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Home Range or Foraging Radius of Tropical Seabirds potentially affected by Tesoro Hawaii SPM Hose Oil Spill - Determination of likelihood that birds from any particular breeding colony were exposed to oil in their area of activity.

Tropical seabirds such as those found in the waters surrounding the Hawaiian Islands are classified almost without exception as highly pelagic foragers, most dependent on association with subsurface predators such as Yellowfin and Skipjack Tuna (*Thunnus albacares* and *Katsuwonus pelamis*) (Au and Pitman, 1986; Ashmole and Ashmole, 1967; Ballance, Pitman, and Reilly, 1997; Murphy and Ikehara, 1955). Just as the tuna they associate with these birds are highly mobile and they exhibit prodigious abilities to fly long distances to forage. Long distance foraging is correlated with all aspects of their morphology, physiology, and life history including high aspect ratio wings (long and narrow), low wing-loading (low body mass per unit of wing area), ability to produce stomach oil in order to provide food with high energy density for chicks, ability to feed by regurgitation, ability to endure long incubation shifts, and chicks with the ability to survive long periods between feedings.

Any evaluation of the impacts of an oil spill in waters used by tropical seabirds must contain consideration of the long distances that these birds fly on a daily basis. In order to decide which breeding colonies are located within the area that might have been affected by the Tesoro Hawaii SPM Hose Oil Spill we must estimate the home range or foraging radius for each of the species nesting in those colonies and determine if areas through which oil passed fall within that radius of activity for each species.

The enormous distances that such birds cover on a daily basis make it very challenging to directly track individuals and thus determine home range areas. Early attempts using radio telemetry failed because the birds fitted with radio transmitters quickly flew beyond the range of the receivers (Harrison and Stoneburner, 1981; Flint, Unpublished). Advances in the technology of using satellite transmitters have enabled ornithologists to track the largest of the seabirds, albatrosses, but these devices have not yet been used successfully on the smaller species of tropical seabirds. The most effective approaches to calculating foraging range around a colony include marking birds with a highly visible tag or color and observing at sea or calculating flight range based on flight velocity and time away from the nest. Some researchers have also used information about the energetic cost of flight and the average food load to calculate flight ranges.

All of the 22 seabird species breeding in Hawaii (Table 1.), and many other species transiting the area, could have been exposed to the oil. The following discussion includes species that breed in Hawaii and were known to have been oiled and species that were particularly vulnerable during this spill due to their behavior or the timing of their breeding seasons. For several of the breeding species we have estimated foraging radii using values from the literature as the basis for our calculations. These foraging radii include areas of activity that encompass oiled waters based on beach contamination. The consistent pattern of pelagic foraging for all these species indicates all seabird colonies on or around Oahu, Kauai, Niihau, and Kaula were potentially affected by this spill. Figures 1-6 illustrate the large foraging radii of the species in

question. Birds from all colonies were within easy commuting distance of areas known to have been oiled. Furthermore, tropical seabirds may be attracted to oil by fish that aggregate in the water column below the floating oil and thus become contaminated when attempting to feed (Fefer, et al., 1984)

Red-footed Boobies

Figure 1 illustrates the foraging radius calculated below around 4 of the 5 breeding colonies of Red-footed Boobies in the main Hawaiian Islands. On Oahu the birds breed on the Mokapu Peninsula and directly adjacent on Moku Manu Island (same circle for both) The foraging range around breeding colonies at Kaula Rock and Lehua Island off of Niihau are also illustrated. The fifth site is Kilauea Point on the north shore of Kauai where numerous oiled Red-footed Boobies were recovered.

Flight Velocity (Ballance, 1995) 12.8 meters/sec

Feedings per day (Hu, 1991) 1.032 feedings/day for 5 week old chick

Trip Length (Ballance 1995) 11.3 ± 2.0 h (n = 10 birds, 2 to 5 trips each)

Estimated maximum flight time to feeding areas ~6 hours (approximately half of mean trip length)

Estimated foraging radius 276.5 kilometers (171 miles)

Brown Boobies

The only known breeding and roosting sites of Brown Boobies in the high islands of Hawaii are Moku Manu and Kaula (Fefer, Hu, and Naughton, unpublished manuscript). All of the birds of that species that were oiled most likely came from those sites. Therefore, we can assume that all Brown Boobies at Kaula Rock and Moku Manu were potentially exposed.

Masked Boobies

In a radio tracking study of Masked Boobies in the Galapagos, Anderson and Ricklefs (1987) followed tagged birds at sea and never found a Masked Booby feeding any closer than 65 km from the colony. Due to the richer, cold water environment of the ocean around the Galapagos the foraging radii of Masked Boobies around more typical tropical islands in warm water areas with scarcer food supplies are almost certainly much greater. Figure 2 shows foraging range for Masked Boobies calculated using values from central Pacific Masked Boobies.

Flight velocity - 11.0 m/s (Anderson and Ricklefs, 1987)

minimum possible time away from colony on long trips - ~9.5 h (Kepler, 1969)

Estimated flight time to feeding areas - ~4 hours

Estimated foraging radius oceanic island type - 158 km or 98 miles

White-tailed Tropicbirds

These birds nest in cliff cavities on the main Hawaiian Islands and the offshore islands such as Moku Manu and Kaula Rock. Tropicbirds are known to be highly pelagic. Their estimated foraging radius around Kaula Rock is illustrated in Figure 3. Birds nesting anywhere on Oahu, Kauai, Lehua, or Kaula would have had access to the oil.

Feeding Interval - 16.7 h (Schaffner 1990a)
Flight velocity - 13 m/s (Schaffner, 1990b)
Estimated foraging radius - 374 km or 232 miles

Red-tailed Tropicbirds

Red-tailed Tropicbirds also exhibit wide-ranging foraging behavior. They are known to nest on cliffs on Lehua, Niihau, Kaula, Manana Island (off Oahu), Kilauea Point, Molea Point, and Crater Hill (on Kauai). Their nests are typically inaccessible at sites in the main islands so were not checked for oiled birds. Figure 4 indicates the estimated foraging radius of this species around Kaula but they would have access to presumed oiled areas from any of the breeding sites in the main Hawaiian Islands.

Flight Velocity 13 m/s (WTTR, Schaffner, 1990b)
Mean # Feedings per day Johnston Atoll - 1.17 (Schreiber and Schreiber, 1993)
Estimated flight time to feeding areas 10 h
Estimated foraging radius - 468 km or 290 miles

Sooty Terns

Sooty Terns were finishing their breeding season at Kaula Rock, Moku Manu, and Manana Islands at the time of the spill. The following are two calculated estimates of foraging radius in this far-ranging species. These estimates are corroborated by sightings of breeding birds marked with streamers and later sighted from ships at similar distances around Johnston Atoll (Gould, 1974). Figure 5 illustrates the more conservative estimated foraging radius of Sooty Terns around Kaula Rock, Manana, and Moku Manu.

Maximum foraging radius (time away from nest)- 522 km or 324 miles (Flint, 1991)
Maximum foraging radius (energy requirements) - 740 km or 460 miles (Flint, 1991)

Brown Noddies

Brown Noddies nest in large numbers on Kaula Rock and Manana Island but also occur on Moku Manu and Mokolea Rock, Oahu. They frequently have a pulse of breeding activity in late summer - early fall. Figure 6 depicts the estimated foraging radius of Brown Noddies around their colonies at Kaula and Manana Island.

Flight velocity - 9.10 m/s (Schnell and Hellack, 1979)

Mean Incubation shift length - 11.3 h (Megyesi, 1995)
Estimated flight time to feeding areas ~5 hours
Estimated foraging radius 163 km or 101 miles

Dark-rumped Petrels
Newell's Shearwaters

Both of these species were at risk from this spill not only because of where they feed, which is similar to the other birds already discussed, but also because of their habit of congregating offshore prior to sunset (Ainley, et al., 1997). They do not return to their colonies, which are on steep slopes high in the interior of Kauai, until after dark so they sit on the water in a group called a raft.

Bulwer's Petrel

Bulwer's Petrels have extremely long incubation shifts which is generally thought to correlate with distance foraging.

Mean Incubation shifts - 10.2 ± 3.7 days for males at Johnston Atoll
 5.8 ± 5.0 days for females, Johnston atoll
(Megyesi and O'Daniel, 1997)

Wedge-tailed Shearwaters

Long intervals between chick feedings make it likely that this species also flies long distances to feed at sea.

Average trip lengths - 40.9 hours (Baduini, 1998)

Great Frigatebirds

Great Frigatebirds cover huge distances. Breeding birds marked at Tern Island, French Frigate Shoals have been re-sighted at Laysan, Midway, Kure, Johnston Atoll, Wake Island, and the Philippines. These trips indicate that these birds can easily travel thousands of miles. The only breeding colonies for this species in the main Hawaiian Islands are at Kaula Rock and on Moku Manu.

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Table 1. Seabirds of Hawaii (listed alphabetically by common name) including information about endemism, reproduction, and State and federal protection status.

common name	scientific name	Hawaiian name	Endemic to Hawaii?	Breeds in Hawaii?	State status	Federal status
albatross, black-footed	<i>Diomedea nigripes</i>		no	yes	-	M
albatross, Laysan	<i>Diomedea immutabilis</i>	mōli	no	yes	-	M
albatross, short-tailed	<i>Diomedea albatrus</i>		no	no	-	M
booby, brown	<i>Sula leucogaster plotus</i>	ā	no	yes	-	M
booby, masked	<i>Sula dactylatra personata</i>	ā	no	yes	-	M
booby, red-footed	<i>Sula sula rubripes</i>	ā	no	yes	-	M
frigatebird, great	<i>Fregata minor palmerstoni</i>	awa	no	yes	-	M
noddy, black	<i>Anous minutus melanogenys</i>	noho, ʻōpiʻeki	no	yes	-	M
noddy, blue-gray	<i>Procelsterna cerulea saxatilis</i>		no	yes	-	M
noddy, brown	<i>Anous stolidus pileatus</i>	noho kaha	no	yes	-	M
petrel, Bonin	<i>Pterodroma hypoleuca</i>		no	yes	-	M
petrel, Bulwer's	<i>Bulweria bulwerii</i>	ou	no	yes	-	M
petrel, dark-rumped	<i>Pterodroma phaeopygia sandwichensis</i>	ua'u, uava'u	yes	yes	E	M, I
shearwater, Christmas	<i>Puffinus nativitatis</i>		no	yes	-	M
shearwater, Newell's	<i>Puffinus newelli</i>	ā'o	yes	yes	T	M, I
shearwater, wedge-tailed	<i>Puffinus pacificus chloro-hyalinus</i>	ua'u sau	no	yes	-	M

storm-petrel, band-rumped	<i>Oceanodroma castro</i>	aké aké	yes	yes	E	M
storm-petrel, sooty	<i>Oceanodroma tristrami</i>	-	no	yes	-	M
tattler, gray-backed	<i>Sterna lunata</i>	pākalakala	no	yes	-	M
tattler, sooty	<i>Sterna fuscata oahuensis</i>	ewa'ewa	no	yes	-	M
tattler, white	<i>Tringa alba rothschildi</i>	manu'oku	no	yes	T	M
tropicbird, red-tailed	<i>Phaethon rubricauda rothschildi</i>	koa'e'ula	no	yes	-	M
tropicbird, white-tailed	<i>Phaethon lepturus dorothaeae</i>	koa'e'kea	no	yes	-	M

based on Pukui and Elbert (1986)

as reported by Pyle (1992)

E = a species listed by the State of Hawaii as "endangered" under the Conservation of Aquatic Life, Wildlife, and Land Plants Act

T = a species listed by the State of Hawaii as "threatened" under the Conservation of Aquatic Life, Wildlife, and Land Plants Act

M = a species listed by the U.S. Fish and Wildlife Service as "endangered" under the Endangered Species Act

T = a species listed by the U.S. Fish and Wildlife Service as "migratory" and protected under the Migratory Bird Treaty Act

E = a species listed by the U.S. Fish and Wildlife Service as "threatened" under the Endangered Species Act

T = Only the Oahu population is listed by the State of Hawaii as "threatened" under the Conservation of Aquatic Life, Wildlife, and Land Plants Act

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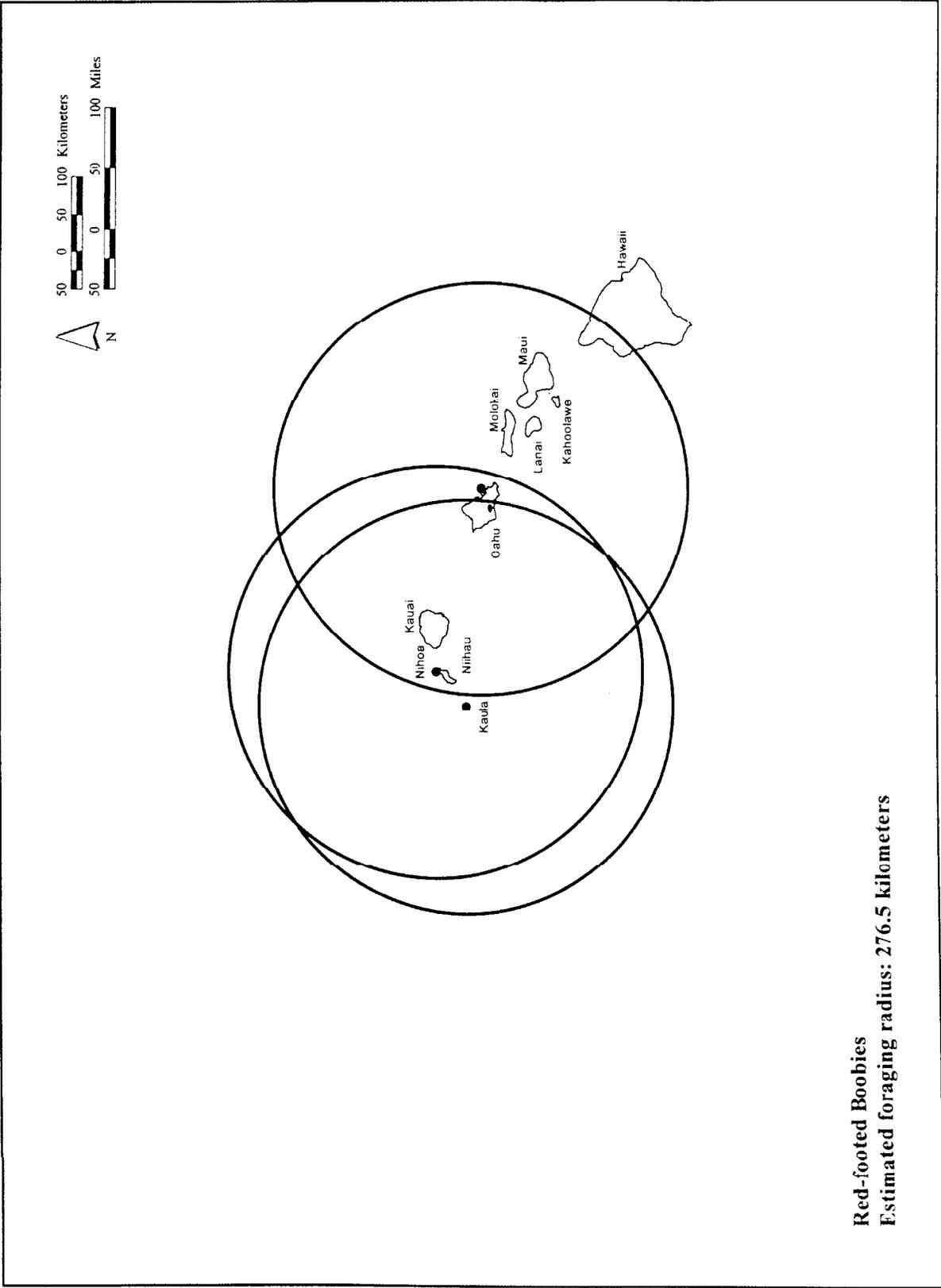
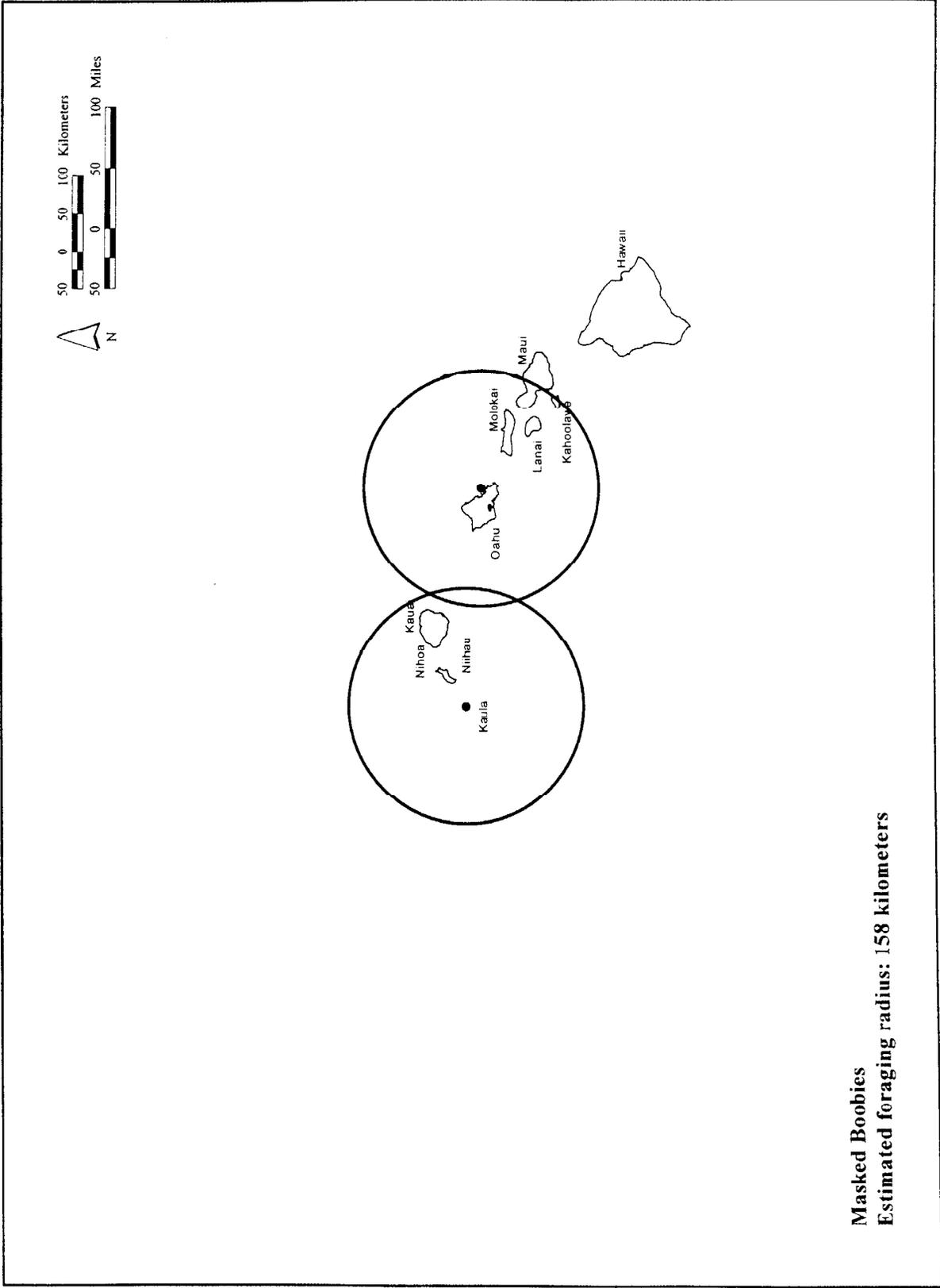
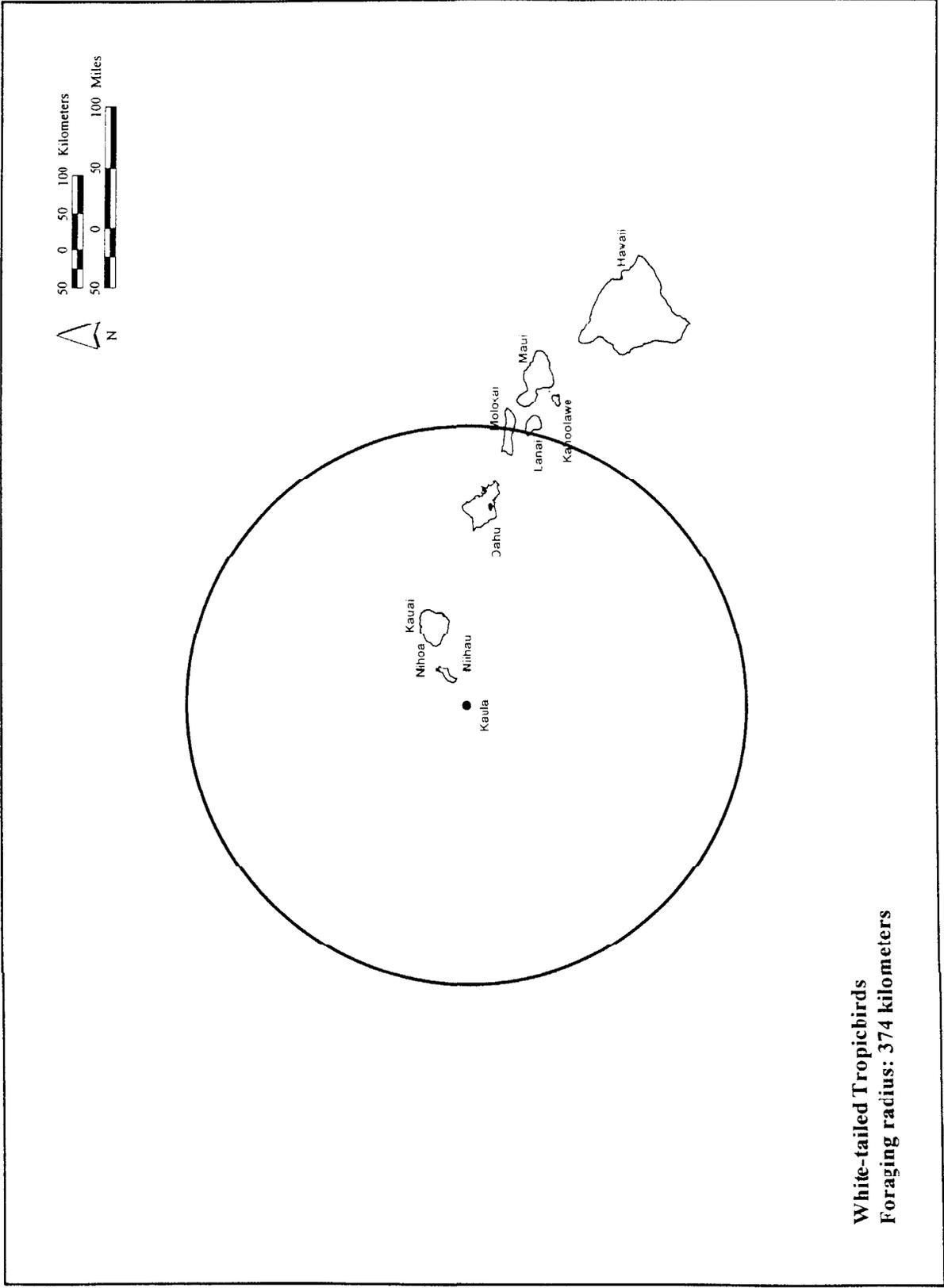


Figure 1.



Masked Boobies
Estimated foraging radius: 158 kilometers

Figure 2.



**White-tailed Tropicbirds
Foraging radius: 374 kilometers**

Figure 3.

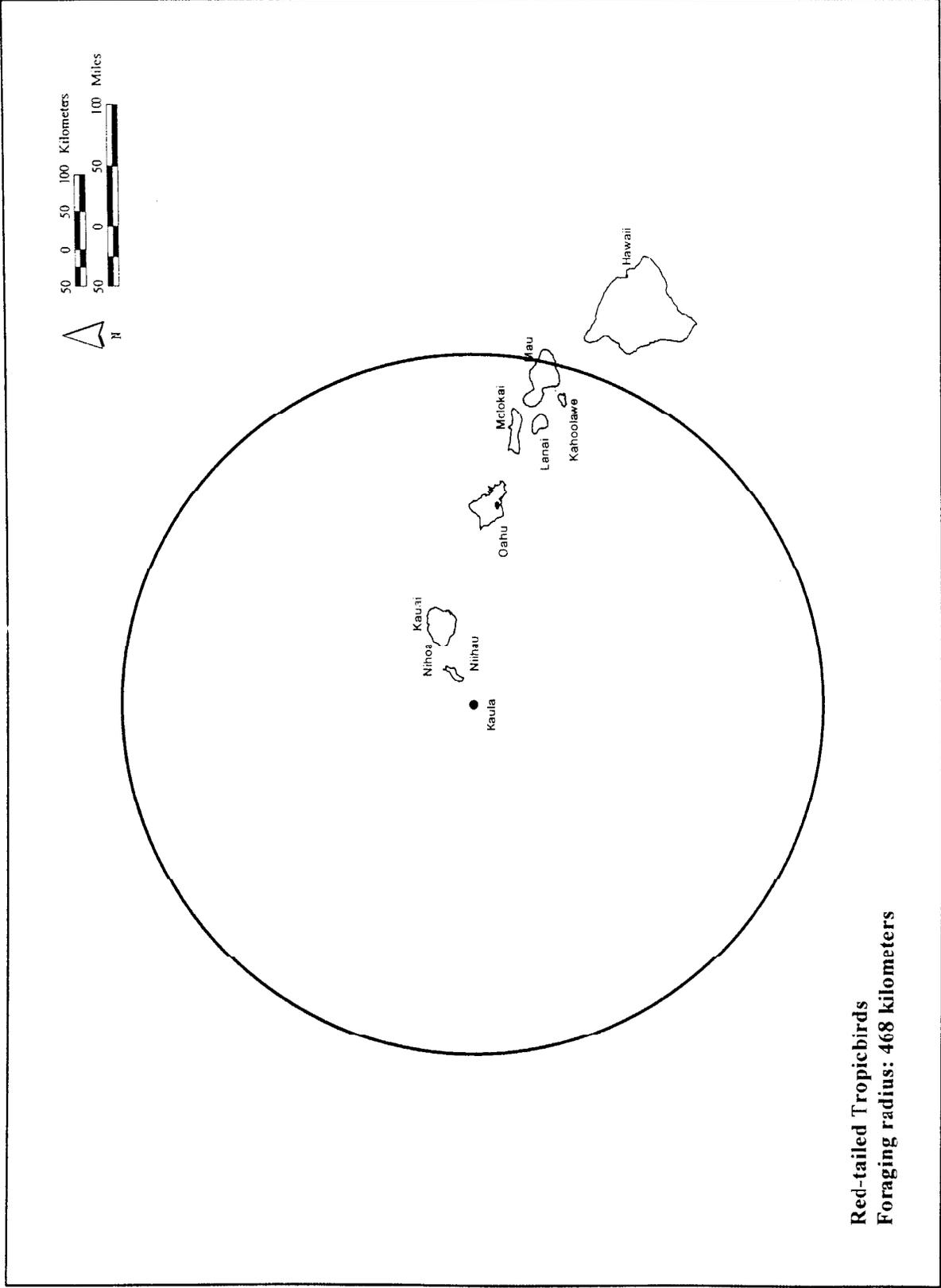
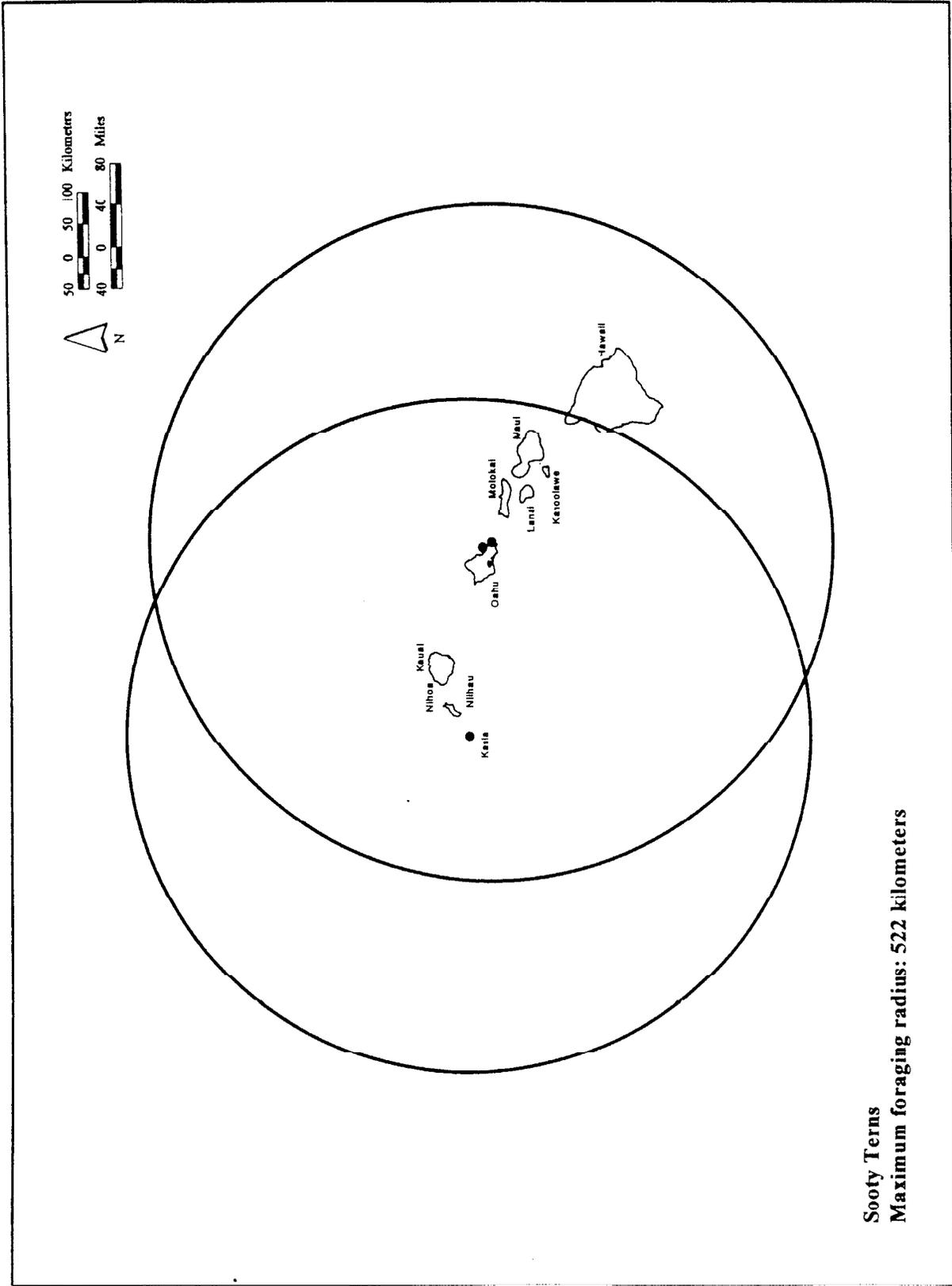
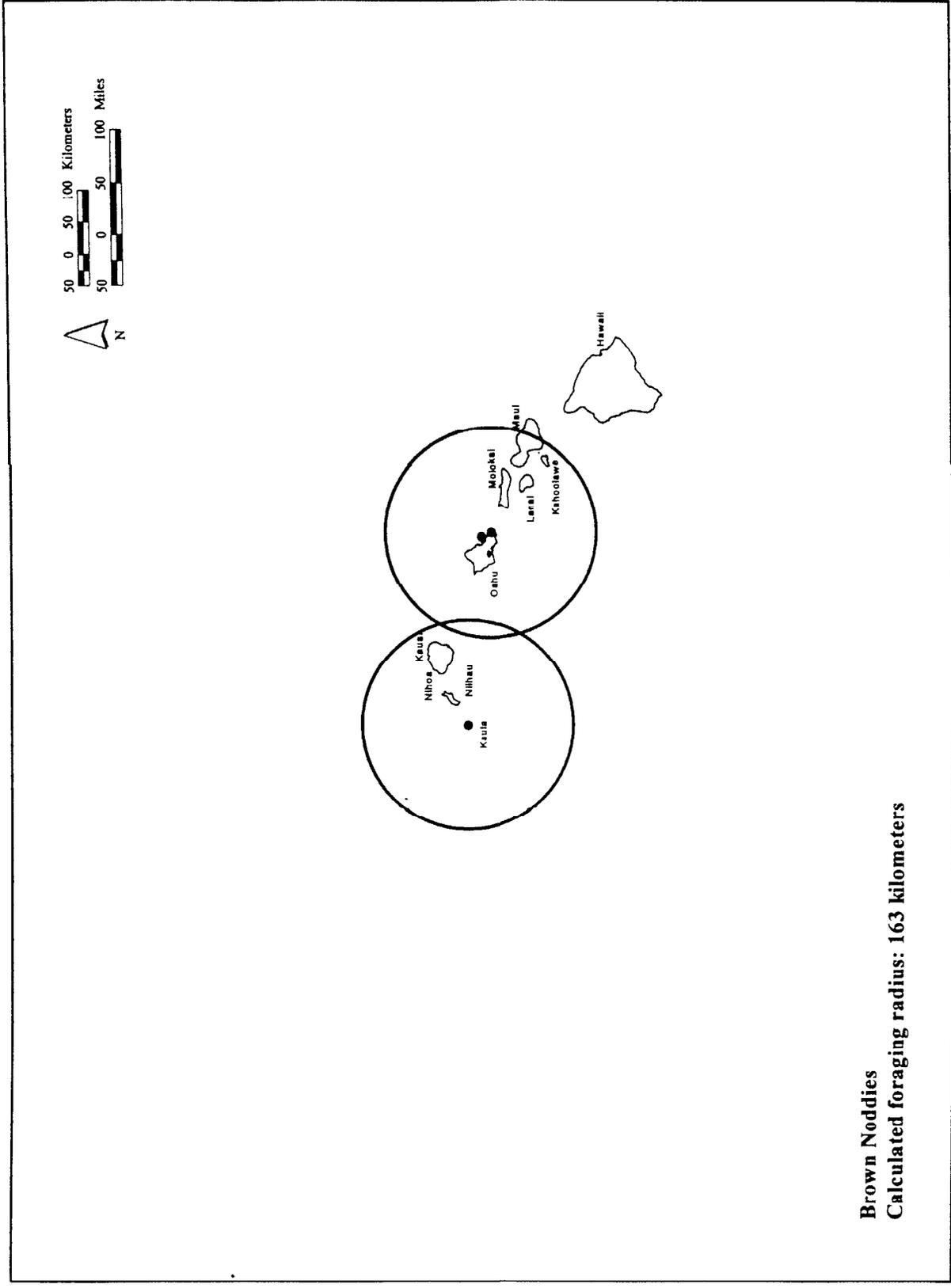


Figure 4.



Sooty Terns
Maximum foraging radius: 522 kilometers

Figure 5.



Brown Noddies
Calculated foraging radius: 163 kilometers

Figure 6.