Dispersal and migratory patterns of San Francisco Bay produced herons, egrets, and terns

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San Francisco Bay, California, including its fringing marshes, supports a large and diverse water related avifauna (Grinnell and Wythe 1927, Sibley 1952, Gill 1973, 1977). Certain of man's alterations of the Bay's shallower wetlands have resulted in increased habitat diversity which has allowed colonization by several species of birds including some colonial nesting species. The extensive dikes associated with salt production and some areas of higher ground created by dredge spoils have provided increased tide-free substratum, some of it insular, suitable for nesting. The resulting numbers of Snowy Egrets *(Egretta thula)*, Black-crowned Night Herons *(Nycticorax nycticorax)*, Forster's Terns *(Sterna forsteri)*, and Caspian Terns *(Sterna caspia)* using these areas now represent a significant portion of the northern California breeding populations of these species.

In conjunction with a study of the breeding birds of the South San Francisco Bay Estuary (Gill 1973, 1977) from 1971 to 1973, we banded 187 Great Blue Herons *(Ardea herodias)*, 1499 Snowy Egrets, 1615 Black-crowned Night Herons, 2943 Forster's Terns, and 743 Caspian Terns; often this represented a substantial portion of these species banded in the western states during these years (Table 1). Recoveries from these bandings through 1977 plus additional recoveries from a few earlier and some more recent bandings provide the data for this report on dispersal patterns and migration of San Francisco Bay produced herons, egrets, and terns.

Methods

We banded nestling and some post-nestling but still flightless young with standard U.S. Fish and Wildlife Service aluminum bands. The herons and egrets are from a mixed colony nesting on the ground or more recently on coyote bush *(Baccharis pilularis)* 1—2 m tall growing on dredge spoils deposited on former salt marsh on Bair Island near Redwood City (Figure 1). A few recoveries from bandings in 1976 and 1977 by Michael Rigney are included. Young Forster's Terns were banded in their natal colonies, usually on remnants of old dikes, now isolated in several salt evaporation ponds built on former salt marsh in south San Francisco Bay. Young Caspian Terns were banded in colonies on dikes on Bair Island and along Coyote Creek near Drawbridge (Figure 1). Recoveries through 1977 from these bandings were furnished by the U.S. Bird Banding Laboratory, Laurel, Maryland (Table 1).

We have generally followed the terms used by Berndt and Sternberg (1968) in distinguishing between migration and dispersal. Birds recovered in the non-breeding seasons in southern California and in Mexico are considered to have been in migration. All other birds recovered outside the natal ten-minute block of latitude and longitude are considered to have dispersed. Some of these birds were in true breeding dispersal and would have bred, or in the case of older birds may already have bred, on Bair Island or at locations other than the natal colony on Bair Island (see below). We do not know how far young birds, and adults, wander from Bair Island to feed and to roost in the period from late summer to the next spring and yet return to Bair Island to nest. Our knowledge of their normal foraging range is meager. Visits to Bair Island in fall and winter have revealed that the herons and egrets do not roost at the rookery in the non-breeding season. More precise knowledge of foraging range, alternative roosting sites, and true breeding dispersal will depend on more detailed studies of individually marked birds.

In our analysis, recoveries of birds less than eleven months old are considered direct and the birds to be juvenile. Recoveries of birds greater than ten months of age are considered indirect and the birds to be adult. In our treatment of dispersal we include only those juveniles recovered outside of the 10-minute block of latitude and longitude of banding or known to be recovered away from the colony. All birds recovered as adults are included. Recovery distances are direct heading distances from the natal colony. Because of the relatively small sample sizes and wide ranges in recovery

Table 1. Numbers banded in the San Francisco Bay area compared with numbers banded in western North America as a whole, 1966-1977.

Species	Year												
	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	Total
Great Blue Heron													
San Francisco Bay	—	—	—	—	—	107	24	56	3	—	10	25	225
Western N. America[1]	289	53	117	333	160	364	203	208	47	131	153	108	2156
Snowy Egret													
San Francisco Bay	—	—	—	—	—	406	200	893	1	1	267	—	1768
Western N. America	48	98	287	362	423	529	207	1025	150	27	609	190	3955
Black-crowned Night Heron													
San Francisco Bay	—	—	—	—	—	800	252	563	2	2	368	—	1987
Western N. America	9	10	83	287	393	915	261	660	27	136	682	197	3660
Forster's Tern													
San Francisco Bay	—	—	—	—	—	670	677	1596	—	—	—	—	2943
Western N. America	10	35	183	9	—	677	677	1596	—	64	71	108	3430
Caspian Tern													
San Francisco Bay	53	143	217	—	—	555	66	122	—	--	—	—	1156
Western N. America	193	194	441	48	10	555	136	409	35	83	70	400	2574

[1]Data from Western Bird Banding Association for Alaska, Yukon, British Columbia, Alberta, Washington, Oregon, Montana, Idaho, California, Nevada, Utah, Wyoming, Colorado, Arizona, New Mexico, and western Mexico. Dashes indicate no birds reported banded that year.

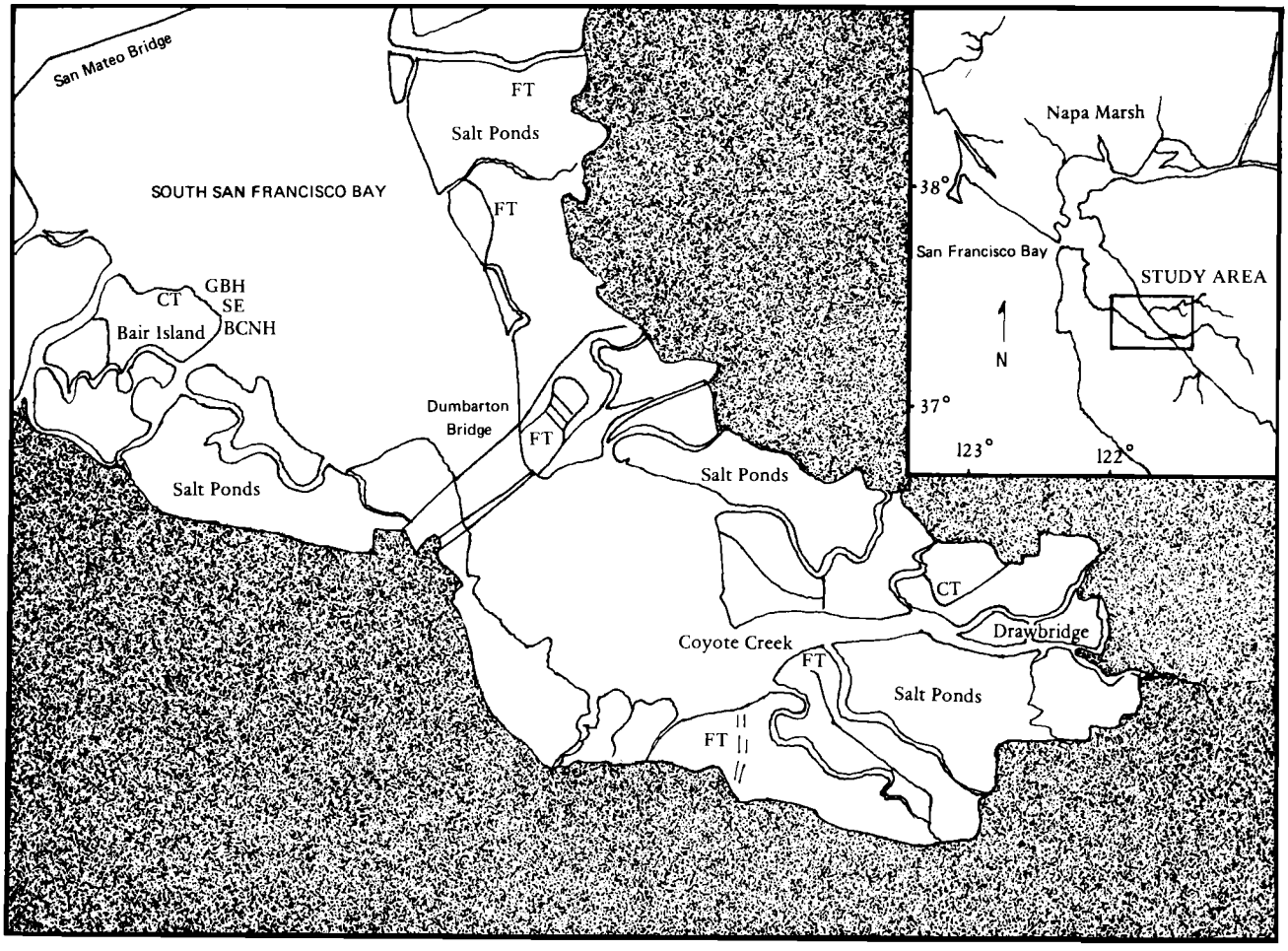

Figure 1. Location of nesting colonies of Great Blue Herons (GBH), Snowy Egrets (SE), Black-crowned Night Herons (BCNH), Forster's Terns (FT), and Caspian Terns (CT) in South San Francisco Bay, 1971 — 1977.

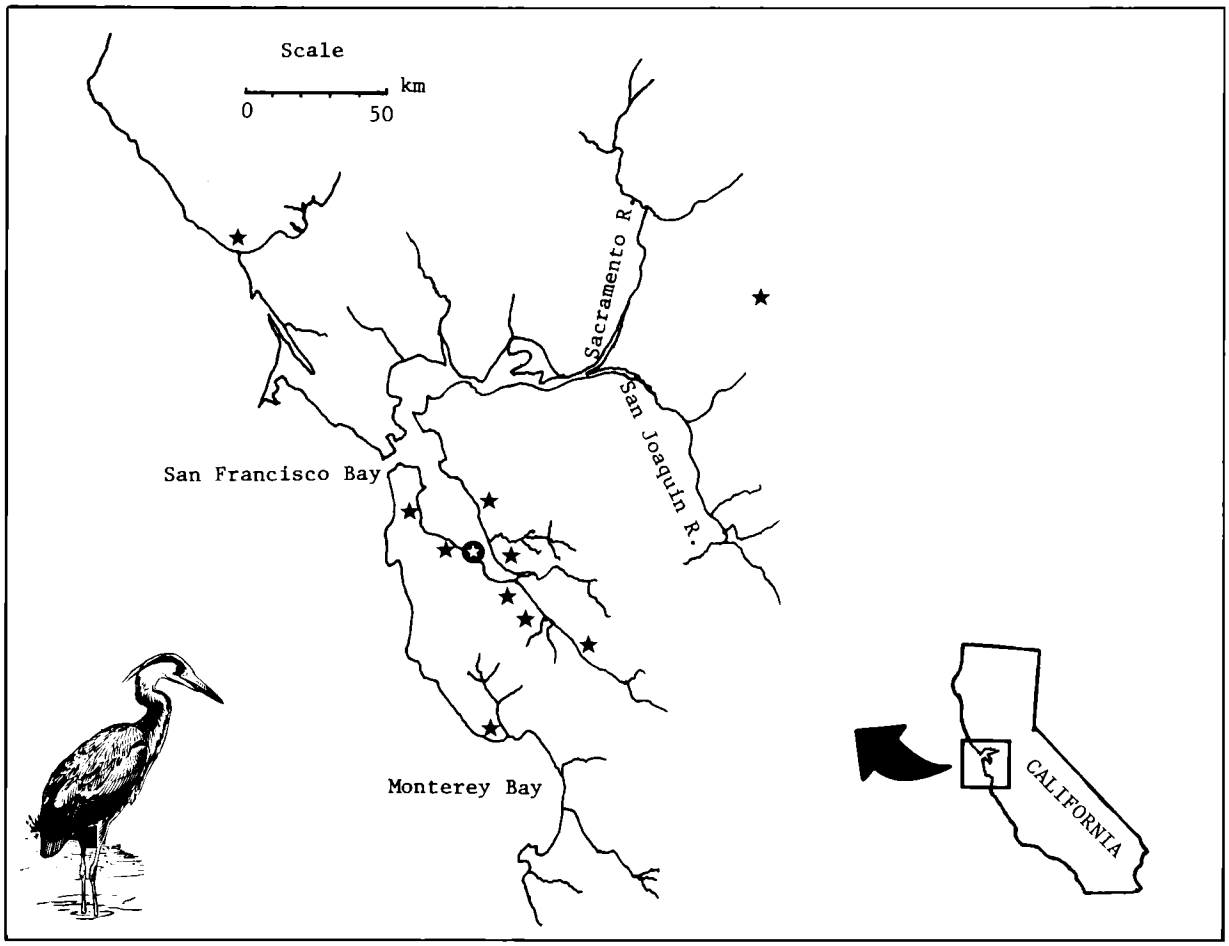

Figure 2. Locations of recoveries (★) of Great Blue Herons banded as juveniles on Bair Island, 1971 — 1977, including one recovered at the natal colony (✪).

Table 2. Recoveries to 1977 from Great Blue Herons, Snowy Egrets, and Black-crowned Night Herons banded on Bair Island, San Francisco Bay, California.

Recoveries following:	Number	Mean age (mo)	Median distance (km)	Range (km)
Great Blue Heron (225 banded)				
Dispersal				
Direct (<11 mo)	6	3.3	40	8—135
Indirect (>10 mo)	5	24.6	19	0—32
Snowy Egret (1766 banded)				
Migration				
Direct (<11 mo)	5	8.8	681	566—2643
Indirect (>10 mo)	2	28.5	333	248—418
Dispersal				
Direct (<11 mo)	14	7.0	27	16—209
Indirect (>10 mo)	8	32.2	24	16—32
Black-crowned Night Heron (1983 banded)				
Dispersal				
Direct (<11 mo)	43	4.3	32	5—518
Indirect (>10 mo)	16	26.8	26	3—280

Table 3. Recoveries to 1977 from Forster's Terns and Caspian Terns banded on dikes in South San Francisco Bay, California

Recoveries following:	Number	Mean age (mo)	Median distance (km)	Range (km)
Forster's Tern (2943 banded)				
Migration				
Direct (<11 mo)	5	7.8	576	515—1931
Indirect (>10 mo)	1	43.0	784	784
Dispersal				
Direct (<11 mo)	7	3.3	51	16—68
Indirect (>10 mo)	1	15.0	16	16
Caspian Tern (1156 banded)				
Migration				
Direct (<11 mo)	9	7.2	1770	676—2736
Indirect (>10 mo)	10	27.5	2308	451—3943
Dispersal				
Direct (<11 mo)	6	3.3	52	13—1529
Indirect (>10 mo)	6	44.0	147	16—966

distances we have used the medians of these distances and judge them to have greater meaning than either arithmetic or logarithmic means. Vector diagrams (Burtt and Glitz 1969, 1977) were constructed to show proportionate movement between natal colony and recovery sites for each species. Separate vector diagrams for recoveries of obvious migrants and for the remaining recoveries, assumed to represent post-natal dispersal, are presented for the Snowy Egret, Forster's Tern, and Caspian Tern. Vectors were determined for each of the 30° sectors of the compass. Chi-square tests were made on the pattern of numbers of recoveries in the twelve 30° sectors to determine extent of deviation from randomness.

Results and discussion

Great Blue Heron

Numbers of breeding pairs in the Bair Island colony have varied from about 30 to 50 (Gill 1973) since its discovery by William Anderson (pers. comm.) in 1967. Nests are located 1-2 m above the ground on *Baccharis* growing on dredge spoils. These very accessible nests have facilitated the only bandings of Great Blue Herons to date from the San Francisco Bay area. Seven or more additional small colonies, all in tall trees, are known from the area.

The 11 recoveries from 225 nestlings banded on Bair Island suggest a marginally non-random dispersal, but in agreement with Palmer (1962) show no evidence of migration (Figure 2,4). The median distance of direct recoveries of 40 km, when compared with the median of 19 km for indirect recoveries (Table 2), suggest these herons have a tendency to return to the natal area to breed as adults. Indeed, the recovery of one 29-month-old heron at the natal colony suggests it may have returned to nest there.

Snowy Egret

Numbers of breeding pairs in the Bair Island colony have increased from 150 when first discovered in 1969 to more than 350 in 1973 (Gill 1977). Nests were mostly on pickleweed *(Salicornia* spp.) and gumplant *(Grindelia* spp.) along tidal sloughs, where they were subject to flooding during May and June tides, from 1969 to 1973. Beginning in 1971 and finally completed by 1975 was a change from ground nesting to nesting in *Baccharis* around the periphery of the Great Blue Heron colony. Since 1977, however, a small number of egrets have reverted to nesting on the ground on *Salicornia* and *Grindelia* (Michael Rigney and Kepler Stone, pers. comm.). Within the main colony from one to five nests were commonly placed in single *Baccharis* bushes about 2 m high. Although together in the same greater heronry, Great Blue Herons (apparently the original colonizers), Snowy Egrets, and Black-crowned Night Herons tended to cluster their nests. This partitioning of nest sites among ciconiiforms is consistent with reports of Palmer (1962) and McCrimmon (1978).

Of 29 recoveries from 1766 nestlings and non-flying juveniles banded on Bair Island, seven were of birds which had made a typical south-eastward migration to southern California or Mexico (Figure 3). The five direct recoveries were at the five longest recovery distances (Table 2). These migrations are similar to those reported by Loftin (1966) and Davis (1968) for eastern North American Snowy Egrets. They provide new information to that reported by Palmer (1962) who states that western North American populations move only a few hundred miles from south-eastern Oregon, northern Nevada, Utah, and Colorado. Egrets must leave these areas because cold winter temperatures preclude their survival. He had no information on possible migratory movements by California egrets which breed in areas, such as San Francisco Bay, which are also suitable wintering grounds.

Two indirect recoveries of birds 22 and 35 months old, recovered in April and May, could (1) have been intercepted in northward migration from wintering grounds farther south, or (2) may represent birds which dispersed southward and were resident in the areas of recovery. Because the only five undoubted migrants were of birds less than a year old, we suggest that some juveniles are programmed to migrate their first winter, but that adults in central coastal California tend to be resident — or migrate shorter distances as is true of adults of several other species, particularly gulls.

Dispersal as judged from 22 recoveries (Figure 3,4), whether the birds were recovered directly or indirectly, was non-random and occurred in directions which took them to areas of appropriate habitat. In 17 of the 22 cases, distances were less than 50 km from the natal colony. The five instances of longer range dispersal (50, 80, 105, 135, and 209 km) were to especially suitable habitat farther to the north and northeast.

Black-crowned Night Heron

Over much of its range in North America this species is a "notable migrant and considerable wanderer; also individuals pass the winter in northern portions of the breeding range" (Palmer

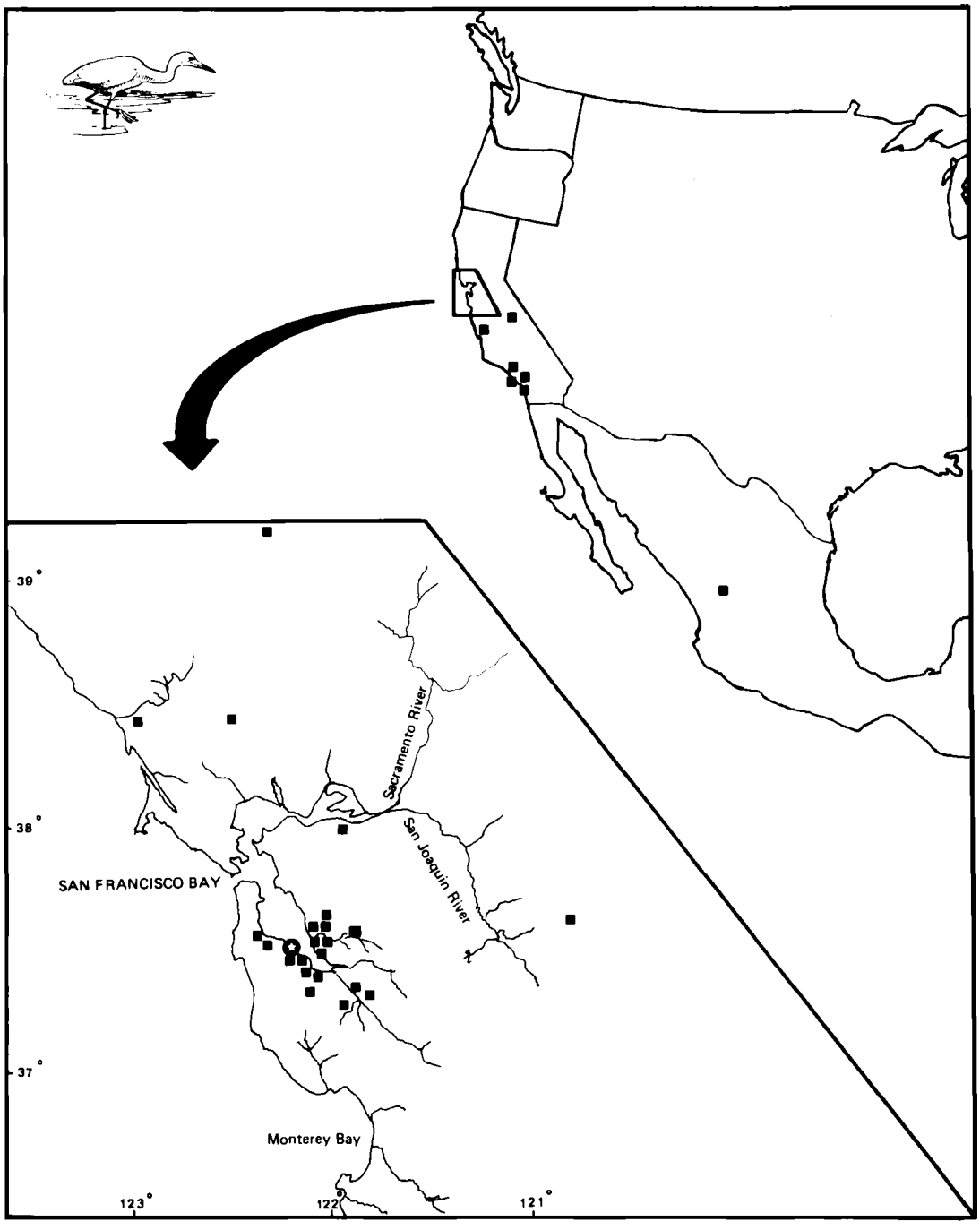

Figure 3. Locations of recoveries (■) of Snowy Egrets banded as juveniles on Bair Island (✪), 1971 — 1977.

1962). Our data suggest San Francisco Bay area night herons are non-migratory, but show a typical dispersal pattern.

This abundant breeding species in northern California has long been associated with San Francisco Bay (Gill 1977). Its habit of nesting on or near the ground is at variance with its pattern in most of North America (see Palmer 1962). When first discovered on Bair Island in 1967 the night herons were nesting on *Salicornia* and *Grindelia*. In 1973 Richard Mattish (pers. comm.) found that of 609 nesting pairs, 182 had moved into the *Baccharis* on dredge spoils. Here they nested 1 to 2 meters above the ground in association with Great Blue Herons and Snowy Egrets. Most recently (1977 and 1978) nearly all nested in *Baccharis* and

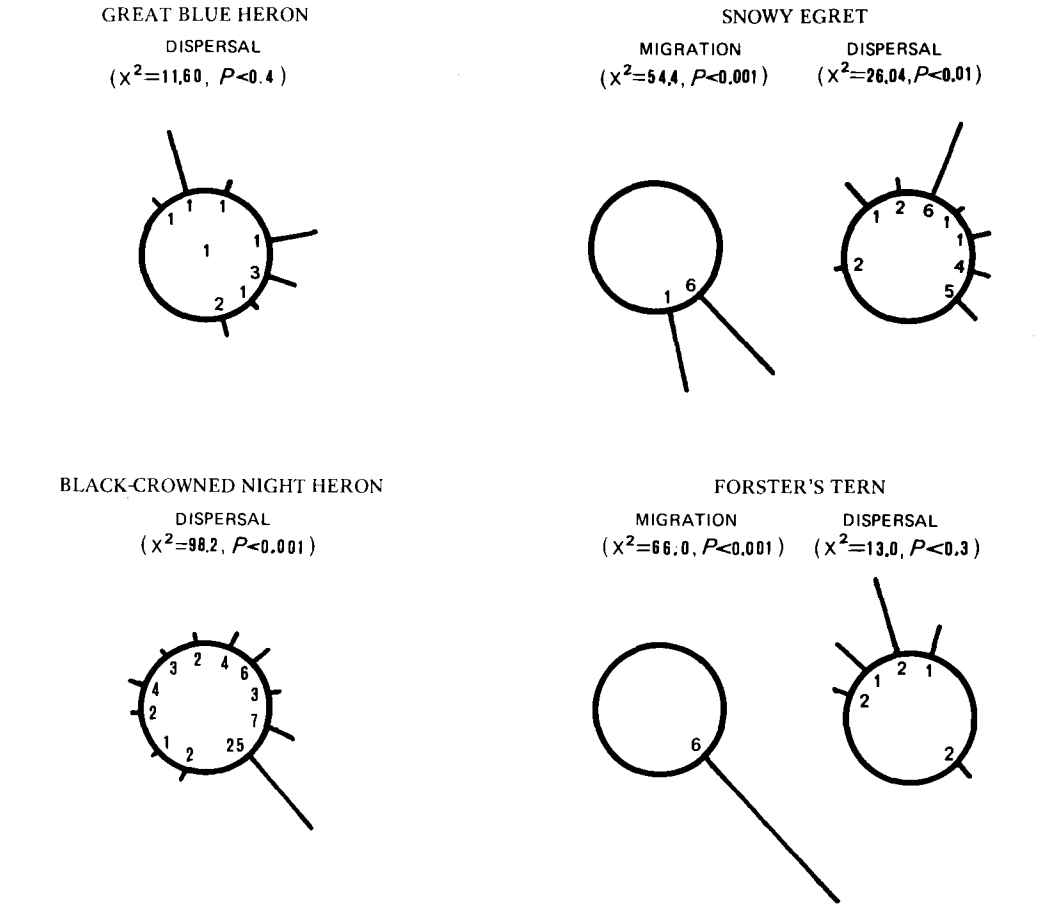

Figure 4. The proportionate distance and direction of recoveries of dispersing Great Blue Herons and Black-crowned Night Herons, and of dispersing and migrating Snowy Egrets, Forster's Terns, and Caspian Terns. Numbers refer to sample size in each 30° sector of the compass.

Dispersal, as evaluated by the Chi-Square (X^2) test of recoveries in each of the twelve 30° compass sectors, is marginally non-ramdom (P = 0.25 to 0.40) in the Great Blue Heron and Forster's tern; is non-random (P = 0.01 to 0.001) in the Snowy Egret and Caspian Tern; and clearly non-random (P<0.001) in the Black-crowned Nigth Heron. Migration, as similarly evaluated with the Chi-Square test of recoveries, is clearly non-random (P<0.001) in the Snowy Egret, Forster's Tern, and Caspian Tern.

less than 50 pairs on the lower ground vegetation (M. Rigney and K. Stone, pers. comm.).

Of 1983 juvenile night herons banded on Bair Island, 59 have been recovered (Table 2). Dispersal is non-random (Figure 4,5) with birds following the edge of greater San Francisco Bay and its tributaries either south through the Santa Clara Valley to Monterey Bay drainages or northeast through the Carquinez Strait and into the Sacramento-San Joaquin Delta where they tend to move south into the San Joaquin Valley. This association with water courses is to be expected. Although Houston (1967) did not present it as such, his plot of recoveries in Saskatchewan appears to overlay major river courses. The 25 herons recovered in the 120 — 150° vector zone (Figure 4)

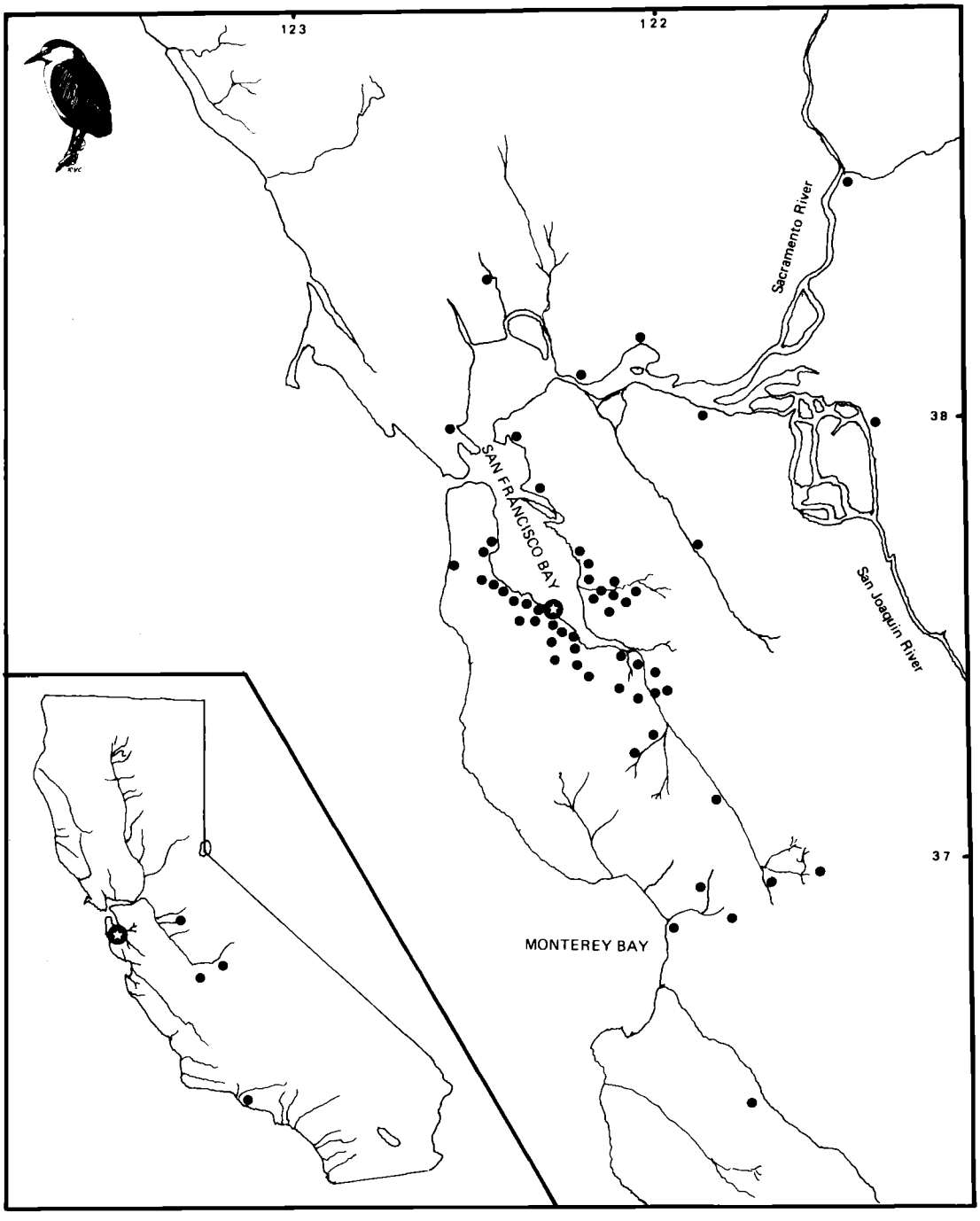

Figure 5. Locations of recoveries (●) of Black-crowned Night Herons banded as juveniles on Bair Island (★), 1971 — 1977.

include only one possible migrant and 24 birds recovered in dispersal. This sector contains favorable habitat and is apparently frequented by more people likely to report recoveries to the U.S. Bird Banding Laboratory. In February 1972 a 7-month-old heron was found dead in east Los Angeles 518 km southeast of Bair Island. Whether this bird was in typical migration and would have returned to the San Francisco Bay area, or represents a case of longer distance dispersal, cannot at this time be determined.

Forster's Tern

A relatively recent addition to the breeding avifauna of the San Francisco Bay area, nesting was first reported in 1948 (Sibley 1952). Now some

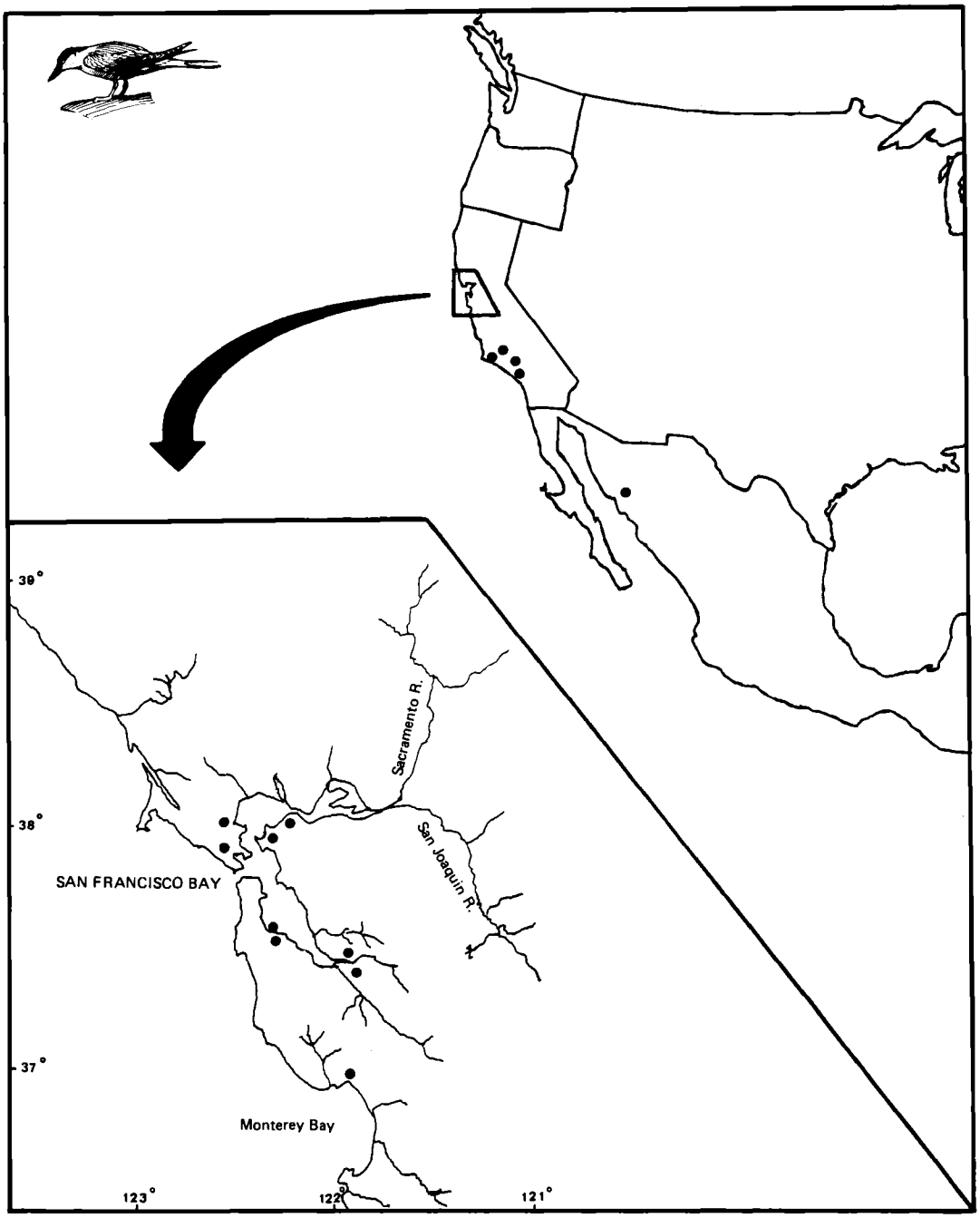

Figure 6. Locations of recoveries (●) of Forster's Terns banded as juveniles on South San Francisco Bay, 1971 — 1977.

13 colonies, totaling approximately 3000 pairs, are found mainly on small dredge spoils islets in salt evaporation ponds in south San Francisco Bay and Napa Marsh north of San Pablo Bay (Figure 1).

Six of the 14 recoveries (Table 3 and Figure 6) from 2943 young banded on south San Francisco Bay during 1971-1973 confirm the migratory status of this species. Of these six birds recovered during migration, five are from the Los Angeles — San Diego coastal area and one is from Sinaloa, Mexico on the west coast of the Gulf of California. Friedmann et al. (1950) reported Forster's Terns as abundant in Sinaloa between October and April; Arbib (1974, 1975, and 1976) indicates *S. forsteri* regular at San Blas, Nayarit (21° N latitude); and Blake (1977) reports them occasionally as far south

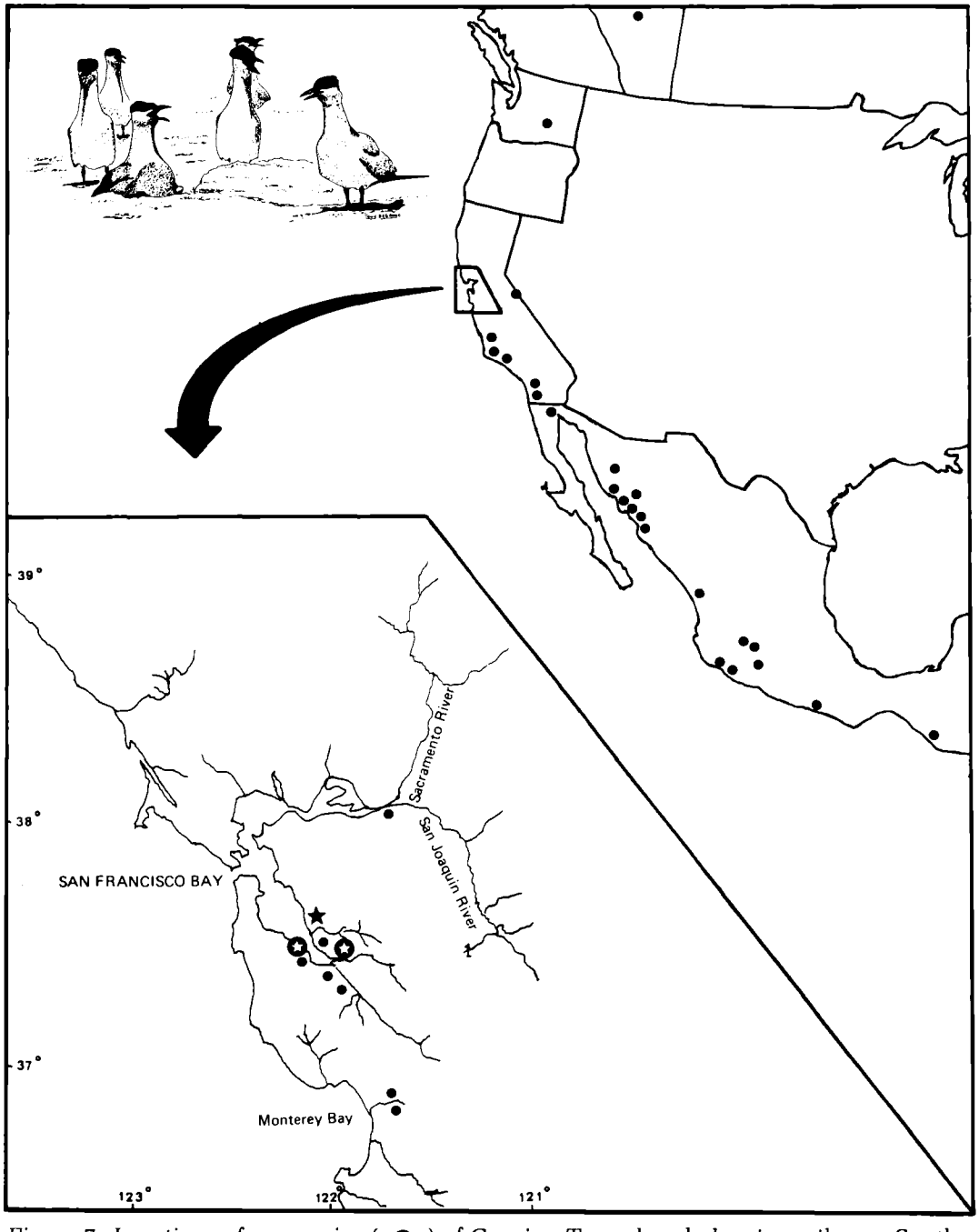

Figure 7. Locations of recoveries (●) of Caspian Terns banded as juveniles on South San Francisco Bay, 1955 — 1977. Banding locations of juveniles in this study (✪) 1971—1977 and most earlier bandings (★) prior to 1971.

as Guatemala (15° N latitude). Although five recoveries were direct, that is of birds less than 11 months old, one 43-month-old tern was recovered in January at San Diego. Our observations and recoveries confirm the reports in Arbib (1974, 1975, and 1976) that nearly all Forster's Terns leave the San Francisco Bay area each winter and that most juveniles and adults winter from coastal southern California well down the west coast of Mexico. The eight San Francisco Bay area recoveries suggest (Figure 4,6) that dispersal is chiefly northerly, perhaps accounting for expansion of colonies into the Napa Marsh.

Caspian Tern

First reported breeding in the San Francisco Bay

area in 1916 (Grinnell and Miller 1944), present numbers approximate 900-1000 pairs in four colonies. There are few reports of them wintering in central California and only small numbers occur in southern California in winter (Arbib 1974, 1975, and 1976). The west coast of Mexico appears to be the important wintering area. Recoveries, however, reflect a bias from large population centers and probably do not reflect the true winter distribution along west coastal Mexico. The most southerly recovery is from southern Chiapas (14°50′ N, 92°20′ W) which appears to be near the southern limit of the winter range on the Pacific coast (Blake 1977). We found no indication that Pacific coast produced Caspian Terns winter along the Gulf of Mexico or the Caribbean Sea.

Recoveries from 743 Caspian Terns we banded from 1971 to 1973 (Table 1) are substantially reinforced by recoveries from another 1197 banded on San Francisco Bay prior to 1969, yielding a total of 31 recoveries. They confirm the strongly migratory behavior of the species (Table 3 and Figure 4,7) with 16 of the 19 winter recoveries from Mexico.

Especially noteworthy are recoveries from the state of Washington and the province of Alberta. These two birds apparently represent long distant dispersers of the type which account for leap-frog colonization of areas quite removed from the colony of origin. Our small sample size prevents an analysis of seasonal movements. We have, however, found seasonal and age-specific differences in movement of Caspian Terns when these data are combined with those from terns banded in southern California (Gill and Mewaldt MS).

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