Did or Could Seabirds "Halo" Pitcairn Island for Fletcher Christian?

How did Fletcher Christian, leader of the mutiny on the *Bounty*, find Pitcairn Island when the supposed location was 342 kilometers west its actual location? This study in applied historical geography explores whether seabirds were potential navigational beacons pointing to the whereabouts of Pitcairn Island. Flight distances were extracted from seabird foraging range studies that employed global positioning system (GPS) with tracking devices. These data were used to construct foraging range buffers around Pitcairn and the other three islands of the Pitcairn Islands (Oneo, Henderson, and Ducie). The results indicated that seabirds extend island sighting distance and perhaps guided Christian to Pitcairn Island.

KEYWORDS: GPS, Fletcher Christian, historical geography, *HMS Bounty*, Mutiny on the Bounty, seabirds

Introduction

How did Fletcher Christian, leader of the infamous mutiny on the *Bounty*, find Pitcairn Island when the on-board reference had it 342 kilometers[1] west from its actual longitudinal position? Did Christian just zigzag along its supposed parallel as thought by Christian's great great-great-great grandson, Glynn Christian, in his outstanding investigation recounted in *Fragile Paradise;* [2] or as the meticulous anthropologist Henry Evans Maude supposed, Fletcher "had only run along the latitude."[3] [4] However, if one assumes the coordinates available to Fletcher were insufficient to find Pitcairn Island, what other factors might have given clues to its whereabouts? This investigation explores the potential that

seabirds alerted the mutineers of Pitcairn's location. The first European sighting of Pitcairn Island by British Captain Philip Carteret on July 2, 1767, included a referenced to a "vast number sea birds about it."[5] Because Pitcairn Island rises over 347 meters above sea level, Carteret sighted the island 15 leagues away (approximately 72 kilometers). The question posed is "[W]hether the foraging range of seabirds extended the sighting range of the Pitcairn Islands from the foretopmast crosstrees of the HMS *Bounty*?

The mutiny on the *Bounty* includes three major events; however, our focus is on the final segment of the journey with Fletcher Christian searching for Pitcairn Island. There are numerous books, articles, reports, movies, and plays recounting, romanticizing, and or psychologizing this most famous of all mutinies that occurred on April 28, 1789, on the *HMS Bounty*. Fletcher Christian, the master's mate, put Lieutenant Bligh and eighteen others in the ship's launch off Tofua (Tonga, South Pacific) to almost certain death. Bligh, however, led his loyalists on an epic survival adventure, a fascinating tale on its own right. Back on the *Bounty*, and after an abortive settlement on Tubuai (French Polynesia), sixteen of the *Bounty*'s crew, comprising mutineers and loyalists, elected to return to Tahiti. Captain Edward Edwards of the *HMS Pandora* later captured the surviving seamen, and their return journey is another classic of maritime survival. Fletcher Christian, and the remaining eight mutineers, six Polynesian men, twelve women, and one girl eventually arrived at the mischarted, remote, and uninhabited Pitcairn Island.[6] These were ideal hideaway characteristics for a motley crew hoping to elude the long reach of the British Admiralty. So nearly nine months after the mutiny and some 12,500 kilometers crisscrossing the South Pacific, the *Bounty* sighted its final destination, Pitcairn Island, on January 15, 1790.[7] The account given here is a meagre outline of events; scholars and amateur historians spend lifetimes exploring all aspects surrounding this rather insignificant but romantic maritime event. For those interested in learning more about the mutiny on the *Bounty* see the historical accounts by Hough,[8] Lummis,[9] Wahlroos,[10] Alexander,[11] Christian,[12] or one of the numerous other books available.

Study Area

This section includes three aspects of the study area integral to this investigation. Of course, we need to know Pitcairn Island's actual location and distances to the three other islands of the Pitcairn Islands. These will be included in our analyses to determine if there are intersecting seabird foraging ranges that might have given the mutineers a clue on the direction to their final destination. Further, one needs to be aware of the dubious latitude and longitude coordinates that Fletcher Christian had available to locate Pitcairn Island. The third element of the study area includes the track of the *Bounty* on route to Pitcairn Island. These three factors encompass the study area and set the stage for this investigation.

Actual Location

Pitcairn Island is located the South Pacific Ocean at 25° 04' S, 130° 06' W, and is southeast of Tahiti, French Polynesian (Figure 1).[13] [14] [15] Pitcairn Island is one of four scattered islands that includes Oeno, Henderson, and Ducie. Together these form the Pitcairn Islands, an overseas territory of the United Kingdom. These islands are situated just south the Tropic of Capricorn with Pitcairn Island the furthest south (Figure 2). The closest island to Pitcairn is Oeno Island (23° 56' S, 130° 44' W), an atoll about 143 km distance; the others include Henderson Island (24° 22' S, 128° 19' W) an uplifted coral platform at 193 km, and Ducie Island (24° 40' S, 124° 47' W) another atoll at 470 km.[16] [17] Pitcairn is the most substantial of these islands being of volcanic origin with its highest point Big Ridge at 347 meters.[18] Of these four islands, Pitcairn alone contains suitable resources to support a small permanent population; the others, could just manage a respite. For example, castaways from the *Essex* made landfall at Henderson Island on December 20, 1820, one month after its infamous sinking by a sperm whale (Moby Dick). The survivors were to find sustenance from a meagre and erratic spring and unwitting tropicbirds for eight days before heading out toward South America.[19] Pitcairn Island's current population is about 54 with most descendant from the mutineers and their Polynesian consorts, the other three islands are uninhabited.

Pitcairn Island: Lost in Space, 1767-1808

Pitcairn Island was "discovered" by Captain Philip Carteret on July 2, 1767, as he was approaching from the east. His original journal of this voyage, published in 1965 for the Hakluyt Society, recorded the coordinates, 25 ° 02' S and 133 ° 30' W, for Pitcairn Island.[20] However, on board the *Bounty*, Fletcher Christian had access to Hawkesworth's edited version of Captain Carteret's handwritten journal.[21] There are two problems with the coordinates given in Hawkesworth's edition of *Voyages*. First, Hawkesworth introduced an error of 5° in transcribing Pitcairn Island's latitude at 20° 2' S.[22] However, as Maude realized almost sixty years ago, this was an obvious error.[23] One can read the entries before and after July 2, 1767, to see that 20° would have been a leap; further a chart included between the narrative records Pitcairn Island's coordinates as 25° 02' S and 133° 30' W. So inconsistencies with latitude should have been inconsequential as Maude and Christian mention. The second problem is that Hawkesworth's transcription of Carteret's longitude of 133° 21' W (on page 561) was off 9' W from the longitude on the foldout chart mentioned. The latitude and longitude given on the chart, 25° 02' S, 133° 30' W, match Carteret's journal; these were 3° 24' west or 342 km from Pitcairn's actual position (see "Pitcairn?" on Figure 1).[24] According to Wahlroos, Carteret's chronometer, a precise timepiece used in maritime navigation to determine longitude, was "inaccurate" and "defective," and this explains the error.[25] If traveling from west to east, Fletcher Christian would have to cover an additional 342 kilometers eastward to reach Pitcairn. According to Alexander, even in 1808, Captain Folger, an American Sealer, coming from the opposite direction or east, came across Pitcairn Island much sooner than expected.[26] Six years later by "chance & meer accident,"[27] the *HMS Briton* and *Tagus* stumbled upon Pitcairn Island. Captain Pipon wrote, "we considered ourselves nearly 200 miles from it, when land was discovered, & we verily believe that in Sight was a new discovery."[28] Pitcairn Island was literally lost in space.[29] Pitcairn Island was isolated, remote, and small-sized, with a violent surf making it difficult to locate and challenging to approach; further, it had water, fertile soil, a temperate climate, and the good fortune of

being uninhabited in 1790. However, it did present evidence of previous Polynesian occupation with a scattering of domesticated plants, artifacts and pictographs. Could there have been a better spot for mutineers to evade capture? Probably not.

Post Mutiny: Maude's Reconstruction of the Bounty's Track

Numerous accounts, even contemporary ones, gloss over the *Bounty's* track after leaving Tahiti for the final time, for example, Chandler writes, "for some months they sailed the Pacific and eventually found lonely, uninhabited Pitcairn…"[30] So where did the *Bounty* go after depositing Lieutenant Bligh on April 28, 1789? Knowledge of the *Bounty*'s track after the mutiny suffered major gaps until Maude's reconstruction from first-hand accounts. While there are still questions, Maude's paper, published in *The Journal of the Polynesian Society*, was a masterpiece in piecing together available sources. His sketched chart depicts the probable route of the *Bounty* after the mutiny on April 28, 1798. Maude's map does not include a scale, north arrow, parallels and meridians, and other map elements to assist the reader. Nevertheless, given the paucity of sources — two eyewitness accounts and some supporting reports— this simple map is a major contribution of the *Bounty's* whereabouts after the mutiny.[31] One eyewitness was the boatswain's mate James Morrison on board the *Bounty* during the mutiny and until its final departure from Tahiti on September 23, 1789.[32] The other eyewitness was Jenny (Teehuteatuaonoa), the Tahitian consort of mutineer Isaac Martin. She provided first-hand accounts from where Morrison left off, the *Bounty's* final departure from Tahiti to its eventual arrival on Pitcairn Island.[33] Jenny ultimately made it off Pitcairn Island and circuitously returned to her home on Tahiti. She provided interviews after leaving Pitcairn Island that appeared in the *Sydney Gazette* and the *Bengal Hurkaru*.[34] Those interested in the details of this excellent example of historical sleuthing should read Maude's article, *In Search of a Home: From the Mutiny to Pitcairn Island (1789-1790).*[35]

Our focus here is the *Bounty's* final approach to Pitcairn Island, between December 15, 1789, and January 15, 1790. However, before that the *Bounty* began its journey heading southeast about November 15, 1789, from around Hunga Tonga and Hunga Ha'apai (near Tongatabu, Tonga) and looping "into cooler climates to find hospitable winds." [36] The *Bounty* followed the 40th parallel eastward until swinging north around the 130° W meridian. [37] Christian had effectively advantaged the *Bounty* to the general circulation around the South Pacific Subtropical High, first the Westerlies (poleward side) and then the Southeast Trades (equatorward side).[38] With these trajectories, the *Bounty* could transport itself in the general vicinity of Pitcairn Island. The assumption here is that the *Bounty* approached Pitcairn's supposed location from the south then sailed east when not sighting the island. Fletcher's track is similar to Bligh's second breadfruit expedition that carried the *HMS Providence* "south of the 48th parallel" until reaching "the longitude of Tahiti, whereupon he turned northward."[39]

Methodology

The "Did" in the title refers to historical evidence that seabirds contributed to finding Pitcairn Island; whereas, the "Could" explores the scenario that seabirds might have been instrumental in the search of this remote South Pacific island. Using Carteret's mention of seabirds swarming around Pitcairn, maritime historian Richard Hough in *Captain Bligh and Mr. Christian: The Men and the Mutiny* assumed the *Bounty* received a similar welcome on January 15, 1790.[40] Caroline Alexander in *The Bounty: The True Story of the Mutiny on the Bounty*, excluded seabirds altogether as there were no firsthand accounts to support this claim.[41] While Hough and Alexander differ on the presence or absence of seabirds, neither account is sufficient to claim that seabirds were or were not useful beacons to Fletcher Christian. However, Captain James Cook, mentions encountering the "presence of birds, seals, and seaweed" on approaching the east coast of North Island, New Zealand.[42] Lewis recounts modern-era traditional Micronesian navigators stressing that making landfall "was determined by the very important land signs, especially clouds, waves, and birds."[43] Seabirds were so numerous on first arrival that John

Adams is recorded saying that besides the ship provisions, the mutineers subsisted on the abundant seabirds and fish. [44]

In *We, the Navigators*, David Lewis relives and reviews the ancient art of Polynesian and Micronesian navigation.[45] [46] He envisions the possibilities of modelling the factors (island elevation, clouds, seabirds, smell, swell patterns, deep phosphorescence or "under water lightening," and stars) that contribute to locating and detecting islands or landfinding. He was in essence imagining a geographical information system (GIS) experiment before such software applications became common practice. Lewis cautioned that while modelling landfinding would be plausible, he thought that results would be ephemeral with the ever-changing elements of an ocean environment. While this is true, one simple solution would be to calculate island-sighting distances using the height of a lookout on crosstrees of the ship's mast and island elevation, and to complement this with seabird foraging ranges, and even with wave height. Other factors, that might increase or decrease island sighting such as atmospheric refraction, cloud cover, and inclement weather are outside this study's scope, and forthrightly given the general nature of this investigation, superfluous. Line of sight (LOS) calculations will provide the distance the Pitcairn Islands (Pitcairn, Oeno, Henderson, and Ducie) would have been visible from the approaching *Bounty*. Seabird foraging ranges extending outside an island's line of sight (LOS) will increase its detection. Even seabirds foraging within the island's LOS would provide guidance during inclement weather and poor visibility.

Calculating Line of Sight Distance

To generate the LOS distance the following data were required: 1) maximum elevation of Pitcairn, Oeno, Henderson, and Ducie Islands, and 2) height from approaching ship (i.e., crow's nest or topmast crosstrees). The elevation data for Pitcairn, Oeno, Henderson, and Ducie Islands are from the European Commission.[47] The Pitcairn Islands include four widely spaced islands and includes two atolls, Oeno the

furthest west, and Ducie, the furthest east at 2 meters and 3 meters, respectively. Henderson Island is an uplifted coral platform rising about 30 meters and then there is Pitcairn Island rising 347 meters above sea level (Table 1).

The *Bounty*, a square-rigged ship, was 90' 10" by 24' 4" with three masts, a fore, main, and mizzen.[48] The masts were not a single pole, but joined from sections. For example, the height of the structure included a foremast proper of 51 feet, a topmast of 34 feet and 3 inches, a gallant mast of 17 feet and 3 inches, and a polehead of 8 feet and 7 inches.[49] So from the foremast lookout position on the topmast crosstrees, the height would include the foremast proper of 51 feet plus a topmast of 34 feet and 3 inches minus the ship's draft of 11' 4." If assuming an additional five feet for a lookout standing on the crosstrees, the total distance above the water would be about 79 feet or in metric, 24.1 meters. [50]

Knowing the height at which a lookout was standing on the foretopmast crosstrees and each island's elevation, the distance the islands became visible from the *Bounty* was calculated. The formula used here is $D = \sqrt{(2rh_1)} + \sqrt{(2rh_2)}$, where D = distance, r = radius of Earth in kilometers (6367.45), h_1 = height at the *Bounty's* foretopmast crosstrees in meters/1,000, and h_2 = elevation of island in meters/1,000.[51] Having the greatest elevation, Pitcairn Island can be viewed the furthest offshore at 84 km, and Oeno Island with the lowest elevation just 22.6 km (Table 1). Wave height could also have increased the sighting distance of the Pitcairn Islands. However, during the month (January) that the *Bounty* would have been approaching Pitcairn, wave heights of 4 meters would have occurred on average less than 10% of the month. That being the case, wave height was excluded from the final analysis, further, 4 meter waves increase sighting distance a mere 1.4 km.[52] Factors such as atmospheric refraction, cloud analysis, coconut trees, and other influences that might increase island detections were excluded from analysis.

TABLE 1 Line of sight distances from the *Bounty* to Pitcairn, Oeno, Henderson, and Ducie Island.

Pitcairn Islands	Elevation (m)	Height (m) *Bounty's* Foretopmast crosstrees	Sighting Distance (km)
Pitcairn	347	24.1	84.0
Oeno	2	24.1	22.6
Henderson	30	24.1	37.1
Ducie	3	24.1	23.7

Foraging range studies, employing tracking devices and the global positioning system (GPS), were gathered for the brown booby (*Sula leucogaster*) = BRBO, red-footed booby (*Sula sula*) = RFBO, and the masked booby or blue-faced booby (*Sula dactylatra)* = MABO (see Table 2). For each *Sula* species, the distances encompassing 50%, 68%, and 95% of the observations (seabirds) defined radii used to construct buffers. These foraging buffers were superimposed over each islands' sighting boundaries (Figures 2-4). If seabirds foraged outside an island's LOS (sighting range based on height of ship and elevation of island) then seabirds would extend, and therefore, enhance island detection.

Foraging Ranges for Select Seabirds

This analysis includes information on the foraging range of white or fairy terns *Gygis alba*, boobies (*Sula* species), and frigatebirds (*Fregata minor)* found on present-day Pitcairn, Oeno, Henderson, or Ducie Islands.[53] These seabirds are pelagic or oceanic birds that forage outside the continental shelf or greater than 8 km offshore; however, no simple definition suffices, as exceptions exist. [54] According to AviBase,[55] terns are current on all four islands, and all have the red-footed and masked boobies, and frigatebirds. The two atolls on the extreme west (Oeno) and east (Ducie) do not support populations of BRBO.[56] Surveys from the late 1950s[57] and more recently from Irving and Dawson[58] have documented these seabirds on the Pitcairn Islands. Unfortunately, seabird populations have diminished at present with ongoing threats over the years from rats, cats (on Pitcairn Island) and

humans. Efforts have been ongoing to eradicate rats on Henderson Island and other seabird havens of the Pacific.[59]

The assumption is that these same species were around in 1790, and in larger numbers. Lummis' statement that seabird eggs gathered from Pitcairn's cliffs "were so numerous that they were even collected as pig fodder" supports this notion.[60] Since the Pitcairn Islands were uninhabited at first European contact, seabirds, especially those breeding on Pitcairn Island with its sheer cliffs, were not threaten from humans, but still had the infamous Polynesian rat to dodge (*Rattus exulans*). Archaeologists have recovered several RFBO and MABO bones from prehistoric Polynesian sites on Henderson Island.[61] [62] [63]

Lewis cites some conservative estimates on the foraging ranges of terns (40 km), BRBO (48 km), RFBO (80 km), blue-faced or MABO (80 km), and frigatebirds (120 km).[64] These are estimates from actual Polynesian navigators sailing with Lewis, together with other "modern" studies from the 1940s-1960s.[65] [66] Studies from that era timed the duration of seabird foraging trips to estimate distance; global positioning system (GPS) and tracking devices for birds were a future innovation. As late as 2004, Gaston reported few completed seabird studies because of the expense of using GPS and telemetry devices.[67] Since then, there have been studies completed on masked, red-footed, and brown boobies, several on frigatebirds, but none was found for terns from the South Pacific. Recent studies using GPS technologies are becoming more common after 2010; however, more studies are required to document the foraging behavior of different seabird species and locales (Table 2). Even with these more sophisticated studies, it is difficult to generalize on seabird foraging range because distance and duration change during stages of breeding (incubation, chick rearing).

There are numerous factors that influence distance seabirds travel to forage including the distributions resources such as colony sites, upwelling, and other factors such as life stage (incubating or

brooding), and gender, to name some.[68] However, the meta-analysis of recent studies offers a sense of possible foraging ranges for BRBO, RFBO, and MABO; though these also illustrate the substantial variability existing between and within species. These biological studies were from across the southern hemisphere reaches of the Pacific or Indian Oceans, with an exception or two (Table 2). The statistics (mean, standard deviation, and maximum) from individual studies create a challenge to reemploy toward other situations. For example, while most of the studies involved seabirds during incubation or chick rearing, or both, no attempt was made to separate these out. Seabirds forage greater distances during incubation than chick-rearing periods, so again our results offer a conservative estimate of the extent seabirds might have contributed to land detection. Nevertheless, since the objective here is to illustrate the possible, the author finds this acceptable. While the *Bounty* was approaching Pitcairn Island during the first two weeks of January, it is likely that these *Sula* species were breeding, and created a halo around Pitcairn Island.[69] [70] This is because the BRBO, RFBO, and MABO are "central place foragers when breeding" and return to nesting sites during incubation and chick rearing.[71] Data from GPS studies were amalgamated with foraging distances re-calculated with 50% (mean), 68% (mean +/- 1 standard deviation), and 95% (mean +/- 2 standard deviations) of the observations for BRBO, RFBO, and MABO. [72] *Sula* foraging buffers were superimposed on each island's sighting distance (Table 1, Figures 2-4).[73]

TABLE 2 50, 68, and 95% Foraging Range Distances from GPS studies.

Common/ Scientific Name	**# GPS Seabird Tracks**	***Distance (km) 50%***	***Distance (km) 68%***	***Distance (km) 95%***	**Study Areas**	**Sources (footnote)**
Brown Booby *Sula leucogaster*	44	**26**	**40**	**55**	Baja California Peninsula; Palmyra Atoll, Pacific Ocean; Swain Reefs/Great Barrier Reef	Weimerskirch et al. (88); Young et al. (85); Bunce et al. (87)

Red-footed Booby *Sula sula*	437	**56**	**95**	**132**	Palmyra Atoll, Pacific Ocean; Tern Island, Pacific Ocean; Tromelin Island, Indian Ocean; Europa Island/Mozambique Channel	Young et al. (85, 86); Kappes et al. (82); Weimerskirch et al. (80); Mendez et al, (79)
Masked Booby *Sula dactylatra*	321	**66**	**111**	**148**	Palmyra Atoll, Pacific Ocean; Tern Island, Pacific Ocean; Phillip Island, southwestern Pacific Ocean; Tromelin Island, Indian Ocean; Clipperton Island, eastern tropical Pacific	Young et al. (85, 86); Sommerfeld et al. (83, 84); Kappes et al. (82); Weimerskirch et al. (68)

Note: Distances rounded to nearest kilometer; calculations are available from the author on request.

Results

Line of Sight Distances

A lookout on the crosstrees of the *Bounty*'s foretopmast could, barring overcast skies, precipitation, or other factors that detract from visibly, detect Pitcairn Island at 84.0 km away. The three other islands, being of much lower elevation, would be visible from 31.7 km (Henderson), 23.7 kilometers (Ducie), and 22.6 km (Oeno) (Table 1 and Figure 2). The lookout position from the *Bounty*'s foretopmast crosstrees at 24.1 meters above the water line contributed 17.5 kilometers of each of these readings; while not enormous, this does increase one's chance of detecting an island. For example, at sea level Pitcairn is visible about 66.5 km about, but from the *Bounty's* mast detection increased to 84 km.

First Encounters - The Great Frigatebirds

On entering the LOS buffer of Pitcairn Island's supposed location, Fletcher Christian might have observed first occasional frigatebirds (*Fregata minor*) hovering aloft as these pirates of the sky cover enormous distances. Weimerskirch et al. reported maximum distances of 1,444 km and 600 kilometers,

respectively, for individuals from Aldabra Island (southwestern Indian Ocean) and Europa Island (Mozambique Channel).[74] Couple this with the fact that frigates do not necessarily return to land each night, and can remain aloft for a succession of days, indicates that these seabirds are not particularly useful in island detection. Nonetheless, frigatebirds might have given Christian a general clue that islands existed somewhere well beyond the horizon.

Having entered the southern half of the supposed location's sighting buffer, and ultimately crossing Carteret's coordinates (25° 02' S, 133° 21' W) without success, Fletcher Christian "then sailed east" 258 km (342 km – 84 km) toward the horizon.[75] Continuing eastward the *Bounty* ventured outside the eastern half of the supposed sighting distance (258 km – 84 km). Now, just 174 kilometers separated the *Bounty* from Pitcairn Island. It would another 26 km before entering the MABO's 95% range (Figure 2). At this point, the crew might have encountered an isolated masked booby with several studies reporting maximum-recorded distances of 227, 230, 241, and 249 kilometers.[76] [77] [78]

Finding Pitcairn

If the *Bounty* had continue eastward, the crew might have noticed masked boobies making haste towards Oeno and Pitcairn with the approach of evening. On entering the 95% MABO foraging range, just 148 km separated the *Bounty* from Pitcairn Island, and just 64 km from sighting their final destination— assuming unimpaired visibility. Christian would have followed seabirds travelling the 25th parallel to Pitcairn and ignored those flying northeast towards Oeno. The MABO had the greatest foraging range at each percentage level (50, 68, and 95%) followed by RBBO, and BRBO (Table 2, Figures 2-4). [79] [80] [81] [82] [83] [84] [85] [86] [87] [88] [89] [90] [91] [92] [93] [94] [95] [96] [97] [98] For the 95%, both MABO at 148 km and RFBO at 132 km extended the 84 km sighting distance of Pitcairn Island (Figures 2 and 3). Further, the 95% and even 68% MABO and RFBO foraging buffers around Pitcairn, Oneo, and Henderson Islands coalesce. On sighting Pitcairn, Christian would have been within 84 kilometers, the seabird density would begin to

increase substantially. Brown boobies exist today only on Pitcairn and Henderson Islands. If this were also the situation in 1789-90, BRBO encounters at high densities would be a sure sign of nearing Pitcairn, even during inclement weather. Sightings of BRBO would begin around 55 km offshore, with densities increasing toward shore (Figure 4). While BRBO's foraging range are contained within Pitcairn's sighting distance of 84 km, these seabirds expand Henderson's detection from 37 km to 55 km.

Had Christian managed to pass Pitcairn Island (i.e., inclement weather), there might have been high densities of MABO, RFBO, and BRBO, not to mention other seabirds (i.e., white terns), hovering close to shore (Figures 2-4) and east of the 130° W meridian. This would have given the mutineers another opportunity to find Pitcairn Island, but this would have required turning the *Bounty* around and following the seabirds going in the now in the opposite direction. Had Christian still failed to locate Pitcairn Island, another option offering short-term respite would have been Henderson Island 193 km northeast. While Ducie Island supports MABO and RFBO residents, their 95% foraging ranges are outliers (Figure 4). Perhaps Christian would have headed back toward Tahiti, rather than continuing eastward another 470 km to Ducie (Figure 4).

Discussion

This investigation explored the possibility that seabirds directed Fletcher Christian and the *Bounty* to Pitcairn Island. Most seabirds return to a central place to roost at nighttime, while there are exceptions (i.e., frigatebirds travel great distances and remain aloft for days and nights), navigators can hold their position and wait to see how many and what direction seabirds dart towards evening. Three elements contributed to establishing the study area, these include Pitcairn Island's supposed location, its actual location, and the track of the *Bounty*'s approach. If the *Bounty* sailed to Pitcairn Island's supposed location, and not finding it as expected, Christian would then have followed the 25th parallel. Under this scenario, the telltale signs of seabirds would almost certainly guide the *Bounty* to Pitcairn Island or at

the least to Oeno or Henderson that could offer temporary relief. Recent GPS studies exploring the foraging ranges of brown, red-footed, and masked boobies allowed for the construction of seabird foraging buffers around four islands in the Pitcairn Islands. Therefore, as Fletcher Christian crossed into the LOS zone of Pitcairn's supposed location, he might have been aware that the given coordinates were incorrect. At this point, Christian might have observed an occasional frigatebird and then masked and red-footed boobies on going further east (Figures 2-3). As the *Bounty* continued to sail eastward, the higher densities of red-footed and masked boobies would be returning towards evening eastward to Pitcairn Island (Figure 3). On penetrating Pitcairn Island's LOS buffer, higher densities of MABO, RFBO, and closer in, BRBO would have been a further clue to the presence of land (Figure 4).

There are of course some limitations to this study. For starters, studies on seabird foraging ranges, are still scant, but increasing. Most of these studies postdate 2000, with most appearing since 2010. However, too few seabird species have been tracked using GPS, and further, coverage of geographic regions including the Pitcairn Islands are lacking. Local studies would have allowed tuning of foraging patterns and account for directional biases, if any, generated from resource distribution and wind patterns.[99] [100] While this investigation suggests seabirds were likely signposts for the *Bounty*'s search, there is also a modern-day application involving seabirds and Pitcairn Islands. In 2016, the Pitcairn Islands established the Pitcairn Islands Marine Reserve (PIMR).[101] Its area corresponds with Pitcairn Islands' exclusive economic zone minus 12 nautical mile buffers around Oeno, Henderson, Ducie, and Pitcairn, including an extension from the latter to the 40 Mile Reef (Adams Seamount), which are available for non-commercial sustainable fishing.[102] Local GPS seabird projects would provide valuable information on seabird foraging patterns useful in managing the PIMR. In conclusion, it was possible that seabirds directed Fletcher Christian to Pitcairn Island in 1790. Seabirds would have in effect created a hovering halo surrounding this infamous and isolated rock in the South pacific. Of course

factors such as clouds, swell patterns, deep phosphorescence, coconut trees, smell, and seaweed and branches might have further alerted Fletcher Christian and the *Bounty* to Pitcairn Island.

Figure Captions

FIGURE 1. Study Area: Pitcairn Islands, South Pacific

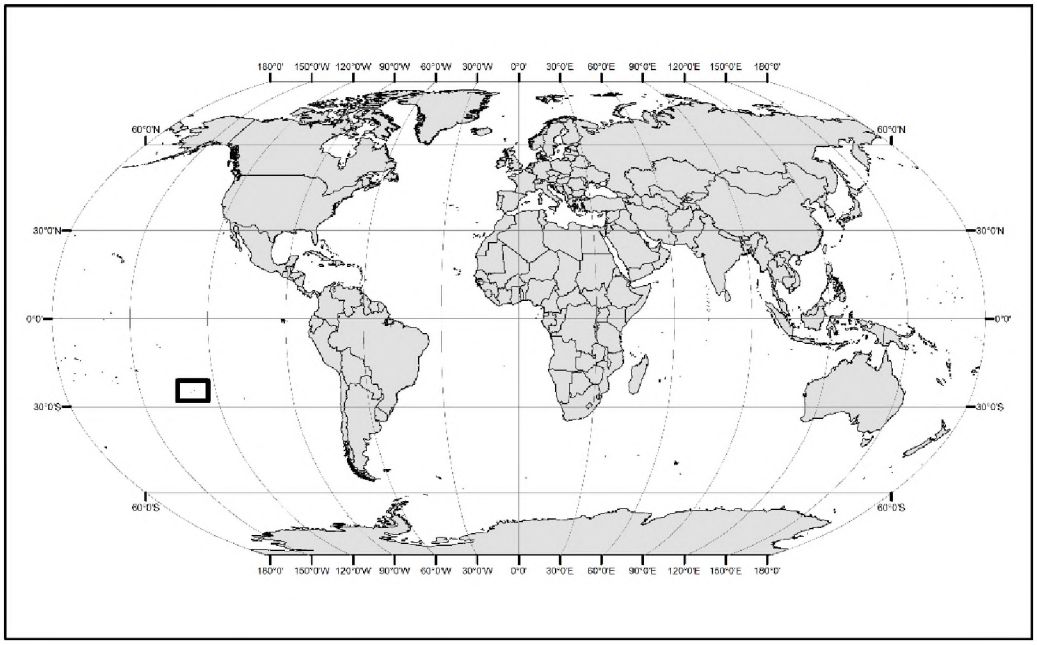


FIGURE 2. Masked Booby (*Sula dactylatra*) 50, 68, and 95% Foraging Ranges

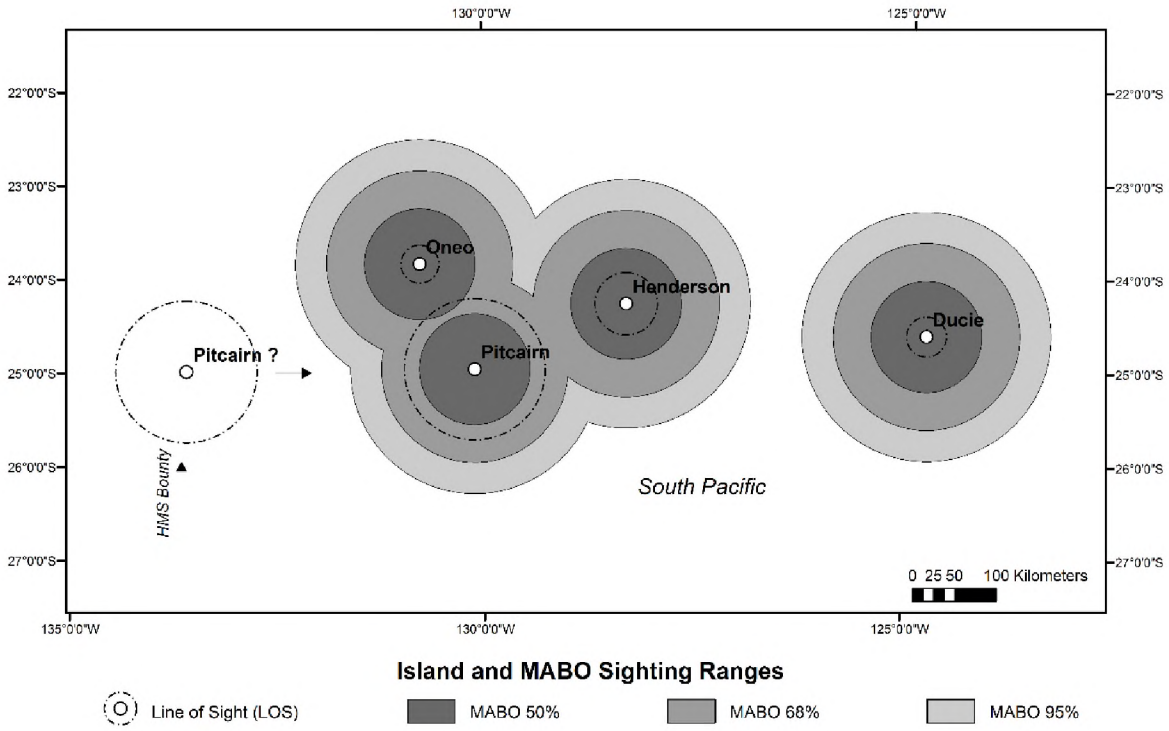


FIGURE 3. Red-footed Booby (*Sula sula)* 50, 68, and 95% Foraging Ranges

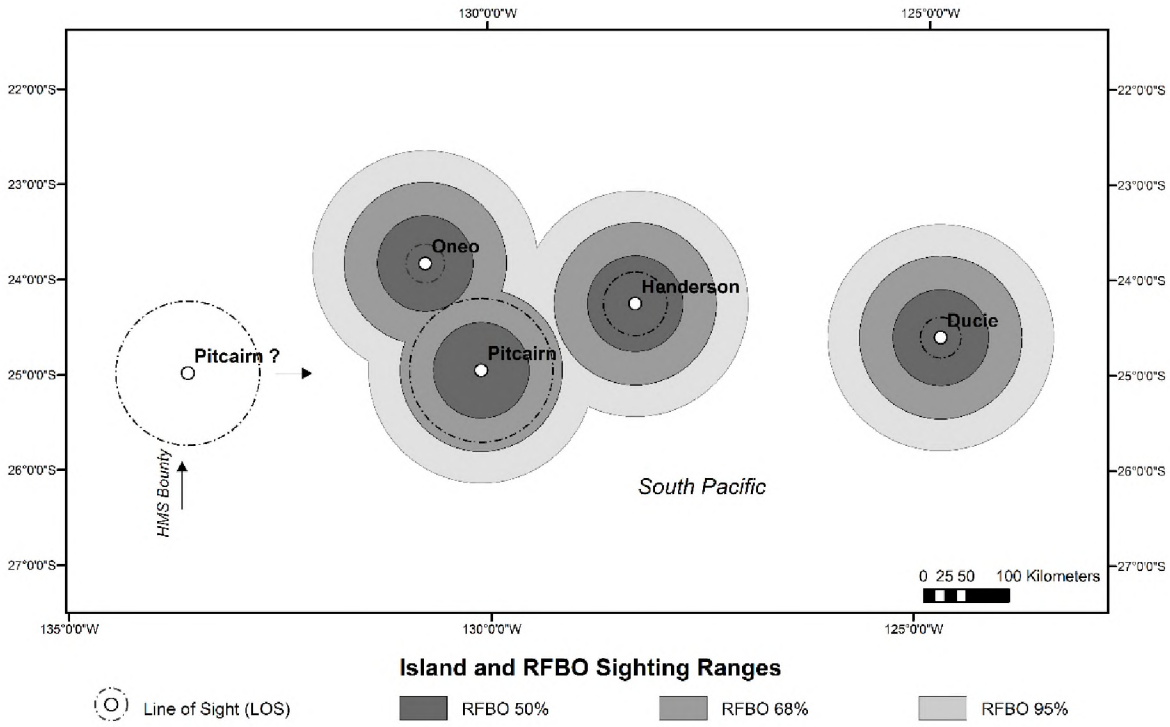
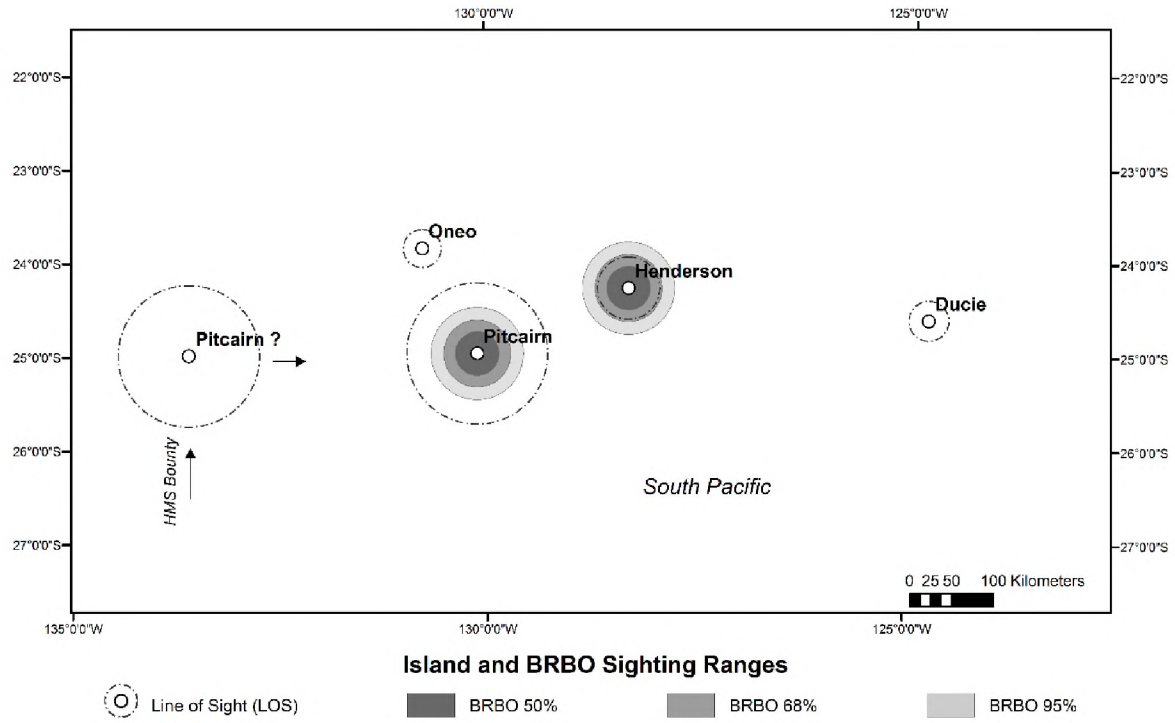


FIGURE 4. Brown Booby (*Sula leucogaster*) 50, 68, and 95% Foraging Ranges



[1] The distance between Pitcairn Island's supposed and actual locations was determined using ArcMap's 10.2 "Measure" tool. The geodesic or shortest path between 25° 02' S, 133° 30' W (supposed) and 25° 04' S, 130° 06' (actual - Adamstown) is 343.102 km using WGS 1984 (datum) and UTM Zone 9S Transverse Mercator (projection). If we then subtract 1 km, the horizontal distance between Adamstown (25° 04' S, 130° 06') and Pitcairn's west coast, the distance between Pitcairn supposed and actual locations is 342.102 km.

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