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TECHNICAL REPORT TO THE CALIFORNIA COASTAL COMMISSION

E. Metals and Radiation

MARINE REVIEW COMMITTEE, INC.

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TABLE OF CONTENTS

APPENDICES

SUMMARY

Operation of the condenser cooling systems at SONGS involves pumping large quantities of seawater through the generating station and returning the water to the local marine environment. Both radioactive and nonradioactive effluents are discharged into the cooling waters passing through the generating station, and metal containing structures within the generating station are exposed to erosion and corrosion via contact with sea water. Although the MRC did not sponsor its own long-term field research program to study the potential impacts of radionuclide and metal emissions, several studies of metal and radionuclide concentrations in the environment were done for the MRC, and other relevant information has been collected by Southern California Edison (as part of their required monitoring programs), as well as by other researchers. Because this report is a review of the available evidence coming from a number of disparate sources, its format differs from other MRC Technical Reports, most of which have emphasized the analysis of data collected by the MRC to answer the specific question at hand.

Our review of the available information indicates that the amounts of metals or radioactive materials released from SONGS are unlikely to cause substantial ecological impacts on the marine community. This conclusion is based upon information from MRC-sponsored studies of activity levels and metal concentrations in the tissues of sand crabs and mussels; measures of metal concentrations in mussels from the State Mussel Watch Program; reports to the Regional Water Quality Control Board on SONGS' discharges of metals; and various reports detailing activity levels in SONGS' effluents and selected marine organisms from the vicinity of SONGS.

The State Mussel Watch Program (SMW) has used mussels to monitor the quality of California coastal waters for over a decade. They established a station near the San Onofre discharges in 1985-1986. Metal concentrations reported from the San Onofre station by the SMW were quite similar to concentrations at several relatively "clean" Channel Island stations and to values at coastal reference stations. They were also lower than the concentrations in the source material collected at Bodega Head. Because the metal concentrations seen in the mussels transplanted near San Onofre were not high in comparison with other stations, SMW discontinued the San Onofre station after the 1985-1986 transplant. The MRC also transplanted mussels near San Onofre, twice during 1976-1977 and once in 1986. In general, the metal concentrations seen in these transplants were not especially high, and were lower than concentrations above which SMW flags a site for special attention. Our ability to compare the MRC results with SMW results is hampered to some degree, however, because most SMW transplants used the California mussel while the MRC used the bay mussel.

In the two MRC mussel studies, mussels were arrayed at varying distances from SONGS. Only in the 1986 study were stations located upcoast as well as downcoast of SONGS. The results of both studies indicated that metal (especially manganese) concentrations declined with increasing distance downcoast from SONGS. However, in 1986 metal concentrations continued to increase upcoast of SONGS, peaking in concentration about 4.5 km upcoast of SONGS, near the mouth of San Mateo Creek. The most striking result from the two transplants during 1976-1977 was that metal concentrations were much higher during the winter transplant than during the spring transplant. Possible explanations for the differences include (a) reductions in metal concentrations in response to the increase in gonad mass in

the spring, (b) higher metal concentrations in response to higher sediment load during the winter, or (c) increase in metal concentration in response to the lower operating status (and thus more intermittent pumping) of SONGS Unit 1 during the spring period. Although all three of these factors may partially explain our results, we believe that only the first one can explain why the concentrations of all assayed metals were higher in the winter period. During all three transplants the growth rates of the mussels were lower at the sites nearest SONGS. This effect appears to be independent of metal concentrations in the mussels, and is probably caused by suspended sediments in SONGS' discharges interfering with the feeding of the mussels.

Data on metal concentrations in sand crabs come from a survey in 1982 by Dr. Adrian Wenner of the University of California, Santa Barbara, a former MRC contractor, and surveys by the MRC in 1983 and 1986. The one consistent result from these studies is that manganese concentrations tended to be higher in the general vicinity about SONGS in comparison with more distant beaches. This area of higher manganese concentrations may have extended as far as 30 km upcoast and downcoast from SONGS. Within this region there appear to be several local maxima, and the concentrations nearest SONGS were not the highest in the region. This result is in agreement with the mussel studies, where there was evidence for a local maxima in manganese concentration near the mouth of San Mateo Creek. In 1982 relatively high concentrations of nickel and zinc were seen at the beach 0.4 km north of SONGS, and the concentration of iron was relatively high at the beaches 0.4 and 1.5 km north of SONGS. In later surveys there was no indication of higher concentrations of either nickel or zinc near SONGS. Chromium and iron tissue concentrations were high at the beach 0.4 km north of SONGS in one of two

category of crabs during one of the two surveys during 1983. However, similarly high concentrations were seen in the other category of crabs at a beach 12 km north of SONGS at the same time. On average chromium concentrations tended to be higher in the general area about SONGS during 1986. This higher average is due to the lack of beaches near SONGS at which relatively low concentrations were detected, rather than from exceptionally high concentrations at some of the beaches near the generating station.

Concentrations of metals in the seawater and sediments near SONGS have been sampled by the Southern California Coastal Water Research Project and by Southern California Edison. The MRC sampled metal concentrations in sand. The results of these sampling programs suggest that metal concentrations in the vicinity of SONGS are relatively low in comparison with other sites in Southern California, and do not suggest that there has been a substantial increase in metal concentrations specific to sites near SONGS after Units 2 and 3 came on line. The evidence suggesting that there has been no increase in metal concentrations is stronger for sediment samples than for water column samples since the sediment concentrations were usually above detection limits and because we expect that sediment concentrations are, in some sense, an integrated measure of the sediment's exposure to metals over some time period in the past. Although we are less certain about whether SONGS has increased metal concentrations in the receiving waters, the concentrations observed at all times during the period after Units 2 and 3 began operating (1985 - 1987) were well below current conservative estimates of chronic toxicity.

Reviews of possible sources of metals (in particular chromium) within SONGS did not uncover sources large enough to lead to significant contamination of the receiving waters or to chronic violations of effluent limitations established in SONGS' permits. Review of the concentrations of metals in SONGS' combined discharges reported by SCE to the Regional Water Quality Control Board showed that SONGS was usually in compliance with discharge limitations. This is significant because the discharge limitations are based on estimates of the concentrations at which chronic exposure to each metal in the receiving waters would lead to adverse biological effects. Alone, neither the examination of possible sources of metals within SONGS, nor the review of metal concentrations reported in the combined discharges convincingly exonerate SONGS as a significant source of metals. Not all possible sources of metals were considered in the reviews (in particular corrosion and erosion of metallic surfaces and of surfaces painted with chromium-based paints were not included), and there were occasionally high concentrations of various metals in the combined discharges. Because the combined discharge is only sampled once every six months, we can not rule out the possibility that the occasionally higher concentrations represent high discharges over significant periods of time. We recommend that the current sampling program be augmented either by more frequent sampling or the placement of mussels in the discharge waters, following standard SMW procedures. However, the discharge monitoring and reviews of metal sources within SONGS certainly do not suggest that there is a problem with contamination of the marine environment with metals by SONGS, and the other sources of information on metal concentrations in the environment reviewed above indicate that such contamination has not occurred.

The concentration of radionuclides in beach sediments, effluents, subtidal sediments and organisms has been routinely monitored by SCE, and the results have been reported to the Nuclear Regulatory Commission. The MRC evaluated the concentration of radionuclides in sand crab tissues during one survey during 1986. Radionuclides are present in detectable quantities in organisms near SONGS, and in the MRC sand crab survey station-related radionuclides were detected in sand crabs at distances as far as 10 km from the plant. Nevertheless, the evidence strongly supports the view that the release of radioactive effluents from SONGS has not lead to measurable ecological effects on the local marine biota. This conclusion is based primarily on two observations: 1) maximum estimates of routine radiological releases from SONGS would result in exposures of local marine organisms to dose rates approximately 100 times lower than the lowest levels found to produce any sublethal effects in controlled laboratory experiments; and 2) measures in tissues of organisms collected near SONGS reveal that generally less than 10% of the total internal specific activity is due to artificial radionuclides released by the plant, the rest coming from natural sources of radiation.

1. GENERAL INTRODUCTION

Operation of the condenser cooling systems at SONGS involves pumping large quantities of seawater through the generating station, and then discharging the effluents into the local marine environment. Both radioactive and nonradioactive effluents are discharged into the seawater passing through the generating station, at various rates and durations. In this report we examine how such changes in the seawater concentrations of metals and radionuclides from SONGS might be impacting the local marine environment. SONGS certainly releases metals since virtually any structure containing metal and exposed to seawater will exhibit some corrosion or erosion. Chromium, copper, iron, nickel and titanium are the metals flagged for special monitoring by the Regional Water Quality Control Board. Manganese, nickel and zinc were reported to be in high concentrations in sand crabs collected at beaches near SONGS in 1982 (Wenner 1982a). More than 100 unstable radionuclides are probably released by SONGS (Final Environmental Statement for SONGS Unit 1, 1973) in radioactive effluents. The activity of 19 unstable radionuclides of particular concern are regularly monitored near SONGS in sediments, seawater, and the tissues of selected marine organisms.

The format of this technical report differs somewhat from other MRC reports because the MRC did not sponsor a long-term field research program to study the potential impacts of radionuclide and metal emissions on the marine environment. Such an investigation was not launched primarily because the MRC believed that routine operations of SONGS would not result in ecologically significant releases of metals or radionuclides into the marine environment (See

SCE & SDG&E 1971 for example).[1] Nevertheless, the MRC did a literature search for evidence of ecological effects of radionuclide releases on aquatic communities, and failed to find strong support for such effects, even when sources were releasing radioactive products at much higher rates than nuclear generating stations. In a majority report, the MRC concluded that radioactive emissions from SONGS were unlikely to result in measurable impacts on the local marine biota (MRC 1979, Doc. 79-04).

The MRC also chose not to launch a comprehensive investigation of potential impacts from substances in SONGS emissions, due to the underlying philosophy of their analytical approach. Rather than attempting to identify and then quantify all possible causes of adverse ecological effects, which may or may not actually be producing impacts, the MRC adopted the program of attempting to first identify ecological effects, and then seeking to identify their specific causes. However, concern over metal releases from SONGS was renewed after a study suggested that reproductive patterns in sand crab populations near the station might be influenced by metallic releases from corrosion within the plant (Wenner 1982a; Siegel and Wenner 1984; see Final Technical Report A: Sand Crabs).

We report on information obtained from a number of sources, which fall into three broad categories: (1) metal concentrations and radionuclide activity levels in marine organisms collected near SONGS; (2) metal concentrations and

[1] On June 28-30, 1976, the Marine Review Committee, at the suggestion of J. Mihursky, the representative for the environmental groups at that time, held a meeting where a panel of experts on the environmental effects of nuclear power discussed the "metals issue". The joint opinion of this panel was that SONGS was unlikely to be a significant source of metals with the possible exception of copper. It was recommended that copper not be used in the cooling system at SONGS. If this recommendation were followed, it was thought that the program should not attempt to detect and follow such materials coming from the plant (*personal communication* from J. Mihursky to W.W. Murdoch on 6/14/89).

radionuclide activity levels in SONGS' effluents, and in seawater and sediments near the plant; and (3) estimates of potential releases of metals in SONGS' effluents, incorporating knowledge of plant structure and chemical inputs. We first describe the relevant findings from tissue concentrations of metals in mussels and sand crabs. Metal concentrations reported in the large baseline set of data collected by the State Mussel Watch Program are examined, and contrasted with the values from MRC studies of metals in mussel tissues (Section 2). We then examine in detail the MRC studies of metals in mussel tissues (Section 3). Section 4 gives the results of MRC-sponsored studies on the concentrations of metals and radionuclides in the tissues of sand crabs. In that section we also consider independent reports on metal concentrations in sand crab tissues near SONGS, provided by Dr. A. Wenner, a former MRC contractor.

Researchers have been monitoring metal concentrations in seawater and sediments at locations throughout the Southern California Bight for a number of years, and some of these studies collected samples in the region of San Onofre. Using these data, and seawater and sediment samples collected by SCE near the generating station, we examine the extent to which SONGS appears to influence metal concentrations in the local environment, and whether these concentrations pose a potential threat to marine organisms (Section 5). In Section 6, we examine measurements of metal concentrations in SONGS' effluents, and evaluate engineering estimates of potential sources of chromium discharges from SONGS.

Finally, we focus on the possibility that radionuclide releases from SONGS might produce adverse ecological effects (Section 7). We examine reports by SCE to the Nuclear Regulatory Commission on radiological releases from SONGS, and

survey the literature for further information regarding the effects of releases of artificial radionuclides into the marine environment.

2. STATE MUSSEL WATCH'S MEASUREMENTS OF METAL CONCENTRATIONS IN MUSSEL TISSUES

2.1 Summary

The State Mussel Watch Program (SMW) has been using mussels to monitor the quality of California coastal, bay and estuarine waters for over a decade. They established a station near the San Onofre discharges in 1985-1986, providing an ideal opportunity to contrast the values recorded there with the extensive and analytically consistent SMW data base. In addition, we compared metal concentrations detected in the MRC-sponsored mussel studies of 1976-1977 and 1986 with those reported in the SMW data base.

Metal concentrations reported from the San Onofre site by the State Mussel Watch were quite similar to concentrations at several relatively "clean" Channel Island stations and to values at coastal reference stations. Mussels from San Onofre had lower levels for eight of the nine metals assessed, compared with the neighboring Oceanside site, which is a coastal reference station specifically located "away from known sources of pollution". Additionally, none of the metal levels detected at San Onofre by SMW in 1985-1986 were close to the 85th percentile for the total SMW data collected from 1977-1986. This percentile is the level at which State Mussel Watch flags a site as relatively polluted, and begins tracking that site more closely.

The values reported in the two MRC-sponsored studies were in general agreement with those detected near San Onofre by the State Mussel Watch. Interestingly, some of the chromium values from the 1976-1977 MRC study were

lower than any ever recorded by SMW. The 1986 MRC study showed somewhat high values for manganese, but the SMW data base reveals that, during roughly the same time period, even higher levels of this element were present at stations both to the immediate north and south of San Onofre. It is thus unlikely that the generating station is the primary source for elevated levels of manganese. In addition, high concentrations of Mn in the tissues of mussels can result when they are exposed to high levels of particulates, even when Mn is not particularly elevated in the environment.

The State Mussel Watch data from 1985-1986 indicated that metal concentrations in mussels at the San Onofre site were not high relative to other sites that are monitored, so subsequent monitoring of this station was discontinued. Although we concur with the finding that the San Onofre region appears relatively "clean" with respect to metal concentrations in 1985, continued use of mussels as bio-indicators at this site could provide valuable information regarding the potential impact of discharges by SONGS on the marine environment, and especially of how they might change through time.

2.2 Background

The State Mussel Watch Program measured metal concentrations in mussels outplanted at San Onofre in 1985-1986, and has been measuring tissue metal concentrations in mussels collected at numerous other stations along the entire California coastline for over ten years. This data base permits us to compare concentrations of trace metals recorded at stations near SONGS with tissue concentrations measured elsewhere, and to contrast the concentrations recorded by

the Mussel Watch Program with those collected in the MRC-sponsored outplants described in Section 3.

Mussels are widely used as bio-indicators because they are a cost-effective means for monitoring pollutant concentrations in the aquatic environment (Goldberg *et al.* 1978; Hayes and Phillips 1987). They are well-suited for use as a bioassay as they are long-lived, and efficient accumulators of toxic substances in their environment (Stephenson *et al.* 1980). The sessile habit of mussels also makes them ideal for transplanting to sites where no resident populations are present. Outplants can be established in areas suspected of having high pollutant concentrations regardless of whether the appropriate hard substrate for mussels is naturally available (Hayes and Phillips 1985).

The State Water Resources Control Board (SWRCB) established the California State Mussel Watch (SMW) as a long-term program for monitoring water quality in California coastal waters, bays and estuaries. SMW has been routinely assessing the concentrations of 9 potentially toxic trace metals in mussel tissues from numerous sites along the California coast since 1977. Currently SMW takes two types of measurements. The first are taken at a set of coastal reference sites and resident *M. californianus* are used in most cases. The second type are taken at "hot-spots" in areas of suspected contamination using transplanted *M. californianus*. Thirty-one stations were initially established in areas thought at that time to be distant from point sources of pollutant discharges. Regular monitoring of these 31 stations was discontinued in 1978, but in conjunction with five coastal references stations, also located away from known sources of pollution and still monitored on an annual basis, these sites provide a broad baseline of trace metal concentrations in mussels.

The SMW uses a standardized methodology in handling and analyzing pollutant concentrations in its samples (Hayes and Phillips 1985; Hayes and Phillips 1987). This is a distinct advantage in assessing spatial or temporal trends in the data, since estimates from different laboratories can differ substantially, probably due to the use of differing analytical techniques (Hayes and Phillips 1986). Details of the methods employed in the SMW program can be found in their annual reports (e.g. Hayes and Phillips 1985; Hayes and Phillips 1987). Values reported here are all in μg/g dry weight.

Two aspects of the studies examined here should be mentioned. SMW transplants and the majority of the resident population data are tissue concentrations from *Mytilus californianus*, the California mussel, while the MRC outplants were *Mytilus edulis*, the bay mussel. This raises the possibility that differences in metal concentrations between the two studies may arise simply from intra-specific variability in tissue affinities for the various metals. We address this potential confound below (see Stephenson *et al.* 1980 for a detailed analysis).

A second consideration involves the duration over which transplanted mussels were deployed in the field. Metal uptake rates can vary widely, a two month period being adequate for assessing the environmental concentrations of some metals, while an outplant duration of six months or more may be necessary for complete tissue equilibrium to occur for metals such as silver, copper or lead (Hayes and Phillips 1985). The SMW uses outplants of four to six months, which should be adequate for most metals. They left mussels at the San Onofre station for 4.9 months.

We contrast metal concentrations from six SMW stations with the concentrations detected by SMW in 1985-1986 at San Onofre, and with concentrations measured by the MRC in its 1976-1977 and 1986 outplant studies (Tables 1 and 3). The SMW stations examined here include the two coastal reference stations within the southern California bight (Royal Palms Beach and Oceanside), which were located by SMW in order to provide a long term baseline set of metal concentrations from regions distant from known sources of pollution. (In spite of this goal, the Royal Palms Beach station is located within several km of the White's Point sewage outfall.) The two Channel Island sites are presented because they presumably exhibit metal concentrations indicative of relatively pristine ocean waters. The station at La Jolla is listed because it is situated near an MRC sampling location for sand crabs. Data from the Bodega Head site are included because this was the source site for mussels transplanted to San Onofre. The individual stations monitored by the MRC in 1976-1977 and 1986 are described in Section 3, but all were located within 15 km of SONGS.

2.3 Results

We first examine data collected by the State Mussel Watch Program, comparing concentrations from the San Onofre station with the program's extensive data base of metal concentrations from other stations in southern California. We then contrast the results of the MRC-sponsored mussel outplants with those of the SMW program.

2.3.1 State Mussel Watch Results

Nine metals were assessed in tissues of mussels outplanted at San Onofre by the State Mussel Watch Program during 1985-1986 (Table 1). None of the metal concentrations at the San Onofre station were elevated relative to the other five sites. In fact, for chromium, lead, mercury, silver, and zinc, concentrations at the San Onofre station were the lowest, compared with the mean concentrations from the other stations (Table 1).

Closer comparison of the San Onofre data with other Mussel Watch stations reveals some interesting points. The Oceanside site is a coastal reference station, specifically chosen to be distant from known sources of pollution (Hayes and Phillips 1987). Yet, all of the mean metal concentrations in mussels from Oceanside were higher than those at San Onofre, with the exception of cadmium. For cadmium, the San Onofre concentration was well within the range observed at Oceanside (Table 1).

The two Channel Island stations were chosen to represent relatively pristine conditions distant from industrial and urban influences. Concentrations of chromium, copper, and mercury from San Miguel and Santa Barbara Islands were quite similar to those found at the San Onofre station (Table 1). This indicates that for many metals, the concentrations in waters near the generating station were indeed similar to those found in areas with minimal anthropogenic input. High cadmium concentrations detected at the island stations probably reflect greater influxes of more northern waters, which tend to exhibit elevated cadmium concentrations due to strong upwelling of mid-depth water (Hayes and Phillips 1987). The aluminum concentration at San Onofre appeared elevated with respect

to the island stations, but was well within the range found at the three other mainland stations, and substantially lower than the mean concentration at Oceanside Beach (Table 1). Manganese also appeared slightly higher at San Onofre than at the islands, but the concentration was *below* the *lowest* concentrations found at two of the mainland stations (Oceanside Beach and Royal Palms Beach), and roughly equal to the mean concentration from La Jolla Beach (Table 1). The higher concentrations of aluminum and manganese at mainland sites in comparison with sites at the islands may well be due to the higher particulate load in mainland coastal waters (Hayes and Phillips 1985).

The State Mussel Watch Program keeps a running tally of metal concentrations measured at all the stations along the California coast. "Elevated data levels" (EDL's) are calculated from this extensive data base, and represent the concentration, for each metal, which equals or exceeds the 85 or 95th percentile of all measurements collected in organisms of that species and exposure type (Table 2; Hayes and Phillips 1987). The concentrations for the EDL's in the SMW Transplanted populations tend to be higher than for the Resident populations (Table 2), probably because transplants are usually located in areas suspected of high pollutant concentrations. Metal concentrations in California mussels deployed at San Onofre, however, were far lower than the 85% EDL for every metal measured, using either the Resident or Transplanted California population EDL's for comparison (Tables 1 and 2). Since the Mussel Watch data come from a variety of sites over a broad range of conditions, the fact that the San Onofre concentrations do not exceed the 85th percentile of these observations indicates that the San Onofre station is probably less exposed to metallic pollutants than many other SMW stations. Although metallic pollution could still be impinging on the San Onofre area, the results presented above suggest that anomalous biological

conditions seen near SONGS, in comparison with other areas, are probably due to factors other than unusually high metal concentrations in the environment there. Further evidence that San Onofre is a fairly "clean" area in terms of metal concentrations comes from a comparison of the concentrations seen by SMW in mussels transplanted there, with the concentration of metals in mussels at Bodega Head, the source site, at the time that mussels were being collected for transplantation to San Onofre. The concentrations seen at San Onofre were generally about the same or less than those seen at Bodega Head (Table 1). The exception was aluminum, which was higher at San Onofre, but higher concentrations of aluminum were seen at the other nearby sites in Southern California (Table 1).

2.3.2 Comparison of the State Mussel Watch results with the MRC-sponsored studies

We examine in detail the evidence for spatial patterns in metal concentrations from two MRC-sponsored mussel outplants in Section 3. Here we contrast the data from those studies with concentrations reported by the State Mussel Watch Program. The MRC outplants used the bay mussel, *M. edulis* as the study organism, and metal concentrations in resident bay mussels are generally higher than those in Resident California mussels (Table 3). For this reason we believe that when we are forced to make inter-specific comparisons, they tend to be environmentally conservative ones.

The concentrations reported for individual metals in the three studies--the 1976-1977 and 1986 MRC outplants, and the 1985-1986 SMW outplant-- were generally similar, exhibiting a range of concentrations for each metal that could occur due to natural temporal fluctuations at a station, even when we ignore the fact

that the 1985 Mussel Watch outplant used *M. californianus* (Table 3). Values from the MRC outplants for most of the metals were within the range of concentrations reported by the SMW from the Channel Island and coastal reference stations (Tables 1 and 3).

The concentration of two metals from the 1976-1977 MRC study appeared to differ somewhat from the concentrations recorded by the SMW at San Onofre during 1985-1986: chromium concentrations were quite low, and copper concentrations somewhat high in the MRC outplants relative to the SMW concentrations (Table 3). Indeed, two of the six chromium concentrations reported in the 1976-1977 MRC study were lower than any found by the SMW in *Mytilus californianus* or *M. edulis* tissues from 125 stations measured over a ten year period (Hayes and Phillips 1987). The three highest copper concentrations were measured near SONGS in 1976-1977 (Table 3) at a time when copper was still a component of that system's cooling system (Section 3). However, these concentrations were all below the 85% EDL for Resident bay mussels set by the State Mussel Watch (Tables 2 and 3). Such high copper concentrations were not obtained by SMW in 1985-1986 or in the 1986 MRC study (Table 3), perhaps because copper conduits in the station had been replaced with titanium and concrete by mid-1981. Possible explanations for the generally higher metal concentrations seen during the "off" than during the "on" 1976-1977 outplants are discussed in Section 3.

The 1986 MRC outplants were slightly elevated in cadmium, copper, manganese and zinc, relative to the 1985-1986 SMW data from San Onofre (Table 3). None of these differences were substantial, however, and the concentrations for copper, and zinc from the 1986 MRC data closely matched the concentrations from the Oceanside reference station (Tables 1 and 3). None of the

concentrations for any of these metals exceeded the 85% EDL for Resident bay mussels (Tables 2 and 3). Although several of the manganese measures in *bay mussels* from the 1986 MRC outplant at San Onofre exceeded the SMW's 85% EDL for *resident California mussels*, even higher concentrations of manganese were detected by SMW in California mussels from relatively nearby sites. For example, in 1985-1986, the State Mussel Watch detected 25.77 μg/g of manganese in Oceanside Harbor, 11.44 μg/g at Oceanside, and only 6.30 μg/g at San Onofre. SMW stations to the north of San Onofre also showed manganese concentrations higher than 10 μg/g that year (Hayes and Phillips 1987).

2.4 Conclusion

The concentrations of nine metals reported by the State Mussel Watch Program in mussels outplanted at the San Onofre discharges indicated that the area is relatively clean with respect to metallic pollution. Comparisons of the SMW concentrations with concentrations recorded from MRC-sponsored outplants also indicate that the San Onofre region has relatively low concentrations of metals.