VWRF DISCHARGE BENEFICIAL USES ON THE DISTRIBUTION AND UTILIZATION OF SANTA CLARA RIVER ESTUARY TIDEWATAER GOBY *EUCYCLOGOBIUS NEWBERRYI*

Prepared for:

NAUTILUS ENVIRONMENTAL

Prepared by:

ENTRIX, INC.
Ventura, CA

Project No. 3115901

September 17, 2004

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1.0
INTRODUCTION

The Santa Clara River Estuary (SCRE) is situated along the Southern California coastline within Ventura County. The Ventura Wastewater Reclamation Facility (VWRF) is located on the north edge of the estuary in the City of San Buenaventura (Figure 1). The Estuary, surrounding marshes and riparian areas constitute the 160 acre Santa Clara River Estuary Natural Preserve. Historically, it is estimated that in the mid-1800's the Santa Clara River Estuary comprised an area of approximately 870 acres. McGrath State Beach and campground are located on the south side of the Estuary (Swanson et al. 1990.).

The Pacific Ocean is approximately 2,000 feet from the point of the VWRF discharge. The mouth of the Santa Clara River is frequently closed off by a sandbar, creating a shallow lagoon. When the sandbar is intact, water in the Estuary floods the lagoon and mud flats, inundating the adjacent marsh and low-lying vegetation. During these periods, water depth in the Estuary can be several feet. The estuary discharges directly into the Pacific Ocean when the sandbar is breached. The sandbar is breached naturally during winter storms or when water pressure from rising water levels in the lagoon forces a breach. When the sandbar is breached, the Estuary is subject to tidal influence.

The Santa Clara River Estuary supports a variety of habitat types including open estuarine, freshwater marsh, brackish marsh, salt marsh, mudflat, and sand dune. The Estuary is home to a wide variety of wildlife including two species of federally listed endangered fish, the tidewater goby (*Eucyclogobius newberryi*) and the southern California steelhead (*Oncorhynchus mykiss irideus*). The federally threatened Santa Ana sucker (*Catostomus santaanae*) and the California Species of Special Concern, arroyo chub (*Gila orcutti*) also occur locally but are considered introduced in the Santa Clara River drainage (Swift et al. 1993).

The objectives of the Tidewater Goby Beneficial Uses Study are to:

1. Document the distribution and habitat utilization of tidewater goby throughout the present Santa Clara Estuary;

2. Describe the hydrology of the Santa Clara River and estuary. The initial study objective consisted of evaluating the historic (i.e., natural) and present day hydrology of the Santa Clara River. However, the historic (i.e., natural) hydrology could not be characterized as the earliest available streamflow data is from 1928 and alteration of the hydrology of the Santa Clara River watershed began in the late 1800s/early 1900s with the commencement of surface water and groundwater extraction activities (Kelley 2002).

3. Describe the beneficial uses that the VWRF discharge might have on the distribution of tidewater goby in the Santa Clara River.

This section describes fish biology and ecology in the Santa Clara River Estuary with an emphasis on tidewater goby.

2.1 ESTUARINE FISHES OF THE SANTA CLARA RIVER ESTUARY

Several native fishes have been collected in the Santa Clara River Estuary that make up a small community typical of relatively natural non-tidal coastal lagoons and river mouths. These fishes are typically dependent on the lagoon or estuary for one or more life stages. In larger tidal estuaries such as Newport Bay, Los Angeles Harbor, Marina Del Rey and San Diego Bay, etc., a larger number of bay species occur because the tidal habitat becomes an extension of the local bay environment and many of these species do not depend on the estuarine environment for survival. Emmett et al. (1991) and Allen et al. (2002) provide much of the background and additional references for the habitat and biology of these species in southern California as well as the wider west coast.

Topsmelt are one of the most numerous fishes in the lagoons and estuaries in both numbers and biomass. The adults can live in both marine and estuarine environments. Adult topsmelt enter bays and estuaries in April or May to spawn, and they attached their eggs to vegetation or other similar objects. The young hatch out and the larvae and juveniles usually occur in large numbers. By summer and fall, thousands, if not millions, of smaller topsmelt can inhabit even small estuaries. In some estuaries, the smallest juvenile topsmelt can be taken for 9 or 10 months of the year, indicating a prolonged spawning period. However, most of the spawning is in the first half of the warm season. Small topsmelt feed on plankton in mid-water schools and provide food for a variety of predatory animals such as terns, halibut, and bass. Topsmelt have been documented to be a prominent food source for least terns (U. S. Fish and Wildlife Service 1980; Atwood and Kelly 1984).

If the estuary closes, adult topsmelt will become stranded within the estuary until the sandbar breaches and an opportunity presents itself for adults to return to the ocean. It is possible that the occasional opening of the estuary increases production of topsmelt by freeing up some space for additional young fish. This possible effect has to be balanced with the temporary reduction in space due to partial draining of the lagoon.

The breaching of the sandbar by winter rains and associated flood flows also allows adult steelhead to enter the estuary from the ocean, and smolts to migrate from the estuary to the ocean. Lagoon or estuarine conditions are important for the smolts to acclimate to the higher salinity of the ocean. Smolts take longer to acclimate than steelhead adults, which can swim relatively rapidly from the ocean into fresh water. The Santa Clara River is home to the southern-most, large population of the federally endangered southern steelhead ESU, and is considered very important for the recovery of this species. It is known that up until the late 1930s or early 1940s, many coastal lagoons and estuaries in southern California were utilized by young steelhead as nursery areas (Kelley 2004).

Since streams are smaller and more intermittent in southern California, coastal lagoons and estuaries may have been even more important than they are farther north. In any case, any management of the Santa Clara River Estuary has to take this into account. The VWRF wastewater effluent probably would be beneficial to steelhead to the extent that it helps maintain a large productive lagoon. However, the water temperature at various points in the lagoon was measured at 23 degrees C during our collection, which is higher than that typically recommended for healthy steelhead growth and maturation, namely about 15 to 20 degrees C. Conversely, it is known, but not very well documented, that southern steelhead may tolerate higher water temperatures, such as 21-25 degrees or so. Pacific lampreys common to the Santa Clara River utilize the coastal lagoon in a manner similar to steelhead, but are much less well known biologically (ENTRIX 1996).

Staghorn sculpin, California halibut, diamond turbot, and striped mullet spawn in the coastal ocean area in winter and early spring. The larvae orient towards coastal lagoons and bays and the youngest juveniles settle in the lagoons and bays. They spend the first year or two in these habitats before maturing and moving out to the ocean. Sculpin and halibut are predatory and prey on gobies, other fish and invertebrates. Numerous sculpin were collected in our survey, and clearly are currently a prominent fish species in the estuary. We did not collect, and there is no known data supporting the presence of diamond turbot and California halibut, but they are expected to occur. Starry flounder (*Platichthys stellatus*) also have a similar life cycle, but are a northern species that is very rare south of Santa Barbara County. Like the diamond turbot, the starry flounder has a much smaller mouth than halibut and preys less on fish. However, starry flounder have been documented preying on tidewater gobies in the Santa Ynez River Estuary (Swift et al. 1997).

Although we did not collect them during our survey, mullet have been documented by several recent studies as being part of the Santa Clara River Estuary fauna. Young of the year mullet enter in the winter or early spring and grow up in the estuary. They feed on detritus on the surface of the substrate and are essentially grazing organisms. Because of this feeding habit they are often indicators of pollution since many chemical pollutants are precipitated out in the surface layer of soft substrates in estuaries and bays. Mullet are a southern species that require relatively warm bays and estuaries, and some anecdotal evidence suggests they have become prevalent in the last 20 to 40 years, possibly because many southern estuaries have become warmer probably due to anthropogenic changes in the drainage (Kelley 2004) or even global warming. Mullet are not a known predator to the tidewater goby.

The Japanese yellowfin goby, an exotic estuarine species, has been occasionally collected in the Santa Clara River Estuary. It was recorded by Lafferty and Page (1997) but in small numbers; Greenwald et al. (1999) took only one in two years. Significantly these few were taken after the high El Nino flows of 1997-1998, when a few were also taken in small lagoons on Marine Corps Base Camp Pendleton (Holland et al. 2001). Japanese yellowfin goby have not been collected since that period, despite multiple surveys in the small lagoons on Camp Pendleton (Kevin Lafferty and Camm Swift personal observations). High runoff from the El Nino storms seemed to allow recruitment to the smaller lagoons not previously invaded. Since the 1997-1998 collections, all records of yellowfin gobies have been from larger, fully tidal estuaries and harbors with extensive muddy substrate that seems to be the preferred habitat. The yellowfin goby attains approximately 20 cm in length and probably would extensively prey on tidewater gobies if given the opportunity. If the Santa Clara Estuary were to become more tidal with expanded mudflats, the yellowfin could become more prevalent, possibly to the detriment of the tidewater goby.

Several species of essentially freshwater fishes have been recorded in the Santa Clara River and its tributaries, namely the native partially armored threespine stickleback and the introduced arroyo chub, fathead minnow, Santa Ana sucker, mosquitofish, green sunfish, and prickly sculpin. The stickleback can typically inhabit coastal lagoons and tolerate some salinity but for some reason is largely absent from the Santa Clara River estuary. We did not encounter them, and Greenwald et al. (1999) only took one in two years of collecting. The Santa Ana sucker and prickly sculpin are very rare in both the Santa Clara River and its estuary. Fathead minnow and arroyo chub can be common in certain reaches of the Santa Clara River, and their effects on tidewater gobies are uncertain. Arroyo chubs naturally occurred, historically, with tidewater gobies in Malibu Creek, Los Angeles County and San Juan Creek, Orange County. They were introduced to the Santa Clara River drainage and may co-exist with gobies. Fathead minnows and mosquitofish have been known to prey on larvae of some fishes and might have an effect on the larvae of gobies. Fathead minnows and mosquitofish both need a few weeks of water temperatures over 20 degrees C. to successfully reproduce, and tend not to do as well close to the coast where the ocean cooling keeps water temperatures too low (Moyle 2002).

Several exotic fish species not recorded in the Santa Clara River Estuary, but known to exist farther upstream in the drainage are largemouth bass, carp, bluegill, and two or three species of catfishes, genus *Ictalurus* and *Ameiurus* (Swift et al. 1993; Moyle 2002). Carp disrupt the substrate during feeding and could disturb and destroy goby nests, allowing other species to prey on tidewater gobies to a varying extent. These exotic species only tolerate low salinities up to approximately 10 ppt; native largemouth bass in Gulf of Mexico estuaries are known to be the most important predators at the lower end of the salinity gradient (Hackney and de la Curz 1981). Green sunfish were not observed or collected during our survey, but they have been reported to occur in the estuary in the past (ENTRIX 1999 and Greenwald 1999). An indirect beneficial use of the wastewater treatment outflow is that it replaces some, if not all, of the original flow that would have come from the river, but does not act as a reservoir for exotic predators that are currently present in the main river.

2.2 TIDEWATER GOBY

The federally endangered tidewater goby, *Eucyclogobius newberryi*, is a small fish that naturally occurs in the estuary and lower Santa Clara River, and the first record for the drainage was September 22, 1974 (LACM 34071-1). Tidewater goby have been collected several times since then, and have been the subject of a number of studies related to tidewater goby biology and operation of the VWRF. The most recent collection was our survey of the estuary and the VWRF outfall channel on March 28 and

April 2, 2004, described in detail later in this report. At least three comprehensive studies of the Santa Clara River Estuary relative to tidewater gobies have occurred since the early 1990s. Lafferty and Alstatt 1995 repeatedly sampled the estuary from 1994 to 1996, and ENTRIX did quarterly surveys in 1999. Both the Lafferty and ENTRIX studies utilized three to five stations to represent the area of the estuary. Greenwald et al. (1999) sampled the lagoon at established stations for 24 months from October 1997 to July 1999 with special reference to tidewater gobies, and the sampling event occurred during an El Nina year. Greenwald et al. had seven stations that better represented the area of the estuary, but left out the wastewater channel and the ENTRIX study sampled the lower most part of this channel. The Greenwald et al. and ENTRIX surveys overlapped in time. This information is a rich source of data for current tidewater goby utilization in the Santa Clara River Estuary.

Earlier historical evidence of tidewater goby presence and utilization in the Santa Clara River Estuary is limited because the earliest actual fish collection known was conducted in 1974. Thus, much of the historical analysis is indirect, based on information from habitat changes over the years that allow inferences about suitability for the tidewater goby. Valuable in this regard is the oldest known detailed topographic map (1855) and aerial photos (1929, 1953, 1978, and 1987) presented by Swanson et al. (1990), and a historical summary of impacts to the river summarized by Kelley (2004) documenting the progressive channelization, water appropriation, and extreme reduction of coastal wetlands.

This document utilizes the information described above, additional detailed information on the water budget of the river, and work done on the distribution and habitat of the tidewater goby on Vandenberg Air Force Base by Swift, et al. (1997), on Marine Corps Base Camp Pendleton (Holland et al. 2001), in central California by Swenson (1999), and a variety of localities by Swift et al. (1989). The analysis is particularly directed at assessing the actual and potential effects of wastewater discharge into the Santa Clara River Estuary on the health of the population of tidewater goby and its habitat.

2.2.1 Tidewater Goby Distribution and Biology

Tidewater gobies are known to occur to some degree throughout most of coastal California, but are specialized for and restricted to small coastal lagoons and, historically, the uppermost brackish areas of many larger bays and estuaries. Despite their preference for relatively low salinity, a wide range of salinities can be tolerated and reproduction can take place from fresh water up to at least 25 parts per thousand (ppt) (fully marine waters are usually about 35 ppt). There are virtually no records of oceanic, near-shore utilization by tidewater gobies, but this most likely does occur when large winter storms wash fish out of estuaries to the ocean. Tidewater gobies have been found in hypersaline conditions (>35 ppt), and laboratory experiments have demonstrated the species can survive for at least a few weeks in water up to at least 45 ppt. (Swift et al. 1989).

If a tidewater goby population is eliminated from a locality, often re-colonization will only occur if another population exists within about 10 km or less, and then only during wet winters when strong storm flows can aid in transfer of fish via the ocean. Thus, many populations have been lost permanently when isolated by distance or when local extirpations have increased the distances between sites. This reduction in populations without re-establishment led to the federal listing of the species in 1994 (Federal Register 59:5494). Recent genetic studies of this species confirm that gene flow is restricted or lacking between several groups of these populations, and these separations date from millions to hundreds of thousands of years ago (Dawson et al. 2001 and 2002).

These genetic studies, based on mitochondrial DNA and cytochrome-c sequences, have disclosed a very distinct group of tidewater goby populations in Orange and San Diego counties. The next genetically distinct population to the north consists of the combined Santa Clara and Ventura River populations; the fish from these two rivers differ from the southern fish as well as from those to the north, from Rincon and Carpenteria Creeks and northward. Although tidewater gobies occur at Malibu Creek, they were artificially established by transfer of fish from the Ventura River in 1991 (Swift et al. 1993). Tidewater gobies from the Malibu Creek populaion recently colonized the lagoon at the mouth of Topanga Creek. Museum specimens exist of tidewater gobies from Malibu Creek until the early 1960s, and some time in the later 1960s they were extirpated. Due to museum preservation methods, it is not possible to get DNA information from many museum specimens so it is not known if the original native Malibu tidewater gobies were genetically related to the Santa Clara River fish or to those farther south. In any case, the tidewater gobies that live at Malibu Creek today are genetically identical to Ventura River fish, and thus very similar to Santa Clara River fish. Historically, populations of tidewater goby occurred in Calleguas Creek, which eventually were extirpated, but these fish still occur in the nearby Hueneme Drain which are genetically part of the Santa Clara-Ventura group. Thus, today only three native populations of this genetically defined sub group of tidewater gobies exist, namely at the mouths of the Ventura and Santa Clara Rivers and in Hueneme Drain Dawson et al. 2002).

Tidewater gobies are typically annual, but some fish may live into a second year. They are distinctive in that the females compete more intensely for mates than the males, a sex-role reversal similar to that seen in phalaropes and a few other vertebrates. The females become more strikingly colored and display more aggressive behavior in competition for access to breeding burrows excavated in sandy areas by the males. Reproduction begins in spring, usually late April or May, and continues into the fall, although usually the greatest numbers of fish are produced in the first half of this time period. The eggs take approximately 6-10 days to hatch at about 15 to 25 degrees C, and the larvae apparently spend a day to a few weeks in open water of the lagoon before settling and becoming benthic carnivores. The exact duration of the larval stage is not known and probably varies with temperature. The diet of the larvae is also unknown. Dietary studies of larger juvenile and adult tidewater gobies indicate a wide variety of animals are consumed, such as oligochaete worms, amphipods, ostracods, water fleas (daphnids), mysids, snails, dipteran larvae, and other aquatic insect larvae. It is likely that adult tidewater gobies will eat almost any invertebrate small enough to be subdued (Swenson 1999; Swift et al 1997).

Sand seems to be the preferred substrate and Swenson (1999) showed experimentally that coarse sand (average diameter of about 0.5 mm) was necessary for the construction of breeding burrows with substrates either too fine or coarse (i.e., silt and gravel, respectively) not preferred or utilized. Males have also been observed to satisfactorily utilize Plexiglas tubes as nesting chambers both in aquaria or when they are placed in the natural habitat. A wider variety of substrate types are utilized by non-breeding gobies for foraging, refuge and dispersal. At some sites, numbers of young tidewater gobies have been documented to move upstream into freshwater tributaries as far as 8 or 9 km, such as in the Santa Ynez River in Santa Barbara County and the Santa Margarita River in San Diego County. This movement is most prevalent in low gradient systems, less than one percent with sandy substrate. Any strong current, higher gradient channels with boulder, cobble and gravel substrate inhibits or prevents upstream movement. Additionally, vertical falls more than 10 or 20 centimeters high cannot be surmounted (Swift et. al. 1997).

In tidal systems, tidewater goby populations are usually concentrated near the area of interface between fresh and salt water, such as the margins of Humboldt Bay, often near tide gates (today), or the uppermost tidal areas of Corte Madera and Novato Creeks in San Francisco Bay (historically). Artificial structures that constrict or eliminate the interface zone between marine tidal and freshwater reaches appear to also constrict or eliminate tidewater gobies. In closed lagoons, tidewater gobies can be abundant more or less throughout the habitat. The vast majority of historic tidewater goby records indicate their presence in water shallower than 1.5 meters. Many of the sites where tidewater goby occur today also have water depths less than 1.5 meters. They apparently can occur in deeper water and do so in Lake Earl, Del Norte County, and possibly in Ten Mile River Lagoon, Mendocino County. At several sites that have been modified by channelization, nutrient inputs, bridge construction, etc., tidewater gobies become tend to be restricted to one or a few tributaries with freshwater inflow and with some natural or artificial separation from the main impacted body of the habitat. These “refuges” are often lateral sloughs or backwaters that experience little or no tidal fluctuation (Swift et al. 1989 and 1997).

Tidewater goby populations usually go through great variations in numbers at particular localities. After winter storms and floods the numbers can be very low, down to a few hundred or less based on studies elsewhere. Beginning with the spring spawning season, the numbers can potentially build up to tens of thousands or more until fall or winter when the cycle can repeat itself. During very dry years when runoff is low or negligible, reproduction can proceed all year and the numbers of fish will remain high. This is also true in locations where a lagoon or estuary has broad marshes or lateral extensions that are not significantly disrupted by high winter flows. Some of the largest systems, such as Lake Earl in Del Norte County or the mouth of the Santa Ynez River in Santa Barbara County, have at least a few million fish in the late summer or early fall. At the other extreme, are very small lagoons or pools at the mouths of small canyons in San Luis Obispo or Santa Barbara counties that never have more than a few fish at any given time. These small lagoons probably do not support continuous, established tidewater goby populations, and are likely only occasionally colonized from larger localities nearby during wet years (Swift et al. 1989 and 1997; Swenson 1999).

2.2.2 TIDEWATER GOBY SALINITY TOLERANCE

Tidewater gobies are well known to have a tolerance for a wide range of salinities, from fresh to even hypersaline conditions, but with a preference for lower salinities, from fresh to about 10-15 ppt. These conditions are widely met in the Santa Clara River Estuary, and we measured fresh or nearly freshwater salinity throughout the estuary. Higher saline water may have existed within the deeper part of the lagoon just inside the outlet to the ocean. Tidewater gobies are also well known to invade reaches in streams with low gradient (less than one percent) and no barriers, but often do not do so in the presence of exotic predators. Of course, drying of the stream often prevents upstream migration, and this may occasionally be a factor in the lower Santa Clara River where the inflows have been appropriated for a long time. A well-developed estuarine system appears to be present in the Santa Clara River, since there is a broad zone of varying salinities and a broad gradient of salinity present. This is due to the continued freshwater inflow from the VWRF, balanced with a periodic marine influence.

A well-developed estuarine zone probably enables tidewater gobies to retreat to more saline areas that deter intrusions by freshwater exotic predators. However, largemouth bass, bluegill sunfish, and channel catfish are known to invade salinities up to 10 ppt or so. In the southeastern United States, largemouth bass have been shown to be the main predator in low salinity marshes where the marine predators are excluded by the reduced salinity. Greenwald et al. (1999) and ENTRIX (1999) found green sunfish to be common in the fresh lagoon present during those collections. Green sunfish probably prey on tidewater gobies and could have an impact. Green sunfish were not collected during the current survey. However, this species is very common in the Santa Clara River a short distance upstream of the estuary, and probably colonizes downstream if the river retains enough surface flow and the lagoon stays fresh for a long duration. Some salinity would also deter the African clawed frog, also absent in our surveys, but common in previous studies.

2.2.3 TIDAL INFLUENCES AND RIVER HYDROLOGY ON TIDEWATER GOBY DISTRIBUTION

Complete tidal action definitely restricts the extent of local distribution of tidewater gobies. At several sites with fully tidal conditions (e.g., Humboldt Bay, Elkhorn Slough, Pescadero Marsh, Morro Bay), the tidewater gobies are found mostly above, and occasionally below, tidal gates or in other marginally elevated sloughs that receive little or no tidal action (Swift et al. 1989). Their preference for brackish conditions probably explains their narrow restriction at such fully tidal sites. Historical records, as well as recent studies, show the Santa Clara River Estuary has a strong tendency to close up for most of the year and, even when breached, will soon begin to close due to natural beach processes. Thus, most of the time only a slight tidal influence is present (ENTRIX 2002a). The slurry pipeline that transports dredged materials from the Harbor to south of the river mouth possibly exerts some control on the behavior of the beach in relation to the lagoon opening, and this should be factored in to any analysis of the lagoon management.

Strong flood flows can produce heavy scour when constrained between the levees present upstream on the Santa Clara River. However, lateral marsh habitat still exists below Harbor Boulevard, and this provides refuge for gobies during flood events and probably partly explains the success of the gobies at this locality. This means tidewater gobies and other small weak swimming aquatic organisms will be less vulnerable to being washed out and prevented from returning. If the system experiences large storm flows and no backwaters or refuges deeper than about 30 cm exist, these small species can become vulnerable. The current conditions of the lagoon provide such refuges; we found deeper sloughs, lateral channels and pools on both sides of the lagoon (the largest near the VWRF outfall channel), and these provided the largest concentrations of tidewater gobies encountered in our surveys.

2.2.4 TIDEWATER GOBY SPAWNING

One reason tidewater gobies have low tolerance to tidal fluctuation is their preference for shallow water for breeding burrows in coarse, unconsolidated sand, usually in 70-80 cm or water or less. This sand is typically at the upper end of lagoons near stream mouths where fresh deltas of sand come in during winter storms. This type of habitat was observed almost everywhere around the lagoon and breeding habitat appears to be very abundant in the current Santa Clara River lagoon. Even the wastewater channel appeared suitable in this regard, but the current may be too swift for tidewater gobies in much of this channel. The only area that seemed less suitable for goby breeding was the main channel of the upper lagoon, particularly the south side that consisted of gravel and cobble substrate and shallow water depth. Some areas on the extreme north and south sides of the lagoon had some muddy substrate, but this was not extensive (Table 2-1). Swenson (1999) showed experimentally that male tidewater gobies required clean coarse sand (approximately 0.5 mm average diameter) to excavate their breeding burrows; substrate either finer (muddier) or coarser was avoided.

2.2.5 NATURAL TIDEWATER GOBY PREDATORS

Several tidewater goby natural predators have been collected in recent fish surveys in the area. At other study locations, steelhead, staghorn sculpin, prickly sculpin, and starry flounder have been documented to feed on tidewater gobies (Swift et al. 1997). These species all evolved together in similar systems and, presumably, tidewater gobies should be able to survive in their presence if adequate cover and refuge sites are present. The development of an expanded area at the salinity interface zone with muted tide should stimulate the development of the tidewater goby and, possibly, mysid populations that would benefit salmonid growth and viability. A lack of data exists supporting steelhead smolt utilization of the estuary, although both upstream migrant adults and downstream migrant smolts undoubtedly pass through the lagoon. It is well known that estuaries and lagoons provide nursery areas for large numbers of smolts, and that growth and subsequent survival can be enhanced by lagoon residence. Part of improving the Santa Clara River Estuary for tidewater gobies should also benefit steelhead. In turn, abundant tidewater gobies would most likely provide a food source for young steelhead.

Table 2-1. Physical parameters and fish catches utilizing an 1/8 inch mesh seine in the Santa Clara River Estuary and VWRF effluent channel on March 28 and April 2, 2004

Haul #*	Area (m2)	Max. Depth (cm)	Substrate	Water Temp (ºC)	Salinity (o/oo)	Tidewater goby	Arrow goby	Staghorn sculpin	Calif killifish	Topsmelt	TOTAL NATIVE	Mosquitofish	Arroyo chub	TOTAL FISH
Physical Parameters						***Fish Counts***								
March 28 (09:45-1800)														
1	40	30	1,2	23	4	2					2	3		5
2	35	25	1,2			7					7	2		9
3	16	10	1,2			0					0			0
4	30	35	2	23	0	21					21			21
5	25	50	2(70),3(30)			1					1			1
6	18	60	"			1					1	6		7
7	16	80	2(50),3-4(50)	17	0	25					25			25
8	12	90	"		0	2					2			2
9	12	50	"			1					1	15		16
10	10	60	"			4					4			4
11	10	70	"			4					4		31	35
12	16	90	2(70),3(30)			1					1			1
13	16	60	1(10),2(90)	23	0	29					29			29
14	24	50	2(50),3(50)			0		1			1			1
15	30	30	2			2					2			2
16	21	90	2			8					8			8
17-19	8	80	2,3,4			3		1			4			4
20	16	60	2			1		1			2			2
21	24	70	2		0	2		1			3			3
22	42	80	2			13		2	2		17			17
23	16	120	2			5		3			8			8
24	16	140	2			4	2	2			8			8
25	35	110	2			1					1			1
26	48	90	2			0				1	1			1
27	44	90	2			3		1			4			4
28	40	20	2			1					1			1
29	24	30	2			2					2			2
30	21	20	2			6					6			6
31	28	70	2			21		1			22			22
32	21	40	2			17		1			18			18
33	40	20	2			1		1			2			2
34	35	15	2	22	5	0					0			0
35	24	15	2			1					1			1
36	42	15	2			1					1			1
37	24	35	2			4					4			4
38	8	70	2			0					0			0
39	8	70	2(80),3(20)	23.5		50					50			50
40	24	80	2			150					150			150
41	32	15	2(60),3(35),4(05)			4					4			4
42	32	15				2					2			2
43	24	24				21					21			21
44	40	40	2(70),3(30)			18		2			20			20
45	40	40	2(70),3(20),4(10)			7					7			7
April 2 (09:30-11:20)														
46	4	80	1,2	23		1					1	15		16
47	6	80	1,2			2					2	25		27
48	6	70	1,2									1		1
49	6	70-80	1,2								0			0
TOTALS						**449**	2	17	2	1	**471**	67	31	**569**

Substrate = 1 mud; 2 sand; 3 gravel; 4 cobble
(60) = 60 percent of substrate type
* See Figure 1 for haul locations

2.3 TIDEWATER GOBY SURVEY

This tidewater goby survey was conducted to document the distribution and habitat utilization of tidewater goby in the Santa Clara River Estuary and the VWRF outfall channel. The survey was conduction during an open phase when the sandbar was breached.

2.3.1 METHODS

Camm Swift and Steve Howard surveyed the estuary and VWRF lower outfall channel on March 28, 2004. On April 2, Dr. Swift and Mr. Howard were assisted by Jeff Trow and Shelly Magier when surveying the upper end of the VWRF outfall channel (Figure 1). All collections were taken with a seine 5.2 by 1.8 meters (m) with 3 millimeter (mm) mesh (17 X 6 feet, one eighth inch mesh) attached with 28.5 gram (gm) weights every 15 centimeters (cm) (one ounce weights every 6 inches). Collections were spaced throughout the estuary and the VWRF outfall channel with maximum water depth, and substrate type recorded. Occasionally water temperature and salinity were measured, water clarity estimated and, at most locations, the position was determined utilizing a handheld GPS unit. All fish were counted and released. Occasional large numbers of gobies were estimated and released to avoid excessive handling or because fish were observed and not collected in the net. All other fish species and occasional invertebrates were also counted and recorded.

2.3.2 RESULTS

This section summarizes the results of the 2004 tidewater goby survey conducted in the Santa Clara River Estuary. Table 2-1, which summarizes the results, precedes this page.

2.3.2.1 Habitat Condition in the Santa Clara Estuary

The estuary was relatively shallow (generally <1 m) and was open to the ocean and flowing outward during our survey. Apparently, it was still open from the large storm flows in late February. Figure 1 depicts the approximate water inundation in the estuary at the time of survey, and is based on project photos and recent aerial photos. Seining sites were placed on the map based on our sketch and field notes, along with the GPS measurements taken during the survey. As indicated by the collection data, the vast majority of the lagoon was less than a meter deep. Only a small area near the outlet of the lagoon was over 1.5 meters deep. The entire estuary on the north side was less than about 60 cm deep, except the actual VWRF outfall channel. This channel is relatively narrow and deep, approximately 70-100 cm deep from one side to the other. At this time of year, the highest "grunion" tides come in the middle of the night and, possibly, the lagoon gets deeper at that time. The substrate in the lagoon and wastewater channel was overwhelmingly sandy with scattered gravel and rocks in some areas. A few backwaters and slowly flowing margins had a veneer of fine sediment and fine particulate organic matter (FPOM), particularly on the north arm at stations 1-3 and at the upper most portion of the wastewater channel.

Even at these sites, the fine sediment and FPOM was near or just a veneer on a sand substrate. Because of the low level of the lagoon little vegetation was present at the waters edge; the shores consisted mostly of gently sloping sand and gravel bars. Very little vegetation was present in the water of the lagoon, and consisted of occasional small patches of green algae attached to a few of the areas of hard substrate. Dense vegetation (macrophytes) exists in the VWRF outfall channel, which appears to exhibit a more stable water level with little tidal fluctuation. The shores are lined with tules, herbaceous vegetation, *Arundo*, and willows. The lower 70 percent of the channel was open with little canopy. Much of the upper 30 percent of the channel was completely choked with freshly sprouting *Arundo* covering the water's surface. The upper 30 percent of the channel downstream from the VWRF also has a 60 to 90 percent canopy of larger willow trees. The water temperature varied from 17 to 23 degrees C, and the surface salinity varied from 0 to 5 ppt. This salinity could vary with the tides and season, except in the river channel and wastewater channel, which should remain fresh. Salinity was not determined at depth near the mouth of the lagoon where it would be expected that bottom salinity would be higher than our surface values. The fact that large numbers of the strictly freshwater arroyo chubs were found in the upper half or so of the wastewater outflow channel indicates salt water influence has not significantly invaded that far upstream in the last year or so at least.

The incoming water from the river and the wastewater channel was relatively clear and the lagoon was more turbid with visibility to 40-60 cm. Flowing water existed only in the VWRF outfall channel, the incoming river channel, the short section of riffle where the north arm of the lagoon emptied into the main body of the estuary, and in the roiling sand of the outflow channel across the beach at the ocean. The river channel contained sand and gravel similar to the riffle area on the north lagoon. The VWRF outfall channel is artificially bordered with levees and always contains flow from the VWRF effluent. Standing and slow moving water in the outflow channel was restricted to relatively steep sides with undercut banks, or adjacent to the narrow band of vegetation along the bank.

2.3.2.2 Seine Haul Results

The earlier 1990s studies by Lafferty and Page (1997), ENTRIX (1999), and Greenwald et al. (1999) found tidewater gobies to be abundant and widespread in the lagoon when it had been closed to the ocean for a long time and populations could build up. Some of Greenwald et al.'s collections were after high El Nino flow periods, and the numbers of gobies were much reduced. However, later in the study, including the time of the two collections by ENTRIX on June 24 and September 20, 1999, hundreds of tidewater gobies were taken during relatively few seine hauls, and clearly thousands were present in the lagoon. On the first date, the lagoon was 1-2 meters deep, and on the second it was mostly 70 to 80 cm deep, and deeper only in the VWRF outfall channel and the lower end of the lagoon just above the outlet. Thus, the estuary configuration during the previous studies was similar during the survey for this study.

The survey described herein also found tidewater gobies to be common, but not uniformly distributed throughout the estuary (Table 2-1). Gobies were clearly more abundant in backwater areas associated with inflow areas and other slow-moving sites away from the freshly scoured channel. Twenty-one gobies were taken in the first backwater in the lagoon below the outlet of the VWRF outfall channel (Station 4), and another 26 farther up the channel under a large mass of downed tules. (Station 7). Another 29 were taken in the blind backwater upstream of the VWRF outfall channel outlet (Station 13). Similarly large numbers of tidewater gobies were taken in backwater areas usually deeper than 30 cm such as at Stations 21-23 (20 gobies), Stations 30-32 (44 gobies), Stations 39-40 (about 200 gobies, fish so numerous they were estimated), and Stations 42-45 (48 gobies). All but Station 40 were deeper, backwater margins of the contiguous estuary. Stations 39 and 40 were isolated pools in the middle of a sandbar at the upper end of the estuary (Figure 1) about 20 by 30 m and up to 80 cm deep. Tidewater gobies were very abundant in this pool with at least 150 taken in one seine haul. During our survey this pool was isolated from the rest of the aquatic habitat which became inundated approximately one week later by VWRF effluent filling the estuary. It is possible that during nocturnal high tides, isolated pools could become temporarily inundated when the estuary is open to the ocean.

This was the first study conducted within the entire VWRF outfall channel for fish species. Tidewater gobies were present in small numbers, and three were collected at the upper end just below the outflow through a pile of boulders. This channel is predominately sandy bottomed that is good substrate for tidewater gobies. Gobies are probably restricted somewhat by the strong flow in the channel, since they typically avoid such habitats at other localities. Tidewater gobies collected during this survey were more prevalent in backwater areas with less flow.

The VWRF outfall channel also supports a population of arroyo chubs, indicating that this channel is not significantly invaded by saline water. Arroyo chubs might tolerate up to about 10 ppt for a few hours or a day, but then would expire, or try to move into fresher water. Mosquitofish were also common in the outfall channel, and can tolerate salinities up to full-strength seawater for short periods.

Several other native and exotic fish species were taken in the lagoon during this survey. In deeper water near the mouth, a couple of arrow goby larvae were collected, and a total of 17 small staghorn sculpin were collected in the main body of the lagoon. Only two adult California killifish and one adult topsmelt were collected, partly since our methods were not as efficient for these larger, more active species. Notably, no clawed frogs were taken. These have been common to abundant in some of the surveys conducted in the late 1990s. We also collected a few invertebrates during this survey. One crayfish was collected at the upper end of the wastewater channel and a few aquatic insects were noted. No shrimp or African clawed frogs that were common in many of Greenwald et al.'s collections were observed during this survey.

3.1 HYDROLOGY OF THE SANTA CLARA RIVER

The Santa Clara River watershed encompasses approximately 1,600 square miles and flows in a southwesterly direction from its headwaters in the San Gabriel Mountains (approximately 70 miles inland) to the Pacific Ocean. Streamflow in the river is typical of coastal Southern California watersheds and exhibits high annual and seasonal variability. In the dry season between May and October, flows are very low to non-existent and, in the wet season between October and April, flows vary in response to precipitation with large storm-driven peak flows that dissipate rapidly (Kelley 2004).

Annual and monthly exceedance flow data calculated for water years 1928-1932, 1950-1993, and 1996-2001 using mean daily flow data recorded at USGS Gage #11114000, indicates that stream flows are typically not measurable (0.00 cfs as measured by the gage) most of the year at the gauging site which is located in Montalvo, California at the Highway 101 bridge crossing. The annual exceedance flow data over the period of record indicates that a flow of 0.03 cfs is equaled or exceeded 40 percent of the time during a given year at the stream gage site or, conversely, flows within the river are less than 0.03 cfs approximately 60 percent of the time during a given year. The monthly exceedance flow data indicates that flows above 0 cfs are only equaled or exceeded 50 percent of the time during a given year between the months of January and April. Based on this information, surface flow contributions to the Santa Clara River Estuary appear to be comprised primarily of high runoff following large storm events. A summary of the annual exceedance flows is provided in Table 3-1 (found after page 3-1) and a summary of the monthly exceedance flows is presented in Table 3-2 (found after page 3-1).

Flows within the river are affected by surface water diversions and groundwater extraction, which reduce the overall flow to the Santa Clara River Estuary. Starting in 1928, the same year the St. Francis Dam disaster occurred, large-scale water diversions began by constructing dirt berms where the permanent Vern Freeman facility stands today. In 1946, water was diverted to the Saticoy spreading grounds. In 1950, the United Water Conservation District (UWCD) was formed and in 1955, the Santa Felicia Dam was constructed on lower Piru Creek. In 1958, the VWRF was on-line discharging treated wastewater to the Santa Clara River Estuary. The permanent Vern Freeman diversion structure was operational in 1991, diverting waster from the Santa Clara River and Piru Creek to the Saticoy and El Rio spreading grounds in the Oxnard Plain for groundwater recharge (Kelley 2004 and www.unitedwater.com).

Table 3-1. Summary of Annual Exceedance Flows in the Santa Clara River at USGS Gage #11114000*

Exceedance Criteria	Corresponding Flow (cfs)
1%	3,310
5%	500
10%	92
20%	6.0
30%	0.42
40%	0.03
50%	0.00
80%	0.00
90%	0.00
95%	0.00
100%	0.00

* Calculated using available mean daily flow data between water years 1927-1931, 1949-1992, and 1995-2001.

Table 3-2. Summary of Monthly Exceedance Flows in the Santa Clara River at USGS Gage #11114000*

Month	Exceedance Flow (cfs)										
	1%	5%	10%	20%	30%	40%	50%	80%	90%	95%	100%
Jan	6,270	964	301	45	11	1.8	0.20	0.00	0.00	0.00	0.00
Feb	20,000	3,970	1,280	308	71	6.2	0.80	0.00	0.00	0.00	0.00
Mar	6,980	2,100	1,240	453	117	30	3.1	0.00	0.00	0.00	0.00
April	2,500	1,260	530	110	20	2.2	0.28	0.00	0.00	0.00	0.00
May	1,220	218	30	5.5	0.98	0.17	0.00	0.00	0.00	0.00	0.00
June	260	64	5.0	0.71	0.15	0.00	0.00	0.00	0.00	0.00	0.00
July	109	9.4	2.4	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	21	0.56	0.15	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sept	18	4.7	0.14	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	23	10	2.3	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	600	37	16	1.3	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Dec	2,710	283	50	3.7	1.0	0.08	0.00	0.00	0.00	0.00	0.00

* Calculated using available mean daily flow data between water years 1927-1931, 1949-1992, and 1995-2001.

Table 3-3. Initial Operation Dates of Major Water Diversions, Dams and the VWRF on the Santa Clara River

Project	Date Constructed	Location
Water Diversion (dirt berm)	1928	Saticoy
Water Diversion (dirt berm)	1946	Saticoy
Santa Felicia Dam	1955	Piru
VWRF on-line	1958	Santa Clara River Estuary
Vern Freeman Diversion	1991	Saticoy

Each of these projects has altered the hydrology of the Santa Clara River in some way during the 20th century. These projects, located upstream of the Santa Clara River mouth, have also had an influence on physical habitat characteristics of the estuary. Natural surface flows and sediment that would potentially make it to the estuary are now diverted from the river throughout most of the year. In order to assess the relative magnitude of the affect of the surface water diversions, annual diversion data between 1928 and 2001 was obtained from UWCD (the operator of the largest diversion on the Santa Clara River) for comparison with the annual discharge recorded at USGS Gage #11114000 over the period of record. An estimate of the percentage of the total streamflow diverted by UWCD was determined by dividing the annual volume diverted by UWCD by the sum of the total annual discharge recorded at the USGS gage and the volume of water diverted by the UWCD. The results of the comparison indicate that on average approximately 51 percent of the total streamflow is diverted from the river by UWCD. The annual discharge and diversion data is presented in Table 3-4 (found after page 3-2).

Surface flows within the Santa Clara River Estuary are augmented by the VWRF facility, which has been discharging to the estuary since 1958. The current pond system and outfall channel at the VWRF were constructed in September 1972 and discharge to the estuary approximately 800 feet downstream of the Harbor Boulevard Bridge. Prior to this date, the VWRF discharge was piped and released near the Harbor Boulevard Bridge. In 1972, the average daily discharge was approximately 3.5 million gallons (pers. comm. Dan Pfiefer VWRF), and the present average daily discharge ranges between 7 and 10 million gallons per day, the equivalent of a flow of approximately 11 and 15.5 cfs, respectively. A summary of the annual discharge records from the VRWF between 1984 and 2001 is provided in Table 3-4 (found after page 3-2). This data was compared with the annual volume of water diverted by UWCD to calculate the percentage of diverted water made up by the discharges from the VWRF. The results of the comparison indicate that on average the discharges from the VWRF make up approximately 12.3 percent of the water diverted upstream of the estuary as shown in Table 3-4 (found after page 3-2).

Table 3-4. Summary of Surface Water Flows at USGS Gage #11114000, UCWD Diversions, and VRWF Discharges

Water Year	Total Flow Recorded at USGS Gage #11114000 (1)	UWCD Diversion (2)	Sum of Recorded Flow at USGS Gage #11114000 and UWCD Diversions (3)	Percentage of Total Streamflow Diverted by UWCD (4)	VRWF Discharges to Santa Clara River Estuary (5)	Percentage of Diverted Water Made-Up by VWRF Discharges (6)
	(Acre-Feet)	(Acre-Feet)	(Acre-Feet)		(Acre-Feet)	
1928-29	29,352	4,680	34,032	13.8%	--	--
1929-30	15,547	7,420	22,967	32.3%	--	--
1930-31	15,752	7,170	22,922	31.3%	--	--
1931-32	132,827	9,596	142,423	6.7%	--	--
1949-50	5,451	9,696	15,147	64.0%	--	--
1950-51	0	0	0	0.0%	--	--
1951-52	191,954	25,367	217,321	11.7%	--	--
1952-53	3,309	21,850	25,159	86.8%	--	--
1953-54	12,369	19,926	32,295	61.7%	--	--
1954-55	945	11,551	12,496	92.4%	--	--
1955-56	14,186	17,159	31,345	54.7%	--	--
1956-57	5,620	13,046	18,666	69.9%	--	--
1957-58	278,445	74,589	353,034	21.1%	--	--
1958-59	19,320	36,180	55,500	65.2%	--	--
1959-60	331	14,267	14,598	97.7%	--	--
1960-61	459	5,495	5,954	92.3%	--	--
1961-62	224,462	48,571	273,033	17.8%	--	--
1962-63	6,217	22,374	28,591	78.3%	--	--
1963-64	4,720	10,846	15,566	69.7%	--	--
1964-65	7,589	16,229	23,818	68.1%	--	--
1965-66	154,100	53,747	207,847	25.9%	--	--
1966-67	114,221	90,272	204,493	44.1%	--	--
1967-68	9,782	45,669	55,451	82.4%	--	--
1968-69	889,483	95,411	984,894	9.7%	--	--
1969-70	52,139	78,745	130,884	60.2%	--	--
1970-71	66,685	64,498	131,183	49.2%	--	--
1971-72	29,708	30,004	59,712	50.2%	--	--
1972-73	200,789	63,627	264,416	24.1%	--	--
1973-74	62,606	60,586	123,192	49.2%	--	--
1974-75	52,296	58,071	110,367	52.6%	--	--
1975-76	17,176	21,898	39,074	56.0%	--	--
1976-77	6,687	22,223	28,910	76.9%	--	--
1977-78	670,619	78,576	749,195	10.5%	--	--
1978-79	177,882	120,193	298,075	40.3%	--	--
1979-80	408,836	97,467	506,303	19.3%	--	--
1980-81	31,176	79,545	110,721	71.8%	--	--
1981-82	31,913	72,002	103,915	69.3%	--	--
1982-83	646,799	73,311	720,110	10.2%	--	--
1983-84	41,896	95,008	136,904	69.4%	--	--
1984-85	5,096	49,581	54,677	90.7%	8,643	15.8%
1985-86	154,645	71,289	225,934	31.6%	9,321	4.1%
1986-87	702	38,251	38,953	98.2%	7,385	19.0%
1987-88	22,999	53,667	76,666	70.0%	9,519	12.4%
1988-89	906	24,984	25,891	96.5%	8,051	31.1%
1989-90	1,587	11,206	12,793	87.6%	7,560	59.1%
1990-91	79,575	37,739	117,314	32.2%	7,081	6.0%
1991-92	253,443	79,564	333,007	23.9%	7,564	2.3%
1992-93	834,651	127,890	962,541	13.3%	7,931	0.8%
1995-96	59,733	72,953	132,686	55.0%	8,315	6.3%
1996-97	61,535	78,441	139,976	56.0%	8,474	6.1%
1997-98	680,578	117,169	797,747	14.7%	6,581	0.8%
1998-99	11,940	88,497	100,437	88.1%	8,324	8.3%
1999-00	50,354	57,759	108,113	53.4%	8,881	8.2%
2000-01	152,261	90,543	242,804	37.3%	8,907	3.7%
Average=	**129,697**	**49,563**	**179,260**	**51.0%**	**8,169**	**12.3%**
Median=	**31,545**	**49,076**	**106,014**	**54.1%**	**8,315**	**6.3%**

NOTES:

1) Calculated using available mean daily flow data between water years 1927-1931, 1949-1992, and 1995-2001.

2) Annual diversion records obtained from UWCD.

3) Sum of recorded discharge at USGS Gage #11114000 and flows diverted at the Vern Freeman Diversion. Assumes no water loss or augmentation between the diversion and the USGS gage.

4) Estimated percentage of total streamflow diverted by UWCD calculated by dividing the annual diversion volume by the sum of the recorded discharge at USGS Gage #11114000 and the volume diverted.

5) Annual discharge records obtained from VWRF personnel.

6) Estimated percentage of diverted flow made-up by the VWRF discharge calculated by dividing the annual VWRF discharge by the volume diverted by UWCD. Assumes no loss of diverted water between the UWCD diversion and the estuary.

3.2 HYDROLOGY OF THE SANTA CLARA RIVER ESTUARY

The Santa Clara River Estuary is, by its nature, a very dynamic environment where hydrologic parameters can vary greatly over the course of any given year. The Estuary is influenced by three primary hydrologic factors: 1) the Santa Clara River inflow; 2) Pacific Ocean tides; and 3) the VWRF discharge. The Santa Clara River inflow varies in quantity, duration, frequency, and intensity from year to year, depending on rainfall and upstream diversions as previously discussed. The Santa Clara River also delivers varying quantities of sediment to the Estuary, which builds the sandbar at the mouth. The Pacific Ocean and its tides also play a major role in forming the sand bar that seasonally impounds the Estuary, as well as causing wave action and degradation of the sandbar. The important aspects of sand bar formation are two: 1) winter storms come from the west and northwest tend to remove sand from the beaches and, combined with high flows, open the lagoon; 2) late spring, summer and fall storms come more from the south and lead to sand build-up and berm formation with the berms getting higher and wider as the season progresses. Although tidal influence from the Pacific Ocean is mostly constant, regional weather patterns, such as El Nino and La Nina, can dramatically influence localized near-shore currents. The VWRF discharge is relatively constant, delivering between 7 and 10 million gallons of treated effluent per day. During the dry season, the VWRF discharge may contribute as much as 100 percent of the non-tidal inflow to the Estuary. There is also an additional runoff contribution from non-point sources, such as nearby agricultural fields.

The composition of waters contributing to the Santa Clara River Estuary is quite variable. During the wet season, Santa Clara River flows can easily exceed 5,000 cfs during intense storm events. Winter near-shore ocean conditions can also contribute storm-induced tidal flooding and overwash. The Estuary is most dynamic under winter and spring conditions because river and ocean influences are quite strong. Frequent flushing and inundation occurs due to sand spit breaching and subsequent closing from longshore drift and tides. Summer and fall inflow is diverted upstream with flow to the estuary typically limited to the VWRF discharge when the large sand spit impoundment is formed at the mouth. The sheer volume of water impounded in the Estuary is the predominant factor in the sand spit breaching.

This section describes the potential beneficial uses the VWRF discharge has on the distribution and habitat utilization of tidewater goby in the Santa Clara River Estuary.

4.1 SANTA CLARA RIVER ESTUARY USABLE AREA

The size of the Santa Clara River Estuary has greatly diminished over time due to encroachment from development including the VWRF plant to the north, McGrath Beach Campground to the south, agriculture, Harbor Boulevard and the Olivas Park Golf Course upstream. This encroachment has reduced the amount of usable area for fish species, including the tidewater goby. Additionally, it has also reduced the amount of natural backwater/marsh habitat that is typically associated with estuaries. This backwater habitat is important as a velocity refuge for fish species and life history stages that are vulnerable to high water velocities.

The Santa Clara River Estuary footprint is such that when high river flow reaches the estuary, it is channelized, directing flow straight to the ocean and breaching the sandbar. Historically, the estuary footprint was much larger allowing river flow to spread out into backwater habitats that existed to the north and south within and upstream of the estuary. Today, backwater habitat at the south side of the estuary is for the most part non-existent because of encroachment. Backwater habitat still exists at the north side of the estuary, which, at times, receives water almost entirely from the VWRF effluent discharge.

The usable area available to fish varies depending on the condition of the sandbar (open or closed), the duration of time the estuary is opened or closed, the discharge entering the estuary from the Santa Clara River and tidal fluctuations while the estuary is open to the ocean. Usable area is based on water inundation in the estuary.

Typically, in the absence of artificial influences, the estuary would close off to the ocean in the spring or early summer and remain closed or nearly so until the onset of winter or late fall rains. The series of maps given in Swanson et al. (1990) demonstrates these conditions in the early years (1929, 1953, 1957, 1974, 1978 and 1987) and, clearly, much more Santa Clara River Estuary area was available, compared with current conditions.

The ENTRIX 2002b Metals Translator Study included daily monitoring of the sandbar condition (open or closed) and the footprint (percent inundated with water) from May 2001 to July 2002 (Figure 2). Looking at this data from July 2001 to July 2002, the estuary was closed and open to the ocean 72 and 28% of the time, respectively.

The amount of goby spawning and rearing usable area decreases dramaticaly when the estuary is open to the ocean. This is also dependent on tidal influences with the estuary filling during high tide and emptying during low tide. Data from the ENTRIX 2002b study indicated that open phase conditions during a dry year, which was the condition during the 2002 study, are short in duration with the estuary continuosly filling from the

VWRF discharge when the sandbar closes. The hydraulic pressure from the constant filling of the estuary seems to be the dominant force in breaching the sandbar during dry conditions. This periodic breaching is implortant in maintaing brackish conditions throughout the year. The influence from the VWRF discharge on tidewater goby usable area is such that it maintains important backwater rearing and refuge habitat and additional wetted-sandy spawning habitat.

4.2 BENEFICIAL USES TO TIDEWATER GOBY

This section describes the potential beneficial uses the VWRF discharge has on the distribution and habitat utilization of tidewater gobies in the Santa Clara River Estuary.

4.2.1 TIDEWATER GOBY DISTRIBUTION AND UTILIZATION IN THE MAIN SANTA CLARA RIVER ESTUARY

Tides and variable salinity make the structure of estuaries more complex than that of streams, rivers, or stratified lakes (Horne and Goldman 1994).

Based on the 2004 fish survey described herein, tidewater goby utilize the entire littoral zone of the estuary (Table 2-1). The survey was conducted while the sandbar was partially breached, and the lagoon was connected to the ocean (Figure 1). When the sandbar breaches, the volume in the estuary drops considerably leaving disconnected pools within the upstream river/estuary interface that can strand fish for an extended period of time. This occurred during the 2004 study where tidewater goby were stranded in diminishing pools. When the sandbar closed a few days after the survey, the VWRF effluent quickly increased the volume of the estuary, inundating the stranded pools. If there was no VWRF discharge, these pools would most likely diminish and stranded fish would be lost from suffocation or predation.

4.2.2 TIDEWATER GOBY DISTRIBUTION AND UTILIZATION IN SANTA CLARA RIVER ESTUARY BACKWATER HABITAT

The only extensive backwater habitat that exists in the present Santa Clara Estuary is located on the north end where the VWRF effluent discharges to the estuary. This backwater area is sheltered from Santa Clara River flow by thick riparian vegetation. The backwater area contains refuge habitat from predators from high water velocities that occur during flashy storm events. Other less substantial backwater habitat also exists, but the quantity of this habitat is dependent on the extent of water inundation in the estuary. Based on our survey results, tidewater gobies for the most part utilized all backwater habitats surveyed.

4.2.3 TIDEWATER GOBY DISTRIBUTION AND UTILIZATION IN THE VWRF EFFLUENT CHANNEL

Tidewater goby were collected throughout the VWRF outfall channel. Although there seems to be suitable spawning habitat in the outfall channel, it appears that they are utilizing it as water velocity and predator refugia. Dense vegetation exists within the outfall channel that can be used as a refuge as well. The outfall channel may also potentially be utilized to escape high salinities during long periods of tidal exchange since this area stays relatively fresh due to the constant VWRF discharge.

The tidewater goby was the most common small fish collected in the estuary during our surveys and the vast majority of these fish were half grown to adult, indicating that very little reproduction had taken place before the survey. Young fish usually start appearing in southern California estuaries about mid-April or later (Swift et al. 1989; Swenson 1999).

Our results correspond to the recent surveys conducted by ENTRIX (1999), Lafferty and Page (1997), Lafferty and Alstatt (1995) and Greenwald et al. (1999) who usually found abundant tidewater gobies except in the winter or early spring after considerable scouring of the lower river and lagoon. These surveys had sites near the mouth of the outfall channel, but not within the channel. The fact that we found the tidewater gobies to be common is probably due to the relatively few winter storms that have scoured the river this year, and the available lateral protected habitat that provides refuge for tidewater gobies when these strong flood events occur.

The depth, substrate, and vegetative cover of the VWRF outfall channel are good to support a limited number of gobies that would inhabit the margins of the channel. However, it would most likely be used as non-breeding forage and refuge habitat by the gobies. This is because the deep, narrow channel caused relatively high velocity for gobies, restricting them to the margins and protected areas of this channel. Although the water velocity in the VWRF outfall channel appeared too high for successful goby breeding during the April 2, 2004 survey, water velocities within the lower portion of the outfall channel are likely to be considerable less when the estuary is impounded, potentially creating adequate goby breeding conditions.

5.1 MANAGEMENT IMPLICATIONS

For the last several years, at least since 1997, tidewater gobies have been relatively abundant at the mouth of the Santa Clara River. This is probably due to the combination of relatively fresh water, abundant sandy substrate, slow-moving or standing backwaters with water deeper than 30 cm or with cover, with little or no tidal fluctuation, and low numbers or lack of native and exotic predators. The VWRF supplies most, if not all, the dry season inflow, and can make up on average 12.3 percent of the water diverted upstream of the estuary. Although reduced to about one quarter of its size in 1855 (Swanson et al. 1990), the estuary is one of the three largest habitats that currently host tidewater goby populations south of Point Conception, the other two being the Ventura River estuary and the Santa Margarita River estuary. The tidewater goby population appears to be of relatively large size and extensive reproduction has taken place in several, if not all, years since 1994. However, several potential threats exist, and these are discussed with reference to the VWRF outflow.

The Santa Clara River Estuary opens to the ocean periodically during the dry season, probably more than it would have under natural conditions, based on comparable systems and the addition of 7 to 10 million gallons of treated effluent throughout the year. This can impact tidewater gobies by suddenly leaving the breeding burrows dewatered. Frequently, the sandbar builds up rapidly after breaching. Winter storms tend to come from the northwest or west, and wash away the sand from river mouths, whereas spring and summer storms tend to come from the southwest or south and build the sand back up (Bascom 1980). If water depth in the estuary stays at 30 cm or lower for any amount of time, clutches of eggs in burrows in the sand and the males guarding them will most likely not survive out of water since the males are forced to the surface and the burrows will collapse (Swift et al. 1989). Since tidewater gobies are known to be able to reproduce in a variety of salinities, small changes in salinity probably do not prevent successful hatching of the eggs.

During the collections on June 24, 1999 (ENTRIX 1999) clawed frog tadpoles and green sunfish were common along with hundreds of water fleas (*Daphnia*) and the water was green with phytoplankton. The estuary had been closed for weeks. In September 20, 1999, the water fleas and clawed frogs were entirely absent and the water was lower and saltier. The estuary had been partially drained for several weeks. When closed, the large relatively fresh estuary supports abundant tidewater gobies, but also encourages green sunfish and clawed frogs that prey on gobies. Later, emptying of the estuary left the tidewater gobies still abundant, albeit more restricted, but the green sunfish and frogs were absent. It is not certain if the green sunfish and frogs were washed out to the ocean or if they retreated upstream due to the high salinity from a partial tidal influence.

Based on our survey and several fairly extensive recent fish collections in the estuary, tidewater gobies appear to thrive and continue to exist in relatively large numbers. Our methods were not sufficiently inclusive to collect other estuarine species, and a series of seasonal samples with a variety of equipment is necessary to fully address them. The Santa Clara River Estuary and inflow from all sources is maintaining good reproductive and rearing habitat and provides all aspects needed for tidewater goby survival. The largest potential adverse effects on tidewater goby in the Santa Clara River Estuary are loss of aquatic usable area from increased water diversions and pumping and encroachment from levee's constricting the estuary and associated floodplain.

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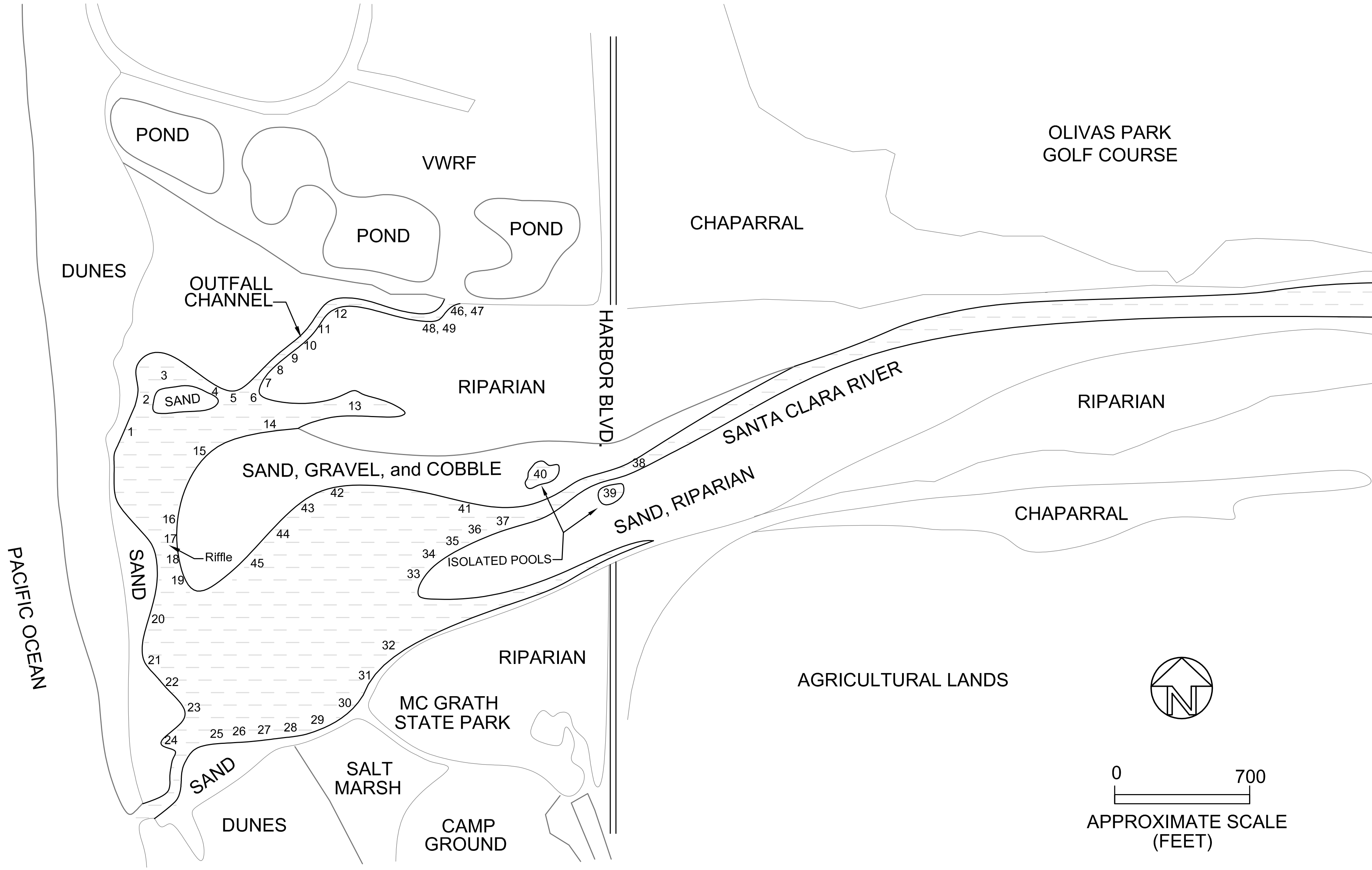
APPENDIX A

FIGURES



Legend

1-49 Seine hauls (see Table 1 for catch summary)

Water inundation on March 28, 2004 during fish survey

ENTRIX

Figure 1

Santa Clara River Estuary
Tidewater Goby Survey Map

CK: JLC

DATE: 05/04

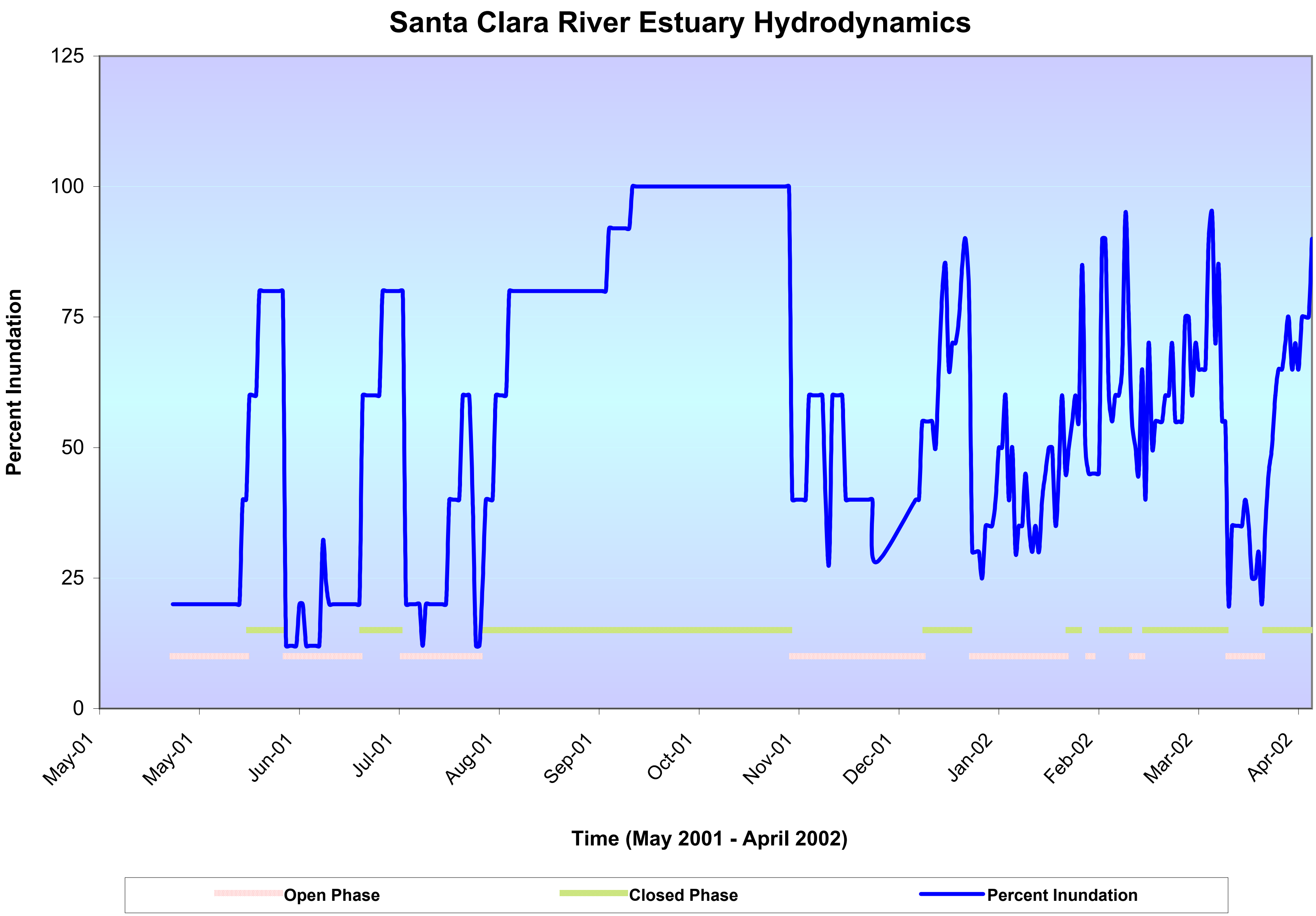


Figure 2. Santa Clara River Estuary Percent Inundation From 5/01 to 4/02