total of 16 raw trips), to avoid obvious location fix error due to lack of satellite reception by the device given the rocky walls of the nest location. We then calculated metrics for each trip: maximum distance from the nest, total trip duration, total trip path, and maximum speed per trip. We excluded from summary calculations some "unclear" trips that had less than 6 GPS fixes (5 trips, data still shown in Figure 1 as black points), given potential satellite errors explained above. We also excluded one trip that had too many gaps (1 southbound trip, data shown in the Figure 1 as points only). Because Red-legged Cormorant trips were generally short (especially beach trips, see Results), we added 1.2 km to all total path length results per trip, to account for the "trip buffer" of 0.6 km away from the nest mentioned above. We used a simple filter to select apparent foraging locations defined as little to no movement away from the colony while at sea, by selecting all slow speed intervals (< 10 km/h) for any locations during a trip away from the nest (> 0.9 km); given that cormorants are pursuit

divers and should go underwater to look for fish, they may remain in one position or slightly displace themselves according to the GPS fixes (and potential error) (Bracis et al. 2015; Bennison et al. 2018). We produced a kernel density of these foraging locations using the function *kernelUD* from the adehabitatHR package (Calenge & Fortmann-Roe 2024). Parameters for the kernel were used as default settings with a grid of 60 and estimation of the smoothing parameter was the ad hoc method ("href").

RESULTS

This Red-legged Cormorant made several foraging trips per day (3-5) with an average maximum distance from the nest of 5.63 km (2.26 - 10, SE = 0.96, for a total of 11 trips). Maximum flying speed per trip was 54.62 km/h on average (Table 1). Interestingly, the bird repeatedly returned to a beach's surf zone each morning (we identified the area after inspection of satellite images as the wave break or surf zone of the beach, at 2.26 km from the nest, see Figure 1) presumably to groom or bathe, but we cannot discard foraging activity. Additionally, we detected a cluster of points that could represent flights away from the nest of short durations (1-3 minutes, 1-4 GPS fixes) also in early morning hours (see small cluster of points north of the nest location in Figure 1) but were excluded from the trip classification due to uncertainty of the locations and given the slow speeds detected and low number of GPS fixes. The Red-legged Cormorant left the nest as early as 6:10 and 6:40 AM and returned to the nest as late as 4:15 and 4:30 PM.

Potential foraging areas as determined by the kernel density (Fig. 2) are consistent with the maximum distance of long trips (mean long trip =7.86 km, SE = 0.505, range = 6.4 - 10.0 km, n = 6, excluding beach trips) and within a circle of 3 to 6 km away from the colony (Fig. 2, black and blue circles), and even farther away on one trip. The tracked individual showed movement patterns toward deeper water away from the coast, and with distances away from the nest farther than expected and previously recorded (Frere et al. 2008), mean of 1.9 and max of 4.1 km).

DISCUSSION

The equipped Red-legged Cormorant showed an unusual and very diverse range of foraging locations all around the nest/breeding site, which is quite remarkable for a species considered a benthic feeder along the Pacific and Atlantic coasts, and that is known to make short foraging trips in Argentina. In Peru, the Red-legged Cormorant and the Guanay Cormorant (*Leucocarbo bougainvilliorum*) can be found inhabiting the same guano islands and headlands. Previously, these two species appeared to exhibit distinct foraging strategies: Guanay Cormorants were considered pelagic feeders, foraging in large aggregations (flocks), whereas Red-legged Cormorants were considered benthic feeders, typically hunting alone or in small groups (Duffy 1983). However, based on this study, it is possible that Red-legged Cormorants may be pelagic feeders as well, exploiting common pelagic prey of Guanay Cormorants, the Peruvian anchovy (Zavalaga & Paredes 1999). Additionally, on average our individual flew shorter distances but reached faster speeds than sympatric Guanay Cormorants (Weimerskirch et al. 2012). On the other hand, Red-legged Cormorants in the Atlantic have now been described to forage on pelagic prey (Morgenthaler et al. 2016, 2025), which may be the case also in Peruvian Red-legged Cormorants given the potential foraging locations away from the rocky shores (Fig. 2).

Moreover, other benthic-feeding species tend to forage at a limited number of sites, such as Pelagic Cormorants (*Urile pelagicus*), or show high repeatability as in Great Cormorants (*Phalacrocorax carbo*) (Kot-

Table 1. Metrics of classified trips for the tracked Red-legged Cormorant at Punta Atico in 2018, considering trips with no significant gaps in GPS fixes (1 southbound trip and trips with less than 6 fixes) and of more than 0.6 km away from the nest (n = 10). Calculations do not include initially classified trips which may be potential device error (less than 6 GPS fixes).

Trip metric	Mean	SE	Min.	Max.
Total trip duration (minutes)	40.36	7.60	7.40	69.98
Maximum flying speed (km/h)	54.65	0.77	51.29	59.18
Maximum distance from nest (km)	5.63	0.96	2.26	10.02
Total path length (km)	13.11	2.34	4.75	21.69
Total trip duration (hours)	0.67	0.13	0.12	1.17

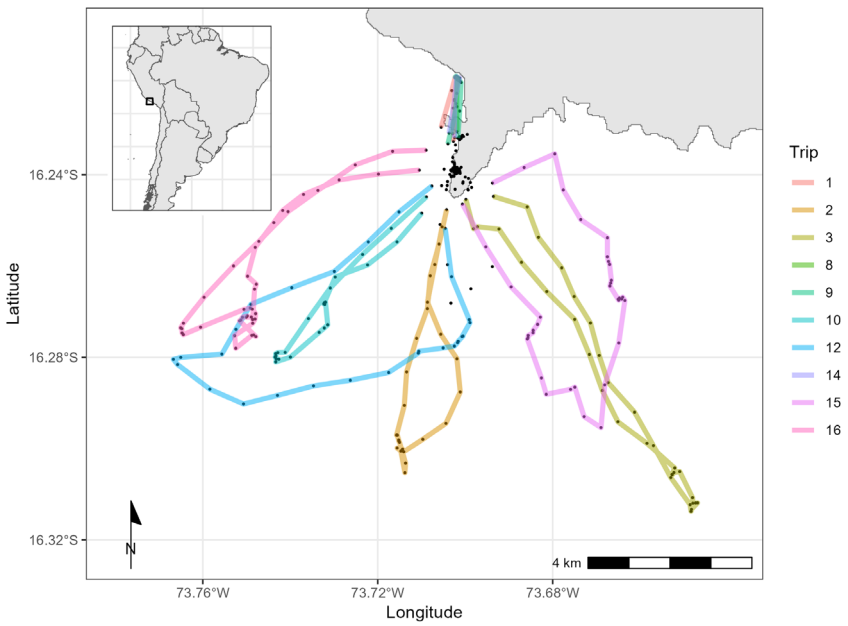

Figure 1. Foraging trips and raw GPS locations of a Red-legged Cormorant tracked at Punta Atico during February 2018. Colors represent complete classified trips with more than 6 GPS fixes and no significant gaps. Main cluster of points represents nest location.

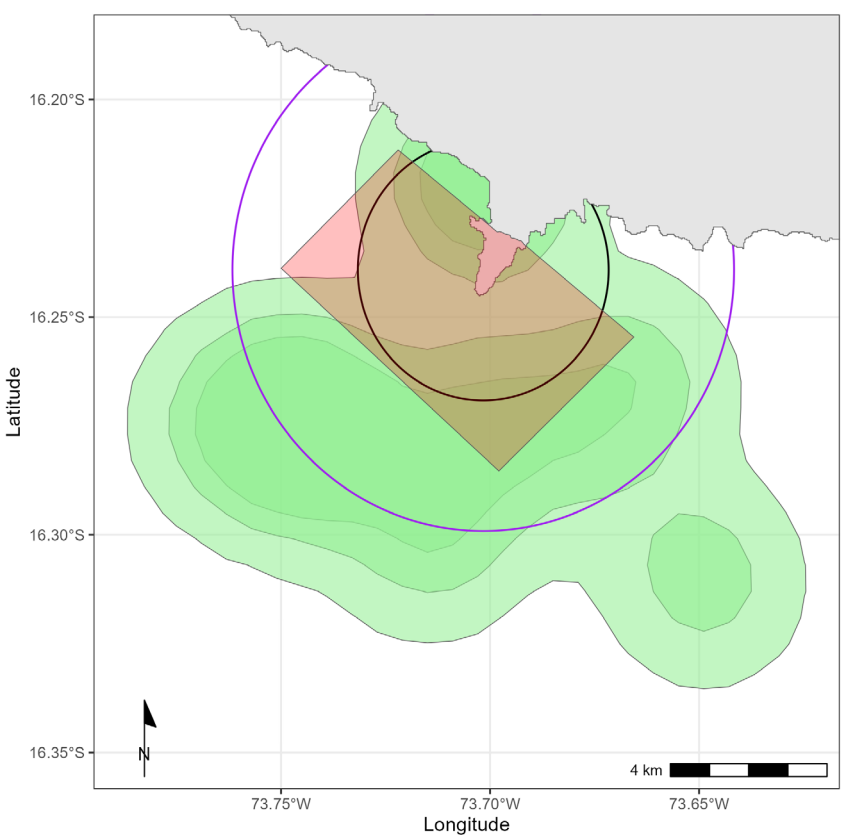

Figure 2. Foraging density areas defined with locations of a Red-legged Cormorant tracked at Punta Atico during February 2018. Outlines, transitioning from darker to lighter green areas represent 95, 70, and 50th percentile kernel probability of locations classified as foraging (speeds slower than 10 km/h and more than 0.9 km away from the nest). Black and blue circles represent 3 and 6 km radius from the nest, respectively. Red polygon represents extent of protection under the Reserva Nacional Sistema de Islas, Islotes y Puntas Guaneras (RNSIIPG-SERNANP).

zerka et al. 2011; Potier et al. 2015). In comparison to other more pelagic species like Cape Cormorants (*Phalacrocorax capensis*) that perform longer foraging trips than Red-legged Cormorants, Cape Cormorants have a tendency to forage along the coastline and make short trips of 7 km on average (Ryan et al. 2010; Hamann et al. 2012), unlike what we see in this Red-legged Cormorant.

Red-legged Cormorants in Peru inhabit many rocky islands, islets, and cliffs within and outside the jurisdiction of Reserva Nacional Sistema de Islas, Islotes y Puntas Guaneras, which protects the sea around the 33 islands and headlands up to 2 nautical miles. They are listed as Near Threatened in the IUCN Red List (IUCN, 2025) and Endangered under Peruvian classification (SERFOR 2018). Our new tracking results indicate that Red-legged Cormorants, like many seabird species along the Pacific coast of Peru, travel several times a day farther away than the standard 2 nm-protection buffer (see polygon in Fig. 2). This may be an important consideration for management of the species. Additionally, many locations where Red-legged Cormorants nest along the Peruvian coast lack any protection whatsoever, increasing the risks this species faces under habitat degradation, both marine and terrestrial, and fisheries interactions. Additionally, the foraging trips recorded with an offshore direction, pose a new concern about the potential use of pelagic prey by this species and the interaction with open water coastal fisheries and the effects of warming events on pelagic foraging grounds. Further research on diet composition, diving depths, and more tracking data are necessary to better understand the foraging ecology of this species on the Pacific coast, especially off Peru where protection efforts on marine habitats are important.

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REFERENCES

Barros R, Norambuena HV, Raimilla V (2014) Breeding Population of Red-Legged Cormorant (*Phalacrocorax gaimardi*) along the Araucania Region Coast, South-Central Chile. *cowa* 37:331–334. doi: 10.1675/063.037.0311

Bennison A, Bearhop S, Bodey TW, Votier SC, Grecian WJ, Wakefield ED, Hamer KC, Jessopp M (2018) Search and foraging behaviors from movement data: A comparison of methods. *Ecology and Evolution* 8:13–24. doi: 10.1002/ece3.3593

Bracis C, Gurarie E, Moorter BV, Goodwin RA (2015) Memory Effects on Movement Behavior in Animal Foraging. *PLOS ONE* 10:e0136057. doi: 10.1371/journal.pone.0136057

Calenge C, Fortmann-Roe S (2024) adehabitatHR: Home Range Estimation

Crawford RJM, Jahncke J (1999) Comparison of trends in abundance of guano-producing seabirds in Peru and southern Africa. *South African Journal of Marine Science* 21:145–156. doi: 10.2989/025776199784126006

Duffy DC (1983) The Foraging Ecology of Peruvian Seabirds. *The Auk* 100:800–810. doi: 10.1093/auk/100.4.800

Frere E, Gandini P, Ruiz J, Vilina YA (2004) Current status and breeding distribution of Red-legged Cormorant *Phalacrocorax gaimardi* along the Chilean coast. *Bird Conservation International* 14:113–121. doi: 10.1017/S0959270904000139

Frere E, Millones A (2021) Red-legged Cormorant (*Poikilocarbo gaimardi*), version 1.1. Birds of the World. doi: 10.2173/bow.relcor1.01.1species_shared.bow.project_name

Frere E, Quintana F, Gandini P, Wilson RP (2008) Foraging behaviour and habitat partitioning of two sympatric cormorants in Patagonia, Argentina. *Ibis* 150:558–564. doi: 10.1111/j.1474-919X.2008.00824.x

Gandini P, Frere E, Quintana F (2005) Feeding Performance and Foraging Area of the Red-Legged Cormorant. *Waterbirds: The International Journal of Waterbird Biology* 28:41–45

Garcia-Cegarra AM, Ramirez R, Orrego R (2020) Red-legged cormorant uses plastic as nest material in an artificial breeding colony of Atacama Desert coast. *Marine Pollution Bulletin* 160:111632. doi: 10.1016/j.marpolbul.2020.111632

Hamann M, Grémillet D, Ryan P, Bonadonna F, Van Der Lingen C, Pichegru L (2012) A hard-knock life: the foraging ecology of Cape cormorants amidst shifting prey resources and industrial fishing pressure. *African Journal of Marine Science* 34:233–240. doi: 10.2989/1814232X.2012.709960

Hijmans RJ, Roger Bivand, Emanuele Cordano, Krzysztof Dyba, Edzer Pebesma, Michael D. Sumner (2023) terra: Spatial Data Analysis

Jahncke J, Checkley DM, Hunt GL (2004) Trends in carbon flux to seabirds in the Peruvian upwelling system: effects of wind and fisheries on population regulation. *Fisheries Oceanogr* 13:208–223. doi: 10.1111/j.1365-2419.2004.00283.x

Kotzerka J, Hatch SA, Garthe S (2011) Evidence for Foraging-Site Fidelity and Individual Foraging Behavior of Pelagic Cormorants Rearing Chicks in the Gulf of Alaska. *The Condor* 113:80–88. doi: 10.1525/cond.2011.090158

Meza-Chuquizuta C, Zavalaga CB, Lozano-Sanllehi S, Gonzales-DelCarpio DD (2024) Prevalence of plastic debris in nests of two cormorant species in Peru. *Marine Pollution Bulletin* 205:116601. doi: 10.1016/j.marpolbul.2024.116601

Morgenthaler A, Millones A, Gandini P, Frere E (2016) Pelagic or benthic prey? Combining trophic analyses to infer the diet of a breeding South American seabird, the Red-legged Cormorant, *Phalacrocorax gaimardi*. *Emu - Austral Ornithology* 116:360–369. doi: 10.1071/MU15101

Morgenthaler A, Millones A, Gandini P, Procopio D, Frere E (2025) Sympatric seabirds: exploring multidimensional niche partitioning among four cormorant species. *Marine Ecology Progress Series* 752:169–186. doi: 10.3354/meps14751

Potier S, Carpentier A, Grémillet D, Leroy B, Lescroël A (2015) Individual repeatability of foraging behaviour in a marine predator, the great cormorant, *Phalacrocorax carbo*. *Animal Behaviour* 103:83–90. doi: 10.1016/j.anbehav.2015.02.008

R Core Team (2024) R: A Language and Environment for Statistical Computing

Ryan PG, Pichegru L, Ropert-Coudert Y, Grémillet D, Kato A (2010) On a wing and a prayer: the foraging ecology of breeding Cape cormorants. *Journal of Zoology* 280:25–32. doi: 10.1111/j.1469-7998.2009.00637.x

SERFOR (2018) Libro Rojo de la Fauna Silvestre Amenazada del Perú, Primera edición. SERFOR (Servicio Nacional Forestal y de Fauna Silvestre), Lima, Perú

Vilina YA, Gonzalez JL (1995) Observations of breeding red-legged cormorants *Phalacrocorax gaimardi* in the north of Chile. *Marine Ornithology* 22:247–250

Weimerskirch H, Bertrand S, Silva J, Bost C, Peraltilla S (2012) Foraging in Guanay cormorant and Peruvian booby, the major guano-producing seabirds in the Humboldt Current System. *Mar Ecol Prog Ser* 458:231–245. doi: 10.3354/meps09752

Zavalaga CB, Frere E, Gandini P (2002) Status of the Red-Legged Cormorant in Peru: What Factors Affect Distribution and Numbers? *Waterbirds: The International Journal of Waterbird Biology 25:8–15*

Zavalaga CB, Paredes R (1999) Foraging behaviour and diet of the guanay cormorant. *South African Journal of Marine Science* 21:251–258. doi: 10.2989/025776199784125980