MEC 1983 SAND CRAB PROJECT
FINAL REPORT

VOLUME 1

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October 5, 1984

Mr. H. Kaspar
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531 Encinitas Blvd. Suite 105
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Dear Mr. Kaspar:

Marine Ecological Consultants (MEC) is pleased to submit the Final Report for the 1983 Sand Crab Project. The report presented here benefited from reviews of an earlier draft submitted in June 1984. MEC completed all agreed upon changes, which are fully integrated into this report, within the time frame authorized by the MRC.

The Report contains:

(1) Volume 1, which includes an Executive Summary, the report proper, Summary and Conclusions, and References; and

(2) Volume 2, comprised of eight Appendices giving detailed support to information presented in the report body, and one Appendix which provides an annotated history of sand crab studies that were conducted relative to SONGS.

The 1983 study demonstrated that sand crab populations in the San Onofre area differed from those in other areas of the southern California Bight primarily in terms of female reproduction, which appeared to be less. The occurrence of high percentages of females in the San Onofre area with clutches of spent egg cases rather than developing eggs, which had been reported in previous studies, was observed in 1983. A question still remaining after the present study is whether or not these clutches of spent egg cases resulted from normal hatching of eggs or disrupted egg maturation. Additional study is needed to conclusively answer this question.

Results of the 1983 study showed that much of the variability among beach sites in the measured attributes of sand crabs could be accounted for by correlations with the physical/chemical environment of the beach habitats. However, it must be emphasized that correlation does not demonstrate causal relationship and additional work will have to be done before causal relationships can be established.

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Finally, without metal and non-metallic pollutant data, we were unable to determine whether pollutants were related to the sand crab attributes that differed between beach sites near SONGS and other beach sites to the north and south. We did find that the sand crab attributes that previous investigators had suggested were potentially related to metals could be attributed to natural environmental factors.

Sincerely,

Arthur M. Barnett

Arthur M. Barnett
Principal Investigator

EXECUTIVE SUMMARY

The sand crab Emerita analoga, a prominent component of the open sand beach community adjacent to SONGS, was investigated relative to SONGS during 1976-1977 (Auyong, 1981) and during 1980-1982 (Wenner, 1980;1982). These studies suggested that sand crab populations near SONGS were different from those farther away. The Marine Review Committee (MRC) commissioned a study in 1983 to determine whether or not this difference was significant when the variability among populations from several different beaches in southern California was considered. If SONGS beach sites were found to be significantly different possible explanations were to be explored. This report presents the findings of the 1983 study, conducted for the MRC by Marine Ecological Consultants (MEC).

This study statistically compares sand crab populations at fifteen beaches in southern California, including six sites sampled in the earlier studies (Auyong, 1981; Wenner, 1980, 1982). Three surveys were made during the season (June, July, August) when sand crabs were most abundant and breeding on the beaches. Quantitative random or stratified-random sampling strategies, with replication, were used to control for within-beach variation. All beach sites were sampled within a four or five day period to control for short-term temporal variation.

Variables were measured to characterize both the physical-chemical environment and the potential food resource for sand crabs at each beach site. In addition, sand crab population attributes were examined that related to abundance, size distribution, female reproduction, and genetics. To provide continuity with the previous studies, attributes of size distribution and reproduction examined in past studies were re-examined when appropriate.

The abundances of male and female sand crabs appeared lower at beach sites within 12 km of SONGS in June relative to other sites, seemingly as a result of both a delay in recruitment of planktonic young and a delay in colonization by juveniles and adults from the subtidal zone. In July and August, the abundances of males and females at sites within 12 km of SONGS were within the variation found elsewhere.

Size attributes appeared to be related, at least in part, to differences in recruitment, presence of overwintered individuals in the population, and initiation of reproduction. Consequently, sizes of sand crabs at beach sites near SONGS typically fell within the variation found at other beach sites. However, fewer large overwintered individuals were generally found at sites within 15.5 km of SONGS.

The principal sand crab breeding season in 1983 spanned about two months (August - September), which is shorter than previously reported. This may have been related to the atypical El Nino conditions, which caused high cobble conditions on some beaches in early summer and reduced overall primary production.

Within 12 km of SONGS, the fraction of reproductive females (bearing either eggs or spent egg cases or both) generally was lower than at beach sites elsewhere. Also there was a decrease with proximity to SONGS in the fraction of the spent females (8-13 mm carapace length) preparing to brood again in August. This, together with the late start of the reproductive season at SONGS beaches, indicates that females within 12 km of SONGS produced fewer clutches of eggs than at sites elsewhere.

Reproductive females within 12 km of SONGS differed from those at most other sites in that they predominantly carried clutches comprised of spent egg cases in August and September. High percentages of spent

females also occurred at Hermosa Beach (100 km N) and Venice Beach (115 km N) in September. Reproductive females at other sites, and at Hermosa Beach in August, predominantly had clutches of developing eggs.

The occurrence of high percentages of females with spent egg cases near SONGS previously has been suggested to result from premature disruption of egg maturation (Wenner, 1982). It was further suggested by Siegel and Wenner (1984) that the disruption might be related to metals contamination from SONGS operation, agricultural runoff of pesticides, and/or increased turbidity due to Plant operation.

However, the implications of high fractions of spent females near SONGS in 1983 remain uncertain and controversial. Alternatives based on disrupted egg maturation, reproductive synchrony, or end of season persistence of spent egg cases were examined; supportive information was found for each alternative. Of particular importance was the finding that there was a higher incidence of spent egg cases in clutches of developing eggs from females near SONGS and Hermosa Beach. This indicates that a certain amount of egg disruption occurred at sites near SONGS and at least at one Los Angeles beach in 1983.

For those attributes that differed between SONGS and other sites, identification of related environmental variables was made by multiple regression analyses. Cluster analyses of beach sites were consulted to indicate whether the correlations with individual variables made ecological sense.

The apparent delay in recruitment and colonization of sand crabs to beach sites within 12 km of SONGS seemed to be related to the physical character of the habitats. Since sand crab larvae are planktonic, we cannot disregard the possibility that later recruitment in the San Onofre area may have been related to intake withdrawal or entrainment, even though SONGS operation occurred only intermittently in 1983.

The fraction of females in breeding condition (bearing either eggs or spent egg cases) was generally lower at beach sites where food availability was reduced, seston was higher, where the water was cooler, and where the sediment was coarser. More clutches of developing eggs had spent egg cases at beach sites with coarser sediments or extensive cobble coverage, or both. Furthermore, fewer batches of eggs were produced by females at sites where recruitment may have been later, where sediments were coarser, and where food was generally less available. These observations suggest that, in general, reduced reproductive potential is associated with later recruitment, less food, more seston, and coarse, unstable beach substrate. These habitat attributes characterize beach sites near San Onofre. Some of the habitat variations are natural, and some may be related to SONGS construction or operation. The relatively coarser sediment of beach sites within 15.5 km of SONGS is primarily natural, having been identified as such before SONGS Unit 1 was built (Shepard, 1950). However, there is some evidence that beach sediments in the immediate vicinity of SONGS have been altered by SONGS construction activities (ECO-M, 1984).

The association of increased breeding activity with sites having more chlorophyll-phaeopigments and less particulates in the water (seston) suggests that seston could be unacceptable as sand crab food and could inhibit feeding by clogging their setose antennae. The SONGS discharge water is expected to contain an increased seston component, comprising fine-grained inorganic particles and organics. However, although the Unit 1 discharge water can mix into the surf zone, the discharges from Units 2 and 3 are expected to be directed offshore by the diffuser system and therefore are unlikely to impact the beach.

The charge that metal pollutants from SONGS or other sources, or non-metallic pollutants from agricultural sources might disrupt egg maturation or reduce breeding was not addressed in this study, although the appropriate samples have been collected.

This report is organized into two volumes, the main text and supplementary appendices. Volume 1 contains 6 chapters: (1) Introduction, (2) Methods and Materials, (3) Results and Discussion, (4) Summary and Conclusions, (5) Tables and Figures, and (6) Literature Cited. Volume 2 contains nine appendices (A-I) of supplementary information. For those interested only in the objectives and conclusions of this report, we recommend reading the Introduction, Summary and Conclusions, and Appendix I, which presents an annotated history of sand crab studies that were related to SONGS.

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1.0 INTRODUCTION

Under a mandate from the California Coastal Commission the Marine Review Committee (MRC) has undertaken studies of the effects of the San Onofre Nuclear Generating Station (SONGS) on the surrounding marine environment and its inhabitants. The shoreline habitat adjacent to SONGS is open sand beach. The sand crab, Emerita analoga, is a prominent component of the sand beach community, and was investigated relative to SONGS during 1976-1977 (Auyong, 1981) and during 1980-1982 (Wenner, 1980; 1982). This report presents the findings of a 1983 study, conducted for the MRC by Marine Ecological Consultants.

Sand crabs, Emerita analoga (Stimpson, 1857), live on intertidal sand beaches along the west coasts of North and South America (Efford, 1970). On the beach they feed by passively straining small food particles from the wave wash with their plumose antennae (Efford, 1966). Because of the constant movement of water and sand they are not strictly sedentary and may move some distance in a given beach area during their juvenile-adult lifetime. It has been estimated that males may live for a little more than one year and females perhaps up to 3 to 5 years (Dudley, 1967).

The life cycle of sand crabs includes a planktonic larval stage. Although breeding can occur year-round, most reproductive females are found on the beaches during late spring and summer months (MacGinitie, 1938; Cox and Dudley, 1968). The eggs, fertilized externally by males, are carried by the brooding females for about a month (Cox and Dudley, 1968; Fusaro, 1980a). The young hatch in the surf zone as zoea larvae and drift in the coastal currents for an estimated 1.5 to 4 months (Johnson, 1940; Wharton, 1942; Barnes and Wenner, 1968). Females may produce from one to several broods during the summer, depending on their age and environmental conditions (Cox and Dudley, 1968; Fusaro, 1980a).

At the shore, the successful larvae metamorphose from the more advanced, megalopa larval stage into juvenile sand crabs (Johnson, 1940; Dudley, 1967). Depending on when they recruit, the juveniles may mature into sexually active adults during their first summer on the beach. Abundances on beaches are usually highest in spring and summer as a result of recruitment from the plankton. Not all the post-megalops sand crabs are necessarily up on the beach faces at a particular time, however. Subpopulations apparently take refuge in the subtidal sands at least some of the time, where they are inaccessible to beach sampling (sections 2.1.3.1 and 3.2.2.1 of this report).

Age structures, average individual growth rates, and egg production can differ between natural populations of sand crabs on nearby beaches (Cox and Dudley, 1968; Fusaro, 1980a). These variations are related to differences in time of recruitment (Efford, 1970) and to differences in environment (Fusaro, 1980a). Well-defined natural genetic differences between populations seem unlikely because recruits from the plankton probably originate from a mixture of parent beaches.

During their life cycle, sand crabs could be directly affected by SONGS in at least three ways. SONGS might change the availability of food--most of the plankton which pass through the seawater cooling system is killed and appear in the discharge water as detritus (EQA and MBC, 1973; Barnett et al., 1980). An increase in detritus of an inappropriate size (1 mm to 2 mm) could interfere with the filter feeding of sand crabs.

SONGS Unit 1 releases metals (primarily copper) as a result of corrosion of condenser tubing (USAEC, 1973), which might interfere with enzyme actions or other physiological functions. Toxicity studies have indicated that growth of crab larvae is adversely affected by

concentrations of free cupric ions in seawater slightly above ambient levels (Sanders et al., 1983). SONGS Units 2 and 3 condenser tubes are made of titanium rather than of a copper-nickel alloy, which should preclude copper and nickel discharges (USNRC, 1981).

SONGS might affect recruitment to beach populations by affecting pelagic larval stages. Most larvae drawn into the plant are killed (EQA and MBC, 1973; Barnett et al., 1980) and therefore unavailable as recruits to beach populations. Larvae entrained in the discharge plume also could be lost to local beach populations either through mortality or physical displacement.

SONGS may indirectly affect sand crabs by altering their beach habitat. There is some evidence that the median grain size of the beach sediment directly to the south of the plant has increased because of construction activities. Non-beach sediment excavated from the bluffs adjacent to the plant was deposited on the beach. Also, normal downcoast sand transport has been interrupted since 1974 by a temporary seawall (equipment laydown pad) directly seaward of the plant (ECO-M, 1984).

Although SONGS has a thermal discharge, it is not predicted that elevated temperatures will significantly affect beach populations of sand crabs. No correlation was found between temperature and sand crab population structure during a period of Unit 1 operation (Auyong, 1981). This was so despite the tendency for the Unit 1 discharge to direct the plume towards shore (Koh et al., 1974). Because of the projected dispersive effect of the diffuser systems and offshore movement of the discharge plume, temperature effects are not predicted from the operation of Units 2 and 3.

The reports from the previous studies have suggested that SONGS may affect the growth and reproduction of sand crabs. Because there are no appropriate pre-SONGS observations of sand crabs at San Onofre, the effects were evaluated by comparing sites at varying distances from SONGS. From a survey of five beach locations within 6.5 km of SONGS, Auyong (1981) reported that sand crabs living within 1.5 km north of the plant grew less rapidly and matured at a smaller size during the 1977 breeding season (primarily July and August). No correlation emerged between observed differences in habitat variables (temperature and organic solids in the wave wash zone) and these differences in sand crab population structure.

Wenner (1980, 1982) compared those 1977 data with observations from other years. From this he inferred that growth and reproduction were curtailed in the vicinity of San Onofre by SONGS operation in 1977. Wenner's assessment of sand crab population structures in 1980, 1981 and 1982, when SONGS was semi-operational, seemed to indicate less of an effect on growth. But he found unexpectedly low incidences of females carrying eggs at sites within 6.5 km of the plant in July 1981 and at distances to about 15 km north and 20 km south of SONGS in July 1982. Instead of carrying eggs, adult females were carrying masses of empty egg shells.

Wenner considered the high proportion of females with spent egg cases to have been a consequence of disrupted egg maturation rather than post-partum observations of synchronized release of larvae. This interpretation was based in part on a laboratory experiment. Living specimens of mature females ($\geq$ 12 mm carapace length), most of which had spent egg cases, and males were taken to the laboratory and held in flowing-water tanks. After 3 weeks 37% of the females had extruded new