Tracking Humboldt penguins on Isla Choros

Reserva Nacional Pingüino de Humboldt, Chile

25 November – 17 December 2022

Fieldwork Report

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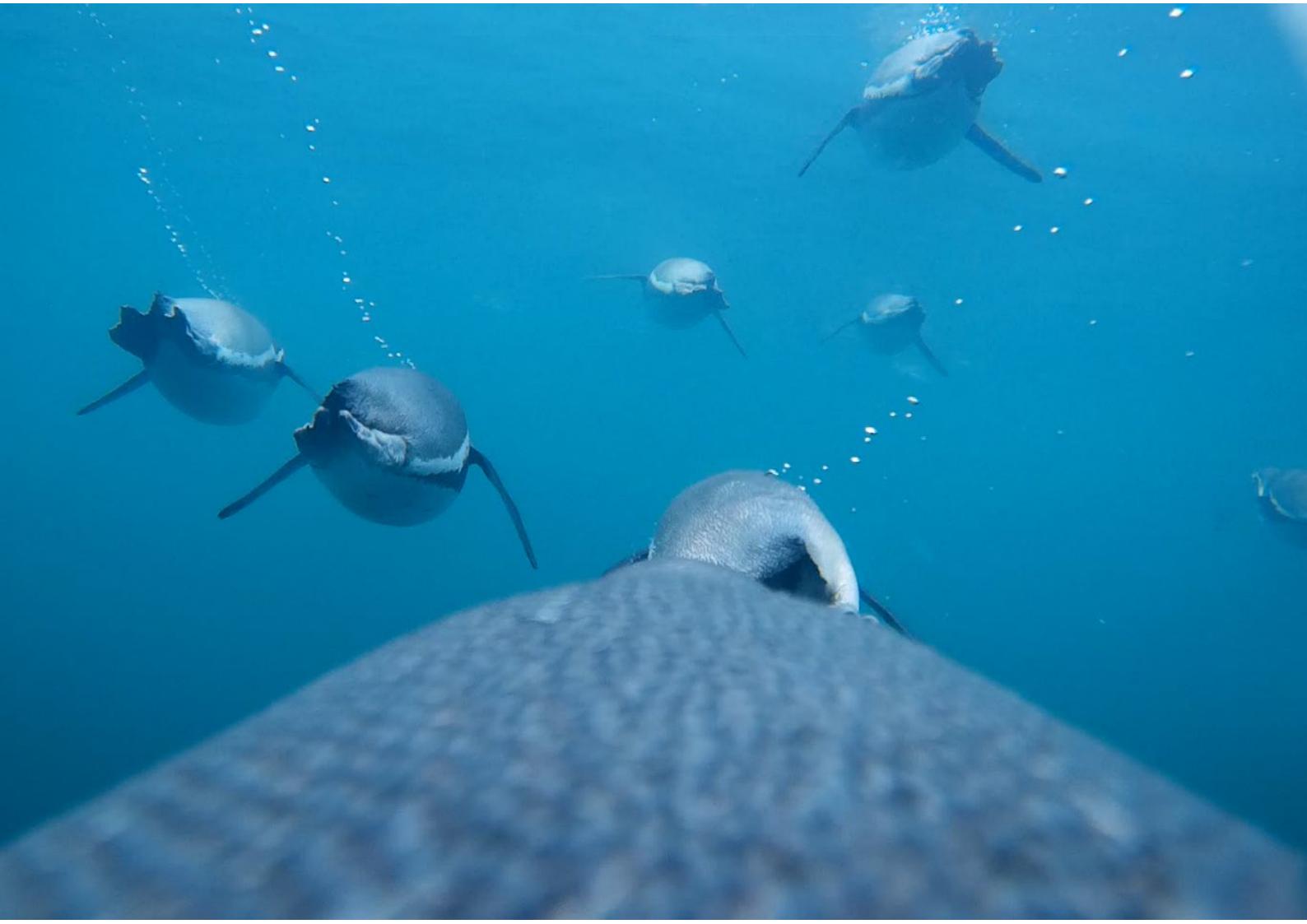

Fieldwork Report
25 November – 17 December 2022

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Project: **Tracking Humboldt Penguins on Isla Choros, Chile**

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Contents

Title page - Photo (over shoulder of Aji); Header – Photo (over shoulder of Pasta) taken with PenguCams programmed and deployed by Ursula Ellenberg and Maximilliano Daigre.

Highlights of a PenguCam deployed on Humboldt penguin female Pasta observed foraging collaboratively over several hours can be watched here, video compiled by Thomas Mattern.

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Executive Summary

From 25 November to 17 December 2022, our small team stayed on Isla Choros, Reserva Nacional Pingüino de Humboldt, Chile, to study at-sea distribution and diving behaviour as well as obtain preliminary data on prey choice of breeding Humboldt penguins *Spheniscus humboldtii*. The core work was performed by Maximiliano Daigre Valdés and Ursula Ellenberg with some help by Karen Lau Alarcon during the first week of fieldwork.

(1) During our stay on the island, we mapped a total of 381 active Humboldt penguin nests. As in previous years, greatest nest densities were found in the north and the east of the island. Still, compared with the penguin nesting densities Ursula remembers from working on Isla Choros during 2001-2003, Humboldt penguin numbers particularly in the northern and eastern breeding areas have considerably declined over the past 20 years.

(2) Nests of the 12 individuals marked during the winter tracking period (compare June 2022 fieldwork report) were revisited. We found seven of the nests active and in five cases could confirm one individual marked on the respective nest in June as one of the pair encountered in November. This is the first evidence of Humboldt penguins breeding twice a year at the Humboldt Penguin National Reserve.

(3) We marked a further 16 penguins with transponders (Trovan, 11mm). Of these 13 birds (8 females, 5 males) were fitted with GPS dive data loggers (AxyTrek, TechnoSmart, Italy, https://www.technosmart.eu/) that record geographic position (via GPS receiver, recorded every 1 minute) and dive data (via pressure sensor, recorded every 1 second).

(4) In addition, we deployed 6 penguins (by chance all females) with high-definition video cameras (PenguCam, New Zealand, https://pengu.cam/) in combination with smaller dive data loggers (AxyDepth, TechnoSmart, Italy, https://www.technosmart.eu/). Three of these birds carried a GPS logger following PenguCam retrieval, the other three were deployed with PenguCams only that were not followed up with GPS loggers when the PenguCam was retrieved; one due to difficult access of the nest and the remaining two due to the arrival of avian influenza in Chile that was threatening to cut our planned fieldwork short.

(5) Logger deployments yielded GPS and dive data for 12 birds (7 females, 5 males), and dive data for the 6 birds deployed with PenguCams representing 736 hours of at-sea time spread over 41 different single-day, 2 two-day foraging trips, and one brief evening trip (38 from GPS loggers, 6 from dive loggers deployed in conjunction with the PenguCams).

A total of 16,562 GPS positions as well as 24,320 dives events were recorded. Some birds achieved maximum dive depths of up to 100m, however, most birds focussed their efforts shallower with a median maximum dive depth of 65m. The median dive distance between two consecutive GPS fixes was 99m with up to 150m observed. Birds achieved median horizontal travel speeds of 1m/s and travelled on average 43.9km during their foraging trip (range 3.7km-77.2km). Most foraging activity took place within 10km of Isla Choros with some birds ranging up to 30km away. The comparably short foraging ranges are likely a result of the productive marine environment around the Humboldt Penguin National Reserve during La Niña with good food availability close to the island.

(6) The six video loggers deployed were all successfully retrieved and provided 23.5 hours of high-definition video footage that is yet to be analysed. Preliminary results show that while some birds foraged solitary and exclusively pelagically often near the surface for fish larvae or small forage fish and squid, other birds preferred to forage in groups of more than 50 individuals herding demersal fish. This behaviour has not yet been observed in Humboldt penguins and leads to much higher risk of bycatch mortality, since a single net could catch an entire group of birds hunting together.

(7) One female was deployed with a GPS logger on 10 December and last seen via surveillance camera leaving her nest on 12 December. Subsequent nest checks only encountered her partner attending two chicks that were still alive during our last check on 17 December. It is unlikely that a bird previously doing predictable one-day foraging trips (observed via surveillance camera since 4 December) would suddenly embark on a trip of more than 5 days, especially given the excellent foraging conditions close to the island. Thus, it is likely that this bird has perished taking the logger with her. Algeros and fishers operating in Punta Choros as well as CONAF staff have been informed in case the bird has been retrieved from a net or gets washed ashore.

(8) In the Appendix we provide a (A) Table of all 28 Humboldt penguins marked with transponders during our work on Isla Choros so far; (B) an overview table of the preliminary analysis of dive parameters; (C) list of all bird species observed during our stay; as well as miscellaneous observations of (D) a vampire bat exploring an active Humboldt penguin nest containing two chicks; (E) Inca terns *Lacosterna inca* entering/exiting (nesting?) an abandoned Yunco *Pelecanoides garnotii* burrow at the southern colony.

Resumen

Del 25 de noviembre al 17 de diciembre de 2022, nuestro pequeño equipo permaneció en Isla Choros, Reserva Nacional Pingüino de Humboldt, para estudiar la distribución en el mar y el comportamiento de buceo, así como obtener datos preliminares sobre la elección de presas de los pingüinos de Humboldt (*Spheniscus humboldti*) en reproducción. El trabajo central fue realizado por Maximiliano Daigre Valdés y Ursula Ellenberg con la colaboración de Karen Lau Alarcón durante la primera semana de trabajo en la isla.

(1) Durante nuestra estadía en la isla mapeamos un total de 381 nidos activos de pingüinos de Humboldt. Como los años anteriores, las mayores densidades de nidos se encontraron en el norte y este de la isla. Aún así, en comparación con las densidades de nidificación de pingüinos que Ursula recuerda de su trabajo en Isla Choros durante 2001-2003, el número de pingüinos de Humboldt, particularmente en las áreas de reproducción del norte y el este, ha disminuido considerablemente en los últimos 20 años.

(2) Se volvieron a visitar los nidos de los 12 individuos marcados durante el periodo de seguimiento invernal (compárese con el informe de trabajo de terreno de junio de 2022). Encontramos siete de los nidos activos y en cinco casos pudimos confirmar un individuo marcado en el mismo nido en junio como uno de la pareja encontrada en noviembre. Esta es la primera prueba de que los pingüinos de Humboldt se reproducen dos veces en el año en la Reserva Nacional Pingüino de Humboldt.

(3) Marcamos otros 16 pingüinos con transpondedores (Trovan, 11mm). A 13 de estas aves (ocho hembras, cinco machos) se les instalaron registradores de datos (*data loggers*) de inmersión GPS (AxyTrek, TechnoSmart, Italia, https://www.technosmart.eu/) que registran la posición geográfica (mediante un receptor GPS, grabando cada un minuto) y los datos de inmersión (mediante sensor de presión, grabando cada un segundo).

(4) Además, equipamos seis pingüinos (todas hembras) con cámaras de vídeo de alta definición (PenguCam, Nueva Zelanda, https://pengu.cam/) en combinación con pequeños registradores de datos de inmersión (AxyTrek, TechnoSmart, Italia, https://www.technosmart.eu/). Tres de estas aves llevaron un registrador de datos de inmersión GPS después de la recuperación de la PenguCam, las otras tres se equiparon solo con las PenguCam y no fueron seguidas con un registrador de datos GPS cuando se recuperó la PenguCam; uno debido al difícil acceso al nido y los dos restantes por

dificultades logísticas asociadas con la llegada de la influenza aviar a Chile que amenazaba con truncar nuestro planificado trabajo de campo.

(5) Los despliegues de los registradores proporcionaron datos de inmersión y GPS de 12 aves (siete hembras, cinco machos), y los datos de inmersión para las seis aves desplegadas con PenguCams representaron 736 horas de tiempo en el mar repartidas en 41 viajes de búsqueda de alimento de un solo día, dos de dos días, y un viaje corto durante la tarde (38 de los registradores GPS, 6 de los registradores de inmersión equipados junto con las PenguCams). Se registraron un total de 16.562 posiciones GPS, así como 24.320 eventos de inmersión. Algunas aves alcanzaron profundidades máximas de inmersión de hasta 100m, sin embargo, la mayoría de las aves concentraron sus esfuerzos a menor profundidad con una profundidad máxima de inmersión media de 65m. La distancia media de inmersión entre dos posiciones de GPS consecutivas fue de 99m, observándose hasta 150m. Las aves alcanzaron velocidades de desplazamiento horizontal medianas de 1m/s y recorrieron una distancia mediana de 43.9km (rango 3.7km-77.2km). La mayor parte de la actividad de alimentación tuvo lugar dentro de los 10 km de la Isla Choros con algunas aves que recorrieron hasta 30 km de distancia. Los rangos de alimentación comparativamente cortos son probablemente el resultado del ambiente marino productivo alrededor de la Reserva Nacional Pingüino de Humboldt durante "La Niña" con buena disponibilidad de alimento cerca de la isla.

(6) Los seis registradores de video desplegados se recuperaron con éxito y proporcionaron 23,5 horas de imágenes de video de alta definición que aún no se han analizado. La evidencia preliminar sugiere que mientras algunas aves se alimentaban solitaria y exclusivamente pelágica a menudo cerca de la superficie por pequeños o juveniles peces y calamares, otras aves prefieren forrajear en grupos de más de 50 individuos arreando peces demersales. Esto nunca se había observado antes en pingüinos de Humboldt y conlleva un riesgo mucho mayor de mortalidad por capturas incidentales, ya que una sola red podría atrapar a todo un grupo de aves cazando juntas.

(7) Una hembra fue desplegada con un registrador GPS el 10 de diciembre y fue vista por última vez a través de una cámara de vigilancia saliendo de su nido el 12 de diciembre. En posteriores revisiones del nido sólo se encontró a su pareja atendiendo a dos pollos que seguían vivos durante nuestro último chequeo el 17 de diciembre. Es poco probable que un ave que anteriormente realizaba predecibles viajes de alimentación de un día

(observada mediante cámara de vigilancia desde el cuatro de diciembre) se embarcara de repente en un viaje de más de cinco días, especialmente dadas las excelentes condiciones de búsqueda de alimento cerca de la isla. Por tanto, es probable que esta ave haya perecido llevándose el registrador de datos con ella. Algueros y pescadores que operan en Punta de Choros, así como el personal de conaf, han sido informados en caso de que el ave haya sido recuperada en una red o sea arrastrada hasta la orilla.

(8) En el Apéndice proporcionamos una (A) tabla de los 28 pingüinos de Humboldt marcados con transpondedores durante nuestro trabajo en Isla Choros hasta el momento; (B) una tabla general del análisis preliminar de los parámetros de buceo; (C) lista de todas las especies de aves observadas durante nuestra estadía; así como observaciones misceláneas de (D) un murciélago vampiro (*Desmodus rotundus*) explorando un nido activo de pingüinos de Humboldt con dos pollos; (E) gaviotines monja *Lacosterna inca* entrando/saliendo (¿nidificando?) en nidos/cavidades abandonadas de yuncos *Pelecanoides garnotii* en la colonia sur.

Zusammenfassung

Vom 25 November bis zum 17 Dezember 2022, arbeitete unser Team auf „Isla Choros“, einer der drei Inseln im Humboldt Pinguin National Schutzgebiet in Chile, um die Nahrungsökologie von Humboldt Pinguinen *Spheniscus humboldti* sowie ihre Verbreitung auf See zu erforschen. Die Forschung wurde von Maximiliano Daigre Valdés und Ursula Ellenberg durchgeführt. Karen Lau Alarcon half gelegentlich während der ersten Woche der Feldarbeiten.

(1) Während unseres Aufenthaltes auf der Insel kartierten wir 381 aktive Humboldt Pinguin Nester. Wie erwartet, aus Erfahrung in vorherigen Jahren, wurde die größte Nestdichte im Norden und Osten der Insel festgestellt. Verglichen mit den erwarteten Nestdichten basierend auf Dr Ellenbergs Forschungsarbeiten im Schutzgebiet während der Sommer Brutsaisons 2001-2003, ist die Zahl an Pinguinen in den vergangenen 20 Jahren erheblich zurückgegangen.

(2) Die Nester der 12 während der Forschungsarbeiten im Winter markierten Pinguine (vergleiche Report der Feldarbeit im Juni 2022) wurden erneut aufgesucht. Wir fanden sieben der Versuchsnester aktiv und konnten in fünf Fällen nachweisen, dass der zugehörige markierte Vogel erneut einer der beiden Partner war. Dies ist der erste Nachweis, dass Humboldt Pinguine hier zweimal im Jahr brüten können.

(3) Während dieser Studie markierten wir weitere 16 Pinguine mit Transpondern (Trovan, 11mm). Von diesen wurden 13 Vögel (8 Weibchen und 5 Männchen) mit GPS Tauchloggern ausgerüstet (AxyTrek, TechnoSmart, Italy, https://www.technosmart.eu/). Die Geräte speichern die geographische Position (via GPS Antenne, einmal in der Minute) und Tauchdaten (via Drucksensor, jede Sekunde).

(4) Zusätzlich rüsteten wir 6 Pinguine (alles Weibchen) mit hoch-auflösenden Videokameras aus (PenguCam, New Zealand, https://pengu.cam/) in Kombination mit kleineren Tauchloggern (AxyDepth, TechnoSmart, Italy, https://www.technosmart.eu/). Drei der Vögel wurden beim Entfernen der PenguCam mit einem GPS Logger versehen, die restlichen drei wurden nach Bergung der PenguCams ohne Logger wieder freigelassen; in einem Nest war der Zugang zu schwierig für ein sinnvolles Einsetzen eines GPS Loggers, von der Ausrüstung der beiden anderen Vögel wurde abgesehen, als uns bekannt wurde, dass die Vogelgrippe nun auch in Chile ausgebrochen war, und wir uns auf eine mögliche schnelle Abreise von der Insel vorbereiten sollten.

(5) Zwölf Vögel (7 Weibchen, 5 Männchen) brachten gute GPS- und Tauchdaten wieder und alle sechs PenguCams konnten mit Video und zugehörigen Tauchdaten geborgen werden. Daraus resultierende Daten umfassen 736 Stunden auf See verteilt auf 41 Tagestouren, zwei Übernachttouren und einem kurzen Abendausflug (38 von GPS Loggern, 6 von PenguCam/Tauchloggern). Insgesamt wurden 16.562 GPS Positionen wie auch 24.320 Tauchgänge registriert. Einige Vögel erreichten Tauchtiefen von bis zu 100m, die meisten Pinguine aber tauchten weniger tief (Median maximale Tauchtiefe 65m) und verbrachten einen Grossteil ihrer Nahrungssuche oberflächennah. Die Vögel erreichten horizontale Reisegeschwindigkeiten von 1m/s und legten im Durchschnitt 43.9km während eines Beutezuges zurück. Der Fokus der Nahrungssuche fand im Umkreis von 10km von der Insel statt, auch wenn einige Vögel sich bis zu 30km von der Insel entfernten. Diese relativ geringen Distanzen können wahrscheinlich auf das während La Niña extrem produktive Meeresgebiet direkt um die Insel zurückgeführt werden.

(6) Die sechs Videologger wurden alle erfolgreich geborgen und lieferten insgesamt 23,5h Material, das derzeit noch ausgewertet wird. Erste Sichtungen zeigen, dass obwohl Pinguine oft solitär, pelagisch und oberflächennah nach Fischlarven, kleinen Fischen und Kalmaren jagten, arbeiteten drei der Vögel mit gelegentlich ueber 50 Artgenossen zusammen, um benthische Schwarmfische zu jagen. Dieses Verhalten ist bislang noch nicht beobachtet worden und erhöht das Beifangrisiko erheblich: Ein einziges Stellnetz könnte somit eine ganze Gruppe gemeinsam jagender Pinguine auf einmal fangen.

(7) Ein Weibchen wurde am 10 Dezember mit einem GPS Logger ausgerüstet und zuletzt auf Überwachungskamera beobachtet, wie sie ihr Nest mit zwei wohlgenährten Küken am 12 Dezember verlässt. Sie wurde danach bis zum letzten Nestcheck am 17 Dezember nicht wieder gesichtet. Es ist unwahrscheinlich, dass ein erfolgreich brütender Altvogel mit kleinen Küken, der alternierend mit Partner Tagestouren unternahm (Überwachungskamera am Nest seit 4 Dezember), auf einmal eine Exkursion von über 5 Tagen antritt, insbesondere bei den augenscheinlich guten Nahrungsbedingungen direkt um die Insel. Daher muss davon ausgegangen werden, dass der Loggervogel verstarb. Lokale Algensammler und Fischer wie auch CONAF wurden informiert falls der Vogel irgendwo aus einem Netz geborgen oder angetrieben wird.

(8) Im Anhang findet sich (A) eine Tabelle mit den bislang 28 Humboldt Pinguinen, die auf Isla Choros makiert wurden; (B) ein zusammenfassender Überblick von Tauchparametern; (C) Liste aller beobachteten Vögel; und (D) Beobachtung einer Vampirfledermaus, wie sie ein aktives Humboldt Pinguin Nest mit zwei Küken auskundschaftet.

Nest searches

Between 25 November and 15 December 2022, comprehensive nest searches were conducted across all parts of the island with exclusion of penguin landing beaches and the small (~150 nests) neotropic cormorant *Phalacrocorax brasilianus* colony in the Northeast of the island to reduce human disturbance impact (Figure 1). We mapped 381 active Humboldt penguin nests and 1586 empty but previously occupied nests during 82 hours of designated search effort.

Nest densities were highest in the northern and the eastern regions of the island when compared to the ocean facing western side, with a small number of nests established in the upper ranges or on top of the island's high plateaus (Figure 1). Observations using binoculars (Leica, 42x10) from the first plateau (while well concealed from resting penguins below) suggest that we may have missed up to 10 nests per bay on the busy Eastern landing beaches and a few additional nests in the West. Some of the steep eastern slopes were not included in ground searches due to health and safety concerns. However, scans with binoculars revealed little sign of penguin presence.

Neotropic cormorants are extremely timid and human approach may cause abandonment of an entire colony resulting in egg or chick loss to the ever-vigilant gulls. Hence, we carefully searched only the cacti along the fringes around the colony. We are glad to report that by keeping a close eye on cormorant behaviour and dropping back when the first birds showed signs of vigilance, we did not cause any nest abandonment. As a result, we may have missed a few nests of penguins breeding within the cactus field occupied by the neotropic cormorant colony. However, penguin nest numbers in the Northeast were comparable to counts completed during June 2022, when the cormorants were not present, and the entire colony area could be searched.

Most (274) of the active nests had one adult present guarding chicks (72%), in two cases both adults were present with the chicks, 45 birds were still on eggs (12%), and 29 (8%) of the nests contained post-guard chicks, in another 29 cases prone sitting adults were encountered deep within nest caves and contents (likely eggs or small chicks) could not be established without causing unnecessary disturbance; in two cases only eggs were found with no adult present. To our knowledge, through our careful approach, we did not cause any of the penguin nests to fail.

Most of the nests were below rocks (46%), protected by rocks (9%), or in rock caves (6%), with the remaining covered by vegetation (shrub and/or cactus, 34%) or protected by vegetation (5%). Only one nest was found in the open with little protection.

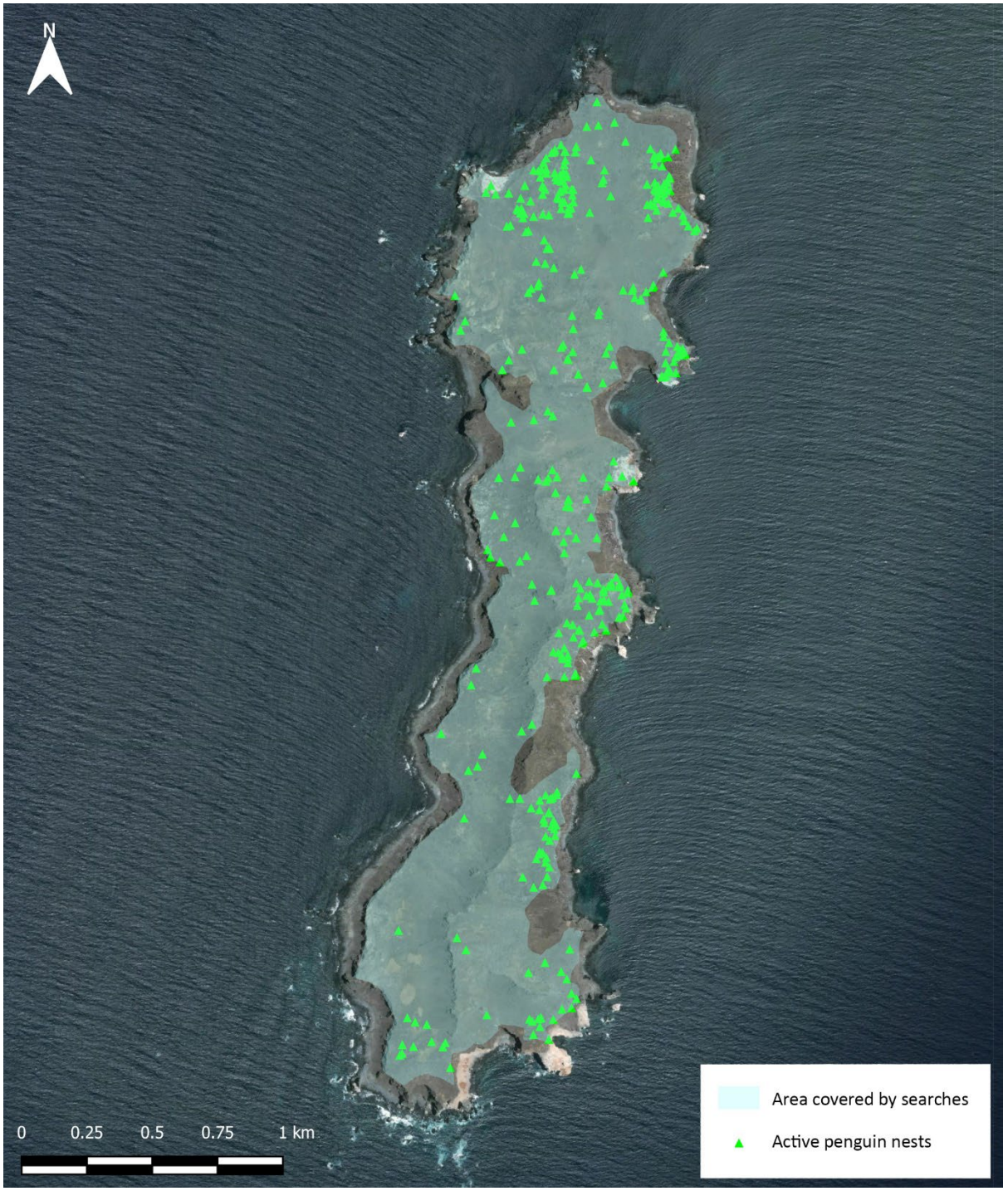

Figure 1. *Location of all mapped Humboldt penguin nests (green triangles) on Isla Choros, Humboldt Penguin National Reserve, 25 Nov – 14 Dec 2022. The area covered by nest searches derives from GPS track logs is marked in colour. Note that we decided not to search for nests along penguin landing beaches and within the neotropic cormorant colony to reduce disturbance impact. Some steep unstable slopes in the island's southeast were avoided to keep searchers safe.*

First account of double breeding

Nests of the 12 individuals marked during the winter tracking period (see previous fieldwork report from June 2022) were revisited. We found seven of the nests active and in five cases could confirm an individual marked on the same nest in June as one of the pair encountered in November (nests CH-A1-09, CH-A2-02, CH-A4-15, CH-A4-18, CH-W-04; see Appendix). Despite repeated nest checks we only ever encountered unmarked birds on the remaining two nests, in the case of nest CH-A2-06 both partners were quite different in appearance and were confirmed as both unmarked. This is the first evidence of Humboldt penguins breeding (successfully!) twice a year at the Humboldt Penguin National Reserve.

Figure 2. *Maximilliano getting a read of a marked female breeding successfully in June and attending two eggs in the same nest (CH-W-04) on 29 November 2022. Both eggs hatched with two chicks present when we last checked the nest on 15 December 2022.*

GPS dive logger and PenguCam deployments

Of all mapped nests, only a fraction was deemed suitable for logger deployments. Suitable nests had a single attending adult penguin, contained chicks of at least one week of age, and were fully enclosed with only a single entrance to reduce the chance of nest abandonment potentially resulting from the interaction with the attending bird.

Loggers were deployed between 25 November and 17 December 2022 on 16 adult Humboldt penguins from different nests. Morphometric measurements revealed that these were eleven females and five male penguins. Penguins were carefully removed from the nest either by hand or by using a leg crook made from rigid wiring, by hooking one of the bird's feet or flippers and gently walking it out of the nest cavity. Once in hand, the bird was placed head first into a cloth bag and weighed with a handheld spring balance (5kg Pesola). Subsequently, tracking devices were deployed. During deployment, the head of the bird was kept within the cloth bag to reduce stress exposing the beak to facilitate breathing while allowing the bird to rest prone in a natural position. The device was placed on the lower back to reduce drag once at sea. Following device deployment, morphometric measurements were taken, and the bird marked with a transponder (11mm TROVAN) before releasing it back into the nest. All 16 birds immediately returned and stayed with their chicks following release.

To record three-dimensional foraging trips, we used AxyTrek Marine GPS dive loggers (AxyTrek, TechnoSmart, Italy, https://www.technosmart.eu/) that monitor at-sea movements and diving behaviour. The devices are streamline shaped (dimensions: 70mm x 40mm x 15mm; Figure 4). The units are powered by a 1600 mAh battery which allowed an operation time of 7-10 days. Each unit weighed 50 grams.

Figure 4. *AxyTrek Marine GPS dive logger. 100- and 10-Peso coins for scale (by Thomas Mattern).*

Following monitoring of ideal logger nests with surveillance cameras (Bushnell Trophy Cam – low glow) to establish nest attendance patterns, we chose six nests for the deployment high-definition video loggers (PenguCam, New Zealand, https://pengu.cam/) which were deployed in conjunction with AxyDepths (TechnoSmart, Italy, https://www.technosmart.eu/) to provide depth and accelerometer data in conjunction with the videos. Accelerometer data are currently being evaluated by Karen Lau who is doing a Master Research Project with us on the energy expenditure of Humboldt penguins during foraging comparing the winter and summer breeding period. Using our PenguCam footage, accelerometer data will be evaluated using corresponding penguin foraging behaviour. The six birds attending at the time of deployment were by chance all females. Devices were attached to a penguin's back with waterproof adhesive tape. Using a cut-out template, the proposed position of the device on the bird was marked. Then a series of tape stripes were threaded under the feathers (Figure 5a&b) before placing the device on the spot and wrapping the loose ends of the tape around the device (Figure 5c).

Figure 5. *Ursula & Maximiliano attaching a PenguCam logger to a Humboldt penguin (by Karen Lau).*

One small cable tie was threaded around feathers and unit to ensure the logger stayed in place and penguins could not preen off tape and device (Figure 6a). Device removal was simply a reverse of the process; tape stripes were twisted and could easily be peeled off the feathers so that no permanent damage was caused to the penguin's plumage (Figure 6b-c).

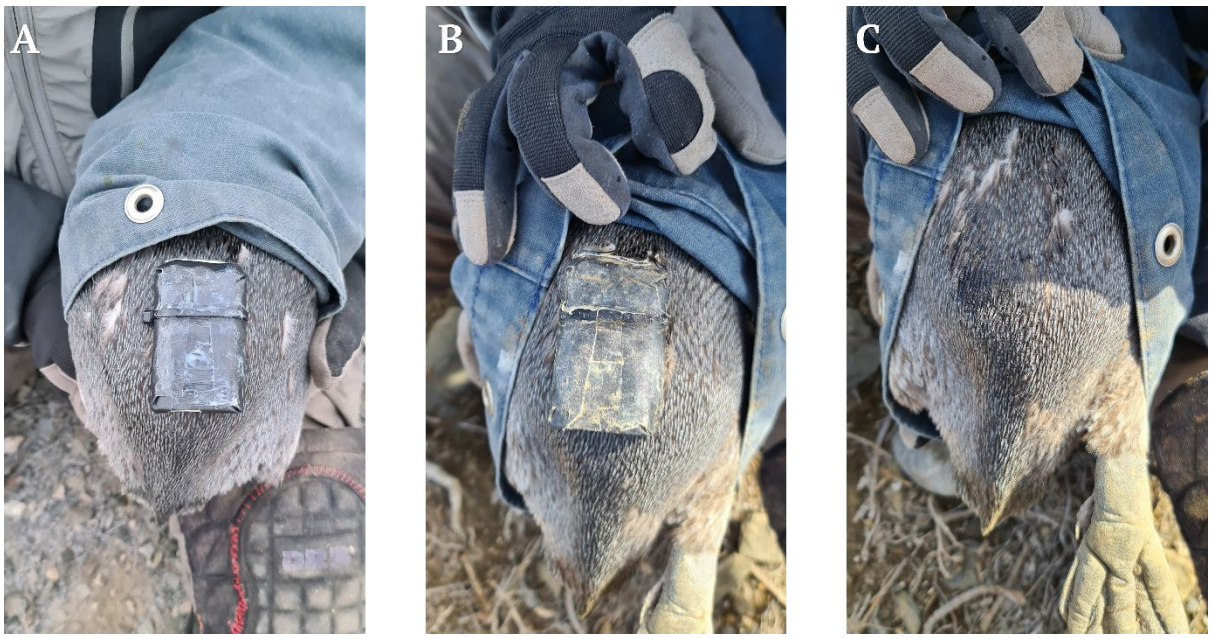

Figure 6. *GPS dive logger during deployment (A), after recapture of the penguin five days later (B), and state of plumage after removal of device and tape (C) (photos by Thomas Mattern).*

Device deployments took ca. 15 minutes from capture to release of the bird, including capture and weighing of the attending bird as described above, taking morphometric measurements required for sexing the bird, as well as individually marking the bird with a transponder. Device removal and release back into the nest, took less than five minutes.

GPS dive loggers were recovered after 4-7 days. PenguCam loggers were recovered following one single foraging trip. One of the 16 birds fitted with devices disappeared and could not be recovered. The GPS logger was subsequently lost (see page 19).

Preliminary results

Logger deployments yielded GPS and dive data for 12 birds (7 females, 5 males), and dive data for the 6 birds deployed with PenguCams representing 736 hours of at-sea spread over 41 different single-day, 2 two-day foraging trips, and one brief evening trip (median 15.6h, range 1.4h-47.8h). A total of 16,562 GPS positions as well as 24,320 dives events were recorded. Some birds achieved maximum dive depths of up to 100m, however, most birds focussed their efforts shallower with average dive depths of only 17.5m and a median maximum dive depth of 65m. Birds achieved median horizontal travel speeds of 1m/s and travelled on average 43.9km during their foraging trip (range 3.7km-77.2km; compare overview table in Appendix). These data allowed the reconstruction of 38 complete foraging trips (Figure 7). Most foraging activity took place within 10km of Isla Choros with some birds ranging up to 30km away. The comparably short foraging ranges are likely a result of the productive marine environment around the Humboldt Penguin National Reserve during La Niña with good food availability close to the island.

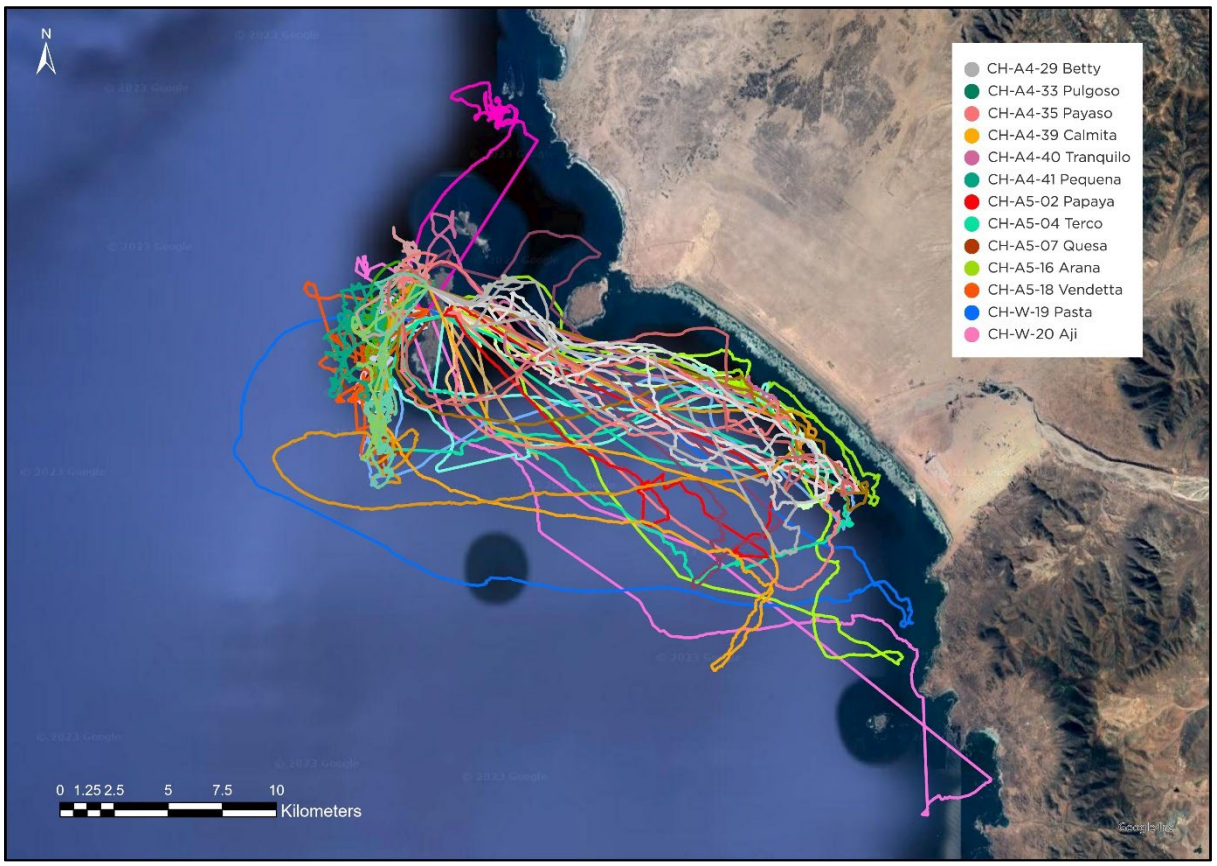

Figure 7. Twelve penguins tracked with GPS devices from Isla Choros, Humboldt Pinguin National Reserve, returned at total of 38 complete foraging trips (2-4 trips per bird, lines with similar hue represent different trips performed by the same bird). These tracks can be explored in greater detail using following link: https://penguintracking.org/humboldt/)

The six video loggers deployed were all successfully retrieved and provided 23.5 hours of high-definition video footage. These include 20 hours of continuous video footage and a further 3.5 hours of shorter video clips at the end of the video logger's battery capacity. Some videos were taken at low light conditions including at night. The data has yet to be analysed in detail. Preliminary evidence suggests that some birds successfully foraged solitary near the surface for small fish including anchoveta and sardines (Fig 8, a-i), fish larvae (Fig 8, j-l) and squid (Fig 8, m-o).

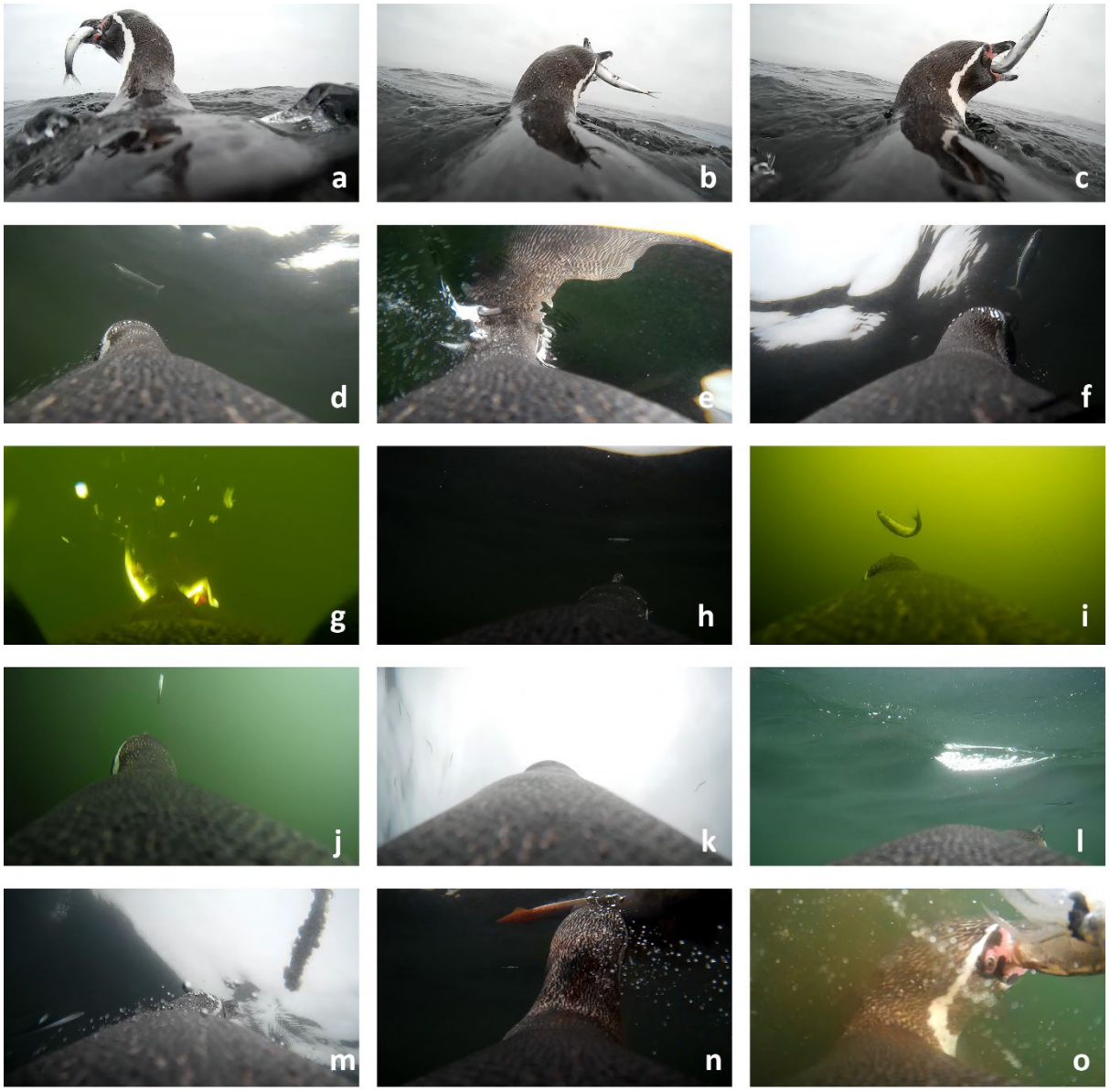

Figure 8. Screen captures of PenguCam carried by Humboldt penguin female "Calmita" on her single day foraging trip on 2 Dec 2022. The bird caught most prey near the surface by ambushing prey from below. Prey included small forage fish (a-i), fish larvae (j-l), and squid (m-o).

The productive waters near the coast/East of the islands often had a green tinge with comparably poor visibility at depth. Some of these areas contained high quantities of jellyfish. Penguins routinely checked lions mane jellyfish *Cyanea capillata* for small commensal fish hiding within the tentacles (Fig 9) while ignoring smaller species of jellyfish. About every third lions mane jellyfish yielded success (Fig 9, e-f)

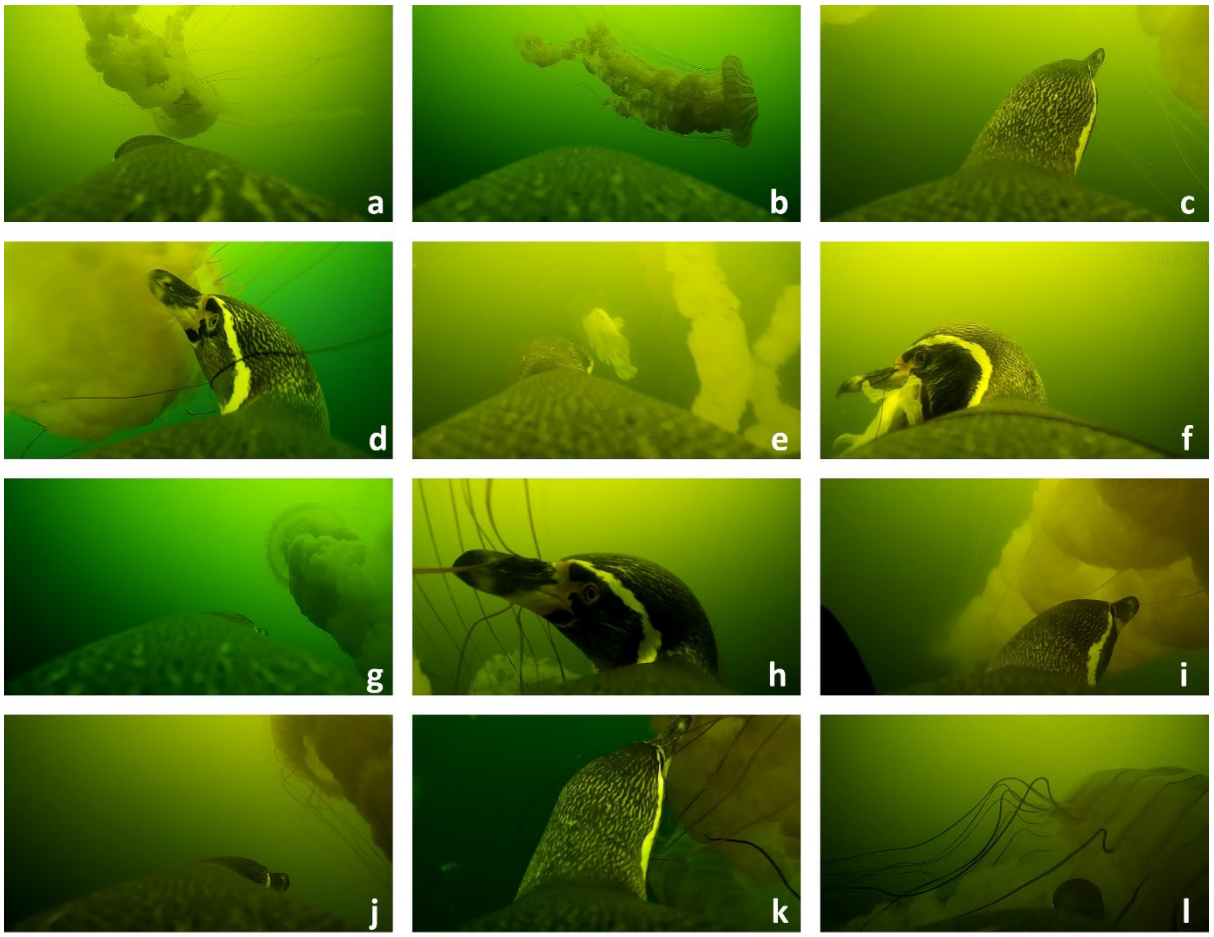

Figure 9. Screen captures of PenguCam carried by Humboldt penguin female "Calmita" on her single day foraging trip on 2 Dec 2022. Lions mane jellyfish opportunistically encountered were routinely checked for small commensal fish (seen in e & f) hiding among the tentacles.

Three penguins foraged solitary and exclusively pelagically often near the surface for individual fish or small/juvenile swarm fish and squid (Figure 8 & 9), the other three penguins were observed foraging occasionally in groups of more than 50 individuals while herding demersal fish at depths of between 65-95m in the clearer waters to the west of the island (see video). This latter behaviour has so far not been observed in Humboldt penguins and leads to much higher risk of bycatch mortality, since a single net could catch an entire group of birds hunting together.

Loss of bird carrying GPS device

Nest CH-W-30 was monitored with a surveillance camera from 4 December to establish nest attendance patterns. The pair worked well together and did alternating one-day trips to feed their chicks; hence, the pair was deemed reliable for video logger deployment. On 8 December we deployed a PenguCam on the attending female ("Flecha", ID 956 0000128 37001). She brought back fantastic and unexpected footage of cooperative foraging on benthic fish. The PenguCam logger was recovered following a single foraging trip 10 December and, as in other birds, she was deployed with a GPS logger at the same time. The female was last seen via surveillance camera leaving her nest on 12 December (Figure 10). Subsequent nest checks only encountered her partner attending two chicks that were still alive during our last check on 17 December, however, had obviously not been fed recently. Currently, the island is closed as a precautionary measure by local authorities in response to the arrival of avian influenza, thus planned subsequent nest checks could not be carried out.

Figure 10. *Final observation of Humboldt penguin female "Flecha" on 12 December 2022 leaving her nest CH-W-30 situated up the access track to the left under rock overhang behind bush. Insert on left is the same bird on the nest guarding her two chicks on 5 December 2022. Insert on right is a close-up pointing out the small, streamlined GPS logger on her lower back.*

It is unlikely that a bird previously doing predictable one-day foraging trips (observed via surveillance camera since 4 December) would suddenly embark on a trip of more than 5 days, especially given the excellent foraging conditions close to the island. Thus, unfortunately we must assume this bird has perished taking the logger with her. Algeros and fishers operating from Punta Choros as well as CONAF staff have been informed in case the bird has been retrieved from a net or gets washed ashore somewhere.

Next steps

Following our first successful year studying the foraging ecology of Humboldt penguins during La Niña conditions in 2022, we propose to (1) continue this research for a further two years to include the ENSO neutral conditions forecasted for 2023 (NOAA, 17 January 2023) as well as again different conditions possibly even El Niño in 2024, so we can develop a better understanding of Humboldt penguin marine requirements in this highly dynamic coastal ecosystem.

Based on the co-operative foraging observed via PenguCams we fear that Humboldt penguins are at a much higher risk for bycatch particularly in coastal gillnet fisheries than previously thought. In conjunction with the apparent decline of Humboldt penguin nesting pairs on Isla Choros we suggest (2) to expand the current project and get a new MSc student on board to analyse the temporal spatial overlap of penguin foraging with fishing activities around the reserve in collaboration with SERNAPESCA, a suitable candidate has already been identified. Dr Alejandro Simeone would be happy to act as primary supervisor.

To inform environmental impact assessments in relation to the proposed mining harbours Dominga and Cruz Grande adjacent to important foraging areas of Humboldt penguins we suggest (3) expanding the project to include additional important and potentially affected penguin breeding sites such as Tilgo and Isla Pajaros.

The apparent dramatic decline of Humboldt penguins on Isla Chañaral, a previous stronghold for the species remains to be investigated, thus (4) we hope that some research into the marine ecology and breeding biology of penguins breeding on this largest and northern most island of the reserve can be realised in the foreseeable future.

Data on Humboldt penguin marine ecology and foraging hotspots can then be used to inform the implementation, expansion, and management of the Marine Protected Area around the islands of the Humboldt Penguin National Reserve.

Acknowledgements

Karen Lau Alarcon helped during the first week of our stay. Karen travelled together with Nico Luna Ignacio and Andrea Varela who studied the resident diving petrels *Pelecanoides garnotii*. All three are based at the Universidad Católica del Norte in Coquimbo and were wonderful company in the field. We are grateful for the support by "Tio Willy" Guillermo Barrera, his son Maikol who not only provided transport to and from the island but also had a wealth of local knowledge they generously shared with us.

This project took place under CONAF permit (numbers 014/2021 and 020/2022) and was made possible through the generous financial support by Gabriele and Werner Knauf, **Sphenisco e.V.**

Appendix

(A) **Table 1.** Humboldt penguins marked on Isla Choros with TROVAN (11mm) transponders during June, November and December 2022 (page 24). Data is sorted according to bird ID.

(B) **Table 2**. Overview of foraging parameters of Humboldt penguins tracked with GPS loggers (bird name only) or PenguCam loggers (bird name_CAM) for each individual foraging trip. Note, PenguCam loggers were combined with the smaller AxyDepths providing information on dive parameters but no GPS position to reduce logger size and promote natural behaviour (page 25-26).

(C) **Table 3.** Bird check list (page 27).

(D) Miscellaneous observation of vampire bat exploring active penguin nest (page 28).

(E) Miscellaneous observation of Inca tern using a yunco burrow (page 28).

Bird ID	Date	Tagger	Sex	Weight (g)	Bill depth (mm)	Bill length (mm)	Nest ID	Comments
956 0000112 69201	5 December 2022	Maximiliano Daigre	Male	4700	24.1	63.5	CH-A5-16	
956 0000112 86418	16 June 2022	Thomas Mattern	Female		24.45	62.16	CH-A4-18	nest active both in June and Nov, with marked bird present
956 0000112 87668	26 November 2022	Ursula Ellenberg	Female	3650	23.8	72.4	CH-A5-02	
956 0000112 92907	15 June 2022	Thomas Mattern	Female	3800	24.44	61.06	CH-A4-15	nest active both in June and Nov, with marked bird present
956 0000112 94767	15 June 2022	Thomas Mattern	Male	4900	27.71	64.32	CH-W-01	not active in Nov
956 0000112 95485	26 November 2022	Ursula Ellenberg	Female	3800	22.9	57.9	CH-A4-29	
956 0000112 95813	4 December 2022	Ursula Ellenberg	Female	3800	21.5	58.7	CH-W-19	
956 0000112 96751	12 December 2022	Ursula Ellenberg	Female	3800	23.3	59.6	CH-A9-06	
956 0000112 98809	18 June 2022	Maximiliano Daigre	Male				CH-E-01	not active in Nov
956 0000112 99001	4 December 2022	Ursula Ellenberg	Female	4150	25.5	66.7	CH-A5-10	
956 0000112 99443	16 June 2022	Thomas Mattern	Female		23.32	60.96	CH-A4-17	nest active both in June and Nov, but no marked bird encountered
956 0000113 05685	16 June 2022	Thomas Mattern	Female	3900	25.56	64.34	CH-A2-02	nest active both in June and Nov, with marked bird present
956 0000113 07226	3 December 2022	Ursula Ellenberg	Female	3550	23.5	63.9	CH-A4-41	
956 0000113 08472	14 June 2022	Thomas Mattern	Male				CH-A1-09	nest active both in June and Nov, with marked bird present
956 0000113 11976	16 June 2022	Thomas Mattern	Male	4000			CH-A4-16	not active in Nov
956 0000113 12478	1 December 2022	Ursula Ellenberg	Female	4000	24.3	72.4	CH-A4-39	
956 0000128 25952	15 June 2022	Thomas Mattern	Female	3700	22.25	60.92	CH-W-04	nest active both in June and Nov, with marked bird present
956 0000128 26065	27 November 2022	Ursula Ellenberg	Male	4350	25.8	66.7	CH-A5-04	
956 0000128 27072	26 November 2022	Ursula Ellenberg	Male	4700	27.3	72.4	CH-A4-35	
956 0000128 29009	14 June 2022	Thomas Mattern	Female		23.34	69.8	CH-A1-08	not active in Nov
956 0000128 29086	4 December 2022	Maximiliano Daigre	Female	4300	24.3	59.5	CH-W-18	
956 0000128 30090	3 December 2022	Ursula Ellenberg	Male	4750	26.6	67.6	CH-A4-33	
956 0000128 30722	14 June 2022	Thomas Mattern	Female				CH-A1-03	not active in Nov
956 0000128 35818	5 December 2022	Ursula Ellenberg	Female	3700	24.2	60.1	CH-W-20	
956 0000128 35928	19 June 2022	Thomas Mattern	Female		23.32	61.02	CH-A2-06	nest active both in June and Nov, but no marked bird encountered
956 0000128 36680	27 November 2022	Ursula Ellenberg	Male	4350	27.7	64.4	CH-A4-40	
956 0000128 37001	8 December 2022	Ursula Ellenberg	Female	3950	23	61.7	CH-W-30	
956 0000128 37051	27 November 2022	Ursula Ellenberg	Female	3800	23.8	56.6	CH-A5-07	

Foraging trips	No of Dives	Trip Start	Trip End	Mean Dive Time	Mean Dive Distance	Mean Max Depth	Absolute Max Depth	Mean Foraging Efficiency	Mean Homerange (km)	Max Homerange (km)	Travel Distance (km)
Betty											
1	575	27/11/2022 01:09	27/11/2022 18:52	41.0	94.4	10.7	47.2	0.30	10.0	18.3	48.3
2	755	29/11/2022 06:30	29/11/2022 18:20	31.9	85.6	7.3	44.59	0.29	11.5	18.0	44.9
3	602	01/12/2022 01:05	01/12/2022 19:11	50.4	92.1	14.4	48.98	0.31	8.5	18.2	52.0
Pulgoso											
1	427	05/12/2022 01:20	05/12/2022 18:28	47.0	96.0	24.3	94.62	0.22	5.7	8.3	35.5
2	320	07/12/2022 06:06	07/12/2022 17:58	61.6	98.2	37.9	99.25	0.20	4.7	7.4	28.6
Payaso											
1	535	27/11/2022 08:06	27/11/2022 18:27	39.9	93.5	10.9	72.39	0.36	1.5	3.3	28.7
2	647	28/11/2022 18:24	29/11/2022 15:17	49.8	114.4	13.5	59.37	0.35	8.3	15.4	51.5
3	679	30/11/2022 18:30	01/12/2022 14:48	46.0	123.3	9.3	57.29	0.34	12.5	18.9	56.0
Calmita											
1	655	04/12/2022 06:31	04/12/2022 19:31	38.8	101.3	9.8	63.82	0.28	13.2	19.3	55.1
2	660	06/12/2022 06:43	06/12/2022 22:16	48.5	114.3	15.8	84.2	0.30	9.4	16.7	64.6
3	574	07/12/2022 19:46	08/12/2022 20:02	45.3	106.7	10.8	56.76	0.28	12.0	19.6	55.2
Calmita_CAM											
1	613	02/12/2022 06:22	02/12/2022 19:04	43.0		10.6	71.06	0.30			0.0
Tranquilo											
1	621	29/11/2022 06:05	29/11/2022 18:33	47.0	114.0	14.2	68.04	0.33	10.0	15.2	45.2
2	474	30/11/2022 21:54	01/12/2022 16:30	49.3	114.2	11.0	45.54	0.35	13.5	17.1	50.7
Pequena											
1	272	04/12/2022 06:31	04/12/2022 15:10	45.3	68.4	25.0	73.91	0.22	3.4	4.6	18.3
2	331	05/12/2022 18:43	06/12/2022 15:53	65.4	95.0	38.6	89.07	0.19	2.2	3.2	33.9
3	634	07/12/2022 18:37	09/12/2022 18:25	64.3	93.5	37.1	97.69	0.22	3.4	5.9	64.5
Papaya											
1	601	28/11/2022 05:05	28/11/2022 15:25	34.1	83.1	8.5	41.79	0.32	10.4	18.1	40.5
2	577	30/11/2022 06:30	30/11/2022 17:08	38.1	97.2	9.6	58.97	0.30	12.0	18.3	47.0
3	603	01/12/2022 14:48	02/12/2022 09:37	37.5	88.6	9.8	52.05	0.32	10.4	16.0	42.8
Terco											
1	742	28/11/2022 05:29	28/11/2022 19:48	38.5	90.4	9.9	38.75	0.29	9.1	14.3	51.5
2	788	30/11/2022 06:05	30/11/2022 19:43	38.5	94.3	10.6	87.75	0.31	12.0	17.2	50.3
3	633	02/12/2022 03:30	02/12/2022 19:12	37.9	82.2	8.1	33.27	0.28	14.7	18.5	47.5

Foraging trips (continued)	No of Dives	Trip Start	Trip End	Mean Dive Time	Mean Dive Distance	Mean Max Depth	Absolute Max Depth	Mean Foraging Efficiency	Mean Homerange (km)	Max Homerange (km)	Travel Distance (km)
Quesa											
1	905	28/11/2022 06:59	28/11/2022 20:44	29.3	74.5	7.1	43.34	0.30	5.2	6.9	15.6
2	342	30/11/2022 07:09	30/11/2022 18:55	64.6	152.3	30.1	73.43	0.27	2.5	3.6	8.2
Peligrosa_CAM											
1	292	05/12/2022 02:20	05/12/2022 16:58	54.9		30.3	92.05	0.19			0.0
Arana											
1	444	06/12/2022 00:40	06/12/2022 18:30	54.2	111.4	16.4	72.42	0.27	10.2	17.1	48.8
2	35	07/12/2022 18:12	07/12/2022 19:33	59.4	112.6	17.2	56.84	0.33	0.7	1.3	3.7
3	542	08/12/2022 22:18	09/12/2022 18:43	60.7	108.5	17.6	64.19	0.33	14.1	23.0	63.6
4	511	12/12/2022 03:37	12/12/2022 18:26	49.6	100.4	15.9	58.39	0.25	12.4	19.0	50.3
Flecha_CAM											
1	464	08/12/2022 22:20	09/12/2022 18:40	62.1		18.3	77.06	0.34			0.0
Patranka_CAM											
1	703	13/12/2022 06:34	13/12/2022 19:14	32.5		8.9	59.95	0.26			0.0
Vendetta											
1	444	06/12/2022 00:40	06/12/2022 18:30	54.2	111.4	16.4	72.42	0.27	10.8	17.8	49.9
2	35	07/12/2022 18:12	07/12/2022 19:33	59.4	112.6	17.2	56.84	0.33	1.3	2.0	4.7
3	542	08/12/2022 22:18	09/12/2022 18:43	60.7	108.5	17.6	64.19	0.33	14.8	23.7	64.5
4	511	12/12/2022 03:37	12/12/2022 18:26	49.6	100.4	15.9	58.39	0.25	13.0	19.6	51.2
Pasta											
1	407	05/12/2022 06:44	05/12/2022 19:04	46.6	67.5	25.2	85.79	0.21	2.3	3.3	22.8
2	599	07/12/2022 06:40	07/12/2022 21:59	47.2	125.9	16.7	96.64	0.27	9.3	18.9	60.9
3	760	09/12/2022 06:43	09/12/2022 22:21	36.1	100.1	8.8	66.14	0.29	14.4	23.2	68.0
Pasta_CAM											
1	1142	11/12/2022 04:43	12/12/2022 22:15	39.1		13.1	95.68	0.27			0.0
Aji											
1	266	07/12/2022 21:03	08/12/2022 18:37	80.8	92.9	54.8	97.15	0.16	2.9	4.7	27.8
2	1046	09/12/2022 23:34	11/12/2022 00:31	38.7	108.1	9.5	69.68	0.33	17.9	29.5	77.2
3	675	12/12/2022 04:44	12/12/2022 20:27	52.5	83.3	14.2	47.55	0.40	8.1	9.5	40.0
Aji_CAM											
1	337	05/12/2022 20:59	06/12/2022 18:16	64.3		39.1	92.33	0.21			0.0

List of birds observed on Isla Choros during 25 Nov – 17 Dec 2022

Local name	English name	Latin name	Breeding (*)
Pingüino de Humboldt	Humboldt Penguin	*Spheniscus humboldti*	*
Yunco	Peruvian Diving-Petrel	*Pelecanoides garnotii*	*
Fardela negra	Sooty Shearwater	*Ardenna griseus*	
Ave trópico de pico rojo	Red-billed Tropicbird	*Phaethon aethereus*	
Piquero	Peruvian Booby	*Sula variegata*	*
Pelícano	Peruvian Pelican	*Pelecanus thagus*	
Lile	Red-legged Cormorant	*Phalacrocorax gaimardi*	*
Gunanay	Guanay Cormorant	*Phalacrocorax bourgainvilli*	*
Yeco	Neotropic Cormorant	*Phalacrocorax brasilianus*	*
Garza grande	White Heron	*Ardea alba*	
Huairavo	Black-crowned Heron	*Nycticorax nycticorax*	*
Bandurria	Black-faced Ibis	*Theristicus melanopsis*	*
Jote de cabeza colorada	Turkey Vulture	*Cathartes aura*	*
Jote de cabeza negra	Black Vulture	*Coragyps atratus*	*
Aguilucho	Variable Hawk	*Buteo/Geranoaetus polysoma*	*
Halcón peregrino	Peregrine Falcon	*Falco peregrinus*	*
Zarapito	Wimbrel	*Numenius phaeopus*	
Queltehue	Southern Lapwing	*Vanellus chilensis*	
Pilpilén negro	Blackish Oystercatcher	*Haematopus ater*	*
Pilpilén común	American Oystercatcher	*Haematopus palliatus*	*
Perdicita	Least Seedsnipe	*Thinocorus rumicivorus*	
Gaviota de Franklin	Franklins Gull	*Leucophaeus pipixcan*	
Gaviota dominicana	Kelp Gull	*Larus dominicanus*	*
Gaviota peruana	Belcher's Gull	*Larus belcheri*	
Gaviotín monja	Inca Tern	*Lacosterna inca*	*
Gaviotín sudamericano	South American Tern	*Sterna hirundinacea*	
Tórtola	Eared Dove	*Zenaida auriculata*	
Pequén	Burrowing Owl	*Athene cunicularia*	*
Picaflor del norte	Oasis Hummingbird	*Rhodopsis vesper*	
Minero	Common Miner	*Geositta cunicularia*	*
Bandurilla	Scale-throated Earthcreeper	*Upucerthia dumetaria*	*
Churrete costero	Seaside Cinclodes	*Cinclodes nigrofumosus*	*
Tijeral	Plain-manteled Tit-Spinetail	*Leptasthernua aegithaloides*	*
Mero gaucho	Black-billed Shrike-Tyrant	*Agriornis montana*	*
Golonrina chilena	Chilean Swallow	*Tachycineta leucopyga*	
Golondrina bermeja	Barn Swallow	*Hirundo rustica erythrogaster*	
Chercán	House Wren	*Troglodytes aedon*	*
Yal	Mourning Sierra-Finch	*Phrygilus fruticeti*	
Diuca	Common Diuca-Finch	*Diuca diuca*	*
Chincol	Rufous-collared Sparrow	*Zonotrichia capensis*	*

Vampire bat exploring active penguin nest

Vampire bats *Desmodus rotundus* were regularly observed flying around our camp at night and on occasion landing. Surveillance camera footage provides evidence of a vampire bat entering a penguin nest with two chicks while the attending adult appears agitated. Both chicks were found apparently healthy and unaffected during subsequent nest visits. The extend of interaction or potential effect of vampire bats on Humboldt penguins on Isla Choros is currently unclear.

Figure 11: *Screenshot from surveillance video showing agitated penguin and vampire bat sneaking up on ground level to explore penguin nest (CH-A9-06) with two chicks below cactus in background. The bat later takes flight past the penguin and off out the left top corner of the track camera frame.*

Inca tern using yunco burrow

Inca terns *Lacosterna inca* breed in small numbers in rock crevices along the southern cliffs of Isla Choros. During penguin nest counts in the South we observed an Inca tern entering and exiting a yunco *Pelecanoides garnotii* burrow in the centre of a small colony in sandy soil on the first plateau near the southern bird cliffs. Potential nesting or scavenging could not be confirmed. This is to keep a record of such rather unusual behaviour. In the past (2002/03) we observed chungungos/marine otters *Lontra felina* preying on large yunco chicks in colonies on the first plateau. Interestingly, not a single chungungo nor any tracks or sign was observed during our stay despite the apparent increase in numbers of yuncos.