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LEAST TERN FORAGING ECOLOGY AT THREE MAJOR CALIFORNIA BREEDING COLONIES

JONATHAN L. ATWOOD, Department of Biology, University of California, Los Angeles, California 90024
DENNIS E. MINSKY, Department of Biology, California State University, Long Beach, California 90840

The California Least Tern (*Sterna antillarum browni*) historically nested commonly on coastal beaches from Monterey County, California, to Cabo San Lucas, Baja California (Grinnell 1928, Grinnell and Miller 1944). However, substantial population declines were documented in the subspecies' United States range during the years following World War II, and the population was given Federal and State endangered species status in 1969 and 1971.

Because most of the Least Tern's decline in California seems to have resulted from disturbance or destruction of nesting areas, recent protective efforts have focused on the breeding colonies themselves, and research has generally emphasized breeding biology, nesting requirements and population trends (Massey 1974; Massey and Atwood 1978, 1981; Atwood et al. 1979). Yet in spite of early suggestions that loss of estuarine foraging habitat may also have contributed to the California Least Tern's decline, little attention has been given to the population's foraging ecology aside from an indirect analysis, based on fish dropped at nesting sites, of food habits (Atwood MS), a 1-year study of daily and seasonal fluctuations in feeding activity at a single colony (Collins et al. 1979), and some brief speculations that tidal estuaries represent the principal foraging habitat (Wilbur 1974, Massey 1977).

Recent and dramatic increases at several California Least Tern breeding areas, where formerly extensive estuarine habitat has been almost entirely destroyed, raised questions of where terns from these colonies were obtaining food, and how important the remaining estuarine areas near these sites were to the colonies' continued growth and success. During 1980-1981 we studied foraging activities at two of these large, growing colonies that are essentially lacking nearby, viable estuarine foraging habitat; in 1982, observations were made at a third site located adjacent to a relatively undisturbed river mouth.

STUDY AREAS AND METHODS

Observations of Least Tern foraging activity were made during 1980 and 1981 at the Venice Beach and Huntington Beach breeding colonies located at Dockweiler State Beach, Los Angeles County, and Huntington State Beach, Orange County, respectively. In 1982, data were collected in the vicinity of the Santa Margarita River nesting area, located on the U.S. Marine Corps Base, Camp Pendleton, San Diego County. All sites are historic nesting areas which, with protection during the spring and summer months, have supported substantial numbers of nesting Least Terns in recent years (Table 1). Not only have these colonies consistently been among the largest in California since 1978, Venice Beach and Huntington Beach have also been the most significant in terms of number of young produced; from 1978-1981, approximately 41% of Least Terns successfully fledged in California have come from these two sites (California Department of Fish and Game, unpubl. data). All three study colonies are situated relatively distant (greater than 5 miles) from other major Least Tern nesting areas and, during 1980-1982, the small colonies at Playa del Rey (0.8 miles ESE of Venice Beach), Upper Newport Bay (5.0 miles NE of Huntington Beach), and White Beach (3.5 miles N of Santa Margarita River) either failed early in the nesting season or were not used at all. Therefore, we have made the assumption that most or all foraging Least Terns observed in the study areas were individuals associated with the breeding colonies under investigation.

All potential Least Tern feeding areas were identified within a 5 mile radius of each nesting site, and observation stations were selected that allowed quick surveys of foraging terns (Figures 1, 2, 3). Habitat was broadly characterized for each station, and included (a) open ocean, (b) flood control channels and channelized rivers, (c) degraded saltmarsh channels with little or no tidal flow, (d) freshwater and sewage treatment ponds, (e) sheltered marinas, (f) shallow, brackish lagoons, (g) relatively undisturbed river channels, and (h) natural, unchannelized river mouths. Not all habitats were represented within 5 miles of each study colony. In comparison with potential foraging habitats that historically occurred at Venice Beach and Huntington Beach, estuarine and freshwater areas have been almost entirely eliminated by landfills, channelization and marina dredging; at the Santa Margarita River, extant estuarine and freshwater habitats are reduced and somewhat degraded compared with historic conditions (Salata 1981).

Table 1. Numbers of Least Terns nesting at three southern California colonies, 1978-1982.

	Approximate number of breeding pairs[a]				
	1978	1979	1980	1981	1982
Venice Beach	60-75	80-95	150-165	140-160	150-185
Huntington Beach	75-90	80-95	70-90	109-122	85-111
Santa Margarita River	30-40	32-40	47-65	50-105	110-140

[a]California Department Fish and Game, unpubl. data.

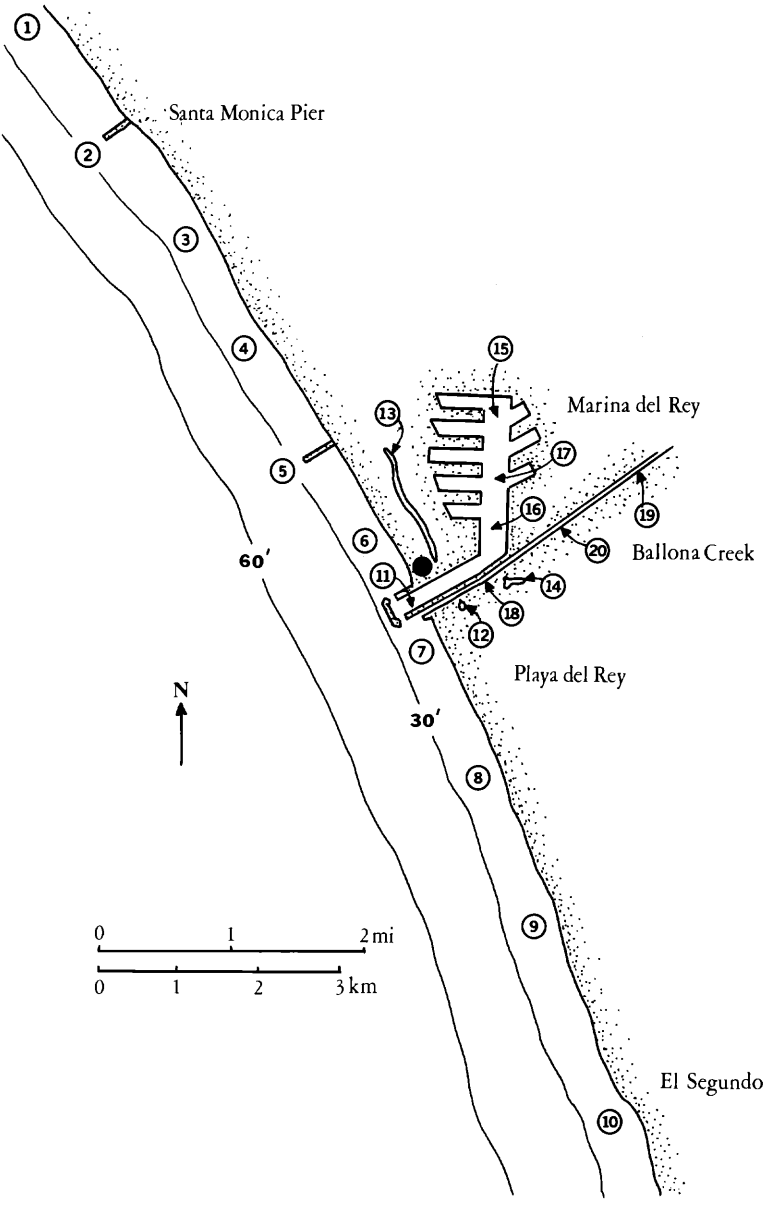

Figure 1. Least Tern foraging survey stations at Venice Beach, Los Angeles County. Solid circle indicates location of breeding colony.

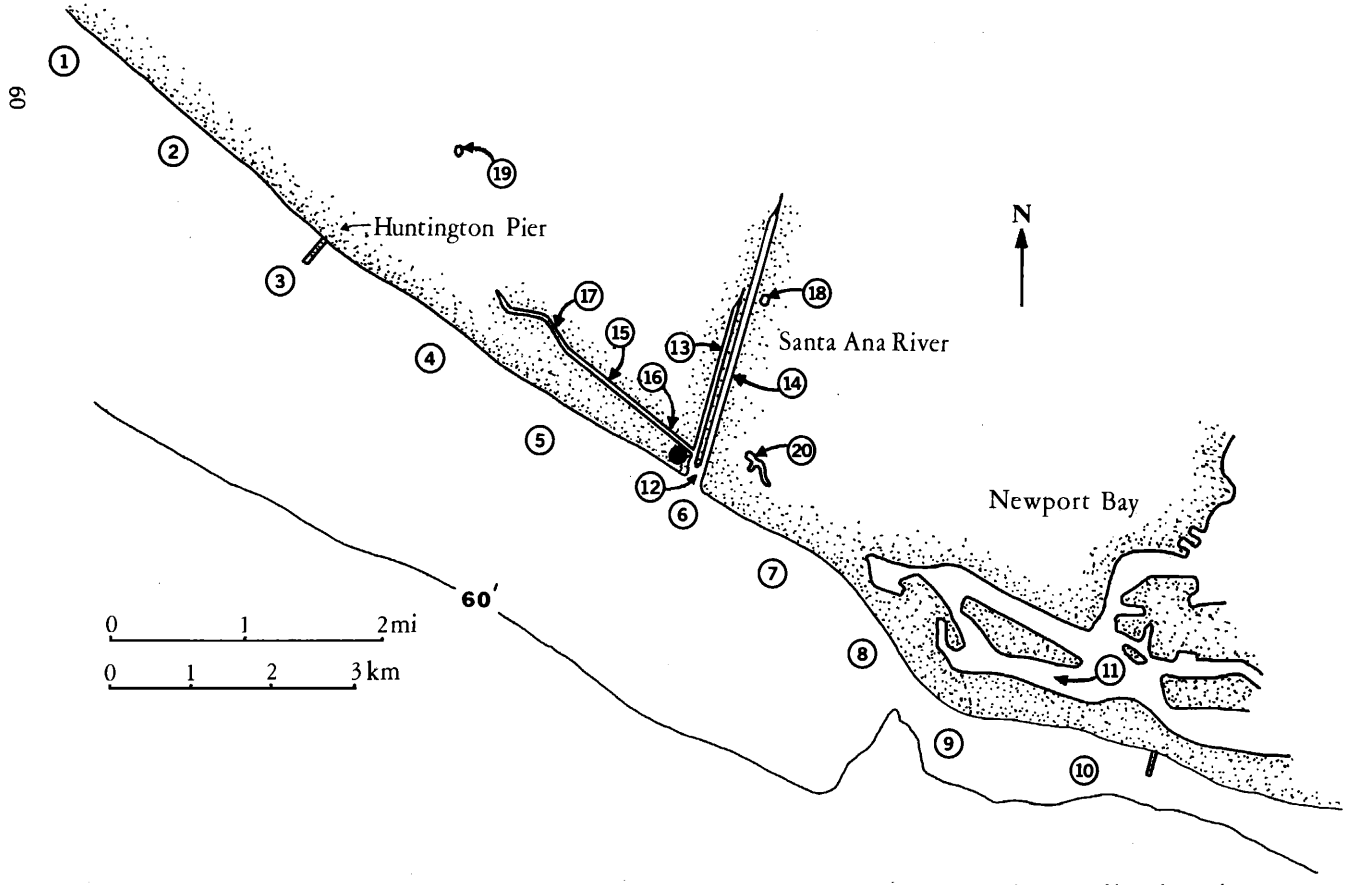

Figure 2. Least Tern foraging survey stations at Huntington Beach, Orange County. Solid circle indicates location of breeding colony.

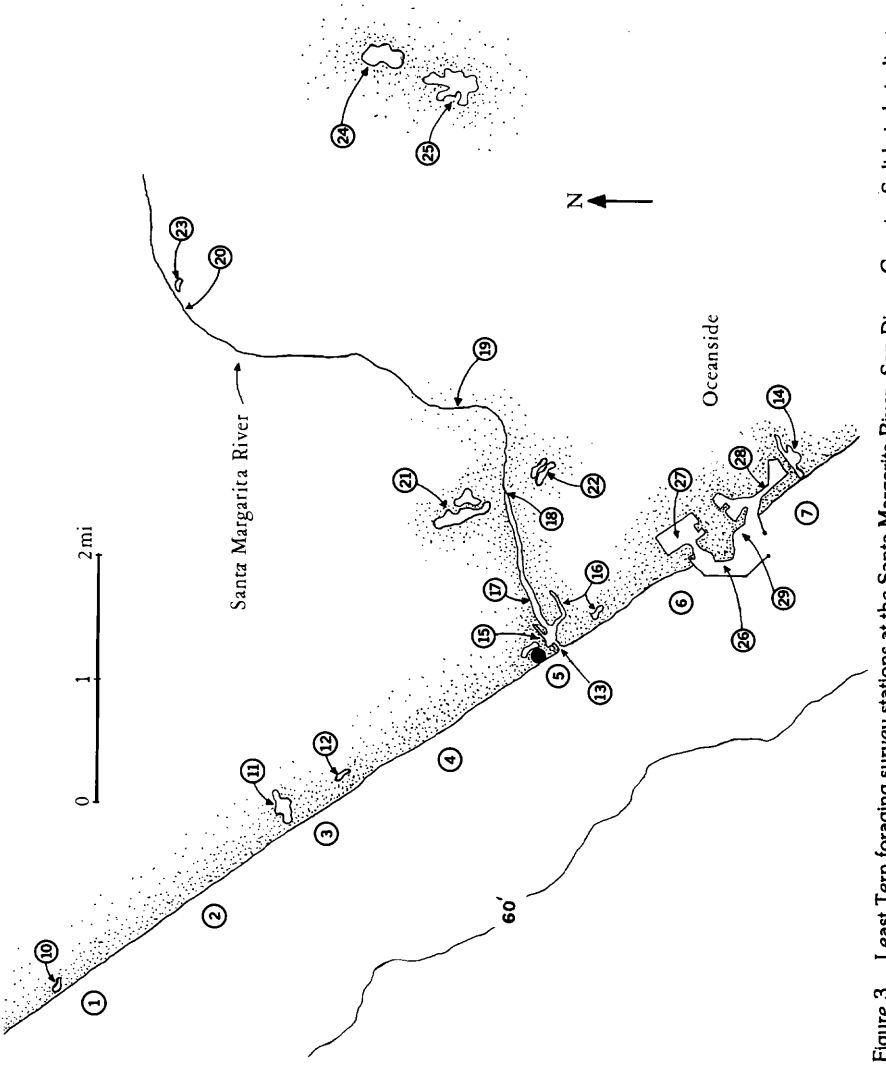

Figure 3. Least Tern foraging survey stations at the Santa Margarita River, San Diego County. Solid circle indicates location of breeding colony.

Each station was visited within a 90-minute period beginning approximately 30 minutes after sunrise. Although simultaneous observations from each station were beyond the scope of the present study, we feel that variations in intensity of foraging activity during the 90-minute time span of each survey were probably so minor as to not affect overall results (Collins et al. 1979). Furthermore, we doubt that occasional duplicated observations (i.e., the same bird recorded at more than one station) would alter general patterns in recorded foraging activity.

During 1980, surveys were conducted at Venice Beach and Huntington Beach on four dates, spaced so as to represent each major phase of the tern nesting cycle (courtship, incubation, feeding of chicks and post-fledging dispersal). In 1981, six surveys were performed at these two sites at approximately 2-week intervals. Eleven surveys, including three pairs of consecutive-day observations, were made at approximately 2-week intervals at the Santa Margarita River in 1982; additional information regarding the Santa Margarita River study is provided in Minsky (1982).

Observations were made with 10 × binoculars from each station, and the number of Least Terns visible during each of five 1-minute scans of the survey area, spaced at 1-minute intervals, was recorded. The behavior of each individual was classified as follows: (a) foraging, including birds actively plunging into the water or clearly searching for prey, (b) transit, including birds engaged in high, direct flight with no evident searching behavior, (c) courting, including birds in fish flights or aerial glides (Wolk 1974), and (d) bathing or loafing. Only birds considered to be foraging at the time of observation are included in the present analysis. Simultaneous with each set of surveys made from land in 1980, boat transects were also conducted at approximately 0.5-mile intervals moving parallel to the coastline offshore to approximately 5 miles.

Data supplementing the present study have been collected by Atwood since 1977 at most southern and central California Least Tern nesting areas; Minsky has studied the species on Cape Cod, Massachusetts, and in southern California since 1974. Relevant information based on this experience, especially concerning foraging behavior during post-fledging dispersal, is included in this report.

RESULTS

Data collected during foraging surveys at Venice Beach, Huntington Beach and the Santa Margarita River are summarized in Tables 2, 3 and 4. At least 75% of all foraging activity occurred in the ocean on 9 of 10 surveys at Venice Beach, on 8 of 10 at Huntington Beach, and on 8 of 11 at the Santa Margarita River. Approximately 90-95% of such ocean feeding was within 1 mile of shore in water less than 60 feet in depth. Least Terns were rarely seen foraging in the ocean at distances from shore of 1-2 miles, and never were encountered farther than 2 miles offshore. Non-ocean habitats in the vicinity of the study colonies received limited use by foraging terns; in particular, marina areas, which were well represented near all colonies, were little used. At Venice Beach and Huntington Beach, with only one exception, at least 60% of all foraging took place within approximately 2 miles of the nesting sites; at the Santa Margarita River, this pattern was observed on only 6 of 11 surveys

(Table 5). Relatively large numbers of feeding terns were occasionally seen at stations located more than 2 miles from nesting sites at each of the three study areas.

Least Terns appear opportunistic in their foraging behavior, and have been observed on numerous occasions to shift to different feeding areas in response to localized concentrations of suitable prey. During experiments conducted at small artificial feeding ponds near Huntington Beach in 1979, numbers of foraging Least Terns increased from 2 to 24 individuals within 10 minutes of the release of several thousand Mosquitofish (*Gambusia affinis*). Similar vagility in feeding activity is reflected in the present study by fluctuations at particular stations on different dates (e.g., Table 2, stations 7 and 9 on 4 May 1981 and 19 May 1981). During the study, Least Terns at Venice Beach and Huntington Beach fed primarily on Northern Anchovy (*Engraulis mordax*), Topsmelt (*Atherinops affinis*) and Jacksmelt (*Atherinopsis californiensis*) (Atwood MS); a small food sample obtained at the Santa Margarita River colony in 1982 was comparable. While we have no actual data on day-to-day changes in prey population levels at foraging survey stations, all of the principal prey species form large, mobile schools and hence might be expected to vary in abundance at a single location on different dates.

Although the movements of prey species makes specific Least Tern foraging localities difficult to delimit, certain areas did receive consistently high levels of use by feeding terns at Venice Beach (stations 5, 6, 7), Huntington Beach (stations 5, 6, 7) and the Santa Margarita River (stations 4, 5, 6) (Table 6). In general, foraging activity was especially high in nearshore ocean waters near major river mouths.

No clear shifts in habitat utilization or preference were noted near Venice Beach and Huntington Beach during the nesting cycle (Tables 2, 3). However, abundant observations of family groups, frequently including color-banded juveniles identifiable as to natal colony, have indicated that many terns from Venice Beach and Huntington Beach nesting areas disperse following the breeding season to freshwater and estuarine habitats located beyond the areas included in the present study. Use of freshwater Windmill Lake, located approximately 5 miles inland from the Santa Margarita River colony, increased during the period of post-fledging dispersal (Table 4, station 24). Similarly, terns nesting at Purisima Point, Santa Barbara County, fed almost entirely in nearshore ocean areas during periods of courtship, incubation, and feeding of chicks during 1979; after juveniles were capable of sustained flight, family groups dispersed from the vicinity of the nesting area to the Santa Ynez River mouth, located 5.8 miles S of the colony. Comparable post-breeding aggregations of Least Terns at localities that had received little or no foraging use earlier in the season have been observed annually at numerous freshwater, estuarine and protected shallow marine areas in coastal central and southern California, apparently representing a general pattern in the population's behavior.

There is no evidence that failure of previously used offshore food resources "forced" dispersal to these newly utilized foraging localities, as late-nesting pairs at all colonies continued to feed successfully in nearshore ocean areas. Rather, the behavior of Least Terns at freshwater or estuarine foraging sites during the post-fledging period strongly suggests that this shift in habitat utiliza-

tion may be associated with young birds developing their fishing skills. This behavior has been best documented at freshwater Harbor Lake, Los Angeles County, which is known to have been used by foraging Least Terns since at least 1973 (Bender 1974, Massey and Atwood 1980). Importantly, Least Terns seldom appear at Harbor Lake until after the dispersal of fledglings from local breeding colonies in early July. Although no effort has been made to quantify feeding rates, older juveniles at Harbor Lake clearly foraged more frequently and with greater success than did younger birds, which spent most of their time on the ground waiting to be fed by their parent(s).

DISCUSSION

The Least Tern is opportunistic in its foraging habits, and efforts to precisely define "essential" feeding habitats or localities may be met with frustration. Prior to post-fledging dispersal from breeding colonies, most foraging activity occurs within 2 miles of the nesting sites; within this range, terns will probably feed in almost any body of water that supports suitable prey items.

Within a habitat type, certain areas may receive consistently higher levels of use, suggesting that some localities may be of greater importance than others. At Venice Beach, Huntington Beach and the Santa Margarita River, most foraging occurs in relatively shallow, nearshore ocean waters in the vicinity of major river mouths, possibly as a result of water depth, salinity or nutrient supplies which might favor concentrations of suitable prey species. However, these stations are also among the closest feeding areas to the breeding sites themselves, and the heavy foraging activity may be related more to proximity to the colony than to high prey concentrations. Regardless of the cause, we note that even in a superficially uniform and widespread habitat such as nearshore ocean waters, certain sites may be of primary importance in the feeding activities of a Least Tern breeding colony.

Prior to the subspecies' decline, at least 82% of known California Least Tern nesting sites (n = 33) were located within 1 mile of river mouth and/or estuarine habitats (R. Erickson, unpubl. data). This fact, along with the increased probability of seeing feeding terns flying over restricted marsh areas as opposed to open ocean, probably led to the assumption that estuaries are the species' required foraging habitat (Massey 1971, Wilbur 1974). Some presently existing colonies, such as those located at Batiquitos Lagoon, San Diego County, and Anaheim Bay and Bolsa Chica, Orange County, do feed primarily in estuarine habitats (Atwood MS). However, other colonies, including several located adjacent to relatively undisturbed river mouths, appear to forage mostly in nearshore ocean waters. The current absence of significant freshwater and estuarine ecosystems near both Venice Beach and Huntington Beach colonies makes it impossible to establish historic habitat preferences.

Similarly, determination of habitat preferences is difficult at the Santa Margarita River, where estuarine and freshwater habitats are present but substantially altered and reduced. We intend to study foraging behavior at a nesting colony situated in undisturbed habitat in Baja California, where both estuarine and ocean fishing are options, to determine Least Tern foraging preferences under natural conditions.

Table 2. Least Tern foraging activities at Venice Beach, Los Angeles County, during 1980-1981.

Station[a]	Habitat	PERCENT OF TOTAL FORAGING OBSERVED[b]									
		05 May[d] 1980	04 Jun[e] 1980	23 Jun[f] 1980	22 Jul[g] 1980	04 May[d] 1981	19 May[e] 1981	01 Jun[e] 1981	23 Jun[f] 1981	30 Jun[f] 1981	14 Jul[g] 1981
1	ocean	—	—	—	—	9	1	16	0	5	6
2	ocean	13	0	4	16	0	0	2	0	0	2
3	ocean	13	12	9	0	0	8	7	0	3	5
4	ocean	7	3	6	3	0	3	2	0	17	3
5	ocean	7	15	3	22	1	1	19	17	1	1
6	ocean	10	18	16	17	4	1	20	8	6	30
7	ocean	16	24	9	9	0	47	12	13	37	7
8	ocean	14	3	7	3	0	3	3	12	23	18
9	ocean	8	0	22	9	72	16	13	0	1	4
10	ocean	—	—	—	—	0	0	+	0	0	0
11	ocean	3	2	8	1	1	8	3	17	5	5
12	freshwater pond	0	1	0	6	0	0	0	0	0	0
13	degraded saltmarsh channels	4	9	3	0	5	1	0	0	0	0
14	degraded saltmarsh channels	1	4	4	6	7	0	+	0	0	1
15	marina	0	0	0	0	—	—	—	—	—	—
16	marina	0	0	0	6	0	0	2	1	1	12
17	marina	0	0	0	0	0	0	0	0	0	0
18	flood control channel	1	2	5	4	0	11	0	25	+	1
19	flood control channel	0	0	0	0	—	—	—	—	—	—
20	flood control channel	3	7	4	0	0	0	0	8	0	5
	sample size (n)[c]	23.0	20.6	48.8	9.7	18.8	22.0	24.6	25.7	69.2	32.1

[a]Location of observation stations as indicated in Figure 1.
[b]Based on mean values of five 1-minute counts at each station. Thus, if the mean number of foraging terns observed at station A was 3.2, and the total of all station means for that day (n) was 23.7, foraging activity at station A would represent 14% of the total recorded foraging. (+) indicates that observed foraging represented less than 1% of total; (−) indicates that data were not obtained.
[c]Number of foraging terns visible from each station calculated as mean of counts obtained during five 1-minute scans of area; sample size (n) is the total number of means from all stations on a given date.
[d]Main activity of breeding colony — courtship.
[e]Main activity of breeding colony — egg laying and incubation.
[f]Main activity of breeding colony — feeding of chicks.
[g]Main activity of breeding colony — dispersal of fledglings.

Table 3. Least Tern foraging activities at Huntington Beach, Orange County, during 1980-1981.

Station[a]	Habitat	PERCENT OF TOTAL FORAGING OBSERVED[b]									
		05 May[d] 1980	06 Jun[e] 1980	20 Jun[f] 1980	21 Jul[g] 1980	05 May[d] 1981	18 May[e] 1981	02 Jun[e] 1981	17 Jun[f] 1981	01 Jul[f] 1981	13 Jul[g] 1981
1	ocean	—	—	—	—	3	0	0	2	0	2
2	ocean	0	0	0	0	2	0	4	0	0	0
3	ocean	0	0	30	0	6	0	27	0	9	0
4	ocean	2	0	24	3	2	0	3	35	5	0
5	ocean	5	0	18	0	30	0	41	24	11	27
6	ocean	17	57	12	10	3	7	14	4	16	18
7	ocean	25	39	3	3	15	16	3	10	35	3
8	ocean	33	0	0	0	8	0	3	0	5	25
9	ocean	13	0	0	7	13	29	+	7	6	4
10	ocean	0	0	0	7	0	3	+	0	2	0
11	marina	0	0	0	7	0	3	+	0	2	0
12	flood control channel	0	3	0	0	0	7	+	5	+	3
13	flood control channel	0	0	9	7	6	9	+	5	5	7
14	flood control channel	—	—	—	—	0	0	0	0	0	0
15	flood control channel	0	0	0	13	0	13	2	0	0	0
16	flood control channel	—	—	—	—	0	3	2	0	0	0
17	flood control channel	0	0	0	10	0	0	0	1	0	0
18	freshwater pond	0	0	1	17	0	0	0	0	3	0
19	freshwater pond	—	1	0	0	0	0	0	0	0	0
20	degraded saltmarsh channels	3	0	3	23	9	13	0	7	2	9
	sample size (n)[c]	18.1	15.5	20.3	11.8	17.3	6.3	33.7	15.3	35.1	11.3

[a]Location of observation stations as indicated in Figure 2.
[b-g]See explanations, Table 2.

Table 4. Least Tern foraging activities at Santa Margarita River, San Diego County, during 1982.

Station[a]	Habitat	PERCENT OF TOTAL FORAGING OBSERVED[b]										
		03 May[d] 1982	04 May[d] 1982	18 May[e] 1982	01 Jun[e] 1982	02 Jun[e] 1982	18 Jun[e] 1982	29 Jun[f] 1982	13 Jul[f] 1982	27 Jul[g] 1982	28 Jul[g] 1982	11 Aug[g] 1982
1	ocean	3	6	13	+	0	+	0	0	3	0	0
2	ocean	11	16	5	0	0	0	+	3	7	4	0
3	ocean	35	18	0	4	1	12	2	13	15	5	0
4	ocean	10	29	1	14	22	28	35	20	19	+	0
5[h]	ocean	15	5	22	33	24	39	55	52	21	42	70
6	ocean	4	1	0	27	39	17	4	1	0	+	0
7	ocean	16	0	39	11	6	3	2	1	4	2	0
10[i]	brackish lagoon	0	0	0	0	0	0	0	0	0	3	0
11[i]	brackish lagoon	0	0	0	0	0	0	+	0	0	0	0
12[i]	brackish lagoon	0	+	0	0	0	0	0	2	+	11	0
13	river mouth	+	6	+	0	2	0	0	0	0	+	0
14[j]	river mouth	0	5	+	0	0	0	0	0	0	0	0
15	degraded saltmarsh channels/estuary	0	1	3	3	1	+	0	3	5	0	0
16	degraded saltmarsh channels	2	0	2	0	+	0	0	1	0	0	0
17	river channel	0	0	+	0	0	0	0	0	0	0	0
18	river channel	0	0	2	0	0	0	0	0	0	+	0
19	river channel	—	—	0	0	0	—	0	0	0	0	0
20	river channel	0	—	0	0	0	—	0	0	0	0	0
21	freshwater pond/lake	0	0	0	0	0	0	0	0	0	0	0
22	freshwater pond/lake	0	0	0	0	0	0	0	0	0	0	0
23	freshwater pond/lake	0	—	0	0	0	—	0	0	0	0	0
24	freshwater pond/lake	0	—	0	0	0	—	0	1	22	31	19
25	freshwater pond/lake	0	—	0	0	0	—	0	0	0	0	0
26	marina	4	6	4	1	0	0	0	0	0	0	4
27	marina	1	3	0	3	2	0	+	1	0	0	0
28	marina	1	3	8	3	+	+	+	+	0	0	8
29	marina	—	—	4	+	1	+	0	+	3	+	0
	sample size (n)[c]	54.4	51.8	62.4	55.8	56.4	127.2	133.8	56.6	20.8	22.2	5.2

[a]Location of observation stations as indicated in Figure 3.
[b-g]See explanations, Table 2.
[h]A more detailed description of foraging activity at Station 5 is provided in Minsky (1982).
[i]Station 11 was dry after 13 July; stations 10 and 12 were occasionally dry throughout the study period.
[j]San Luis Rey River mouth was blocked after 18 May.

Table 5. Effect of distance from nesting area on Least Tern foraging activity.

Date	Distance from Nesting Site (miles)[a]				
	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5[b]
Huntington Beach					
05 May 1980	25	60	15	0	—
06 Jun 1980	60	39	1	0	—
20 Jun 1980	42	28	30	0	—
21 Jul 1980	53	33	14	0	—
05 May 1981	48	25	21	2	3
18 May 1981	52	16	29	3	0
02 Jun 1981	60	9	27	4	0
17 Jun 1981	45	46	7	0	2
01 Jul 1981	34	48	15	2	0
13 Jul 1981	64	28	7	0	3
Mean ($\bar{X}$)	48.3	33.2	16.6	1.1	1.3
Venice Beach					
06 May 1980	41	25	21	13	—
04 Jun 1980	71	17	12	0	—
23 Jun 1980	44	21	31	4	—
22 Jul 1980	59	18	9	16	—
04 May 1981	11	7	72	0	9
19 May 1981	69	6	24	0	1
01 Jun 1981	54	7	20	2	16
23 Jun 1981	80	20	0	0	0
30 Jun 1981	49	41	5	0	5
14 Jul 1981	44	39	9	2	6
Mean ($\bar{X}$)	52.2	20.1	20.3	3.7	6.2
Santa Margarita River					
03 May 1982	17	20	51	11	3
04 May 1982	12	42	23	16	6
18 May 1982	27	19	39	5	13
01 Jun 1982	36	48	15	0	0
02 Jun 1982	27	64	7	0	0
18 Jun 1982	39	46	15	0	0
29 Jun 1982	55	39	4	0	0
13 Jul 1982	56	22	14	5	1
27 Jul 1982	26	22	19	7	25
28 Jul 1982	42	0	7	15	34
11 Aug 1982	70	12	0	0	19
Mean ($\bar{X}$)	37.0	30.4	17.6	5.4	9.2

[a]Values indicate percent of foraging activity occurring at stations located given distances from nesting sites.
[b]Stations at distances of 4-5 miles from nesting sites were not established at Venice Beach and Huntington Beach until 1981.

Table 6. Principal foraging localities used by Least Terns at three major breeding colonies.

	Station Number[a]																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Venice Beach		2	2	1	**4**	**5**	**6**	3	3	0	1	0	0	1	0	1	0	2	0	0	—	—	—	—	—	—	—	—	—
Huntington Beach	0	0	2	2	**6**	**5**	**6**	2	2	0	0	1	0	0	2	0	0	1	0	2	—	—	—	—	—	—	—	—	—
Santa Margarita River	1	1	3	**7**	**10**	**4**	2	—	—	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0

[a]Location of observation stations as indicated in Figures 1, 2 and 3.
[b]Values indicate number of dates on which station was among the three most heavily utilized feeding localities. Boldfaced numbers identify the three principal feeding localities for each colony during the study period.

Increased use of freshwater and estuarine marsh areas during post-fledging dispersal, when juveniles are developing their foraging skills, suggests to us that such calm, protected waters may be of major significance during this period. Even estuarine and freshwater localities that are distant from active nesting sites and that receive little or no foraging use during earlier stages of the breeding cycle may be used heavily by Least Terns during post-fledging dispersal; loss or disturbance of such areas may reduce the survivorship of dependent young.

SUMMARY

Least Terns at three large southern California breeding colonies foraged primarily in nearshore ocean waters in the vicinity of major river mouths. Most foraging took place within 2 miles of the nesting sites. Substantial alteration and reduction of non-ocean Least Tern foraging habitats in the vicinities of the study colonies made determination of historic habitat preferences impossible. However, increased use of coastal freshwater and estuarine habitats during post-fledging dispersal indicates the importance of such areas during this period.

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Least Terns courtship feeding, May 1981, Venice, California *Photo by Dana Echols*

Least Tern with chicks, July 1980, Anaheim Bay, Seal Beach, California

Photo by Dana Echols