

## Northern breeding range expansion of two *Sula* species at Sutil Island, California, USA

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**ABSTRACT.**—We report a northern expansion of the breeding ranges of the Brown Booby (*Sula leucogaster*) and Blue-footed Booby (*S. nebouxii*) with the first successful breeding of these species at Sutil Island off Santa Barbara Island, California, USA, in 2017 and 2020, respectively. We documented the arrival and breeding of both species through opportunistic monitoring and annual aerial photographic surveys from 2013 to 2022. We first noted Brown Booby attendance on the island in October 2013, and we confirmed breeding 4 years later in October 2017. The number of observed apparent Brown Booby nests (i.e., nest structures attended by adults or where a chick was seen) increased over time from 4 in 2017 to 31 in 2022. The number of birds observed attending the colony also increased overall to a high count of 164 in September 2021. We first observed Blue-footed Boobies in August 2018 and confirmed breeding 2 years later in June 2020 with a Brown and Blue-footed Booby pair that fledged a hybrid chick. We documented 2 nests with chicks in 2021 and observed a non-hybrid Blue-footed Booby in juvenile plumage in July 2022. These are the first confirmed breeding records for *Sula* species in the continental USA and represent a northward shift of both species' breeding ranges.

**RESUMEN.**—Informamos la expansión hacia el norte de los rangos de reproducción del piquero pardo (*Sula leucogaster*) y el piquero de patas azules (*S. nebouxii*) con la primera reproducción exitosa de estas especies en la isla Sutil frente a la isla Santa Bárbara, California, EE. UU. en 2017 y 2020, respectivamente. Documentamos la llegada y la reproducción de ambas especies mediante monitoreo oportunista y estudios fotográficos aéreos anuales entre 2013 y 2022. Notamos la presencia del piquero pardo a la isla por primera vez en octubre de 2013 y confirmamos la reproducción cuatro años después, en octubre de 2017. El número de nidos de piquero pardo que observamos (es decir, estructuras de nidos en las que participan adultos o donde se vio un polluelo) aumentó con el tiempo de cuatro en 2017 a 31 en 2022. El número de aves observadas también aumentó en general a un recuento de 164 en septiembre de 2021. Observamos por primera vez a los piqueros de patas azules en agosto de 2018 y confirmamos la reproducción dos años después, en junio de 2020, con una pareja de piqueros de patas azules y pardos que dieron origen a un polluelo híbrido. Documentamos dos nidos con polluelos en 2021 y observamos un piquero de patas azules no híbrido en plumaje juvenil en julio de 2022. Estos son los primeros registros de reproducción confirmados de la especie *Sula* en los EE. UU. continentales y representan un desplazamiento hacia el norte de los rangos de reproducción de ambas especies.

The Sulidae family includes 6 widely distributed pantropical *Sula* species: Masked Booby (*S. dactylatra*), Nazca Booby (*S. granti*), Brown Booby (*S. leucogaster*), Blue-footed Booby (*S. nebouxii*), Red-footed Booby (*S. sula*), and Peruvian Booby (*S. variegata*; Winkler et al. 2020). Two species, the Brown Booby and Blue-footed

Booby, have expanded their breeding ranges north along the Pacific coast of Baja California, Mexico, over the past couple of decades (Whitworth et al. 2007, Bedolla-Guzmán et al. 2019).

The Brown Booby is a medium-sized (1.0 to 1.5 kg), long-lived (>24 years) seabird found in tropical oceans worldwide (Hennicke et al. 2012,


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Schreiber and Norton 2020). Four subspecies are currently recognized by Clements et al. (2021), with *S. l. brewsteri* breeding in western Mexico on islands in the Gulf of California and far offshore on Clipperton Island and the Revillagigedo Islands (Schreiber and Norton 2020). VanderWerf et al. (2023) suggests that *S. l. brewsteri* would be appropriate to consider as a distinct species based on morphological differences and assortative breeding where nesting overlaps with other subspecies. The previously known breeding range of *S. l. brewsteri* expanded circa 2005 with the establishment of a breeding colony on Middle Rock in the Islas Los Coronados, Baja California, Mexico, after a period of several years of recorded presence of nonbreeding individuals (Fig. 1; Whitworth et al. 2007). Nesting has continued at this site since establishment of the breeding colony, with an estimate of up to 30 nests in 2014 (Sánchez et al. 2022). Prior to the range expansion of Brown Boobies to the Islas Los Coronados, the northernmost colonies were in the Gulf of California on Roca Consag and Isla San Jorge (Mellink 2000). Small numbers of Brown Boobies have been observed annually off the Pacific coast of California, USA, since 1990 (Hamilton et al. 2007). The California Bird Records Committee removed the Brown Booby from its species review process after 2007, as sightings in California have become less rare (Singer and Terrill 2009). From September 2015 through May 2016, a large roosting group of Brown Boobies was noted at Anacapa Island in the Southern California Bight, with a high count of 128 birds on 10 February 2016 at East Anacapa Island.

The Blue-footed Booby is a medium-sized (1.3 to 1.7 kg; Murphy 1936) seabird found along the west coast of the Americas from Peru to the Gulf of California, Mexico. Breeding locations in North America have historically been restricted to islands within the Gulf of California (Hernández Díaz and Salazar Gómez 2020). In 2016, the first record of Blue-footed Boobies nesting on the Baja California Pacific islands was established when a nest with 2 chicks was observed on San Jeronimo Island (Bedolla-Guzmán et al. 2019). In California, a brief influx of Blue-footed Boobies was noted beginning in September 2013, with a high count for the Southern California Bight of 22 birds at Anacapa Island (Rottenborn et al. 2016). This influx was the greatest movement for this species into

California since the early 1970s and involved far more birds than recorded in any previous incursion (Rottenborn et al. 2016). Since 2014, observations of Blue-footed Boobies in California have occurred primarily at Santa Barbara Island and have been regular enough to no longer warrant review by the California Bird Records Committee (Rottenborn et al. 2016).

For both species, the clutch size is usually 2 and the incubation period is about 6 weeks (Nelson 1978). The Brown Booby rarely fledges 2 chicks due to siblicide, but the occurrence of siblicide in the Blue-footed Booby appears to be facultative, and brood size appears to be a function of resources (Nelson 1978). The fledging period can also vary by location and as a function of resource availability but is generally at 13–14 weeks for both species (Nelson 1978).

In this article, we describe our observations of the arrival and breeding of Brown and Blue-footed Boobies at Sutil Island, off Santa Barbara Island, in the California Channel Islands. These are the first confirmed breeding records in the continental USA for these species and represent continued northward shifts of their breeding ranges.

## METHODS

Sutil Island is a small rocky islet (5.2 ha) located approximately 650 m southwest of Santa Barbara Island (33.4756°N, -119.0373°W; Fig. 1). It is owned and managed by Channel Islands National Park, and the surrounding waters are managed by Channel Islands National Marine Sanctuary. The island is composed mainly of volcanic rock with steep north-facing cliff topography and a gentler south-facing slope with sparse vegetation (Fig. 2). Several seabird species breed at Sutil Island, including the burrow- and crevice-nesting Ashy Storm-Petrel (*Hydrobates homochroa*), Black Storm-Petrel (*H. melania*), and Cassin's Auklet (*Ptychorampus aleuticus*), as well as the more conspicuous surface-nesting Western Gull (*Larus occidentalis*), Brandt's Cormorant (*Urile penicillatus*), and Double-crested Cormorant (*Nannopterum auritus*; Carter et al. 1992).

For both species at the focus of this research, most colony observations were conducted opportunistically by California Institute of Environmental Studies (CIES) and National Park Service (NPS) biologists from boats ( $n = 24$ ), aircraft (helicopter;  $n = 10$ ), or on land from

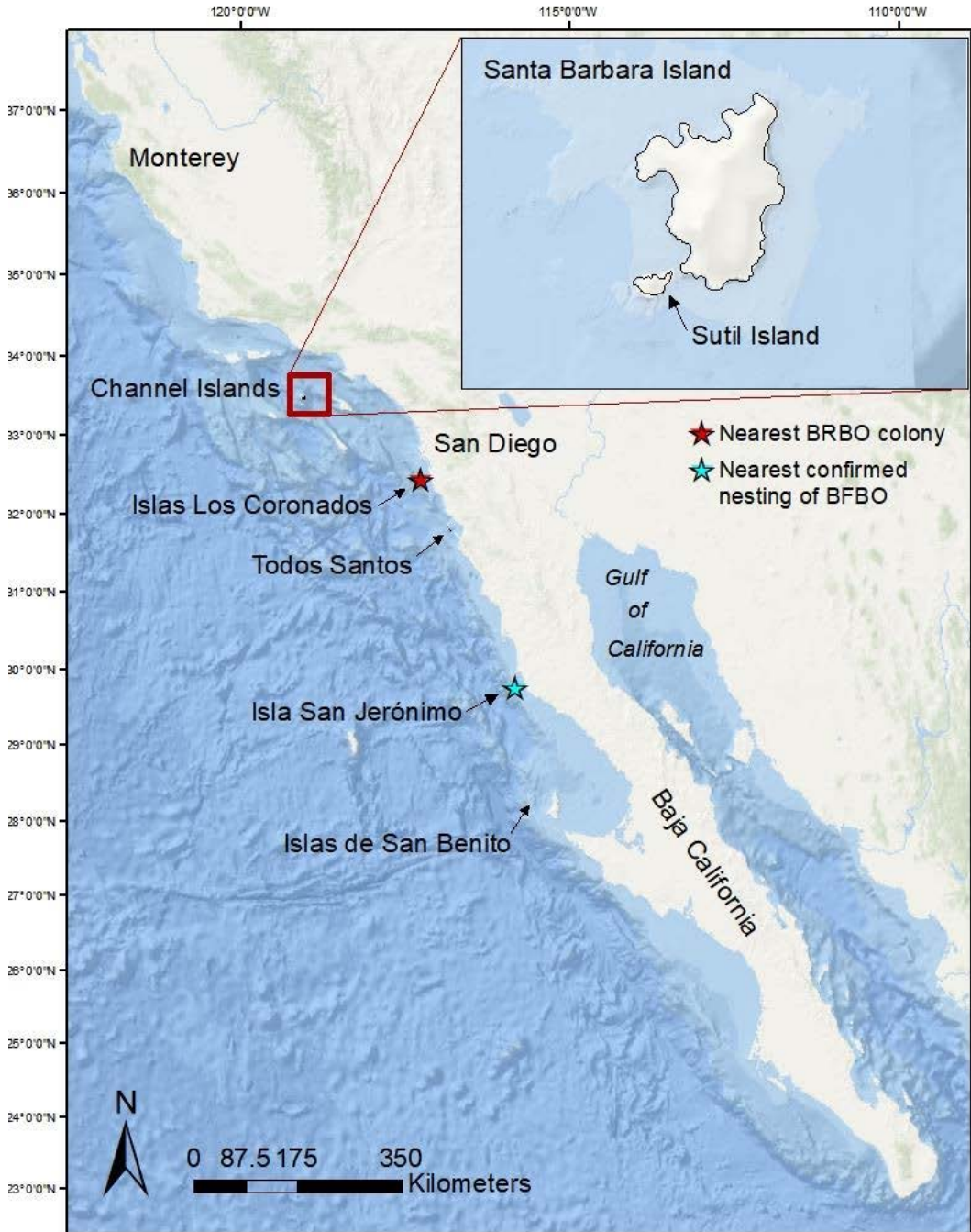


Fig. 1. The northern portion of Brown Booby (BRBO) and Blue-footed Booby (BFBO) breeding ranges within the eastern Pacific Ocean, with the previous northernmost breeding locations of both species denoted with stars. Inset includes detail of the new breeding colony at Sutil Island, off Santa Barbara Island in the California Channel Islands, USA.

adjacent Santa Barbara Island ( $n = 22$ ; Fig. 3). Boat surveys were conducted on NPS vessels during transportation to and from Santa Barbara

Island or during public pelagic birding trips. Land surveys were conducted sporadically by NPS/CIES staff on Santa Barbara Island. Aerial



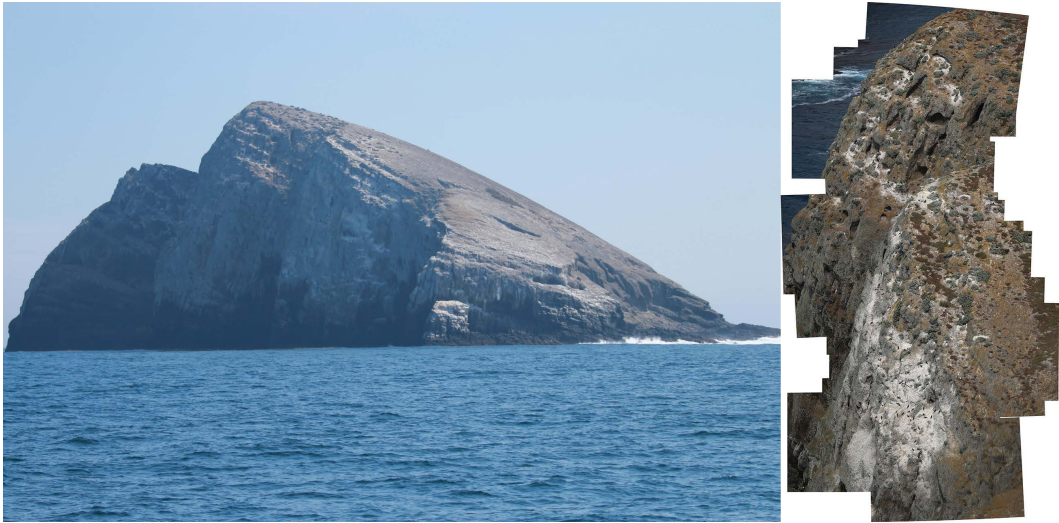


Fig. 2. Sutil Island. *Left*: View of island from boat off northwestern side. Booby nesting occurs mostly along upper ledges of north-side cliffs. *Right*: Aerial view of booby nesting habitat from 1 June 2020.

photographs were taken from a helicopter as part of ongoing aerial surveys for California Brown Pelicans (*Pelecanus occidentalis*) at Santa Barbara Island or during transportation flights to the island. Additionally, fixed-wing aerial photographic surveys led by the University of California, Santa Cruz, were conducted in either late June or early July from 2014 to 2021 ( $n = 7$ , no surveys in 2020; Fig. 3), associated with Double-crested Cormorant monitoring throughout coastal California (USFWS 2017). Aerial photographic and boat surveys allowed the closest proximity to the nesting colony and did not cause any noticeable disturbance. Aerial surveys provided the most complete detection of individuals and nests. While both species are sexually dimorphic to some degree, we were unable to consistently identify individuals to sex given the distance required to survey colonies without disturbance; for the same reason, we did not age individuals older than chicks. Thus, our counts represent all attending birds regardless of age or sex.

## RESULTS

### Brown Booby

Our observed counts of Brown Booby adults, nests, and chicks increased overall from 2013 to 2022 (Table 1, Fig. 3). In the beginning of the study period, sightings were rare; 2 attending birds were observed by boat at Sutil Island in

October 2013, and none were present during an aerial survey on 24 June 2014. However, during a boat survey on 21 August 2014, we observed 10 attending birds present on the island. We conducted occasional surveys by land and boat later in 2014 and in 2015 and observed continued use of the island by Brown Boobies in small numbers, with a high count of 91 birds on 4 September 2015. We did not record any Brown Boobies at Sutil Island in aerial photographs from 20 June 2016.

In 2017, approximately 30 attending birds were present on the island during an aerial survey on 1 July. Later that year, during a boat survey on 7 October, we photographed 3 adults in incubation posture on apparent nest structures. On 28 October, we had an incomplete view of the colony from land and photographed an adult feeding 2 downy chicks, but we were only able to observe the single nest. On a follow-up boat survey on 3 November, we recorded 4 adults that appeared to be incubating or brooding on nest structures. When we resurveyed on 10 January 2018, we observed only 1 Brown Booby on a nest, though its age was not determinable. As a result, we were unable to determine the outcome of the nest with 2 chicks that had been seen in November.

Later in 2018, we detected Brown Boobies on all surveys (with a high count of 75 birds on 29 August), but we did not document successful

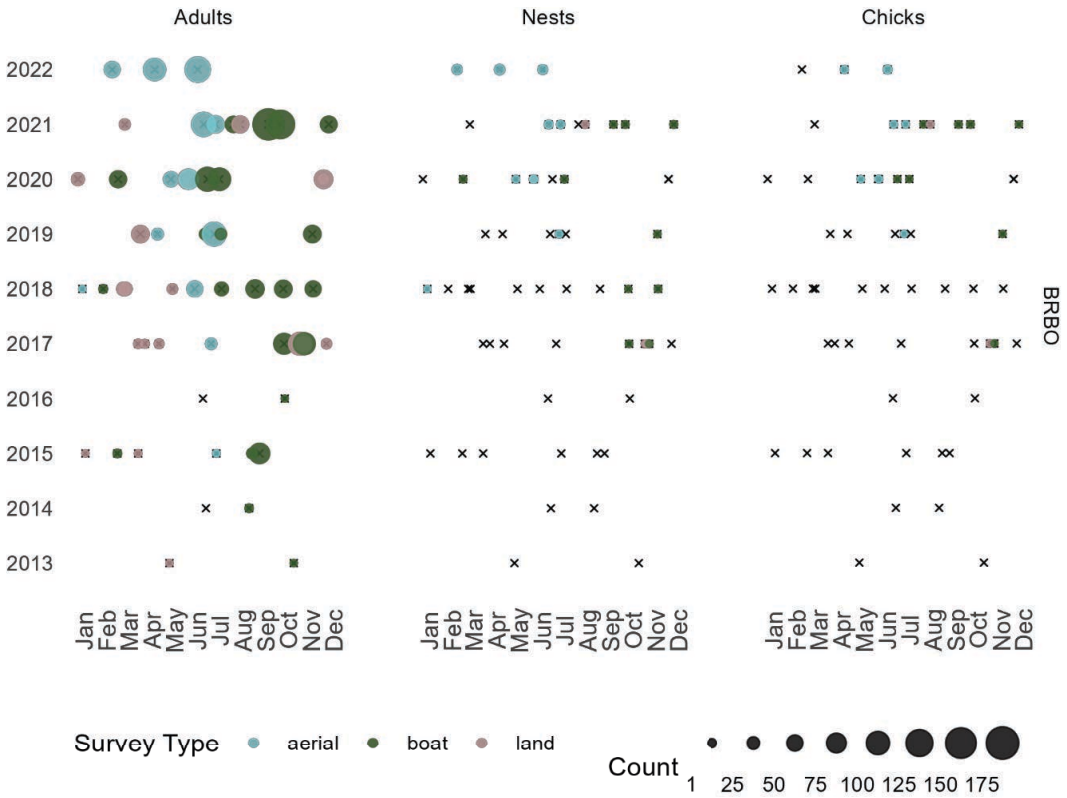


Fig. 3. Brown Booby survey counts of adults, nests, and chicks at Sutil Island in 2013–2022. An × symbol indicates that a survey took place. A shaded circle indicates that adults, nests, and/or chicks were observed; the radius of the circle is scaled to the number observed. The color of the circle indicates the survey type (aerial, boat, or land surveys).

TABLE 1. Summary of our observations of Brown and Blue-footed Boobies on Sutil Island, USA. For adults, we present the high counts observed for the year. For nests and chicks, we present approximate annual totals.

Year	Surveys	Brown Booby			Blue-footed Booby		
		Adults	Nests	Chicks	Adults	Nests	Chicks
2013	2	2	0	0	0	0	0
2014	2	10	0	0	0	0	0
2015	6	91	0	0	0	0	0
2016	2	1	0	0	0	0	0
2017	11	106	4	2	0	0	0
2018	11	75	2–4	0	1	0	0
2019	7	114	6	1	0	0	0
2020	11	115	10	5	1	1	1*
2021	8	164	13	5	4	2	1
2022	4	125	31	12	2	1	0

\*Indicates the Brown and Blue-footed Booby hybrid chick

nesting. During a boat survey on 15 July, we recorded 50 attending birds, with several individuals displaying courtship behaviors and moving nest material. Boat surveys also recorded adults attending nest structures on 6 October (1 nest) and 15 November (2–4 nests). On

21 December, no clear nest structures were seen on the island during a land survey, and we saw no indication of chicks or chick-rearing behavior during any of the prior surveys.

In 2019, aerial surveys documented an increase in nesting activity and attendance between April

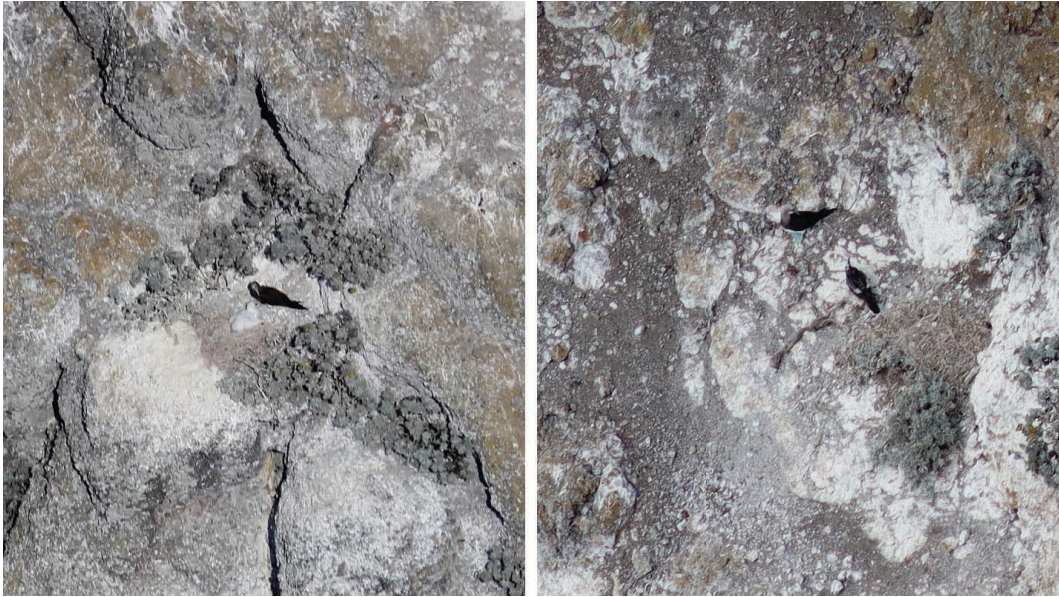


Fig. 4. Aerial photographs of booby chicks at Sutil Island. *Left*: Brown Booby adult with downy chick (7 July 2021, P. Capitolo). *Right*: Blue-footed Booby adult with mostly feathered chick (7 July 2021, P. Capitolo).

and June; we observed 30 birds and no nests on 20 April and 114 birds and 6 nests on 5 July. One of the nests on 5 July had a conspicuous chick about 4 weeks old that we continued to observe via boat surveys throughout the year on 14 July, 24 August, and 14 November, when we observed wing-begging behavior by a Brown Booby in juvenile plumage near that same nest site. The fates of the other 5 nests are unknown.

The following year, during a boat survey on 27 February 2020, we recorded 67 attending birds with 2 adults sitting on apparent nest structures and 2 building nests. During a follow-up aerial survey on 29 March, we observed 2 downy chicks in separate nests attended by adults. An incomplete aerial survey on 13 April revealed a 5-week-old chick in a nest attended by an adult. During aerial and boat surveys between 8 May and 26 June, we observed an increase in the numbers of attending adults from 55 to 115 individuals. We confirmed 8 active nests on 1 June from aerial photographs. Five of these nests had single visible chicks, including a 13-week-old chick (fully feathered but not flighted) in the immediate vicinity of the nest that had contained a 5-week-old chick in April.

In 2021 and 2022, Brown Booby attendance and nesting activity increased further. During aerial surveys in 2021, we observed 13 nests

on 21 June and 9 nests on 7 July, including 6 nests with adults in incubation posture and 3 nests with adults attending single chicks (Fig. 4). On 16 September 2021, we counted 164 Brown Boobies during a boat survey, the high count for the study period. By 19 February 2022, the number of active nests had increased to 21, as documented from aerial photographs. From aerial photographs taken on 16 April 2022, we documented 23 nest structures, including 13 of the 21 observed in February and 10 newly attended nests. Aerial photographs from 13 June 2022 showed 19 active sites that included 10 fully feathered chicks and 2 chicks around 10–12 weeks of age. Of the 31 individual nest sites identified from February to June, 12 produced chicks, 11 were abandoned after documentation, 7 were still in the incubation stage at the time of the aerial survey in June, and 1 was usurped by a Double-crested Cormorant. While we documented at least 10 fully feathered chicks in 2022, we typically could not distinguish fledged juveniles from older immature birds.

#### Blue-footed Booby

We documented Blue-footed Boobies amongst the Brown Boobies during surveys from 2018 through 2022 (Table 1). We observed single individual adults during boat surveys on



29 August, 6 October, and 15 November 2018. We did not record any Blue-footed Boobies during surveys in 2019, but a single individual was observed during a boat survey on 27 February 2020. On 8 May 2020, we photographed an incubating Blue-footed Booby, and on 1 June 2020, we photographed the Blue-footed Booby standing next to an incubating Brown Booby at that same nest. A hybrid chick was well documented on subsequent visits to the island, and this individual was periodically observed on Sutil Island over the next 2 years, with the most recent sighting in July 2022.

In 2021, at least 2 Blue-footed Booby nests were active. From aerial photographs taken on 7 July, a 10- to 12-week-old chick was identified at a nest attended by an adult Blue-footed Booby (Fig. 4). A Blue-footed Booby pair rearing another chick was documented on 16 September.

In 2022, two Blue-footed Boobies were observed attending a nest during an aerial survey on 19 February, but no nesting adults or chicks were observed during aerial surveys on 16 April and 13 June. A juvenile Blue-footed Booby was documented during a boat survey on 9 July with an adult and the previously noted hybrid individual. However, we do not know whether the juvenile was from an undetected nest in 2022 or an older bird that fledged in 2021.

#### DISCUSSION

From 2013 to 2022 at Sutil Island, we documented the arrival and persistence of roosting Brown Boobies, and the onset and increase of nesting attempts from 4 nests in 2017 to 31 nests in 2022. Blue-footed Boobies were first documented by observation of a single adult bird in 2018, and nesting began in 2020. We documented a high count of 2 Blue-footed Booby nests in 2021. Brown Boobies appear to have produced fledglings as early as 2019. Blue-footed Boobies produced a hybrid fledgling in 2020, and non-hybrid chicks were documented in 2021. These observations document the first known breeding for these species in the continental United States and demonstrate a northward expansion of both species' breeding ranges in concert with several influential factors.

Avian species are generally expected to shift poleward to find suitable habitat in response to climate change (Peterson et al. 2002, Auer and King 2014). Increases in sea surface temperature

impact the physiological and ecological tolerances of seabird prey, and prey distribution may shift northward to cooler waters. During the 2014–2016 marine heatwave event, this behavior was described for many northeastern Pacific marine invertebrates (Sanford et al. 2019) and their predator chains—e.g., pelagic red crab (*Pleuroncodes planipes*) followed by tuna species (*Thunnus* spp.) followed by shark species (Cavole et al. 2016). Larval Pacific sardine and anchovy distributions shifted northward in 2015 and 2016, with the greatest total larval concentrations observed since the 1990s in the northern California Current (Auth et al. 2018). This northward shift in the distribution of these important prey species is projected to increase over the next century with climate change (Fiechter et al. 2021, Smith et al. 2021).

In addition to warming sea surface temperatures (Gentemann et al. 2017), the crash of the sardine fishery in the northern Gulf of California, Mexico, the likely source population of these boobies, may have also played a role in this breeding range expansion. The preferred prey for Gulf of California piscivorous seabirds are generally small shoaling pelagic species such as sardine, anchovy, and anchoveta (Mellink et al. 2001, Velarde et al. 2015). The sardine fishery in the Gulf of California decreased from a high fishery catch of greater than 500,000 tons in the 2008 to 2009 season to a low of 3500 to 4500 tons in the 2013 to 2015 seasons (Velarde et al. 2013). As prey availability declined, an “extreme, unprecedented breeding failure” of California Brown Pelicans occurred in 2014 and continued through 2016 in the Gulf of California (Anderson et al. 2017). Years of increased sea surface temperature and fisheries take in the Gulf of California have contributed to the northward expansion of nesting Elegant Terns (*Thalasseus elegans*) into the Southern California Bight (Velarde et al. 2015). Although sardine abundance was also low around the Channel Islands and in the Southern California Bight during the early years of Brown Booby colonization of Sutil Island, the anchovy biomass was at average amounts in this region in 2014 (Gallo et al. 2019). Piscivorous seabirds in the Gulf of California may shift their diets from sardines to a higher proportion of anchovies in years when sardine availability is low (Velarde et al. 2013). The low sardine availability in the Gulf of California may have driven these boobies northward, and

the availability of anchovies in the Southern California Bight may have contributed to their successful colonization.

The interplay of these ecological changes produced a situation in which prey availability within the Brown Booby's regular breeding range in the Gulf of California decreased and the northward emigration of prey items may have drawn foraging boobies into the Southern California Bight. The impacts of the 2014–2016 marine heatwave have been shown to persist for foraging seabirds (Osborne et al. 2020), and the lack of disturbance at Sutil Island, owing to protections by Channel Islands National Park and the Channel Islands National Marine Sanctuary, may have provided Brown Boobies with an attractive roost location with sufficient access to prey availability to support breeding farther north than their previous range.

While our counts of nests and birds were representative of annual colony sizes, survey effort was inconsistent across years, which impacted our ability to monitor breeding efforts and accurately estimate the number of locally roosting boobies (Fig. 3). A greater survey effort is needed to assess breeding phenology, which may be highly variable. Breeding Brown Boobies on islands in the Gulf of California, Mexico, have been reported to incubate from January through May, although within that same study, breeding at Isla San Jorge began 3 months earlier (Mellink 2000). The recent expansion of Brown Boobies to Middle Rock in the Coronado Islands showed egg-laying and incubation to occur between March and May in 2005–2007 (Whitworth et al. 2007). At Sutil Island, nesting has appeared to occur nearly year-round since 2017, as varying stages of nest building, incubation, and/or chick rearing have been observed in most months (February through November).

The establishment of this new colony highlights the need for continued and consistent monitoring of breeding seabirds at the California Channel Islands. In recent years, we have also observed low numbers of Red-footed, Masked, and Nazca Boobies roosting high on the cliff face of Sutil Island, intermixed with the now-regular Blue-footed and Brown Boobies (Benson et al. 2020, 2021, 2022). As these other *Sula* species are affected by many of the same shifts in prey distribution and habitat availability, they may also shift their breeding or foraging ranges northward under increasing pressures

from climate change or other impacts to their regular breeding locations. Continued monitoring will help track community shifts and inform the management of breeding seabirds in the California Channel Islands, as colonization by new species may increase competition for space with existing species and impact prey availability.

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