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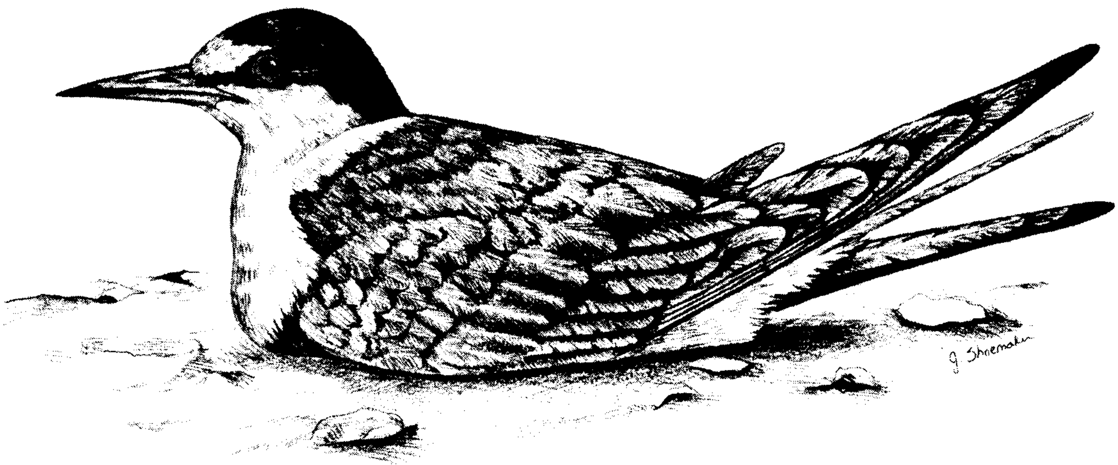
HABITAT SUITABILITY INDEX MODELS: LEAST TERN



Fish and Wildlife Service

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HABITAT SUITABILITY INDEX MODELS: LEAST TERN

by

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PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series [Biological Report 82(10)] which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. This information provides the foundation for the HSI model and may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents the habitat model and includes information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The HSI Model Section includes information about the geographic range and seasonal application of the model, its current verification status, and a list of the model variables with recommended measurement techniques for each variable.

The model is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts. Habitat information about wildlife species frequently is represented by scattered data sets collected during different seasons and years and from different sites throughout the range of a species. The model presents this broad data base in a formal, logical, and simplified manner. The assumptions necessary for organizing and synthesizing the species-habitat information into the model are discussed. The model should be regarded as a hypothesis of species-habitat relationships and not as a statement of proven cause and effect relationships. The model may have merit in planning wildlife habitat research studies about a species, as well as in providing an estimate of the relative suitability of habitat for that species. User feedback concerning model improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning are encouraged. Please send suggestions to:

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CONTENTS

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I thank Jonathan L. Atwood, Jean H. Schulenberg, and Bruce C. Thompson for reviewing and critiquing earlier drafts of the least tern HSI model. The comments and suggestions of these individuals have added to the quality of this model, and their time and contributions are gratefully acknowledged. I also thank Michael L. Peterson, Robert F. Soots, Jr., and Bruce C. Thompson for their contribution to the formulation of the substrate composition variable used in the model. Louis R. Bevier, contractor with the California Department of Fish and Game, Sacramento, Robert F. Soots, Jr., and Bruce C. Thompson provided photographs of least tern nesting habitat included in the model and their contributions are appreciated. Finally, I thank Milton S. Rutstein, National Oceanic and Atmospheric Administration, National Ocean Service, Rockville, MD, and Robert D. Jarrett and Garnett P. Williams, U.S. Geological Survey, Denver Federal Center, Denver, CO, for providing literature and consultation on habitat flooding.

Word processing was provided by Elizabeth Graf, Carolyn Gulzow and Dora Ibarra. The cover was illustrated by Jennifer Shoemaker. Kay Lindgren assisted with the literature search and document acquisition for this project.

LEAST TERN (*Sterna antillarum*)

HABITAT USE INFORMATION

General

The least tern (*Sterna antillarum*) breeds along coastal and freshwater habitats of North, Central, and South America and the Caribbean Islands (American Ornithologists' Union 1983). Three subspecies breed in the continental United States. The eastern least tern (*S. a. antillarum*) breeds along the Atlantic-Gulf coast from the southern tip of Texas (American Ornithologists' Union 1983) to southern Maine (Hunter 1975). The interior least tern (*S. a. athalassos*) breeds sporadically along the major tributaries of the Mississippi River drainage basin (Ducey 1981) and the Rio Grande (Downing 1980). The California least tern (*S. a. browni*) breeds from southern Baja California, Mexico, north to the San Francisco Bay (California Least Tern Recovery Team 1980). Least terns seen along the southern Colorado River and Salton Sea area of southern California may be wanderers from the *mexicanus* subspecies of the nearby Gulf of California (Wilbur 1974). No breeding populations of this subspecies in the continental United States were cited in the literature.

Breeding habitat is generally characterized as open sand, soil, or dried mud in the proximity of a lagoon, estuary, or river (Hardy 1957; Craig 1971; Massey 1971). The least tern has suffered a significant loss of nesting and feeding habitat from human activities, including recreational use and habitat modification due to development (Wilbur 1974; Buckley and Buckley 1976; California Least Tern Recovery Team 1980; Ducey 1981).

Food

Least terns consume small fish that swim near the surface (Tomkins 1959). The method of hunting consists of hovering and diving from a height of "a few feet" (Hardy 1957:50) to 10 m (Moseley 1976) above the surface. Least terns also skim the water for surface-dwelling prey (Bent 1921; Oberholser 1974) and feed on insects on land (Bent 1921; McDaniel and McDaniel 1963; Schulenberg et al. 1980). However, feeding over land is considered rare for least terns (Moseley 1976).

Least terns employ an opportunistic foraging strategy (Atwood and Minsky 1983) and probably exploit any fish species within a certain size range (Moseley 1976). The stomach contents of 49 least terns collected in New Jersey, Florida, and Louisiana consisted of 43.1% silver anchovy (*Engraulis eurystole*), 6.8% menhaden (*Brevoortia tyrannus*), 6.3% mummichogs (*Fundulus heteroclitus*), 5.0% Crustacea, 1.1% silversides (*Menidia* spp.), and 37.7% unidentified items (McAtee and Beal 1912).

Species of fish dropped or discarded by adults in nesting colonies appear to correlate roughly with species actually consumed (Massey and Atwood 1980; Atwood and Kelly 1984). In California, northern anchovy (Engraulis mordax) usually was the most commonly dropped fish followed by topsmelt (Atherinops affinis), jacksmelt (Atherinopsis californiensis), and deepbody or slough anchovies (Anchoa compressa, A. delicatissima) (Atwood and Kelly 1984). In Mississippi, Hays (1980) found Gulf menhaden (Brevoortia patronus) and bay anchovy (Anchoa mitchilli) most frequently dropped at a least tern colony. In addition to these two species, emerald sleeper (Erotelis smaragdus) and rough silverside (Membras martinica) were dropped at colony sites in Texas (B. C. Thompson, Texas Parks and Wildlife Department, Austin; letter dated 9 August 1984). Burroughs (1966) found sand lance (Ammodytes spp.), herring (Clupea spp.), and hake (Urophycis spp.) dropped in least tern colonies in Massachusetts. Hardy (1957) found dropped river shiner (Notropis blennius) on the lower Ohio River and determined this species to be the dominant food of least terns in that area. Schulenberg et al. (1980) collected plains killifish (Fundulus kansae) most often at colony sites in Kansas.

Fish 2.5 to 7.5 cm long were caught and eaten by adult least terns and fed to young in Kansas (Schulenberg et al. 1980). Moseley (1976) found that adult birds in North Carolina ate fish 5 to 8 cm long and fed newly-hatched chicks fish 2 to 4 cm long. In California, adult terns fed on fish from 4 to 9 cm long (Massey 1974) and seemed barely able to swallow northern anchovies 9.5 to 10 cm long, and surfperches (Embiotocidae) 2 cm deep vertically (Massey and Atwood 1980). Eighty-four percent of fish eaten during courtship were < 5 cm long with 50% between 2.5 and 5 cm. Dropped fish collected in California terneries ranged from 3.5 to 9.5 cm long. Chicks < 10 days of age were fed fish < 2.5 cm, whereas chicks older than 10 days and fledglings were fed a broad range of sizes (Massey and Atwood 1980). Massey and Atwood (1981a) concluded that suitable fish for young chicks were nonspiny species < 1.5 cm long. Atwood and Kelly (1984) considered spiny fish and fish with a body depth or rotundity diameter > 1.5 cm as generally unsuitable food items for adult least terns.

Water

No information on least tern drinking water requirements was found in the literature. Food and cover requirements associated with water are discussed under the appropriate sections.

Cover

Adult least terns require no cover during the breeding season. Areas used for mating, nesting, and feeding young have been described as bare (Jernigan et al. 1978). Massey and Atwood (1982) described a night roosting site as a wide stretch of sandy beach.

Least tern chicks abandon the nest within a few days after hatching (Massey 1974). Parent birds tend to lead the chicks toward the colony's periphery (Akers 1975) into more heavily vegetated areas (Moseley 1976). Chicks can wander widely within and outside of the colony (Massey 1974; Akers 1975). Chicks use sparse vegetation and water deposited debris for shade and protection (Hardy 1957; Jernigan et al. 1978; Minsky et al. 1984; Schulenberg and Ptacek 1984).

Reproduction

Least terns generally nest on a flat, unvegetated substrate near a good feeding area (Portnoy 1977) (Fig. 1a), but also can nest successfully on less characteristic sites (Figs. 1b and 1c). Least terns in marine environments nest on islands, peninsulas, beaches, sandbars, and isolated sandpits (Moseley 1976), usually between the high tide line and the area of dune formation (Akers 1975; Hunter 1975; Dorr 1976; Blodget 1978). Most inland least tern nesting occurs along the larger rivers with broad expanses and braided water channels (Ducey 1981), specifically on saltflats and sandbars that become exposed during periods of low water (Stiles 1939; Hardy 1957; Schulenberg and Schulenberg 1982). However, nests also are found in salt marshes (Parmelee et al. 1969) and along lakes (Schulenberg et al. 1980).

Least terns scrape out shallow nests on unconsolidated substrates such as sand, soil, shell, or gravel. Least terns in North Carolina (Jernigan et al. 1978) and in New York (Gochfeld 1983) preferred a coarse sand-shell substrate. Craig (1971) stated that a sand-shell mix provided the best background for the cryptically colored eggs and chicks of least terns in California. Areas of sand-pebble substrate that provide camouflage (Burroughs 1966) are also preferred as nesting sites by least terns (Hardy 1957).

Successful tern colonies have been found on fine-grained substrates (Wycoff 1950; Hays 1980). However, studies in California (Swickard 1972), Oklahoma (Grover and Knopf 1982), Texas (Thompson and Slack 1982), and Kansas (Schulenberg and Ptacek 1984) have associated high egg loss during heavy rains with the poor water permeability of finer grained substrates. Finer materials also are more prone to wind-drifting (Downing 1980; Gochfeld 1983), which can destroy eggs (Burroughs 1966) and possibly young (Ganier 1930). Soots and Parnell (1975) found that shell material helped stabilize nesting substrate in North Carolina. When little or no shell was present, winds caused erosion and shifting sand dunes. On a saltflat in California, least terns apparently avoided nesting on sites containing high amounts of silt and clay (Minsky et al. 1984).

Least tern nesting habitat is generally characterized as ephemeral (Gochfeld 1983), being represented vegetatively by pioneering plant species that are low-growing, scattered, or form dispersed clumps (Jernigan et al. 1978; Thompson and Slack 1982). Total vegetation cover rarely exceeded 20% at colony sites in California (Craig 1971), Kansas (Schulenberg et al. 1980), and Texas (Thompson and Slack 1982). In New York, most nesting sites were in areas of 5 to 25% cover, although sites with > 20% cover were seldom occupied (Gochfeld 1983). Nest sites in North Carolina (Jernigan et al. 1978) and Nebraska (Faanes 1983) were generally located in areas of < 10% cover.

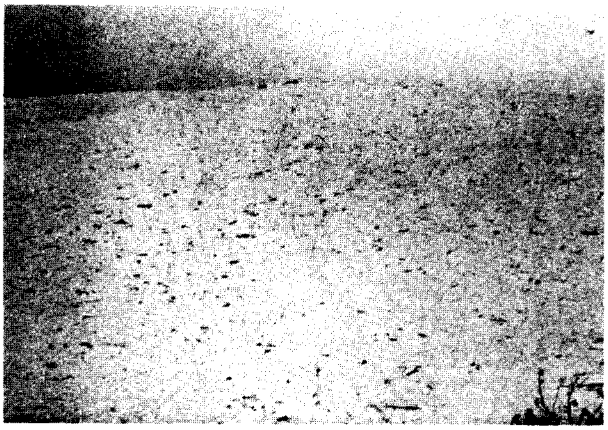

Figure 1a. Preferred least tern nesting habitat consists of flat, open, unconsolidated sites such as this North Carolina coast beach (photo by R. F. Soots, Jr.).

Figure 1b. Least terns can nest in topographically diverse upland habitat. Some least terns in southern California nest on flat areas between 2 m high sand dunes (photo by L. R. Bevier).

Figure 1c. Established least tern colonies can persist in areas of encroaching vegetation and human disturbance such as this site on a Texas Gulf coast island (photo by B. C. Thompson).

Figure 1. Examples of least tern nesting habitat in marine environments.

Jernigan et al. (1978) reported that vegetation height ranged from 0 to 40 cm with a mean of 7 cm in natural sites. Least terns in Kansas nested among 0.6 to 0.9 m tall plants when more favorable habitat was flooded (Schulenberg and Schulenberg 1981). Nests in Mississippi tended to be located among sparse vegetation more often than on open beach (Jackson 1976). Other authors (Akers 1975; Blodget 1978; Grover and Knopf 1982) have noted that least terns tend to nest in close proximity to debris. Occasionally, least tern colonies are found in relatively densely vegetated areas, although some workers attribute this to possible site tenacity (i.e., the tendency of birds to return to the same site year after year) (Downing 1973; Jernigan et al. 1978; Thompson and Slack 1982; Gochfeld 1983) or a response to habitat loss (Moseley 1976) rather than preferential habitat selection. Other authors have stated that least terns move to new habitat when vegetation encroachment occurs (Wycoff 1960; Downing 1973; Buckley and Buckley 1980). Vegetation encroachment on sandbar nesting habitat is a major cause of habitat loss for least terns in the interior (Ducey 1981).

By nature of their close proximity to water, least tern colonies are often threatened by inundation. Flooding by high tides and stream flows can be a major cause of reproductive failure for the least tern (Paige 1968; Blodget 1978; Loftin and Thomson 1979; Ducey 1981; Grover and Knopf 1982; Faanes 1983; Schulenberg and Ptacek 1984). Least terns in marine environments often avoid inundation by selecting the more elevated portions of a breeding site (Akers 1975; Thompson and Slack 1982; Gochfeld 1983), such as lumps and ridges as opposed to flats (Jernigan et al. 1978). Loftin and Thomson (1979) concluded that nests elevated "a few inches" by transplanting an automobile tire over them would stand a better chance of survival from high water. Least terns also can escape flooding by avoiding narrow beaches and by nesting some distance from the high tide line (Gochfeld 1983). Least terns in Long Island, New York avoided beaches < 10 m wide above the high tide line. Similarly, least tern nests in riverine environments often are situated on less vulnerable sites. At a colony site on the lower Ohio River, most nests were located on accumulations of gravel and usually were located well back from the water (Hardy 1957). Wycoff (1960) also noted least terns nesting on relatively higher ridges of gravelly mud in Nebraska. Least terns inhabiting river systems can delay reproduction until after the period of peak river flooding, when suitable nesting sites become available (Bent 1921; Ganier 1930; Stiles 1939; Hardy 1957; Wycoff 1960).

Predation also can be a major cause of nesting failure (Paige 1968; Akers 1975; Blodget 1978; Massey and Atwood 1979). The presence of predators can prevent least terns from nesting (Massey 1971) and cause them to abandon previously occupied sites (Massey and Atwood 1981a). Barriers to mammalian predators include fencing (Massey 1971; Minsky 1980) and the isolation of a colony site by water (Hardy 1957; Swickard 1972, 1974; Faanes 1983). Landin and Soots (1977) noted that dredged material deposits that were used for nesting allowed access to colonies at low tide when located too close to the mainland. They also found that islands > 8 ha were rarely used because predators could inhabit them year-round. Dredge-spoil islands that lack dense vegetation and are not located adjacent to large marshes are less likely to support mammalian predators than are naturally occurring barrier islands (Soots and Parnell 1975). Some terrestrial predators on least tern eggs and chicks include Norway rats (*Rattus norvegicus*), house cats (*Felis catus*), skunks (Mustelidae) (Massey and Atwood 1979), foxes (*Vulpes fulva*) (Minsky 1980), and coyotes (*Canis latrans*) (Grover and Knopf 1982). Least tern eggs and chicks also are preyed on by many avian species. Clumps of vegetation or debris used as cover by chicks can provide little protection from avian predation (Jenks-Jay 1982). In Massachusetts, however, the erection of wood and metal shelters provided protection from avian predators (Jenks-Jay 1982). Clay roofing tiles were used to provide hiding places for chicks from predatory birds in California (Massey and Atwood 1979). Avian predators include several species of raptors, gulls, and corvids.

Interspersion and Composition

Least terns hunt in shallow water areas such as nearshore ocean (Collins et al. 1979; Atwood and Minsky 1983), estuaries, lagoons (Wilbur 1974), rivers, streams, lakes, ponds (Hardy 1957), channels (Collins et al. 1979; Atwood and Minsky 1983), and canals (Fisk 1975). In marine environments, offshore foraging can occur in areas of floating seaweed that provide conditions normally found only in shallow water areas (e.g., minimum surface chop and small fish near the surface) (Massey and Atwood 1979). The movements of prey species tend to make specific foraging localities difficult to delimit (Massey and Atwood 1981a; Atwood and Minsky 1983).

In North Carolina, Jernigan et al. (1978) found that colony sites were in the vicinity of shallow, open water and tidal marshes with ample food supplies. In California, Atwood and Minsky (1983) observed that foraging activities were consistently high in nearshore ocean waters near major river mouths, possibly as a result of ecological conditions such as water depth, salinity, or nutrient supply that favored concentrations of prey species. Massey and Atwood (1980) noted that 75 to 90% of observed feeding activity during courtship, incubation, and feeding of young occurred in the nearshore ocean. Along rivers, shallow water areas formed by meanders or alterations in current flow are favorable sites for nesting and are the areas most frequently fished (Hardy 1957). Of 49 species of dropped fish listed by Atwood and Kelly (1984) in California, all primarily inhabited shallow water areas.

Least tern colonies need to be located close to feeding areas (i.e., extensive areas of shallow water) (Craig 1971). An ideal nesting substrate will not attract nor support breeding pairs if suitable feeding conditions are not present within a reasonable distance (California Least Tern Recovery Team 1980). Coastal least terns commonly breed in close proximity to shallow water areas such as nearshore ocean (Collins et al. 1979; Massey and Atwood 1980), estuaries (Massey 1971; Dorr 1976), and bays (Erwin 1978; Thompson 1982). In North Carolina, Jernigan et al. (1978) found all of 61 observed colonies within 250 m of a large expanse of shallow water. Least terns in Nebraska generally foraged within 100 m of nest sites (Faanes 1983). Although least terns in Kansas occasionally flew 3.2 to 4.8 km from colony sites to feed, birds usually foraged within 1.6 km of colony sites (J. H. Schulenberg, contractor with Kansas Fish and Game Commission, Pratt; pers. comm.). In California, most foraging occurred within 3.2 km of nesting sites (Atwood and Minsky 1983). Massey and Atwood (1980) saw many birds foraging 6.4 km or more from the colony; however, birds found foraging farther than 4 km from the nesting site were suspected to be nonbreeders (Massey and Atwood 1981a). In Mississippi, Hays (1980) noted that although least terns commonly fished in shallow water, they also foraged in deeper water 4.8 to 8 km from shore in the Gulf of Mexico.

Least terns use a variety of aquatic habitats when available. Least terns in the interior have been seen foraging in rivers, lakes, ponds, sloughs, and borrow pits (Ganier 1930). Similarly, the least terns in a colony on the San Gabriel River in California were seen foraging in the river, at the mouth of the river, in a marina, in a flood control canal, in a marsh, and offshore (Massey and Atwood 1979). After fledging, terns in California shifted to quiet, shallow areas such as freshwater lakes and ponds, flood control channels, and saltmarsh channels where the young appeared to be perfecting their foraging skills (Massey and Atwood 1980; Atwood and Minsky 1983). The authors suggested that such areas were critical to the survival of fledglings, and were therefore of major importance to the reproductive biology of the least tern. The authors further suggested that disturbance of nearshore ocean areas and river systems within 3.2 to 4.8 km of active nesting sites should be avoided, and that freshwater habitat within 8 km of the coast as well as salt marshes should be assessed for use by least terns.

Special Considerations

Nesting sites generally are characterized as unstable areas created and maintained by tidal action or flooding. Due to the sometimes transitory nature of nesting habitat, least terns have been described as having strong group adherence and weak site tenacity, which may aid in discovering recently created habitat (McNicholl 1975). In some cases, however, site tenacity can be a more important determinant of site selection than the physical characteristics of an area (Gochfeld 1983; J. L. Atwood, Department of Biology, University of California, Los Angeles; unpubl.). Least tern colonies can display high site fidelity by continuing to use an area year after year for as long as the site remains suitable (Burger 1984), including marginal sites where successful reproduction has occurred previously (Massey and Atwood 1979). In New Jersey, colony sites were abandoned only when predation, human disturbance, or vegetation encroachment reached intolerable levels (Burger 1984). Terns returned to and nested at sites where colonies were completely wiped out the previous year when such sites had been in use for several years. Year-to-year fidelity has been documented for least terns in California by Atwood (unpubl.), who also found that least terns tended to nest in the general vicinity of their natal colonies. Of 190 banded birds studied, approximately 50% nested within 25 km of where they were hatched, and over 80% nested within 50 km of their natal site.

Least tern nesting and feeding habitat has undergone a significant decrease as a result of beach erosion (Downing 1973) and various human activities such as recreational use of beaches (Gochfeld 1983), the development of beach homes (Chambers 1908) and marinas (Massey and Atwood 1980), dam construction (Ducey 1981), channel deepening (Downing 1980), and agricultural drawdown (Schulenburg and Ptacek 1984). Least terns partially compensate for the loss of natural habitat by successfully nesting in marginal areas quite unlike former sites (Craig 1971; Massey and Atwood 1979), although reproductive success in such areas often can be reduced (Atwood, pers. comm.). In California, least terns historically nested on beaches near the mouths of major rivers, bays, and estuaries (Massey and Atwood 1981a). Due to displacement, birds also now nest in areas such as mudflats and landfill sites back from the ocean (Craig 1971; Massey 1974; California Least Tern Recovery Team 1980). On the Atlantic-Gulf coast, least terns commonly nest on dredge and development spoil (Downing 1973; Soots and Parnell 1975; Buckley 1978) and on flat rooftops (Downing 1973; Fisk 1975, 1978a, b). Least terns also have been reported nesting on dredge material (Moser 1940; Wycoff 1950) and sandpits (Swanson 1956; Wycoff 1960) near rivers and lakes in the interior. Other unnatural nesting areas used by least terns include airports (Anderson 1972; Atwood et al. 1979), old parking lots (Texas Waterbird Society 1982; Gochfeld 1983), road shoulders (Texas Waterbird Society 1982), and cultivated fields (Nugent 1974).

Human-related disturbance to least tern colonies occurs in the form of foot traffic, pets, off-road vehicles (Dorr 1976; Blodget 1978), and livestock (Schulenberg and Ptacek 1984). Least terns can successfully nest close to human activity if the nest itself is not disturbed (Craig 1971; Thompson 1982). Brubeck et al. (1981) found a colony of least terns within 5 m of a heavily traveled highway in Texas, and Davis (1968) noted that the daily passing of a train approximately 3 m away from a colony in California did not displace incubating birds. Where human disturbance to the nests is a problem, fencing has been shown in some cases to be an effective means of protecting colonies (Blodget 1978; Massey and Atwood 1979, 1981a). Protection provided by fencing allowed least tern colonies in Massachusetts to become accustomed to vehicles and people (Blodget 1978). Fencing of a colony of three least tern nests in California resulted in an increase to 35 nesting pairs during the same year, and 80 to 95 pairs the following year (Massey and Atwood 1979).

Least tern nesting habitat can be enhanced by the improvement of marginal sites. In California, Swickard (1974) found that poorly drained and camouflaged substrates such as saltflats could be improved by the addition of highly disturbed and displaced sand. Schulenberg and Schulenberg (1982) reported similar results for least tern nesting habitat in Kansas. Swickard (1972) also stressed the importance of vegetation removal, which must be repeated periodically to prevent encroachment (Downing 1973; Massey and Atwood 1979; Schulenberg and Ptacek 1984).

The size of least tern colonies can range from a few to several hundred nesting pairs, and a colony can be divided into subcolonies (Massey 1974). The loss of nesting habitat can either lead to a decrease in colony size (Varza 1975) or complete abandonment of a site (Burger 1984). Erwin (1977) suggested that, because least terns frequently shift nesting sites, a larger amount of habitat than is being used at a given time should be protected in order to accomodate future needs.

The California and interior subspecies of the least tern are listed as endangered (California Least Tern Recovery Team 1980; U.S. Fish and Wildlife Service 1985a). All three subspecies are designated as national species of special emphasis (U.S. Fish and Wildlife Service 1985b).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for application within the entire breeding range of the least tern in the continental United States (Fig. 2). A review of literature pertaining to the least tern indicated that habitat for the three subspecies can be characterized by the same environmental variables. This model was constructed to evaluate the various habitat types inhabited by all of the subspecies and the various habitat types available to a potential population within a subspecies, unless otherwise indicated (see Cover types).

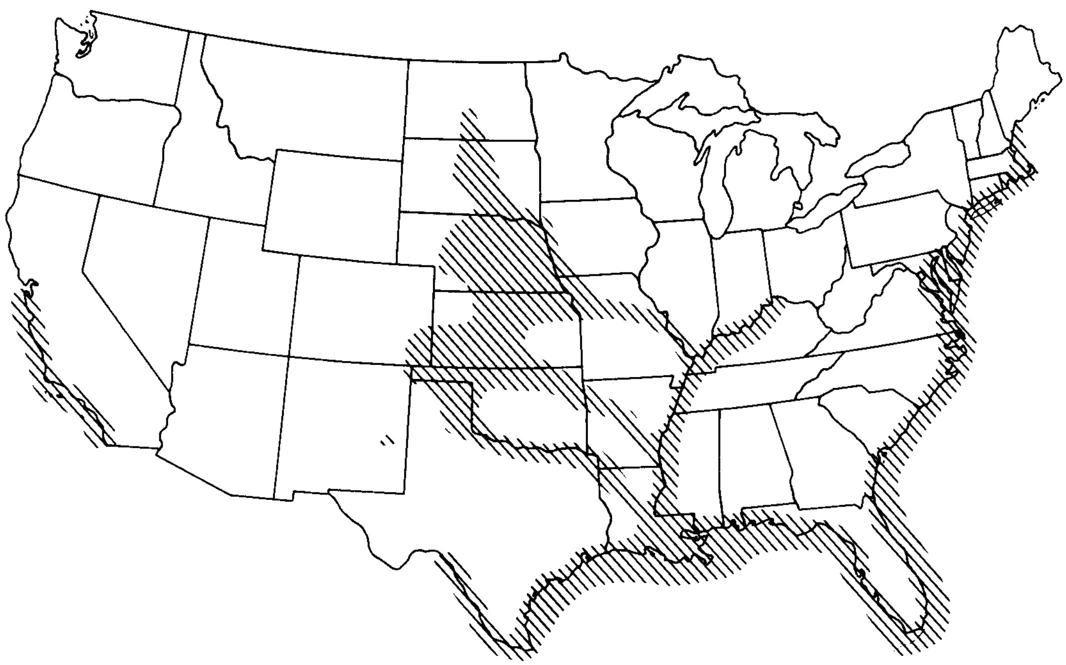

Figure 2. Approximate breeding range of the least tern in the United States (developed from various sources).

Season. This model was developed to evaluate the breeding season habitat of the least tern, specifically during May and June, which are generally the months of peak reproductive effort by the species (Hardy 1957; Downing 1973; Massey and Atwood 1981b). In riverine habitat, extensive flooding can cause reproduction to be delayed into July and August. See Application of the Model for guidance towards the evaluation of habitat that experiences extensive flooding during May and June.

Cover types. This model was developed to evaluate habitat in shore and bottom wetland (SBW), barren land (BL), and desertic herbland (DH) cover types

(U.S. Fish and Wildlife Service 1981), and marine (M), estuarine (E), riverine (R), lacustrine (L), and palustrine (P) aquatic systems (Cowardin et al. 1979). This model also is applicable to unnatural areas of unconsolidated substrate such as dredge material and sandpits, that may simulate natural substrate. Highly unnatural areas such as rooftops, airports, and roads are not considered acceptable areas for evaluation using this model.

It is believed that least terns require large expanses of relatively shallow water for foraging. However, a wide variety of aquatic habitats can contain fish of suitable size for least terns. Due to the opportunistic foraging behavior of least terns, it is assumed that potential least tern foraging habitat is any open body or channel of water, natural or constructed, known to contain or suspected of containing fish < 10 cm long that swim near the surface.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before a species will live and reproduce in an area. The larger least tern colonies typically are found on broad, open nesting sites. However, small or narrow sites of adequate suitability also support some nests. The minimum area to be evaluated is left to the discretion of the user of this model. Some examples of least tern colonies on limited and restricted area sites are presented in Table 1. The relationship between aquatic habitat area and suitability is discussed under Food component.

Table 1. Examples of least tern colony sizes on limited and restricted area sites.

Subspecies	Area	# of nests	Reference
S. a. antillarum	5 m wide beach	6	Hunter (1975)
S. a. antillarum	64.2 m x 18.3 m island	300	Anderson (1977)
S. a. athalassos	38.1 m x 22.9 m island	6	Wycoff (1950)
S. a. athalassos	91.5 m x 20.1 m sandbar	6	Schulenberg and Schulenberg (1982)
S. a. browni	99 m x 122 m fenced enclosure	140-160	Massey and Atwood (1981)
S. a. browni	24.4 m x 54.9 m area of improved substrate	34	Swickard (1974)

Verification level. Previous drafts of this model were critiqued by Jonathan L. Atwood, Jean H. Schulenberg, and Bruce C. Thompson. Comments from these reviewers have been incorporated into the current model. Michael L. Peterson, Robert F. Soots, Jr., and Bruce C. Thompson assisted in the construction of the substrate textural triangle used in the model.

Model Description

Overview. The least tern habitat model considers the ability of the habitat to meet the food and nesting needs of the species as an indication of overall breeding season habitat suitability. The literature indicates that site tenacity plays a major role in least tern habitat use. Due to this behavioral trait, least terns may often nest in areas of relatively low suitability, as defined by this model. It is not recommended that this model be used to determine the value of sites with existing breeding populations of least terns or sites with a history of breeding activity within the past 5 years. This recommendation is made because occupancy can be a function of site tenacity in addition to, and possibly irrespective of, the physical habitat parameters addressed by this model. Due to the threatened and endangered status of the least tern throughout its range, habitats with a history of supporting populations of breeding least terns within the past 5 years should be assumed to have high value even if the model indicates low suitability. However, this model can be used to assess suitability and, subsequently, identify those habitat parameters that can limit the reproductive potential of an existing breeding population. With the distinction between habitat value and habitat suitability in mind, the model can be used as a tool for management.

The following sections provide a written documentation of the logic and assumptions used to interpret the habitat information for the least tern and to explain and justify the variables and equations used in the HSI model. Specifically, these sections identify variables that are used in the model, define and justify the suitability levels of each variable, and describe the assumed relationships between variables.

Food component. Least tern food requirements are related to the abundance and accessibility of small fish. Least terns feed on a variety of small fish species. A discussion of some fish species and size classes commonly foraged by least terns was presented under Food, the habitats used for foraging were discussed under Interspersion and Composition, and the assumptions concerning least tern foraging habitat were discussed under Cover types. The user of this model should use this information and, possibly, the advice of a fisheries authority, as guides to the determination of what aquatic habitats can be considered as foraging habitat.

Least terns will not use an optimum nesting site if the surrounding area does not contain adequate food resources. It is therefore important that the availability of food resources be addressed. This model does not directly measure the availability of fish. As an alternative, it is assumed that a suitable nesting habitat in close proximity to abundant and/or diverse aquatic habitat is a desirable nesting site for least terns. The maximum distance that breeding birds will fly to forage is not known. However, because of the care required by the progeny, it is probable that parent birds will not fly as far as nonbreeding birds during the incubation and chick-rearing period. It is assumed in this model that an area composed of ≥ 50% water within the average maximum flight distance from the potential nesting habitat will provide optimum foraging habitat area (Fig. 3). This is based on the assumption that a nesting habitat that borders an expansive aquatic system (e.g., the ocean or a large river and floodplain) will provide a potential nesting population with ample foraging habitat. It is assumed that the average maximum flight distance for coastal least terns is 3.2 km, based on the observations of Atwood and Minsky (1983) in California. It also is assumed the average maximum flight distance for interior least terns is 1.6 km, based on the observations of Schulenberg (pers. comm.) in Kansas. If breeding least terns behave differently in other areas, these distances should be modified accordingly.

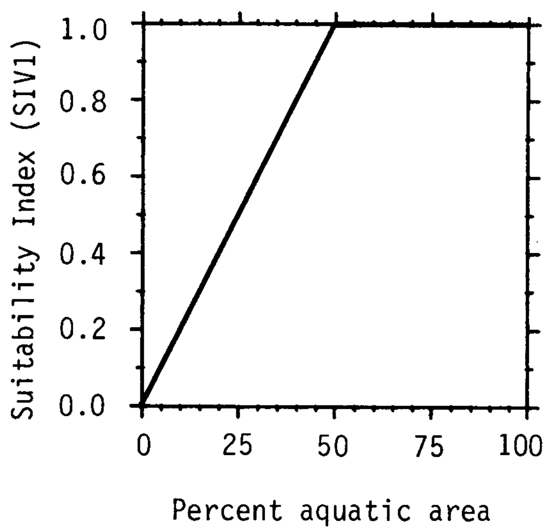

Figure 3. The relationship between the percent of the area within the average maximum flight distance from the potential nesting habitat that is aquatic habitat and the suitability index value for least tern food.

Least terns use and, at times, depend on a variety of foraging habitats. It is assumed that an area that contains a diversity of aquatic habitat types will be: (1) more productive than less diverse areas; (2) more likely to continue to provide food during the incubation and chick-rearing period if one of the aquatic habitat types fails to provide sufficient food supplies; and (3) able to adequately accommodate any possible change in foraging habitat use as the breeding season progresses. Habitat with two or more disparate aquatic systems (M, E, R, L, and P) within the average maximum flight distance is assumed to provide optimum diversity. However, a single, diverse aquatic system such as an estuary (E) or large riverine floodplain (P) can also be highly productive. Therefore, it is assumed that an area composed of a single aquatic system will provide optimum diversity of foraging habitat when it

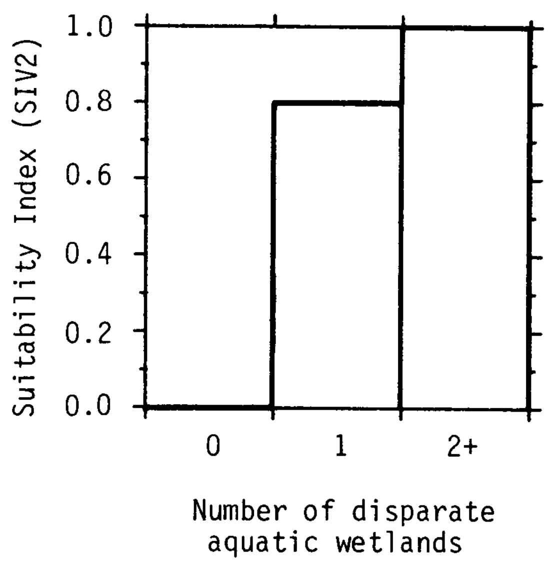

Figure 4. The relationship between the number of disparate aquatic wetlands within the average maximum flight distance from the potential nesting habitat and the suitability index value for least tern food.

contains two or more disparate aquatic (i.e., flooded) wetlands (Cowardin et al. 1979, Table 4) within the average maximum flight distance from the potential nesting habitat (Fig. 4). Again, this distance should be modified if breeding least terns are known to concentrate their feeding activity within a different radial distance. The user is referred to Cowardin et al. (1979) as a guide for the designation and delineation of aquatic systems and aquatic wetlands.

The formulation of SIV1 and SIV2 was based on the assumption that least terns prefer to nest in areas containing extensive areas of water and diverse aquatic habitat. The assumption that extensive and diverse aquatic habitat benefits least tern populations is based on the facts that: (1) most large populations are found along the coast, particularly in the vicinity of inlets; and (2) interior populations of least terns have declined drastically (Ducey 1981) concurrent with a significant decrease in aquatic habitat (i.e., areal extent and, correspondingly, diversity) throughout much of their range (Williams 1978a; Burke and Robinson 1979; Schulenberg and Ptacek 1984).

The suitability index value for food (SIF) is assumed to be a function of the areal extent of surface water and diversity of foraging habitat within the average maximum flight distance from the potental nesting habitat. The relationship between suitability values calculated using Figures 3 and 4 is illustrated in Equation 1. SIV1 is weighted to reflect the assumed greater relative significance of the quantity of foraging habitat.

$$SIF = \frac{2(SIV1) + SIV2}{3} \tag{1}$$

Reproduction component. Reproductive (i.e., nesting) habitat suitability for the least tern is related to a combination of several factors; percent vegetation cover, average height of vegetation cover, type of substrate, susceptibility to flooding, and the amount of predation and human-related disturbance. The first three variables are presented in the following discussions. The latter two factors are addressed under Application of the Model.

Dense, tall vegetation on a potential nesting site can provide cover or convenient perches for predators. Least terns generally nest in areas of sparse vegetation and usually will not nest in areas with > 20% vegetation cover or in areas of tall vegetation. In some cases, sparse vegetation is necessary to protect chicks from exposure to the sun and predators. However, least terns commonly nest successfully in habitats with no vegetation and thus such habitats are considered to be highly suitable. It is assumed that habitats with vegetation between 0% and 15% coverage provide optimum cover suitability (Fig. 5a), and in habitats with 0% vegetation other materials such as water-deposited debris can serve the same purpose as vegetation. It also is assumed that an area will have no suitability as nesting habitat when vegetation exceeds 25% coverage. When percent vegetation cover is < 15% or > 25%, the suitability index for vegetation cover (SIC) is assumed to be determined solely by SIV3 (Fig. 5a).

When percent vegetation cover is ≥ 15% and ≤ 25%, suitability is determined by an assumed synergistic relationship between percent vegetation cover and the average height of vegetation (Fig. 5b). In such cases, it is assumed that an area has no suitability as potential nesting habitat when the average height of vegetation is ≥ 40 cm. When percent vegetation cover is ≥ 15% and ≤ 25%, the SIC is assumed to equal the value obtained using Equation 2.

$$SIC = (SIV3 \times SIV4)^{1/2} \tag{2}$$

Fig. 5a.

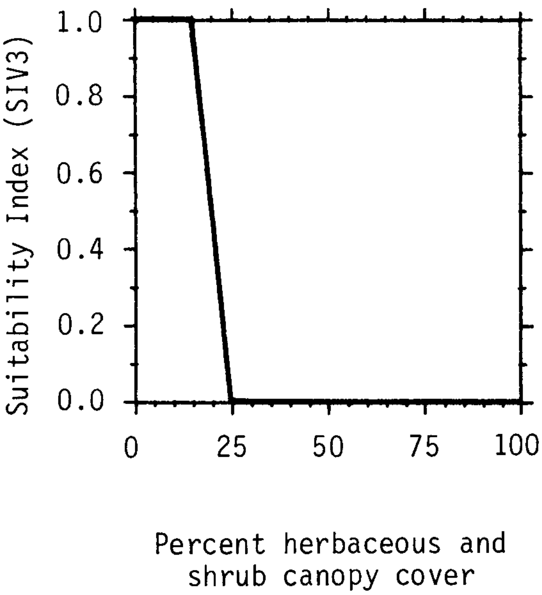

Fig. 5b.

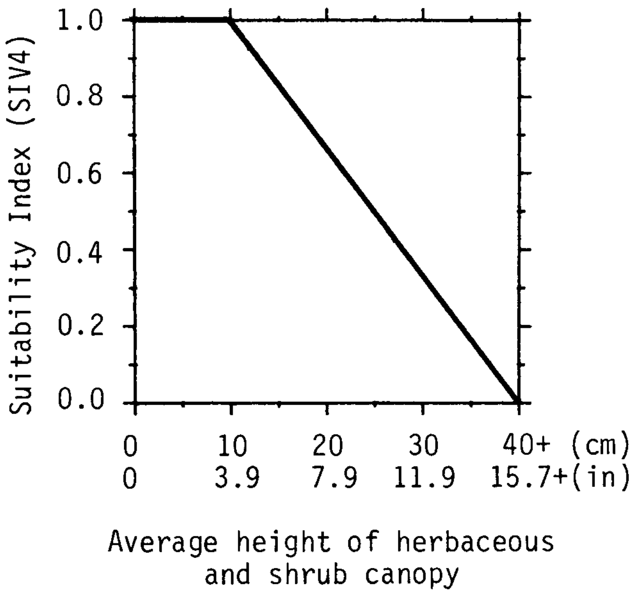

Figure 5. The relationships between vegetation cover and the suitability index values for least tern reproduction.

Least terns generally nest on unconsolidated substrate. Nesting success often is influenced by the type of substrate used. Figure 6 ranks the various mixtures of possible substrates of least tern nesting habitat. The bold lines within the triangle were delineated by a soil scientist (M. L. Peterson, U.S. Soil Conservation Service, Greeley, CO; unpubl.) and divide the triangle into three areas based on perculation characteristics. The upper right area of the triangle represents well-drained substrate, the lower left area represents poorly drained substrate, and the area between these two represents moderately well-drained substrate. Superimposed on the three areas are six shaded categories which were delineated by biologists (R. F. Soots, Department of the Army, Board of Engineers for Rivers and Harbors, Fort Belvoir, VA; pers. comm.; Thompson, pers. comm.) familiar with the requirements of least terns with respect to nesting substrate. These categories represent three classes of nesting substrate described as excellent, good, and poor. The triangle is used to evaluate substrate samples obtained from the potential nesting habitat. The triangle is read in the following manner: (1) locate the percentages of sand, fragmentary material, and silt/clay on their respective sides of the triangle; (2) follow the percentages inward on the triangle parallel with the labeled percentage lines; and (3) the shaded portion in which the three percentages intercept is the quality class into which the sample falls. Each quality class is assigned a corresponding suitability value (SIV5). The suitability values derived from the triangle are based on the following assumptions: (1) the presence of sandy areas is a proximate factor controlling nest site selection; (2) the presence of fragmentary material (e.g., pebbles,

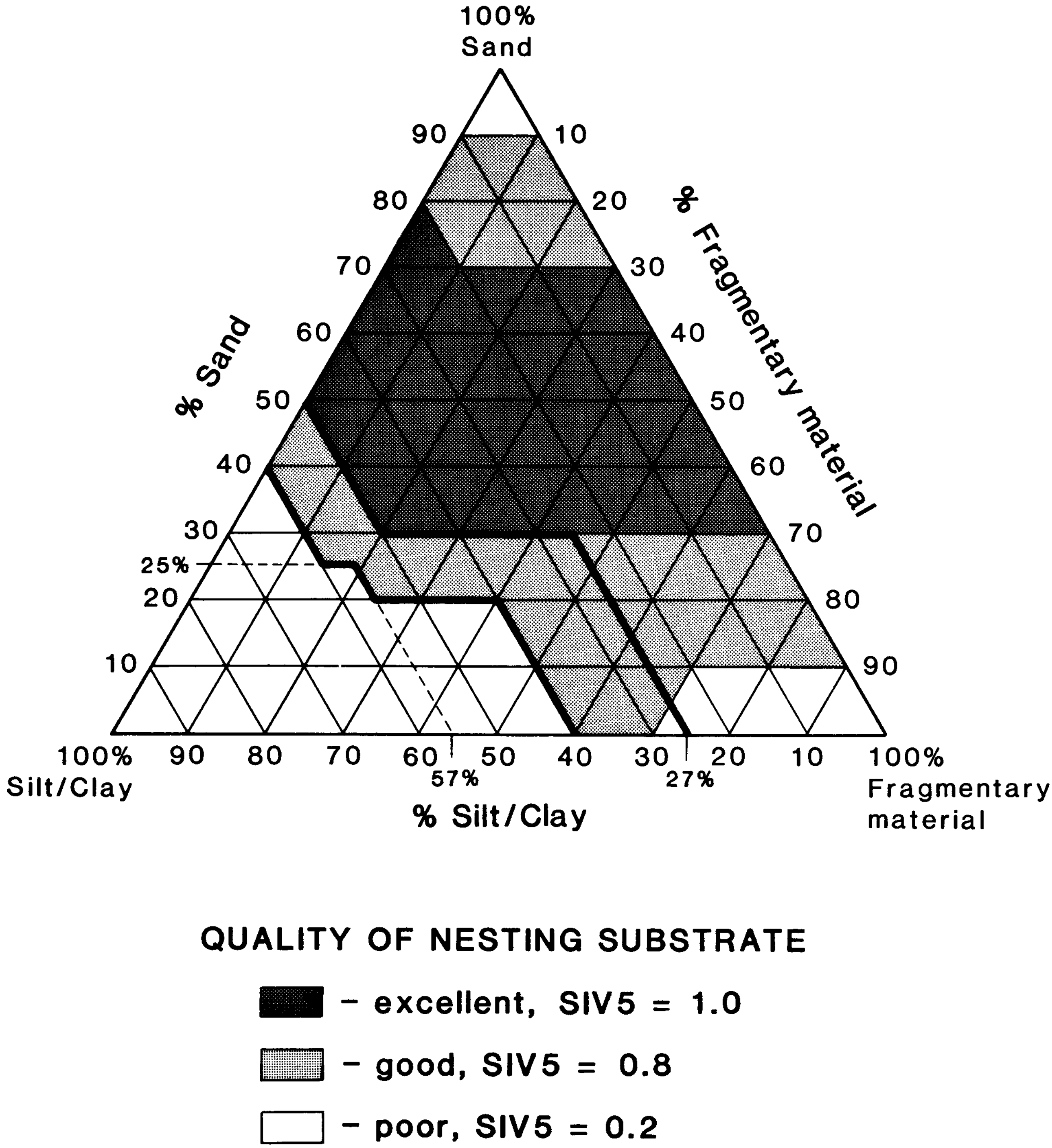

Figure 6. The relationship between substrate composition and the suitability index value for least tern reproduction.

gravel, shell, coral) enhances drainage of the nest site and stabilizes the substrate; (3) large amounts of silt and clay inhibit drainage; (4) least terns prefer not to nest on substrate composed almost entirely of fragmentary material; and (5) consolidated substrate has no suitability for nesting.

The suitability index value for reproduction (SIR) is assumed to equal the lower of the values obtained from an evaluation of vegetation cover (SIC) and substrate composition (SIV5).

HSI determination. Habitat suitability for the least tern is determined by the quality of foraging habitat (SIF) and the quality of nesting habitat (SIR). The HSI for the least tern is equal to the lower of these two values.

Application of the Model

Application procedure. This model was designed to address the major habitat variables that affect the occupancy of potential nesting sites by least terns throughout their range, as indicated by the literature. Due to the wide distribution of the least tern, different subspecies or different potential populations within a subspecies may not be affected by all habitat variables included in the model. Consequently, the user should apply only those variables and procedures that pertain to the geographic area under evaluation. The following methodology is recommended for determining when certain variables apply and how they should be implemented:

SIV1 and SIV2 — Apply to all areas. It is recommended that an average maximum flight distance of 3.2 km be used in marine habitats and 1.6 km in inland habitats.

SIV3 and SIV4 — Apply to all areas.

SIV5 — Applies to the following:

(1) Areas that are dominated by a silt/clay substrate and experience frequent and/or torrential precipitation during May and June. The assumption is that potential nest sites would be threatened by washout.

(2) Areas that are dominated by a sand substrate and experience frequent high winds during May and June. The assumption is that potential nest sites would be threatened by an unstable substrate.

(3) Areas that are dominated by a fragmentary material substrate. The assumption is that such areas would be unattractive to nesting least terns.

If the area of evaluation does not fall into either of the three categories listed above, SIV5 can be excluded as a variable in the model.

Predation and human disturbance, variables not included in this model, can significantly influence the suitability of potential nesting habitat. At this time, no recommendations can be made for measuring and quantifying these variables. If significant predation and human disturbance occur on a potential nesting site, this model may not provide an accurate measure of breeding habitat suitability. The literature shows that these categories of disturbance can be partially or totally controlled by various management techniques (see Reproduction and Special Considerations). This model can be used to identify areas that are more promising candidates for the implementation of management efforts. It should be realized, however, that the control of predation often is quite difficult and many times unsuccessful (B. W. Massey, contractor with U.S. Fish and Wildlife Service, Laguna Niguel, CA; letter dated 17 July 1984).

The periodic processes of inundation, erosion, and deposition associated with flood disturbances are generally necessary for the establishment and perpetuation of least tern nesting habitat. However, such occurrences during the nesting period eliminate potential breeding habitat and are a direct cause of mortality for existing breeding populations (i.e., nests). The threat of flooding as a direct result of precipitation can be mitigated by the composition of the substrate (SIV5). Protection from flooding by high tides or high stream flows, however, can be assumed only if the habitat is located at a higher elevation than the floodwater. It is assumed in this model that only habitat that is at a higher elevation than a prescribed floodwater elevation has potential as nesting habitat. Habitat that is at a lower elevation than the prescribed floodwater elevation is assumed to have a high probability of inundation during the nesting period and, therefore, has no suitability as nesting habitat. The following methodology is recommended for selecting that portion of the habitat that has a low probability of inundation during the nesting period.

In marine systems, potential least tern nesting habitat is subject to inundation by variations in sea level. Records of sea-level variations based on tide stations located throughout the nesting range of the least tern in the United States are maintained by the National Ocean Service (Hicks et al. 1983). It is recommended that the mean high water (MHW) tidal datum (Hicks 1984) be used to represent the floodwater elevation. The mean high water line (MHWL) is used to represent the interface of the land with the water surface at the elevation of MHW. Habitat that is located at a lower elevation than the MHWL is presumed to have a higher probability of inundation than habitat located at a higher elevation than the MHWL. Consequently, only habitat at a higher elevation than the MHWL should be considered and evaluated as potential nesting habitat. The designated MHWL should correspond to the highest single elevation recorded for the combined months of May and June, based on the tide station(s) in closest proximity to the area under evaluation (National Oceanic and Atmospheric Administration 1984). Information on the MHWL can be obtained by contacting:

Tidal Datum Section
NOAA/National Ocean Service
6001 Executive Boulevard
Rockville, MD 20852
(301) 443-8467

In riverine systems, potential least tern nesting habitat is subject to inundation by periodic increases in stream discharge. Each river presents a unique hydrologic problem due to site-specific geomorphology and lateral inflow conditions. Therefore, when attempting to determine the floodwater elevation, users of this model are strongly urged to consult with professionals who are familiar with streamflow conditions in the area under evaluation. Many river systems display irregular flood frequencies, making a concrete definition of a flood regime difficult, if not impossible. The objective is to determine and delineate that portion of the habitat that is least likely to be flooded during the months of May and June.

A determination of the potential nesting habitat's spatial relationship to the floodplain should first be made. A floodplain is defined as that portion of the river drainage that is inundated during a flood (Williams 1978b). A floodplain can be subdivided into an inactive floodplain (i.e., terrace) and an active floodplain (i.e., floodplain). An inactive floodplain is rarely inundated resulting in an insignificant amount of erosion and deposition. An active floodplain is that portion of the floodplain where significant amounts of erosion and deposition have occurred in the recent past (e.g., 10 years). Some river reaches do not have an active floodplain. If a potential site is determined to lie wholly within the inactive floodplain, it can be assumed that the probability of inundation is so low that 100% of the area has potential as nesting habitat. If all or part of the habitat lies within the active floodplain, however, the floodwater elevation should be determined. Since the intensity and time of flooding can be subject to wide variations within and among years, it is recommended that a mean river stage elevation for the combined months of May and June be used to represent the average elevation of flood waters during the nesting period. This elevation would then be designated as the floodwater elevation for May and June. Gaging stations (where maintained) record the river stage discharge data used for obtaining the floodwater elevation. This information can be obtained from several agencies which participate in the National Flood Insurance Program. These include the Federal Emergency Management Agency, U.S. Army Corps of Engineers, U.S. Geological Survey, U.S. Soil Conservation Service, U.S. Bureau of Reclamation, and State water resources agencies. Information also may be available at private consulting firms. In ungaged areas, the user must determine the feasibility of extrapolating river stage discharge data from a gaged site. If extrapolation is judged to be infeasible, the user is advised to attempt to estimate which fraction of the habitat has a high probability of flooding during May and June. The designated area should then be omitted when identifying cover types of potential nesting habitat.

In riverine systems that experience extensive flooding during May and June, least terns may occasionally nest on whatever nonflooded habitat that is available. However, nonflooded habitat during May and June is often covered by dense vegetation due to the lack of frequent flooding that controls vegetation encroachment. For management purposes, potential nesting habitat during May and June can be delineated using the procedure discussed above. Methods of nesting site improvement discussed under Reproduction and Special Considerations can then be implemented on the delineated habitat in order to increase the suitability of the potential nesting habitat during May and June when least terns are prepared to reproduce.

Least terns also can delay reproduction until suitable nesting habitat is exposed by receding floodwater. In areas where delayed reproduction is known to occur on a regular basis, or in areas where little or no potential nesting habitat is exposed during May and June, potential nesting habitat can be delineated using the procedure discussed previously. In these areas, however, a mean river stage elevation for the months of July and August should be used. This alternate method of evaluation is recommended for areas where least terns must delay reproduction into the summer months because it is believed that habitat should be assessed during the period of potential use. However, the user should be aware that, in some cases, potential foraging habitat can be less suitable for least terns during summer months when some aquatic habitat may dry up (Downing 1980).

It is recommended that the model be applied in the following manner:

1. Delineate the potential nesting habitat and evaluate its suitability (SIR) using SIV3, SIV4, and SIV5. For management purposes, special emphasis should be given to island habitat that is less subject to mammalian predation and human disturbance.

2. Using a map or aerial photograph, delineate the average maximum flight distance zone around the perimeter of the potential nesting habitat. On expansive areas of potential nesting habitat, radial distances equal to the average maximum flight distance should be delineated from random points within the habitat. Delineate cover types of all aquatic habitat within the average maximum flight distance that can be considered as foraging habitat (see <u>Cover types</u>). The map or photograph should accurately represent aquatic conditions as they occur during May and June or July and August. This is crucial for an accurate evaluation of a riverine system with an active floodplain.

3. Determine the total aquatic area (SIV1) and number of disparate aquatic systems or wetlands (SIV2) that constitute foraging habitat within the average maximum flight distance zone. Determine the suitability of foraging habitat (SIF) based on SIV1 and SIV2.

If an evaluation of a particular aquatic habitat is desired, potential nesting habitats within the average maximum flight distance of the aquatic habitat should be located. The above procedure should then be applied to the potential nesting habitats. Using this method, the aquatic habitat's relative contribution to the overall reproductive habitat can be determined.

<u>Summary of model variables</u>. The relationships between habitat variables, life requisites, cover types, and the HSI value are summarized in Figure 7. Figure 8 provides variable definitions and suggested measurement techniques (Hays et al. 1981).

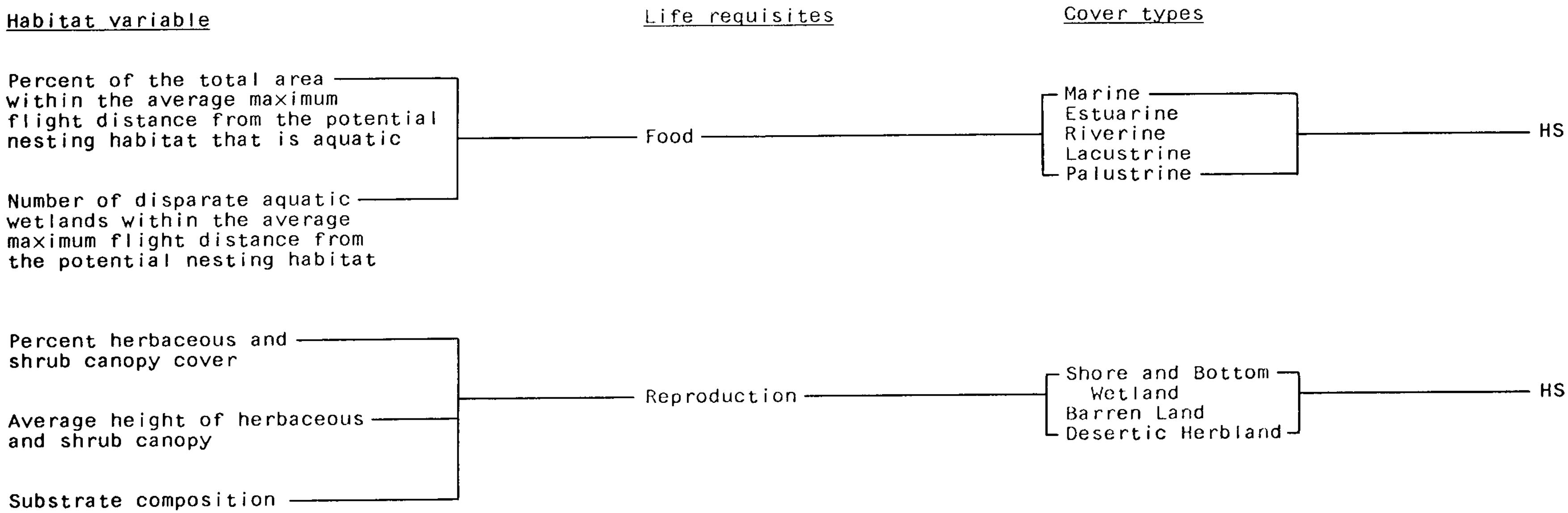

Figure 7. Relationships between habitat variables, life requisites, cover types, and the HSI for the least tern.

Variable (definition)	Cover types	Suggested techniques
Percent of the total area within the average maximum flight distance from the potential nesting habitat that is aquatic.	M,E,R,L,P	Remote sensing, mapping
Number of disparate aquatic wetlands within the average maximum flight distance from the potential nesting habitat.	M,E,R,L,P	Remote sensing, mapping
Percent herbaceous and shrub canopy cover [the percent of the ground surface that is shaded by a vertical projection of nonwoody vegetation and woody vegetation < 5 m (16.4 ft) tall].	SBW,DH,BL	Remote sensing, line intercept
Average height of herbaceous and shrub canopy [the average height from the ground surface to the dominant height stratum of the herbaceous or shrub (woody vegetation < 5 m tall) canopy].	SBW,DH,BL	Line intercept, graduated rod
Substrate composition (the relative proportions of sand, fragmentary material, and silt/clay in the substrate).	SBW,DH,BL	Sieve and hydrometer analysis (American Society for Testing and Materials 1967)

Figure 8. Definitions of variables and suggested measurement techniques.

Model assumptions. This model was developed with information obtained from the published literature and communications with professional biologists familiar with the species and its habitat requirements. It attempts to identify those physical parameters assumed most important in explaining habitat potential, and then attempts to combine those parameters into simple algorithms that yield an index value between 0.0 and 1.0. The major assumptions in this model are:

1. Overall reproductive habitat quality can be assessed by evaluating nesting and foraging habitat quality.

2. Reproductive habitat quality is equal to the lower of the life requisite values. The lower life requisite value is assumed to be the major limiting factor for reproductive potential.

3. The quantity and diversity of aquatic habitat are used as surrogate measures of food abundance. This is based on: (a) the assumption that the abundance and availability of small fish is directly related to these two variables; (b) the suggestion in the literature that least terns prefer abundant and diverse foraging habitat; and (c) the absence of quantitative data that would establish a relationship between fish biomass and least tern abundance.

SOURCES OF OTHER MODELS

Gochfeld (1983) developed a quantitative model of least tern nest site suitability in Long Island, New York. He examined site quality based on width of sites above the high tide line, slope, substrate, and vegetation cover, and site availability based on proximity to potential human disturbance and extent of off-road vehicle tracks. Quality and disturbance criteria were assigned scores of excellent, good, fair, or poor. The quality and disturbance scores were multiplied to obtain a composite habitat suitability score for each site. The composite score was used to classify sites as highly suitable, moderately suitable, or poor. It was found that 98% of colonies were on sites that had been graded excellent or good quality and that 48% of colonies were on sites more or less free from human disturbance. Least terns nested on 67% of the highly suitable sites and 17% of the poorly suited sites. Site tenacity was believed to be at least as important as physical habitat characteristics in determining occupancy.

Gochfeld's model was constructed based on data collected over a two year period in Long Island. His model can be considered to be specific to that area, and may provide more accurate results for habitat in Long Island than would the HSI model in this document. The HSI model was constructed from data collected throughout the breeding range of the least tern in the United States and is assumed to provide a general index of breeding habitat suitability throughout the range of the species.

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16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the least tern (Sterna antillarum). The model consolidates habitat use information into a framework appropriate for field application, and is scaled to produce an index between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). HSI models are designed to be used with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

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