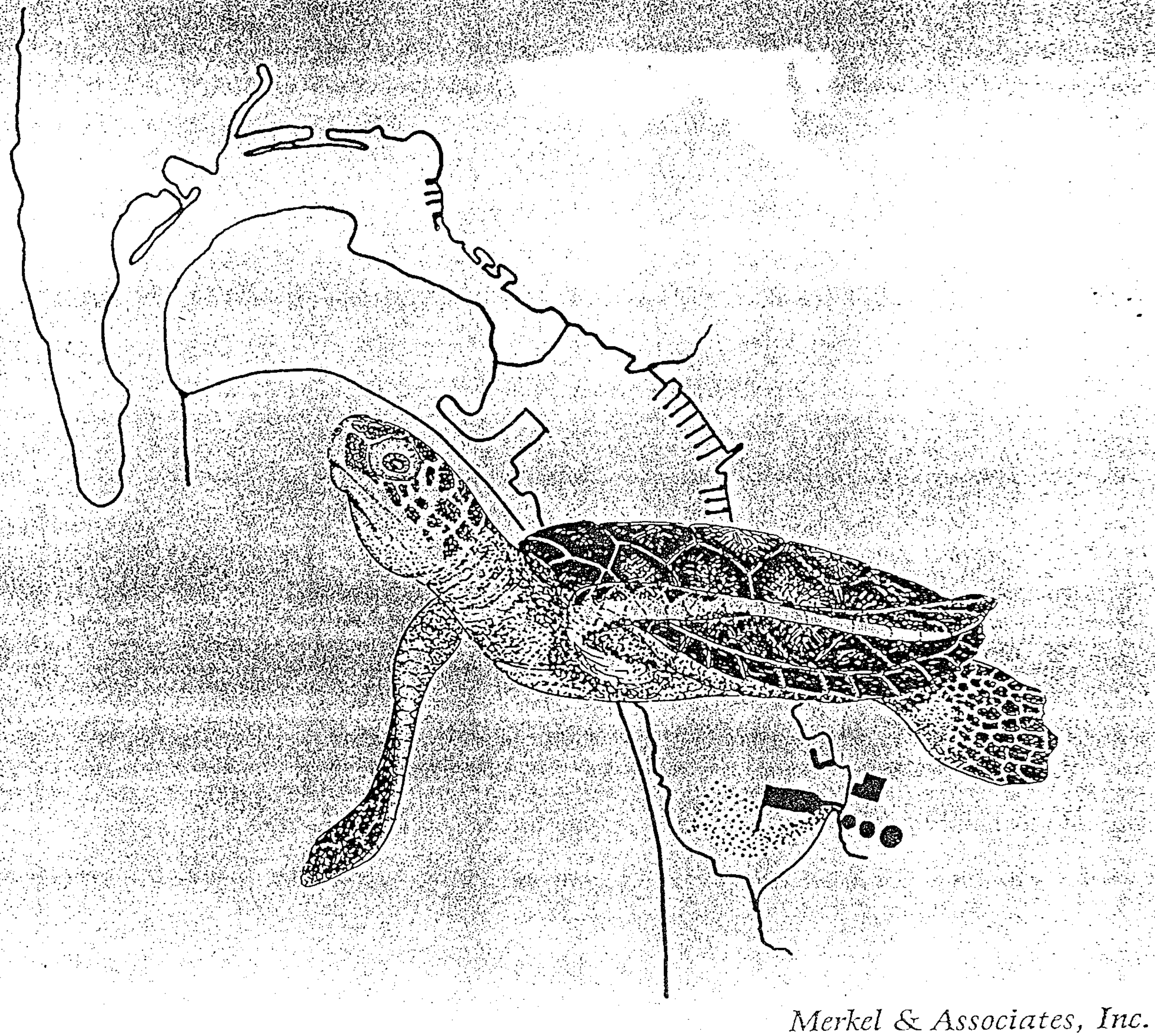
ATTACHMENT 28

A REVIEW OF THE GREEN TURTLES OF SOUTH SAN DIEGO BAY IN RELATION TO THE OPERATIONS OF THE SDG&E SOUTH BAY POWER PLANT



Merkel & Associates, Inc.

A REVIEW OF THE GREEN TURTLES OF SOUTH SAN DIEGO BAY IN RELATION TO THE OPERATIONS OF THE SDG&E SOUTH BAY POWER PLANT

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QUALIFICATIONS OF THE AUTHORS

Donna McDonald worked as a research assistant with Hubbs-Sea World Research from 1987-1994, where she developed a plan for captive propagation and life history studies of sea turtles, as well as compiled and annotated bibliographies of marine mammals, marine aquaculture, effects of noise on wild and domestic animals, and tidewater pollution near San Diego. Ms. McDonald has a Bachelor of Science degree in Wildlife and Fisheries Sciences from Texas A&M University. She is a consultant to the National Marine Fisheries Service (NMFS) Pacific Sea Turtle Recovery Team.

Peter Dutton has a Master of Science degree in Ecology from San Diego State University, and is currently pursuing a PhD in biology at Texas A&M University, working on the genetics of turtle populations. He is a member of the IUCN Marine Turtle Specialist Group, and the NMFS Pacific Sea Turtle Recovery Team.

Ms. McDonald and Mr. Dutton worked together on studies of the San Diego Bay turtles from 1988-1992, and plan to continue studies of this population in late 1995 or early 1996. They developed a sea turtle program at Hubbs-Sea World Research Institute, created a database on the captive sea turtles at Sea World of California, and initiated growth studies on those turtles. Currently, Mr. Dutton and Ms. McDonald are co-Directors of Operations/Principal Investigators of the Leatherback Sea Turtle Research and Conservation Project on St. Croix, U.S. Virgin Islands, where they work under contract to the Virgin Islands Division of Fish & Wildlife to study nesting ecology, physiological ecology, and population biology of the endangered leatherback turtle.

David Mayer and Keith Merkel are senior and principal biologists with Merkel & Associates, Inc. and have years of experience with the study of marine resources of San Diego Bay. Mr. Mayer and Mr. Merkel have conducted numerous investigations of the south San Diego Bay region including a year long avian flight pattern study and an analysis of potential biological effects of increased boating in the region. Both individuals have conducted work on eelgrass habitats found in the south bay including the restoration of this habitat on the Chula Vista Wildlife Island; the dike which divides the intake and discharge channels of the SDG&E South Bay Power Plant. Mr. Merkel and Mr. Mayer have experience with the operations of the power plant through past biological investigations associated with the maintenance dredging of the cooling water intake channel and current work on evaluating thermal discharge effects to a variety of biological resources.

Mr. Merkel is a member of the San Diego Bay Working Group and is well known for his expertise on seagrasses. He has served as a technical advisor to the National Academy of Sciences, Marine Board, on the Role of Engineering and Technology in the Restoration and Protection of Marine Habitats.

TABLE OF CONTENTS

LIST OF FIGURES

A REVIEW OF THE GREEN TURTLES OF SOUTH SAN DIEGO BAY IN RELATION TO THE OPERATIONS OF THE SDG&E SOUTH BAY POWER PLANT

INTRODUCTION

The San Diego Gas & Electric (SDG&E) electric power generating facility in Chula Vista, California (South Bay Power Plant) is presently up for re-authorization of its NPDES permit to discharge cooling water into south San Diego Bay. As part of the environmental review for re-authorization, resource agencies are examining the existing and historic power plant operations as they relate to the effluent and its potential effects on threatened and endangered species, as well as on sensitive bay habitats. To assist in this review, the following document provides information on the status, distribution, and relevant known ecology of sea turtles in south San Diego Bay relative to the South Bay Power Plant thermal discharge. This document was produced by Merkel & Associates, Inc. (M&A) in association with Ms. Donna McDonald and Mr. Peter Dutton, recognized experts on the green sea turtle with specific experience with the south bay population. It is not expected that this document will provide answers to all of the possible questions which may arise regarding plant operations; however, it is believed that this report which reviews relevant studies elsewhere, in combination with observations made on this population, will provide a sound basis for discussions and decisions regarding the current plant operations and the green turtle. This report specifically does not address operational changes which would deviate from historic cooling water temperatures or flows.

SDG&E OPERATIONS

A more thorough history and review of SDG&E south bay operations is found in Ford and Chambers (1973) and MBA (1990). The following account is derived from EA (1994), in which the preceding studies were summarized.

The South Bay Power Plant (SBPP) consists of four units which were brought on-line between 1960 and 1971. Cooling water for power plant operations is taken up from the bay through a channel lying north of an earthen dike (the Chula Vista Wildlife Island) and is discharged by way of a cooling channel which is set off from the bay on the south side of the dike, being discharged approximately 2,000 feet from the power plant (Figure 1). The existing dike separating the cooling water intake and warm water effluent was built in 1963 to reduce mixing rate between the intake and discharge water bodies. The expanded dike which forms the Chula Vista Wildlife Island was constructed out of fill material in 1978-79; however, configuration of the intake/discharge separations was not significantly modified.

EXISTING CONDITIONS

General

South San Diego Bay is an important ecological area for many reasons, but perhaps principally due to the thousands of acres of highly productive intertidal and shallow subtidal environments, including mudflats, salt marsh, salt ponds, and seagrass and algal beds. This portion of the bay is particularly important due to its occurrence within the Pacific flyway, providing resources to a high number of feeding, breeding, or resting migratory birds. It also offers vital habitat to numerous fish species and other aquatic life (MacDonald 1990). Numerous threatened and endangered species permanently or seasonally reside in the southern portion of San Diego Bay. Given the comparatively high levels of urban development which have occurred in central and northern portions of San Diego Bay, the southern region takes on an increasingly important role in southern California's coastal ecology.

Bathymetric Data

San Diego Bay is roughly distinguished by four ecological subregions: North, North-Central, South-Central, and South Bay (R. Hoffman and M. Purdue, as adopted by the San Diego Bay Working Group). The South Bay Ecological Subregion is defined by a roughly east/west line extending between the Sweetwater River channel on the east and Crown Cove on the west flanks of the bay. Along this axis there is approximately a 1-1.5 m decrease in depth between the south end of the South-Central Bay and the north end of South Bay. South of this line, South Bay is characterized by generally very shallow waters (0-2.5 m) with minimal bathymetric variability. The primary exception is the main bay channel, which after passing just south of the Sweetwater River, divides into three smaller channels which ultimately branch to service.a small number of access routes throughout the south bay. Approximately one quarter of the South Bay is occupied by intertidal mudflats.

Based upon preliminary hydrodynamic modelling, these main channels and the branches are believed to facilitate higher rates of water movement during tidal exchanges than the otherwise shallow, flat bay bottom which has extremely low tidal velocities (Don Sutton, NRAD, personal communication). Both the intake and the effluent channels of the SDG&E facility contribute to this channel network and are believed to play an important role in the movement of water in the south bay.

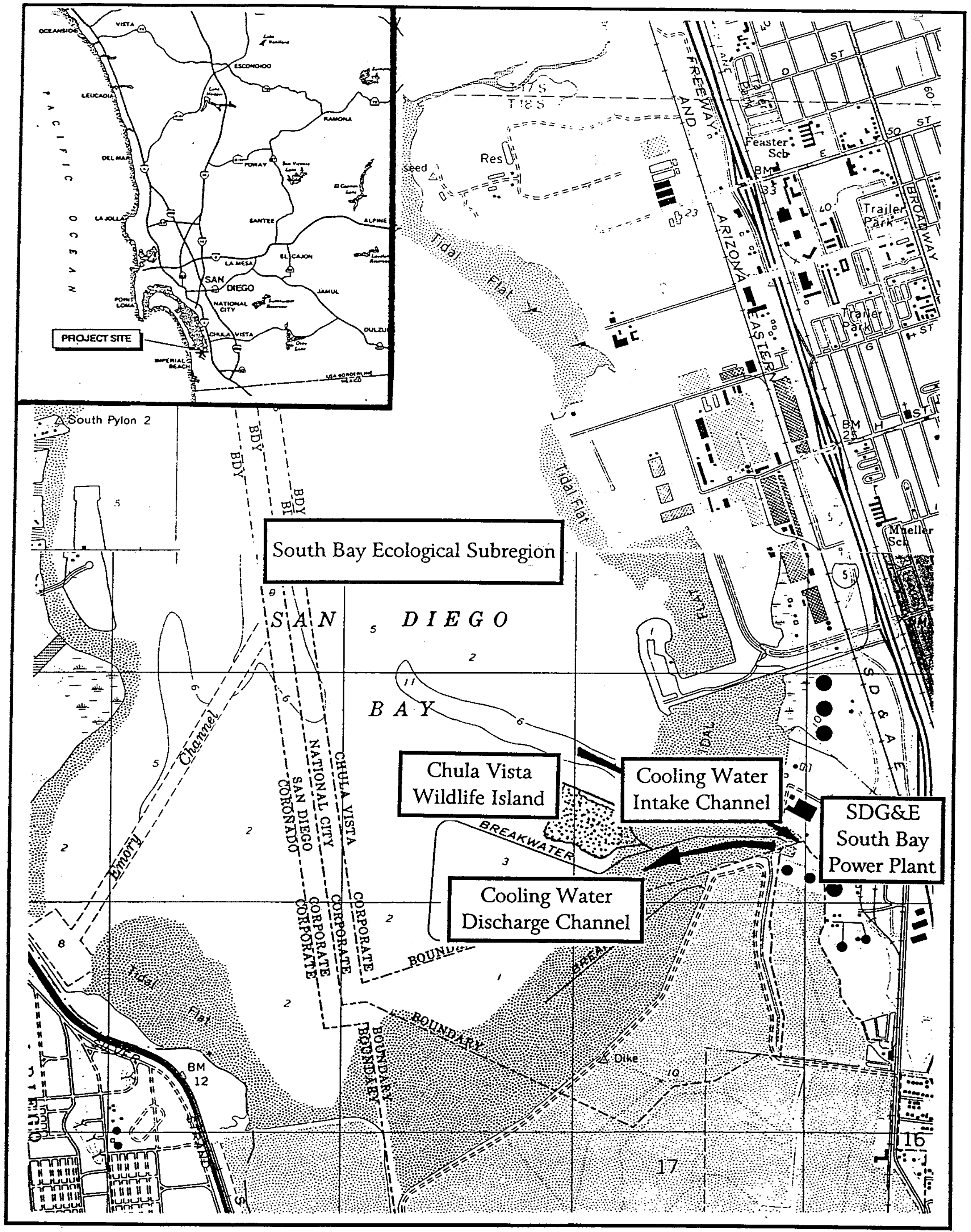


Figure 1. South San Diego Bay study region.

Base MapSource: USGS 7.5' Imperial Beach, Point Loma and National City, CA Quadrangles

Temperature Patterns

Ambient temperatures in the south bay (outside of the influence of the power plant's thermal plume) range from approximately 58°F. (14.4°C) in the winter to 78-79°F. (25.5-26.1°C) in the summer months (EA 1994). This contrasts with 54-58°F (12.2-14.4°C) in winter and 71-73°F (21.7-22.8°C) in summer near the mouth of the bay (EA 1994).

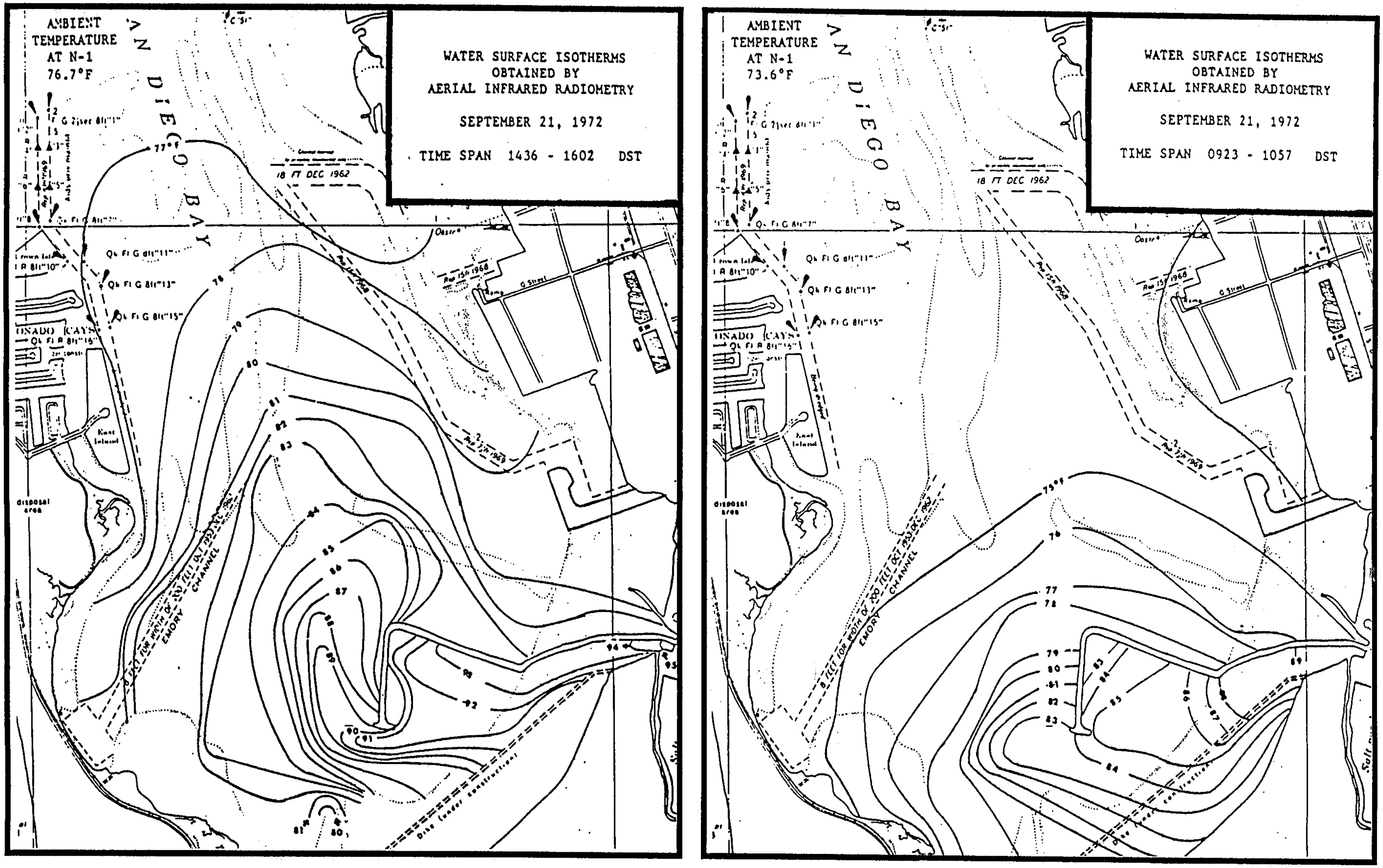
The temperature regime of the south bay can be substantially effected by the cooling water discharge of the South Bay Power Plant. Low current velocities and shallow water provides for the development of well-defined horizontal gradients originating from the South Bay Power Plant (Figures 2 and 3).

When three of the power plant units are in operation, the maximum measured extent of the thermal plume is approximately 4,500-6000 feet from the outer end of the cooling channel, with its extent being markedly influenced by season and the phase of the tidal cycle (Ford 1968; Marine Advisors 1968). The maximum influence of the thermal plume when all four units are operating is approximately 9,000 feet from the point of discharge, and again was notably less during flood tides than during ebb tides (EA 1994; Chambers and Chambers 1973). The 1968 and 1972-73 studies indicate that temperatures higher than 80-88°F (26.7-31.1°C) are generally restricted to the effluent channel. Temperatures usually declined by 3-13°F (1.7-7.2°C) between the beginning (*i.e.*, closest to the power plant) and ending points of the effluent channel (EA 1994). Temperature measurements made during biological investigations have concluded that there is usually no vertically stratified temperature associated with the thermal plume (EA 1994).

Seagrass and Macroalgae Beds

Seagrass communities provide a valuable food and shelter resource to a number of juvenile and adult vertebrate and invertebrate organisms. Eelgrass (*Zostera marina*), the predominant type of seagrass occurring in bays and estuaries along the Pacific Coast of North America, has suffered dramatic declines in the last several decades due to development along the waterfront, dredging and filling projects, and also possibly due to general declines in water quality.

With respect to the present discussion, eelgrass is known to be an important food item of sea turtles, and its presence in high concentrations and in otherwise favorable environmental conditions could be expected to attract turtle use and influence activity patterns within San Diego Bay. The distribution and relative abundance of eelgrass in San Diego Bay was most recently inventoried in 1994 (U.S. Navy, SWDIV, Nat. Res. 1994) (Figure 4). As indicated in Figure 4, although present in small quantities just south and southeast of the discharge channel, eelgrass habitat is far more substantial due west of the

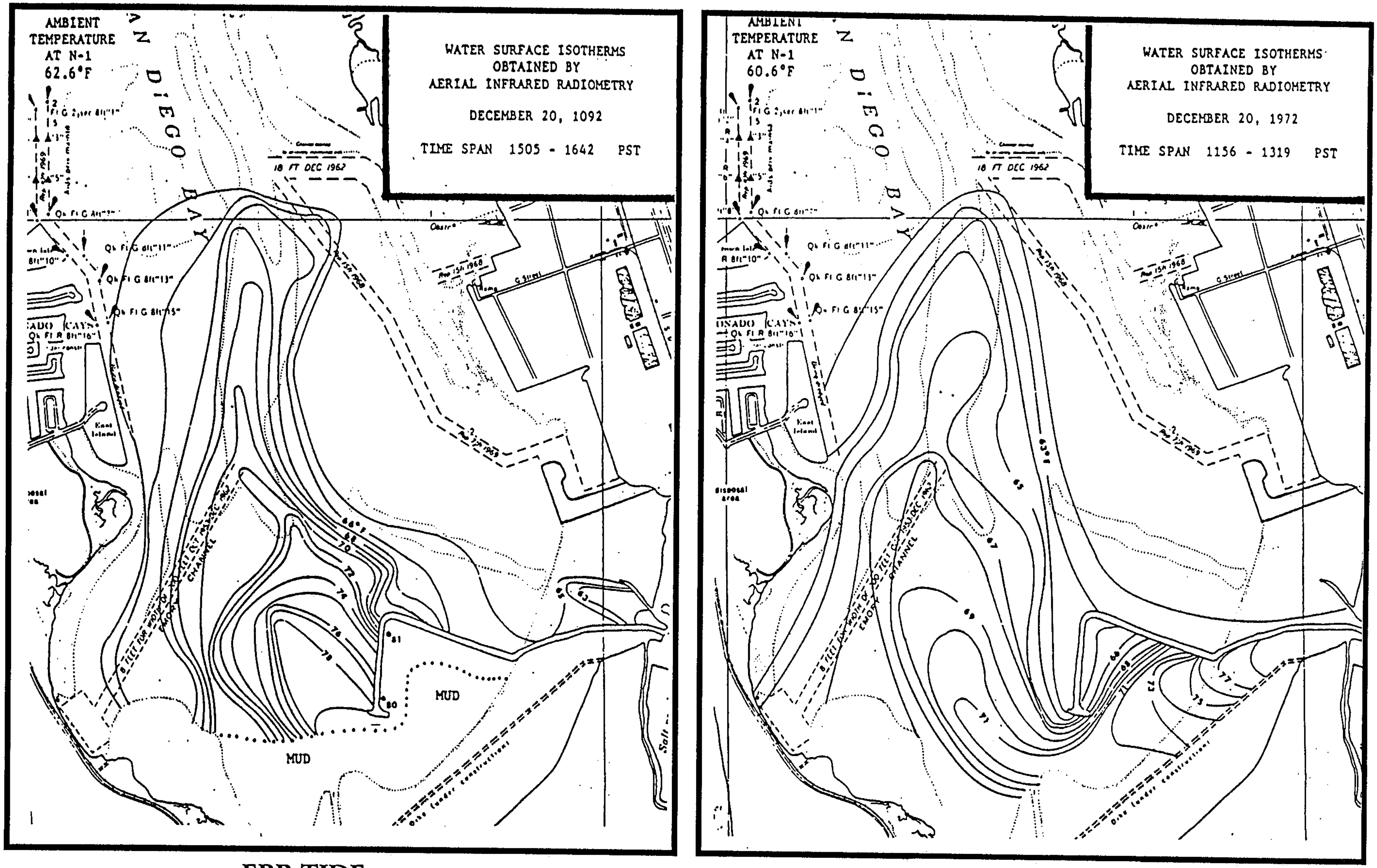


EBB TIDE

FLOOD TIDE

Figure 2. Typical summer season isothermic mapping for the South Bay Power Plant cooling water effluent thermal plume (survey date Sept. 21, 1972)

Source: Environmental Engineering Laboratory. 1973 Triaxial temperature surveys for the thermal plume generation.



EBB TIDE

FLOOD TIDE

Figure 3. Typical winter season isothermic mapping for the South Bay Power Plant cooling water effluent thermal plume (survey date Dec. 20, 1972)

Source: Environmental Engineering Laboratory. 1973 Triaxial temperature surveys for the thermal plume generation.

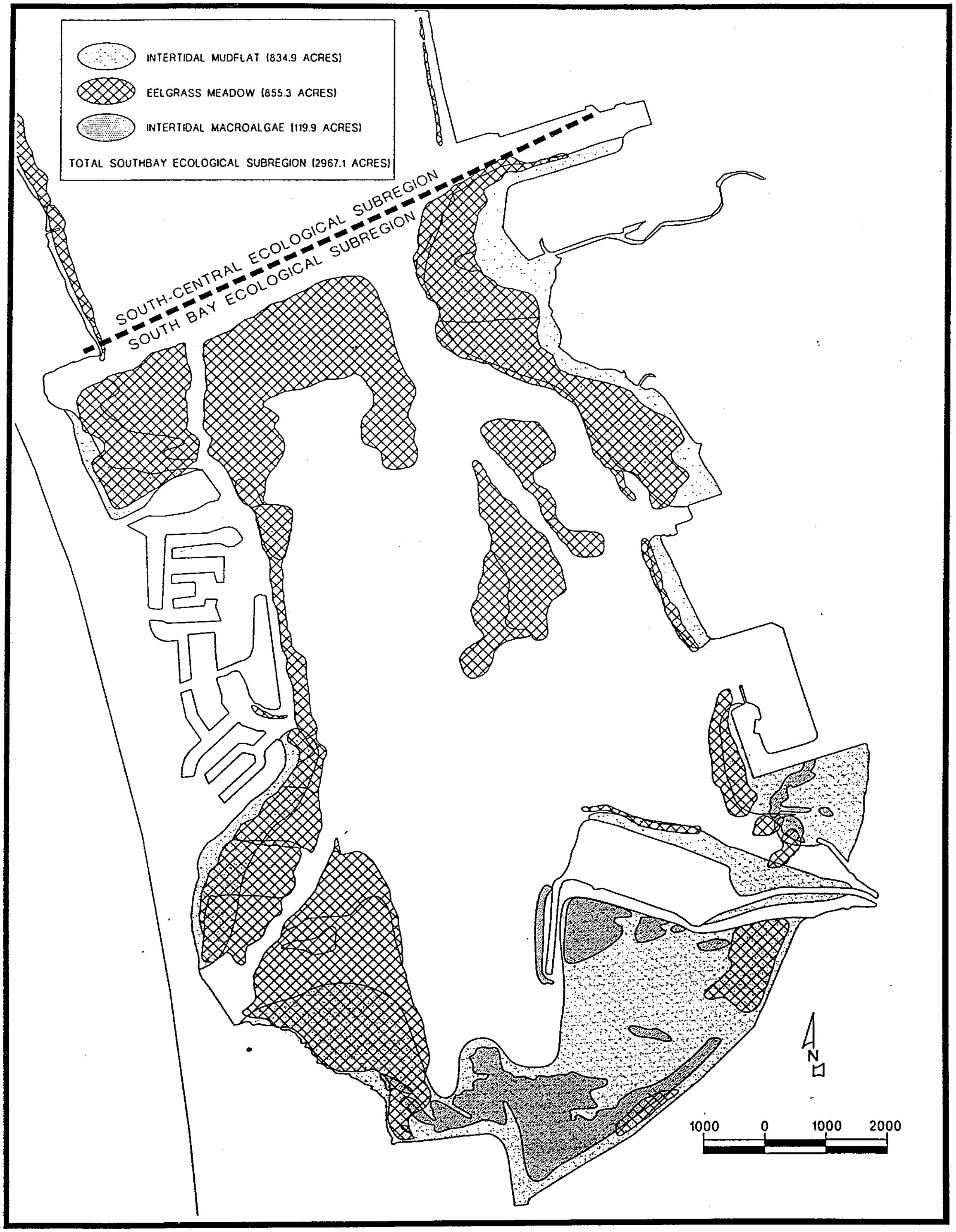


Figure 4. Reported distribution of eelgrass and intertidal macroalgae in the South Bay Ecological Subregion.

Source: USN SWDIV Natural Resources, 1994 (eelgrass); MacDonald et al. 1990 (macroalgae and mudflats)

SDG&E power plant in the shallow waters adjacent to Silver Strand. Over two thirds of all of the eelgrass in San Diego Bay occurs within the South Bay Ecological Subregion.

Another seagrass present in San Diego Bay is *Ruppia maritima*. This seagrass is much more common in southern portions of the bay, and is a regular component within eelgrass beds in this area. *Ruppia* is far more tolerant to warmer temperatures than eelgrass, and also is more tolerant to extreme (high and low) salinity conditions, as evidenced by its occurrence within the Salt Works ponds and brackish water drainages such as the Sweetwater River and Otay River estuaries (K. Merkel, personal observation). However, *Ruppia* is a far more delicate and finely branched plant than eelgrass, and even where it occurs in very dense assemblages it offers a much lower biomass than a low to moderate density eelgrass bed. Because of its fine structure and frequent distribution with eelgrass, *Ruppia* has not been inventoried in any quantitative manner and even qualitative distributional data for the species is anecdotal.

Macroalgae occurs in sparse assemblages as well as thick algal mats in numerous portions of the south bay. Locations of intertidal algal beds of the South Bay were plotted from color aerial photographs in 1988 (MacDonald 1990), and are also shown in Figure 4. The dominant species comprising the mats is reported to be the red alga *Gracilaria verrucosa*, with several species of green alga (*Ulva spp.*, *Chaetomorpha spp.*, *Cladophora* sp., *Enteromorpha* sp.) often forming a substantial part of the algal mat in some areas (MacDonald 1990). Other red alga species present include extensive amounts of *Polysiphonia* sp. and *Dasya sinicola* (SDUPD 1992; K. Merkel, personal observation). The branching ectoproct *Zoobotryon verticillatum* may also contribute substantially to the biomass of the algal mats (MacDonald 1990). Unfortunately, the available documentation does not account for what are sometimes vast concentrations of algae growing subtidally. Subtidal algal beds include a predominance of *Gracilaria* and *Polysiphonia* sp. Such algal beds would be expected to be particularly abundant in the warm, shallow waters overlying the soft sediments in the south bay, and have been observed to be fairly extensive in some portions of the south and central bay (K. Merkel, personal observation).

Difficulties in evaluating the distribution of marine macroflora as a potential food resource include the poor accessibility of much of the south bay to monitoring boats and equipment due to very shallow and turbid waters, as well as the lack of quantification of subtidal algal beds.

Human Activities

Human activity patterns in south San Diego Bay have been more thoroughly reviewed by others (MacDonald 1990; SDUPD 1991). South San Diego Bay generally supports much lower levels of human activity than the central and northern parts of the bay. Although use by power boats is low due to the shallow water, other aquatic activities such as sailboarding, canoeing, kayaking, and jet-skiing occur at a low-to-moderate level, with higher rates noted on weekends and in the summer months. Also, although there exists a 5 mph speed limit for boats using the southern portions of the bay, enforcement of this restriction is greatly lacking outside of the navigational channels, due in part to the shallow water which limits access by Harbor Patrol boats.

GREEN SEA TURTLES

General Description

The sea turtles occurring in San Diego Bay are green turtles (*Chelonia mydas*). Some taxonomists consider the populations of *Chelonia* nesting in Mexico and the southwest Pacific to be a separate species, referred to as the black turtle (also known as the eastern Pacific green turtle) (*Chelonia agassizi*), while others consider them to be a subspecies, or merely a subpopulation, of *C. mydas*. In past reports of the San Diego Bay turtles (McDonald and Dutton 1992; Dutton and McDonald 1990a,b), the turtles were referred to as black turtles in order to distinguish them from other Pacific *Chelonia* populations, notably those nesting in Hawaii. Recent genetic studies have shown that the San Diego Bay turtles are probably of Mexican origin and that "black" turtles are indeed a subpopulation of *C. mydas* (Dutton *et al.* 1994; Dutton *et al.* submitted). Therefore, in this report the San Diego Bay turtles are referred to as green turtles. The green turtle is considered endangered throughout most of its range, including the Mexican nesting beaches.

Distribution

Worldwide

The following information is a synopsis from Márquez M. (1990): The green turtle is globally distributed in tropical and subtropical waters, but is rare in temperate waters. It is, along with the hawksbill (*Eretmochelys imbricata*), the most tropical of the sea turtles. Its normal latitudinal range is within the northern and southern limits of the 20°C (68°F) isotherms, following the seasonal latitudinal changes of these limits. In summer, the limits are about 40°N and 35°S on the western sides of the oceans, and 30°N to 25°S on the eastern sides. During winter, they descend to 30°N and 25°S in the western sides, and to 20°N and 15°S in the eastern sides. Some turtles overwinter outside these limits, and there are records of solitary stragglers outside the normal range, all in non-reproductive stages. (Note: The northernmost record for a green turtle is one from the Gulf of Alaska, reported in the Homer News in 1993. This animal was found dead on the beach.)

Local Records

The SDG&E power plant in south San Diego Bay is the only place on the west coast of the United States where sea turtles are known to aggregate (Stinson 1984). Sea turtles have been sighted in the vicinity of SDG&E facility since the plant's construction in 1960 (SDG&E power plant employees, personal communication, Stinson 1984).

It is not known how the turtles find San Diego Bay, or when the first turtles arrived. Juveniles could enter (or, conversely, emigrate out of) the bay with incursions of warm equatorial currents known as "El Nino" events. The last major El Nino took place in 1983 (McGowan 1983); unfortunately, there are no records of the number of turtles in the bay during that time. During the last two years, smaller El Ninos may have brought more turtles into the bay.

Another theory is that in the late 1800's, turtles may have been incidentally caught in the nets of tuna fisherman in the waters off the Islas Revillajijedos, Mexico, and later released into San Diego Bay. Stinson (1984) compiled numerous newspaper accounts from the late 1800's of turtles being caught in the waters along the San Diego coast and sold to local restaurants. Stinson's historical records also include a turtle cannery on Coronado Island; green turtles were held in pens in San Diego Bay before slaughter, and some of these may have escaped into the bay. In any case, the presence of small juveniles indicates that turtles continue to enter the bay, since there is no known nesting in the San Diego area or anywhere north of Baja California.

Turtles are also seen in Mission Bay. There are several reports in the last five years of fishermen hooking sea turtles, and there has been at least one incidence of a jet-skier colliding with a turtle and killing it. These reports have all involved juvenile turtles.

Although there are no other known aggregations of sea turtles along the California coast, individual turtles are sometimes seen by surfers and fisherman. Turtles are also known to associate with power plants north of San Diego. Files of the National Marine Fisheries Service Stranding Coordinator (provided by Joe Cordaro) contain records of turtle entrainment in power plant intakes at the San Onofre Nuclear Generating Station in San Clemente, and the Redondo Beach Generating Station in Redondo Beach. There is also one record of turtle entrainment from the El Segundo Generating Station in El Segundo, California (Kevin Herbinson, Southern California Edison, personal communication). Turtles have also become trapped by entering the circulating water screen through the intake tunnel at the Scattergood Generating Station in Playa Del Rey. The majority of records are of green turtles, with a few loggerhead records. Most of the trapped turtles were released unharmed. NMFS has received no reports of sea turtle entrainment in the intake valves of the SDG&E Encina power plant in Carlsbad, but surfers have reported seeing turtles near the plant discharge. In contrast to the SDG&E Chula Vista facility, at Encina the effluent water is discharged directly into the ocean, where it rapidly disperses. There have been no reports of entrainment in SDG&E's Chula Vista facility.

Population Estimates

Worldwide

Groombridge (1982) estimates that there are approximately 150 green turtle nesting colonies worldwide, with only 10-15 of these involving as many as 2,000 or more nesting females per year. None of these colonies occur within the insular Pacific region, although Australia's Great Barrier Reef is one of these sites (Limpus 1978, 1982). Mrosovsky (1983) estimates the green turtle population worldwide at 400,000 or more, assuming a 1:1 sex ratio.

However, genetic analysis has revealed a distinct separation of nesting populations (Norman *et al.* 1994; Bowen *et al.* 1992), and research and conservation goals have been to manage each population as a separate unit. Since the San Diego Bay turtles most closely resemble the Mexican nesting population, their numbers should be considered in the context of numbers in that population. Alvarado and Figueroa (1993) report that the estimated "black" turtle nesting population in Michoacan has ranged from 7,000 females in 1987 to only 555 in 1992.

Elsewhere in the Pacific, nesting occurs throughout the Hawaiian archipelago, with over 90% occurs at French Frigate Shoals, Northwest Hawaiian Islands, where 200 to 500 females are estimated to nest annually (Balazs *et al* 1992). Low level nesting (less than 25 females per year) is known or is likely to occur at Laysan Island, Lisianski Island, and Pearl and Hermes Reef. Perhaps 1,000 to 2,000 nesting females occur throughout in the insular Pacific, not including Hawaii (Balazs, in preparation).

Cornelius (1976) estimated the population of nesting females at Playa Naranjo, Costa Rica to be between 125 and 175. In the Galapagos Islands an annual average of 1,400 nesting east Pacific green female turtles was registered between 1976-1982 (Hurtado 1984). Green reported that between 1975 and 1980, a total of 6,722 green turtles (including 611) males were tagged at the nesting beaches and feeding grounds of the Galapagos Islands.

In the Caribbean, the main nesting colonies are in Costa Rica, 800 to 4,908 females per season on the highest use area of the beach. Other estimates have been made for Surinam (1,464 to 2,160) and Venezuela (316 to 479, mean 365 per year) (Ogren 1989).

Several hundred females per year nest on the oceanic islands off the coast of Brazil (Marcovaldi, *In* Ogren 1989). About 283 to 420 females per year nest on Mexican beaches in the Gulf of Mexico and Caribbean (Marquez, *In* Ogren 1989). An estimated 110-263 females per year nested in Florida in 1985-1986 (Ehrhart and Witherington, *In* Ogren 1989).

San Diego Bay

Research conducted by P. Dutton and D. McDonald on the San Diego Bay turtles centered around the outflow channel, with surveys also being conducted from the Chula Vista Marina entrance to just south of the Coronado Bridge, and from the Marina to the bridge over the outflow channel on SDG&E premises.

From March 1990 until March 1993, Dutton and McDonald captured 18 turtles in the effluent channel. These included three mature males, five mature or subadult females, and 10 juveniles. Stinson (1984) estimated the green turtle population in San Diego Bay at 50 turtles. Dutton and McDonald capture data suggests that the current population in San Diego Bay is comparable, and may be slightly larger than that estimated by Stinson. By the third year of their capture effort, roughly one-fourth of the turtles captured during a session already had tags. This suggests that there may be as many as 72 turtles in this population.

The turtles in San Diego Bay appear to concentrate in the effluent channel of the SDG&E power plant and the surrounding waters of south bay, from the Chula Vista Marina to the effluent channel (Figure 5). They are also often sighted along the shore of Coronado Island, just across the bay from the effluent channel, and in other areas where stands of eelgrass exist. Telemetry evidence suggests that they move back and forth between the eelgrass beds and the effluent channel, spending little time in between (McDonald and Dutton, unpublished observations).

Breeding

Green turtles nest in tropical and subtropical waters worldwide, with major nesting grounds found in places with seawater temperatures mainly over 77°F (25°C) (Márquez M. 1990). Although the San Diego Bay population consists of adult females, adult males, and juveniles, there is no evidence of breeding behavior or nesting, with the exception of one unconfirmed report by SDG&E power plant employees of mating near the first outflow pipe. Ocean water temperatures just outside San Diego Bay range from about 54-58°F (12.2-14.4°C) in winter to about 71-73°F (21.6-22.8°C) in summer, just reaching the minimum temperature for breeding for the species. Even in the south bay, ambient water temperatures are generally too cool for nesting, being about 58°F (14.4°C) in winter to about 78.8°F (26°C) for a short time in late summer.

Growth

Background

Length in sea turtles is measured as straight carapace length (SCL) or curved carapace length (CCL). Growth rates vary worldwide with location, and are probably influenced by food type and availability, as well as water temperature. Limpus and Walter (1980) reported growth rates of 1.35 cm/year for immature wild green turtles with curved carapace lengths of 60-90 cm (0.75-0.95 cm/yr for 40-60 m CCL) in Heron Island Reef and Wistari Reef, Australia, and estimated age at sexual maturity for those turtles to be

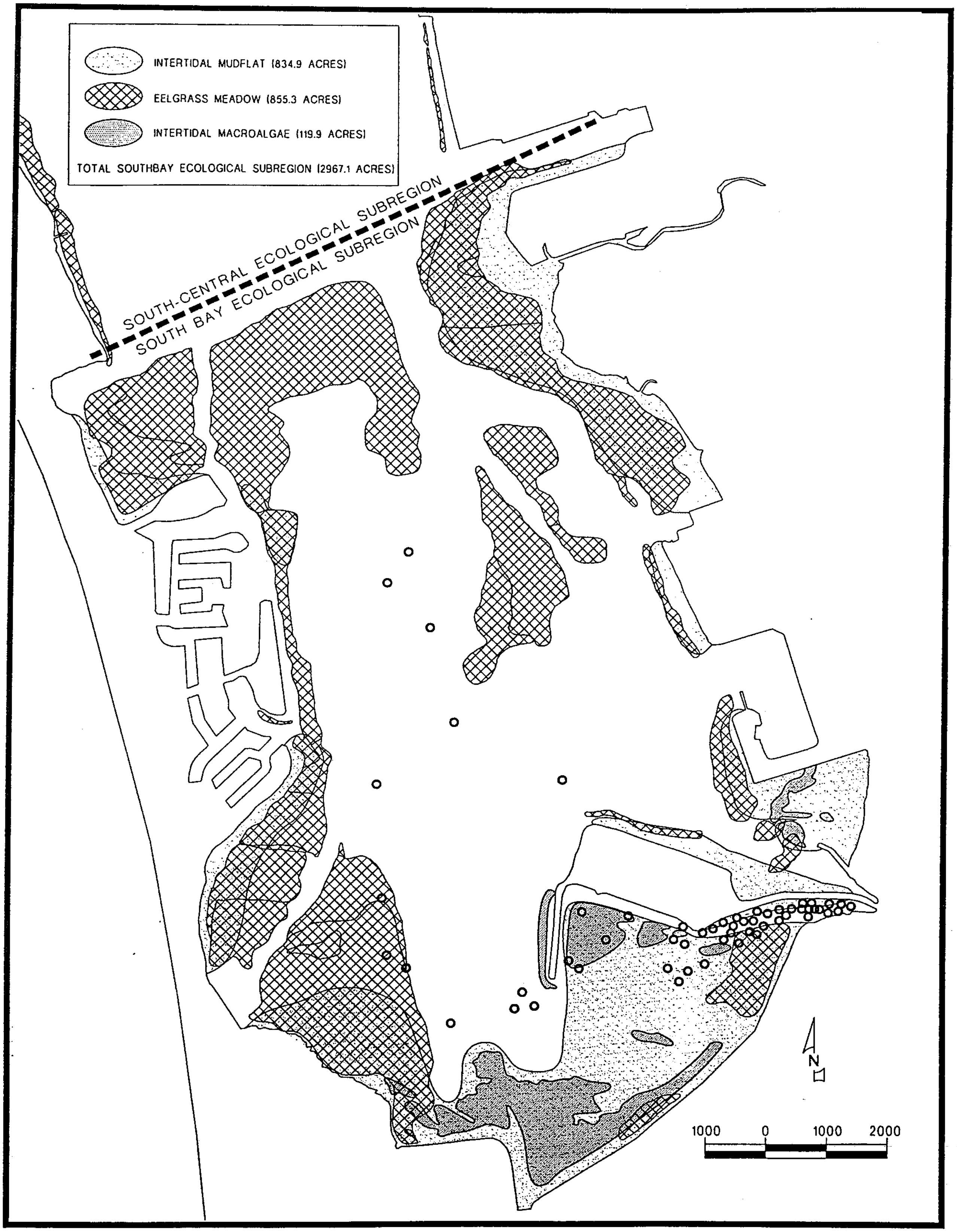


Figure 5. Distribution of green turtle observations in San Diego Bay during a one year study of turtles carrying ultrasonic transmitters.

Source: McDonald and Dutton 1992;
see Figure 4 for base map resource data sources

over 30 years. Galapagos Islands growth rates are even lower: Green (1994) found a mean growth rate of 0.40 cm/yr for juveniles 40-60 cm SCL. In Caribbean waters, growth rates are much higher. Collazo *et al.* (1992) report that juvenile green turtles (20-70 cm SCL) in Puerto Rico grew about 5.1 cm/yr. Boulon and Frazer (1990) report a growth rate of 4.8 cm/yr for juvenile green turtles (25.6-62.3 cm SCL) in the U.S. Virgin Islands.

In the Hawaiian Islands, between 19-28°N, growth rates ranged from about 1-5 cm/yr SCL for turtles measuring 37-59 cm (Balazs 1979, 1982). Turtles foraging at the lowest latitude (19°N) demonstrated the fastest growth rates. Balazs attributed this to forage quality, availability, and abundance, as well as to warmer water temperatures. This extremely fast growth rate was not seen in later years (Balazs, personal communication). Further studies indicated an overall annual rate of growth of about 2.5 cm/yr for all size classes ranging from 35-82 cm (Balazs *et al.* 1994).

Mrosovsky (1980) states that cold temperatures slow the growth of turtles, and cites Owens and Ralph (1978) who reported that loggerhead hatchlings at 31°C (87.8°F) grew significantly larger than groups at 26 or 28°C (78.8-82.4°F). He also cites Hughes (1974) who reported that young loggerheads lost weight when kept at 14 (57.2°F) and 15°C (59°F) for two weeks, and eventually died even after being returned to warm water. Those at 17 and 18°C (62.6-64.4°F) gained weight, but not as fast as those kept at 24°C (75.2°F).

San Diego Bay

In San Diego Bay, growth rates of two juvenile green turtles (SCL 54.4 and 46.7 cm) were 6.7 and 5.1 cm/yr, respectively, while an 86.7 cm female grew 3.9 cm in one year (McDonald and Dutton, unpublished data). These rates are comparable to the growth rates reported for warm Caribbean waters. They are considerably faster than those reported for Hawaii, even though San Diego is several degrees further north (32.4°N) than the Hawaiian archipelago's northernmost point.

Local Movement Patterns

General

Mendonca (1983) used sonic telemetry to track green turtles in Mosquito Lagoon, and found that turtles tracked in winter, when water temperatures averaged below 66.2°F (19°C), occupied significantly larger areas and were more mobile than in summer months. Mendonca theorized that they may be attempting to generate metabolic heat that would enable them to digest the food already in their gut. During low temperature tracks, turtles were rarely encountered in water shallower than 1.2 m deep (Mendonca 1983); most turtles only left the deeper water sloughs (>1.6 m) when temperatures rose above 64.4°F (18°C), and returned to deeper water when the temperature dropped again. Movement during cold-water periods was characterized by a zig-zag pattern with no particular bearing, and periods of non-movement only accounted for 20% of the turtles' total monitored daylight activity. The turtles were virtually motionless from dusk to dawn. None of the monitored turtles returned to the previous night's sleeping spot. When water temperatures were consistently about 86.0°F (30°C) and higher, turtles exhibited a very predictable diel movement pattern. Turtles were found in shallow, extensive grass flat areas during the morning. When water temperatures rose above 87.8°F (31°C), turtles moved to deeper sloughs. Turtles were not found in water less than 1.2 m deep at temperatures of 90°F (32°C) or higher. In late afternoon, when thunderstorms lowered water temperatures, turtles returned to the shallows (to feed) until dusk, when most turtles returned to a customary sleeping site, choosing the same location as the previous night. Depth of sleeping sites ranged from 1.2-2.1 m with a mean of 1.7 m. They stayed within home ranges during summer, with shallow grass flat areas being the center of activity. Periods of non-movement account for 40% of the turtle's day in summer.

Bjorndal (1980) found that turtles rested in specific areas in Union Creek, always in the deepest places in the creek (about 7 m). They spent much of each day at these places, especially during 1000 to 1400 hours.

San Diego Bay

Dutton and McDonald tagged seven turtles with ultrasonic transmitters in south San Diego Bay, and followed their movements for about one year. During tracking sessions, they usually found the transmittered turtles inside the effluent channel, although they were tracked throughout south San Diego Bay (Figure 5). Often individuals were found in the same spot and either remained there for at least three hours, surfacing to breathe every 15-60 minutes, or departed and returned later. One adult female was tracked to just over 3 km north of the discharge channel entrance. A second female (without a transmitter) was sighted with this animal. Dutton and McDonald often tracked the turtles across the bay from the discharge channel, near Coronado Island (approximately 2 km from the channel), where there is a thick bed of eelgrass. Although survey efforts were limited to south of Coronado Bridge, transmitter signal ranges were up to 3 km, and signals were never detected to the north of the study area (McDonald, personal observation).

Turtles were usually found in water deeper than 2 m, but they were tracked in water as shallow as 0.5 m. Most of the turtles were captured at low tide, presumably because they were restricted to the deepest part of the channel and could not avoid the nets.

It is not known whether the turtles in San Diego Bay have wandered into the bay and stayed, or whether they leave periodically (to nest, for example) and then return. Green turtles are known to travel back and forth between a nesting beach and a specific feeding ground (Limpus *et al.* 1992). At least some of the San Diego Bay turtles remain year-round as Dutton and McDonald continued to see turtles throughout the year, and did not observe emigration from the bay in April as has been suggested by Stinson (1984). Earlier conclusions that the population likely leaves the bay in the summer may be an artifact of the turtles' expansion out of the effluent channel and being more widely dispersed in the warmer areas of the south bay. The presence of a possible mating scar on one female suggests that they may leave to mate and nest. Stinson (1984) tagged six animals during the late 1970's, but none of the animals captured by Dutton and McDonald had tags or showed any signs of previous tags. However, one adult female, identifiable by a carapace deformity, is identical to one Stinson tagged. At least ten of the turtles in the present population are juveniles, so there is some continued recruitment into the population.

Food

General

Forbes (1994) reported that stomach samples of green turtles feeding in an algal-based coral reef community in Australia contained 38 species of Rhodophyta, 21 species of Chlorophyta, and 10 species of Phaeophyta. He stated that the algal turf assemblage, containing a heterogeneous mixture of mostly Phaeophyta and Rhodophyta algae, was heavily exploited by green turtles, at times to the exclusion of more readily available species growing in monospecific stands. However, the turtles sometimes suddenly shifted diet when certain other algal species became available.

Garnett *et al.* (1985) found that although most of the green turtles feeding in Torres Strait, Australia, had eaten only algae (mostly the Phaeophyta, but also some Chlorophyta and Rhodophyta), many had eaten both algae and seagrass (*Thalassia*). They calculated that the nutritional value of algae and seagrass was comparable. Since they found no evidence that any of the food was undigested, they considered it unlikely that the dietary preference of the turtles was affected by the digestive capability of the hindgut microflora, as has been suggested by Bjorndal (1980). Their results were contrary to the theory that there are nutritionally distinct populations of green turtles. They concluded that the green turtles in the Torres Strait eat, and are capable of digesting, a wide variety of soft algae and seagrass, and that actual intake by any particular turtle is determined primarily by the food available and by the structure of the local herbivore community. These conclusions are supported by Bjorndal's (1980) observation that in the Caribbean Sea, green turtles feed mostly on *Thalassia testudinum*, the dominant seagrass in this area, and that less than 10% of the total leaf production is utilized by herbivores, although the number of seagrass herbivores is high relative to other areas.

Mendonca (1983) also provides evidence that turtles will eat what is available. In one of the only studies of turtle foraging behavior in which vegetation profiles are given, she found that the dominant root macrophytes in Mosquito Lagoon were manatee grass (*Syringodium filiforme*) (76%) and shoal grass (*Halodule wrightii*) (9.9%). Also present were the red algae *Acanthophora* sp. (6.3%) and *Gracilaria* sp. (6.0%). The grasses were the primary food items in green turtle stomachs, with *Syringodium* found in twice the abundance of *Halodule*, and algae constituting about 8% of the stomach contents. However, seagrasses remained the primary food item even during the winter months when it declined or even experienced die-off.

In the Bahamas, green turtles grazing on seagrass *Thalassia testudinum* maintained "grazing plots" of new growth, which was higher in protein and lower in lignin, by consistently re-cropping within a specific area (Bjorndal 1980). They kept the blades cropped to about 2.5 cm. Green turtles are able to digest *Thalassia*, which is high in fiber, due to gut microflora that digests about 90% of the cellulose in their diet, and by re-cropping plots of young blades (Bjorndal 1980). In contrast to Garnett *et al.* (1985), Bjorndal (1980) reported that the few times during the study that turtles ingested algae (*Sargassum* sp. or *Batophora* sp.), the algae passed through their intestine apparently unaltered. Bjorndal (1980) cites Hungate (1966) who reported that gut microflora are dynamic systems, capable of changing and adjusting to different diets. However, she states that cellulose is the main structural carbohydrate in seagrasses, but is present in very small amounts in algae, which contain complex structural carbohydrates. Gut microflora which digest these food items would be very different. Changing from one to the other would decrease digestive efficiency.

San Diego Bay

Stinson (1984) suggested that the San Diego Bay turtles were feeding primarily on eelgrass growing near the SDG&E effluent channel. Observations by McDonald and Dutton (1992) support this conclusion; however, the diets of the San Diego turtles also include readily available macroalgae. Stomach contents obtained by lavage and a fecal sample consisted entirely of eelgrass in two cases, a mixture of eelgrass and green algae (*Ulva* sp.) in one case, of eelgrass and red algae (*Polysiphonia* sp., probably *Polysiphonia pacifica*) in another, and entirely of *Polysiphonia* sp. in two other turtles (McDonald and Dutton 1992). Since the turtles appear to frequent specific feeding areas, it seems likely that they may be maintaining grazing plots similar to those reported by Bjorndal (1980).

The seagrass *Ruppia maritima* could represent another potential food source, as it at times occurs in relative abundance in the south bay.

Within San Diego Bay, it appears that turtles are capable of exploiting a variety of available food resources. Since travel distances to foraging plots appear to be limited based on tracking, and growth rates are on the extreme high end of those reported for the species, it is unlikely that food availability is limiting to the turtles of the south bay population.

Temperature Range

General

Witherington and Ehrhart (1989) reported that morning temperatures below 46.4°F (8°C) caused hypothermic stunning of green, loggerhead, and Kemp's ridley (*Lepidochelys kempii*) sea turtles, with a greater proportion of green turtles (11%) dying. Smaller turtles were more susceptible to hypothermia, and in all cases the proportion of resident green turtles affected was about twice that of loggerheads. There were only two Kemp's ridleys affected. However, the lagoon systems in which these events occurred have a "trapping effect", and the turtles may not have been able to escape to warmer water when the cold fronts occurred. Cold-stunned turtles may appear within a day if water temperature drops below 46.4°F (8°C); many of those events described began with water temperatures of 39.2°F (4°C). Cloacal temperatures of 22 live cold-stunned green turtles were as low as 4°C (average of 6.1°C); these turtles were warmed and released. Mrosovsky (1980) mentioned Felger *et al.*'s (1976) account of torpid green turtles in the Gulf of California in waters below 59.0°F (15°C) as evidence of hibernation.

Mrosovsky (1980) found that the body temperature of green turtles emerging to nest was up to 3.6°F (2°C) higher than the sea temperature. He cited Standora *et al.* (1979), who found that deep body temperatures of vigorously swimming green turtles in water temperatures of 84.2°F (29°C) were as much as 14.4°F (8°C) above ambient, and theorized that keeping cool in warm water could be more of a problem for turtles than keeping warm in cool water.

Turtles tend to respond to high temperatures by becoming inactive. Heath and McGinnis (1980) found that *C.m. agassizi* from the Gulf of California became inactive at water temperatures of 77-82°F (25-28°C). They report that deep body temperature of both adults and juveniles is consistently 1-2.5°C above ambient, with a greater difference being found in 20°C than 30°C. This difference is maintained even during prolonged periods of inactivity. They found that turtles heat faster than they cool. They report observations by native fisherman in the Gulf of California of large flotillas of green turtles during June to October, when the surface water is 80.6-82.4°F (27-28°C). In contrast, Mendonca (1983) says Mosquito Lagoon *Chelonia* are active at 93.2°F (34°C). These differences in behavior by area could be genetic, or they could indicate acclimatization to different environments; Mendonca's animals were a resident population in a lagoon.

Also regarding temperature is that O'Hara's (1980) report that increasing temperatures from 78-84°F (25.6-28.9°C) to 86-91.4°F (30.0-33.0°C) significantly reduced the speed of swimming loggerhead hatchlings.

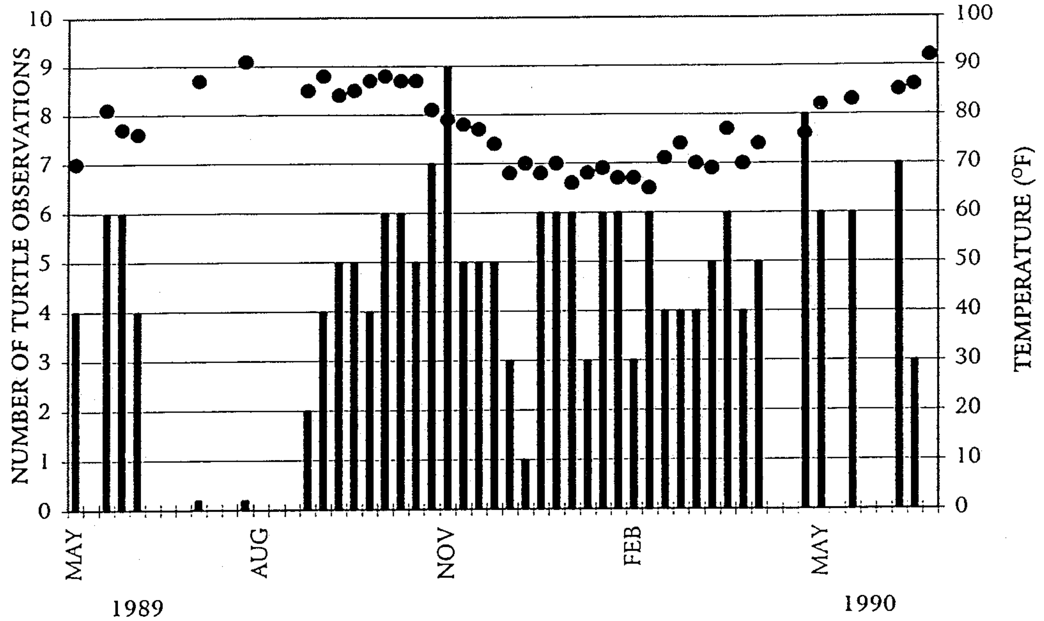
San Diego Bay

During 1989-1992, turtles were present in the effluent channel year-round except when temperatures exceed 90°F (32.2°C); they appeared to disperse further into the bay during the warmer summer months (McDonald and Dutton 1993). Observations of turtles within the effluent channel during 1989-1990 suggest a tightly defined temperature maximum between comfortable temperatures of 88°F (31.1°C) and the 90°F (32.2°C) threshold (Figure 6). Turtles compensated for the temperature extreme by moving further outward into cooler waters of the plume. During the ultrasonic tracking study (January 1991-January 1992), average daily water temperatures in San Diego Bay ranged from 54°F (12.2°C) in January 1991 to 82°F (27.7°C) in July 1990. Corresponding effluent temperatures at the discharge point were 62°F (16.7°C) and 93.2°F (34.0°C). Turtles have been observed actively swimming in the bay in temperatures of 58°F (14.4°C) (McDonald and Dutton 1992).

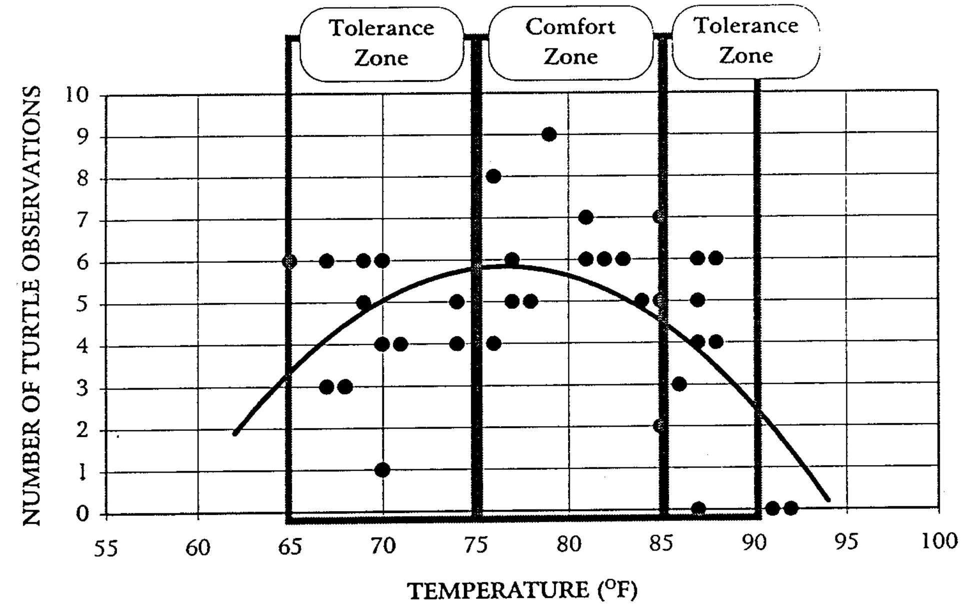
The lower temperatures of 52°F (12.2°C) are approaching the temperature at which turtles have become cold-stunned, and is below the temperature at which turtles have been known to go into torpor (Felger *et al.* 1976). When south bay water temperatures dropped to below 59°F (15°C) for three weeks (including readings at some stations as low as 55.4°F , or 13°C), trawling surveys were conducted in the intake channel to check for turtles in torpor on the channel floor; none were found (Eckert 1994), although there were numerous turtles sighted in the effluent channel during this time. The warm water effluent is apparently enabling these turtles to thrive in an area which can otherwise be too cool for the green turtle.

In general, there appears to be no clear relationship between the number of turtles sighted and effluent channel temperatures under 85°F (29.5°C). However, when the effluent temperature exceeded 90°F (32.2°C), turtles were not observed (Dutton and McDonald 1990a,b). It is likely that turtles move out of the effluent channel in summer both to exploit an expanded thermal comfort zone and to avoid extreme high temperatures; the channel temperature occasionally approached the lethal temperatures reported in the literature (33-40°C [91.4-104.0°F] Bustard 1970, Faulkner and Binger 1927; 37.5°C [99.5°F] Heath and McGinnis 1980). Summer bay temperatures (77.9-80.6°F, or 25.5-27°C) are comparable to those in the effluent channel in winter (usually 64.4-79.7°F, or 18-26.5°C), and well within those temperatures at which green turtles are reported to occur (Mrosovsky 1980; Mendonca 1983; Stinson 1984). This warming of the south bay relaxes the environmental constraints and allows for summer season independence from the thermal discharge.

Also of note regarding temperature is that neither Dutton or McDonald have observed San Diego Bay turtles basking at the surface, a possible means of regulating body temperature. This might suggest that turtles are able to regulate body temperature through other means such as selection of position along the thermal plume temperature gradient.



A. Seasonal relationship of temperature and turtle presence within the cooling water discharge channel. Bars reflect numbers of turtles observed, points are measured temperatures at locations of observations.



B. Relationship between number of turtles observed and temperature of discharge channel waters. Regression curve is a second order polynomial. Thermal zones of occurrence are based on observations of this and other populations of green turtles.

Figure 6. Temperature relationships to turtle observations within the cooling water discharge channel of the South Bay Power Plant.

Source: McDonald and Dutton, 1990

There is relatively little empirical data on use patterns of turtles in San Diego Bay outside of the discharge channel, but they seem to correlate with the bounds of the plant thermal plume and warm summer temperatures. Dutton and McDonald support Stinson's (1984) theory that turtles may be foraging in the eelgrass beds and macroalgae stands in south bay, then returning to the effluent channel where the warmer water would increase digestive efficiency.

Significance of San Diego Bay Population

In terms of importance to the long-term survival of the Pacific green turtle, the San Diego Bay turtles probably represent an insignificant number of animals, especially as so few are mature adults. However, if their numbers actually approach sixty to seventy, with one-third to one-half being mature, their potential contribution to Pacific populations could be substantial. At this time there is no available data to suggest what proportion of the San Diego Bay population is reproductive. If downward trends in Mexican populations continue, San Diego Bay and its turtles could represent an important refuge and "reserve stock" for this population. This reserve may be even more important as it constitutes the only substantial group of genetically similar turtles under direct U.S. protection.

In terms of scientific research, this is considered an extremely valuable group of turtles. The fact that there are juveniles as well as adult males and females, and they are in a relatively small and isolated area where survey coverage is manageable and capture is relatively easy, makes them ideal subjects for long-term studies. They can contribute valuable information on foraging habits, growth in wild populations, migration and movements, temperature preferences, respiratory physiology, seasonal distributions, and behavior. Sea turtles as a whole are difficult to study in the wild, and most of the existing information comes from nesting beaches. Males are a particular problem, as they never come ashore. Studies of growth rates will be especially valuable, as there is very little information on growth rates in the wild or age at sexual maturity.

SDG&E POWER PLANT EFFECTS

Overall, the thermal effluent is considered beneficial to turtles by allowing them to survive and thrive where they would not normally aggregate, and could not otherwise persist during some of the colder winter months. During the times when the effluent temperature rises over 90°F, the turtles leave the channel. Normal operations of the plant result in fluctuations of discharge temperatures and flows which correlate with electric power demand. These effects modify the characteristics of the thermal plume and influence turtle behavior. Warmer water effluent temperature during the summer months force turtles out of the relatively protected effluent channel into the main portion of the far south bay, while at the same time there is a relaxation of thermal constraints in the remainder of the bay.

The result is that the power plant discharge only controls the upper temperature extreme for turtles, while ambient bay temperatures reach tolerable and even favorable temperatures for turtles (Figure 7). Turtles regularly frequent waters between about 64.4°F and 84.2°F (18-29°C). As long as south bay ambient summer temperatures are within this range, the effect of effluent temperatures would be minimal as a controlling factor of turtle distribution. Conversely, during the winter season when ambient temperatures drop, the thermal plume is much more important to the distribution of turtles, creating a limited envelope of tolerable and comfortable temperatures (Figure 7). While turtles can exist in the extreme temperature ranges of those labeled "Unsuitable Zone" of Figure 7, they would likely only use such areas for short periods of time, ultimately returning to the tolerable and comfortable zones within the plume.

In the summer when a greater proportion of the bay is opened up to the turtles, they may be susceptible to impacts by boat traffic. There is evidence of turtles being killed by collisions with boats or boat propellers both in San Diego Bay and Mission Bay (McDonald and Dutton 1992). McDonald and Dutton noted that their Boston Whaler had no observable effect on turtle movements, swim speed or swim direction, whether the boat was moving or stationary, so it is unlikely that they avoid boats. In fact, they were often observed surfacing near the boat.

One potential detrimental effect of the power plant that should be mentioned is the possibility of turtles becoming disoriented by the warm waters of south bay and the effluent channel, causing them to remain in San Diego Bay rather than follow their usual migratory pathways to nesting beaches. To date, studies have not been able to determine if the adults migrate to nesting beaches and until further tracking studies are undertaken, there is no way of determining if this is happening. Based on the available information on known effects, the power plant is believed to be beneficial to green turtles.

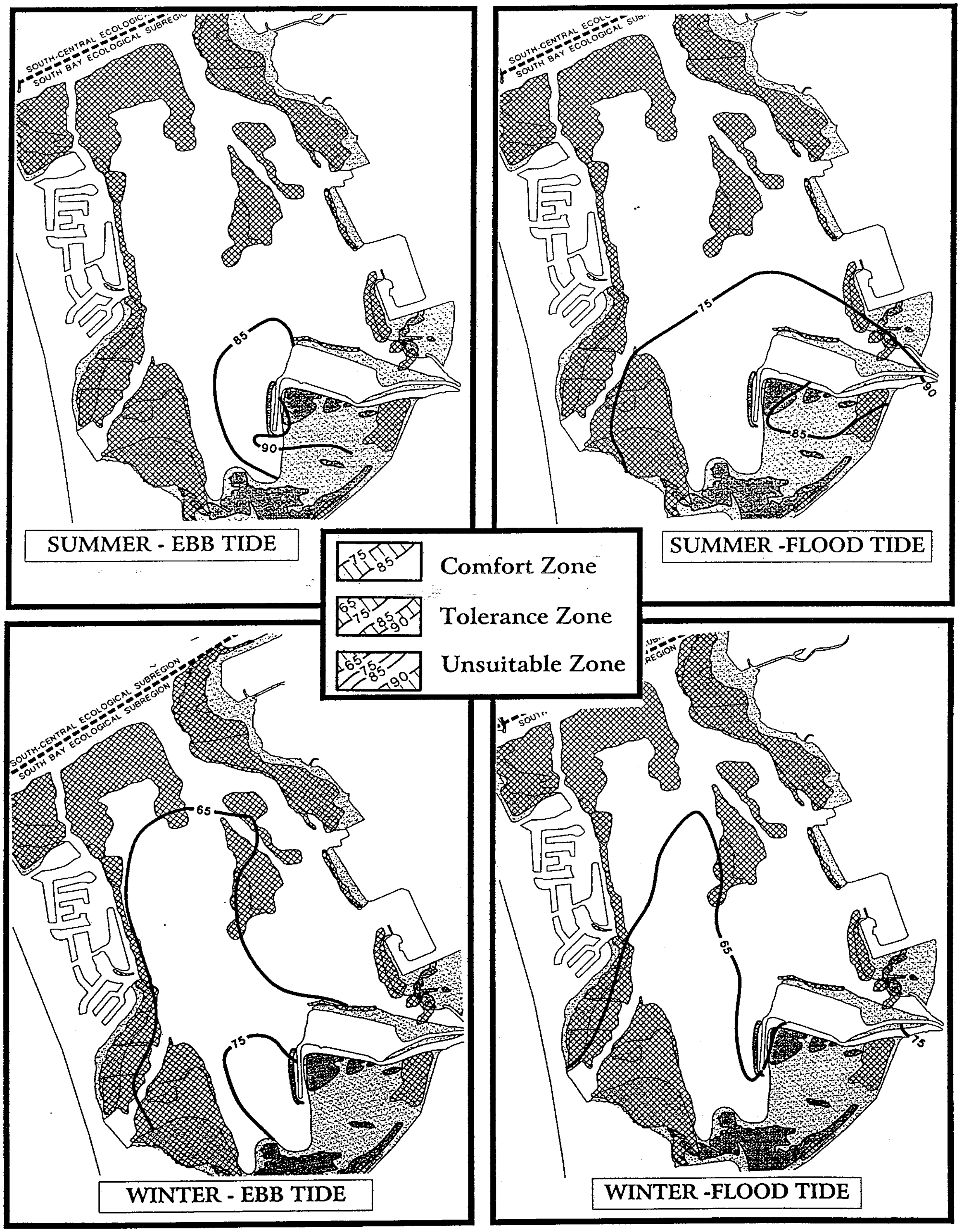


Figure 7. Thermal habitat suitability in relation to green turtles and thermal effluents of the South Bay Power Plant. Winter period discharges are critical to the presence of turtles. Summer discharges set the upper temperature bounds although ambient conditions control lower temperature range limits within the bay.

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