Appendix not included
Especially see P 13-15 + Tables + Figures

PESCADERO MARSH NATURAL PRESERVE SALINITY, TIDEWATER GOBY AND RED-LEGGED FROG MONITORING FOR 1995-1996

Jerry J. Smith
Dawn K. Reis

Department of Biological Sciences
San Jose State University
San Jose, CA 95192

25 June 1997

A Report Prepared for
the California Department of Parks and Recreation
3790-301-722(7)

TABLE OF CONTENTS

INTRODUCTION

The Pescadero Marsh, a 320 acre coastal wetland, includes an estuary/seasonal lagoon at the confluence of Pescadero and Butano creeks, fresh and brackish water marshes, brackish water ponds, and riparian areas along the streams. Modifications to the marsh complex due to past human land uses include restricted water flow, due to a levee system throughout the marsh, and reduced tidal prism, due to both the levees and sedimentation from land uses in the upper watershed.

Although it no longer functions as it did 150 years ago, Pescadero Marsh supports a high diversity of animal and plant life, and is a refuge for a number of sensitive species (Smith 1990; Jennings and Hayes 1990). Federally endangered tidewater gobies (Eucyclogobius newberryi) use the lagoon and marsh habitats. Federally threatened California red-legged frogs (Rana aurora draytonii) and federally endangered San Francisco garter snakes (Thamnophis sirtalis tetrataenia) use the fresher portions of the complex. Low salinity habitat (less than 4 parts per thousand (PPT)) is required for California red-legged frog egg survival (Jennings and Hayes 1990), and relatively low salinity habitat (less than 7.5 PPT) is required for larval survival (Jennings, pers. comm.). Tidewater gobies tolerate fresh or saltwater habitats, but avoid strongly tidal areas when the sandbar is open (Smith 1990). North Marsh and Butano Marsh, partially leveed wetlands in the northern and southern portions of the lagoon/marsh complex (Figure 1), provide extensive habitat for both California red-legged frog and for tidewater goby, but the quality of that habitat depends upon the timing of sandbar formation, water surface elevations, the amount of flooded marshland and upon water salinity.

Portions of the Pescadero Marsh Restoration Project were implemented in the summer and fall of 1993. One modification involved removal of portions of the levees separating North, Middle and East Butano marshes (near water quality stations D3 and D6, Figure 1); previously an opening had been made in the levee separating the eastern end of East Butano Marsh from Butano Creek. These modifications allow Butano Creek flood waters to flow through the Butano Marshes. They also allow tidal water, or water impounded by a closed sandbar, to move much more easily throughout the Butano Marsh complex.

The second major restoration effort involved modifying the northern portion of the marsh complex. A small culvert through the levee separating North Marsh and North Pond from Pescadero Creek was replaced with 6 large culverts and two small culverts (water sampling station B). In addition, a levee that formerly separated North Pond was removed (north of water sampling site C2). Finally, a low levee (designed for + 5.5 feet) was added to separate North Marsh from the channel leading to North Pond. Two large, normally-closed, culverts were installed in the low levee (between water sampling sites C3 and F1 and between C1 and E1). One result of these modifications was to restore tidal action to North Pond, and the channel leading to it, when the 6 large culverts are open; the culverts were to be left open except for brief periods immediately following sandbar closure. The second intended result to was to isolate North Marsh as a fresh-water to mildly brackish-water habitat for red-legged frogs and

San Francisco garter snakes. North Marsh would also serve as a potential refuge for tidewater goby in case yellowfin goby (Acanthogobius flavimanus) became established in the saltier portions of the marsh complex. The only open connection between North Marsh and the remainder of the lagoon/marsh complex was to be a permanently open 12 inch culvert at +4.5 feet extending through the levee between water sampling sites B and E1.

This report describes the results of water level and salinity sampling in 1994, 1995 and 1996 and sampling for adult and larval frogs and tidewater gobies in 1995 and 1996. The monitoring was designed to evaluate the functioning of the estuary/marsh complex in response to the restoration actions and to propose additional management actions to maintain water levels, salinities and other habitat conditions suitable for red-legged frogs, San Francisco garter snakes and tidewater gobies.

METHODS

Water Level and Salinity Sampling

Staff gages were installed at 18 locations in the estuary/marsh complex and also at 3 of the "trout ponds", seasonal, artificial upland ponds (Figure 1). The staff gages at stations S5 (near the north parking lot), H (a ditch on the east side of North Marsh) and at Trout Ponds 1, 3 and 4 are set to arbitrary elevations, but the other 16 gages were surveyed in to read to correct MSL elevation in November 1995. All elevations from surveyed gages given in this report are based on the surveyed elevations; data taken prior to surveying were corrected. Surveyed staff gages are present at the following stations: A, on the downstream side of the Highway 1 bridge; B, on the Pescadero Creek side of the culverts between Pescadero Creek and North Pond/North Marsh; C1, C2 and C3, in the channel between the levee and North Pond; C4, in a small pond adjacent to the channel to North Pond; D3, just west of the levee opening between North and Middle Butano marshes; D6, just west of the levee opening between Middle and East Butano marshes; D5, in a small pond near D6; D8, in the channel on the south side of East Butano Marsh; E1, in the channel on the south side of North Marsh; F1, and F2, in the north ditch and in the open water portion of North Marsh; G2, at the opening to East Delta Marsh; and S1 and S2, in two artificial "sag ponds" in the southwest portion of North Marsh. Most of the gages are redundant at high water levels and when the sandbar is in place. In fact, the surveying was delayed until sandbar formation in November 1995, so that only a small portion of the gages had to be surveyed with a laser transit; the lagoon or marsh water surface was used to level the rest. However, at low water levels or when the sandbar was open, gage heights reflected different evaporation rates and tidal penetration within the estuary/marsh complex.

Salinity and temperature sampling was conducted at the 21 staff gage sites and at 15 additional locations: C5, near the northern shore of North Pond; D1 and D2, in North Butano Marsh; D9 in East Butano Marsh; E2 and E3 in the ditch on the south side of North Marsh; F3, F4 and F5 in North Marsh; G1 and G4, in the channel leading to East Delta Marsh; G3, in East Delta

Marsh; P1, in Pescadero Creek; and S3 and S4, small ponds in the lagoon and North Butano Marsh areas. Not all sites were regularly sampled, because of access problems and redundancy. Most of the relevant information could be gathered by sampling at stations B, C1 and/or C3, C4, D3,5,6, E1-3, F1-2, G1-2, H, and S1-2. These stations were generally sampled 5-7 times in 1995 and 10-23 times in 1996.

At each water sampling site salinity and temperature profiles were determined by sampling at 0.25 meter (m) intervals with a Yellow Springs Instruments Model 30 salinity and temperature meter. The deepest possible profile at the site was sampled by wading or, more usually, by using an 2.5 meter PVC pole to extend the probe out into the channel (like a fishing pole). Condition of the sandbar (open/closed) was recorded during sampling, and status of the culverts (open/closed/leaking) at station B was also recorded.

Water salinity and temperatures were also recorded at red-legged frog egg sites and at larval sampling sites throughout the marsh complex in spring and summer 1996.

Frogs and San Francisco Garter Snakes

In late summer 1995 frog larvae were sampled by dipnet and seine in North Marsh, and adults were tallied during transects associated with water quality sampling.

In 1996 surveys for frog egg masses were conducted throughout the Pescadero Marsh complex on 16 days from 22 February through 30 April; locations of individual egg masses were marked on maps (Figure 2). Mark Jennings assisted on the initial egg and breeding frog surveys, which were concentrated in North Marsh. Larval surveys were conducted with seines and dipnets on 20 days from 17 April through 21 June. Adult and juvenile eyeshine surveys were conducted on 21 evening surveys from 8 March through 21 September. Adult and juvenile day surveys were conducted on many of the above days and on others, totaling 53 surveys from 28 January through 8 December. Larvae, juveniles and adults were identified to species and tallied or densities roughly estimated.

Sightings of San Francisco garter snakes were recorded during water quality or frog sampling surveys in both years.

Tidewater Goby

Tidewater gobies were sampled by seines and dipnet in North Pond, the channel leading to North Pond, and in North Marsh and its north and south ditches in 1995. In 1996 gobies were sampled by seine and dipnet throughout North Marsh and Butano Marsh, while sampling for red-legged frog larvae in April through June. In August they were sampled by seine at 10 sites in the main embayment or in Pescadero and Butano creeks.

RESULTS AND DISCUSSION

Sandbar Formation, Water Levels and Water Movement

In 1993 the sandbar closed in August and was artificially opened to complete restoration work through November. However, the sandbar re-formed in December, backing up saline water throughout the marsh complex. This apparently included flooding over the new low levee and through the small culvert into North Marsh, as salinities there jumped from 5.3 to 11.3 parts per thousand (PPT). On 7 January 1994 the lagoon remained closed, but water levels had subsided to 4.4 feet throughout most of the marsh complex. The sandbar was opened by January storms, and on 2 February culverts through the low levee (at F1/C3 and E1/C1) were opened to partially drain saline water from North Marsh and from the ditch on the south side of North Marsh.

In spring of 1994 the sandbar had closed by mid-May and lagoon levels were high enough to again back water over the low levee into North Marsh. The lowest portions of the low levee, although designed to be at 5.5 feet elevation, were found to be at about 4.7-4.9 feet when surveyed in November 1995. The difference is apparently due to erosion by water flowing over the top, settling and/or improper original fill elevation. The sandbar opened with November rains.

The wet winter of 1994-5, with major storms in January and March, eroded much of the beach, and the "summer" sandbar did not form until late October. Although North marsh was filled to the top of the low levee by the winter rains, it almost completely dried by mid summer. The ditch on the south side of the North Marsh (E1-3) was reduced to a puddle at its west end (E1) by evaporation and leakage through the large culvert (between E1 and C1). The remainder of the marsh was dry in September (E2-3, F2, H), except for several shallow (< 0.25 m) pools in the ditch at on the northern edge of North Marsh (F1, F5) and deeper water (0.75 m) in the two artificial ponds (S1-2). After the sandbar formed in October the lagoon rapidly rose (to 5.2 feet on 12 November and 5.5 feet on 26 November). Although the large culverts between the lagoon and North Marsh/North Pond (station B) were closed, both North Marsh and the channel to North Pond also rose quickly. On 12 November the water west of the low levee (C1-5) was at 4.9 feet, in North Marsh (F1-2) it was at 4.4 feet and in the ditch on the south side of North Marsh (E1-3) it was at 4.6 feet. Water was entering through both small culverts (from B to C1 and E1) and also flowing from the ditch to North Pond (C1-3) across the low levee into North Marsh. By 26 November all areas north of the Pescadero levee had reached 5.4 feet. A plastic waste basket was used to close the small culvert between stations B and C1 on 12 November, so that the rise was mostly due to surface water moving through the small culvert between stations B and E1 (E1 had much fresher water on 12 November than C1-3, and the closure was an attempt to freshen the North Marsh as much as possible during the water level rise). The sandbar opened in early December and remained open the rest of the winter.

In 1996 the sandbar again failed to close until late summer. The bar partially closed in early August and completely closed at the end of August. Again the sandbar closure was too late to

prevent most of North Marsh from drying. The ditch on the east side of North Marsh (station H), the eastern portion of the south ditch (station E3) and most of the open-water portion of the marsh (F2-4) were dry by the end of August. The ditch on the north side of North Marsh (F1, F5), the west end of the south ditch (E1-2) and the two ponds (S1-2) retained pools to 0.25 m deep. After sandbar formation the lagoon water level rose from 3.8 feet on 31 August to 4.8 feet on 17 September. The large culverts at station B were closed, but flow through the small culverts (B to C1 and E1) allowed water levels north of the levee to also rise. By 17-21 September water levels had risen to 3.7 feet west of the low levee (C1-3), 4.4 feet in the south ditch of North Marsh (E1) and 3.5 feet in North Marsh (F1-2). By 11 October the lagoon had reached 5.0 feet, and all areas of North Pond/North Marsh had reached 4.9 feet. The sandbar opened in early November and remained open for the winter.

The ditch at the east side of North Marsh (station H) is hydrologically isolated from the remainder of the marsh, including the ditches along the north (F1,5) and south (E1-3) sides of the marsh, at the water levels observed in this study. It appears to fill primarily with rain and runoff, and its salinities are lower than in the remainder of North Marsh. The two artificial ponds in southwest North Marsh (S1,2) are not merely rainwater catchments, but respond to raising and falling levels water levels in North Marsh and in the channel west of the low levee (C1-C2). The water levels in the two ponds were always with 0.2 feet of each other, and rose 0.5 feet within a week of increased water level in the channel.

Water Levels and Tidal Movements in the Open Estuary

Without the sandbar in place water levels throughout the estuary/marsh system are much lower, even during very high tides. On 3 December 1994 a 6.9 foot tide peaked at about 9:40 at the beach. At station B, upstream of the neck of the lagoon, the highest level was about 5.2 feet, about 1 hour later. Even when the six large culverts at station B were open they slowed tidal movement sufficiently on similar high tides to keep water levels in the channel to North Pond (C1-3) below the 4.7 foot level necessary to top the low levee into North Marsh.

Restricted tidal flow in the narrower channels of the marsh complex generally kept water surfaces to less than 3.0-3.5 feet, even during very high tides. The narrow entrance to East Delta Marsh (G2) is quite far upstream on Butano Creek, so tides are often ebbing before the full tidal height reaches that far. In the Butano Marshes the levee openings at the north end of North Butano Marsh and at D3 and D6 have increased tidal penetration. However, the narrow openings and small marsh channels through which the water flows in the North and Middle Butano marshes usually delay tidal movement enough to prevent tidal penetration into East Butano Marsh. Significant saline water entry into East Butano Marsh would apparently occur rarely except after sandbar formation allows flooding of the entire marsh complex.

On 19 January 1996 Butano Creek flood runoff spread freshwater at elevations of 4.7-5.1 feet throughout the Butano Marshes and East Delta Marsh, inundating (and freshening) much of the marsh habitat.

Trout Pond Water Levels

The "trout ponds" were originally used to raise fish, with water pumped from Pescadero Creek to maintain summer pond levels. The Department of Parks and Recreation retains this appropriative water right, if it is regularly exercised. In the absence of pumping the ponds go dry in summer, even in very wet years. In 1995 they were dry before October. In 1996 Trout Pond 2, which has less than 0.3 m of water in the middle of the rainy season, was dry by March. Ponds 1 and 4, which support dense cattail (Typha spp.) growth and had winter depths to 1 m, were dry by early August. Pond 3 is steep-sided, lacks cattails and can exceed 2 m in depth; it was dry by September.

Salinity in North Marsh and Associated Channels

North Marsh was to have been kept no more than mildly brackish, to ensure habitat for red-legged frogs. However, saline water spilled over the low levee and filled the marsh within months of the completion of the levee in 1993. In March 1994 the salinity of the Marsh (F2), the ditch along the south side (E1) and the sag ponds (S1) exceeded 6.6 PPT (Table 1) and remained saline all year.

Since the low levee turned out to be lower (4.7 feet) than its design elevation of 5.5 feet, the 6 large culverts at station B were kept closed more often during the study period than originally intended (see 1995 and 1996 descriptions, below). The small culverts at station B, which were planned to always remain open, were high enough so that the relatively fresher, lighter, surface waters flowed through them. Most of the time that acted to both raise water levels in North Marsh, and to also freshen them (see below). However, on 3 December 1994 the "fresher" surface waters at station B were 24.4 PPT (compared to 31.7 PPT on the bottom), and this salty water flowed through the small culvert to increase bottom salinities at station E1 to 19.0 PPT.

In 1995 heavy rains diluted the salinity of the marsh. The first salinity sampling was on 22 June, when salinities in the marsh (F1-2), sag ponds (S1-2) and the pond adjacent to the channel to North Pond (C4) had salinities of 3.6-4.7 PPT (Table 1); salinities would have been substantially lower in winter and early spring, when red-legged frogs were breeding and eggs were laid. The ditch on the south side of North Marsh (E1) had drained by June and was very salty (22.6 PPT), due to seepage at the culvert (E1-C1). The marsh had largely dried, and the remaining water was quite saline, by 2 September (7.8 PPT in S2 to 12.9 PPT at F2).

The culverts at station B were open in summer 1995 and the water in North Pond (C5) and the channel to North Pond (C1-3) was tidal and very saline (16.0 - 20.2 PPT) all summer (Table 1). Despite this, the small pond adjacent to the channel (C4) maintained relatively low salinities all summer (4.4-6.7 PPT). Although the pond is connected to the channel at high water levels (around 4.3 feet), tidal flow always remained below that level, preventing high salinity in the pond.

Sandbar closure in late October 1995 re-flooded North Marsh. The large culverts were closed at station B after sandbar closure, but rising saline water from the channel to North Pond (C1-3) flowed across the low levee. On 26 November salinities in North Marsh (F1-2) and the sag ponds (S1-2) were relatively high (4.1- 5.0 PPT), although surface lagoon water flowing through the small culvert (B-E1) into North Marsh had filled the south ditch (E1-3) with fresher water (2.1 PPT) (Table 1).

In 1996 heavy January rains reduced salinities throughout the North Marsh/North Pond complex, which was open to the lagoon only through the small culverts. On 28 January salinities in the the top 0.5 m throughout North Marsh (E1-3, F1-2, H, S1-2) and in the pond adjacent to the channel to North Pond (C4) were 3.6 PPT or less (Table 1). By 24 February most salinities throughout the North Pond/North Marsh complex were 2-3 PPT. The major exception was at the east end of the ditch on the south side of North Marsh (E3). Although the surface water there was quite fresh in January and February (1.4-2.0 PPT), the bottom water was much more saline (5.2-6.7 PPT), apparently due to salts previously accumulated in the ditch.

The large culverts were opened in spring 1996 and North Pond (C- 5) and the channel (C1-3) to it were tidal and saline (14.8 - 28.8 PPT) in May through early August (Table 1). As in 1995, the pond adjacent to the channel (C4) remained relatively fresh (4.9 PPT on 15 June and 6.3 PPT on 31 August).

Prior to sandbar formation in late August, North Marsh habitats progressively dried to shallow puddles and increased in salinity. On 31 August salinities ranged from 5.6 PPT in Sag Pond 2 to 8.4- 9.3 PPT in most of the rest of the remaining marsh (E1, F5, S1). Only the isolated channel at the east end of the marsh (H) was still relatively fresh (2.4 PPT).

When the sandbar formed in late August 1996 the large culverts at station B were again closed, and North Marsh began to fill and freshen from flows through the small culverts. By 8 December salinities in North Marsh (E1-3, F1-2, S1-2) were mostly 1.9 - 2.6 PPT (Table 1).

The small seasonal pond on the west side of Highway 1, near the north parking lot (S5) filled with rain and runoff and was fresh (0.2 PPT); there was no evidence of seepage from North Pond.

Salinity in Pescadero Creek and the Marshes of Butano Creek

Since the sandbar did not close in 1995 until late October, the lagoon was very saline by late summer. On 1 August surface salinity at station B was 13.1 PPT, but salinity at 0.25 m was 20.6 PPT, and at and below 0.5 m was 31.4 PPT. Salinities, especially those near the surface, decreased upstream, closer to freshwater inflow and further from ocean tides. On 2 September the mean salinity of the top 0.5 m near the opening between North and Middle Butano marshes (D3) was 9.4 PPT, and at the opening between Middle and East Butano marshes (D6) it was 5.3 PPT (3.3 PPT or less in the top 0.25 m) (Table 2). Flow from East Butano Marsh was

substantially lower (2.3 PPT). A small pond near the opening between Middle and East Butano marshes (D5) also had low salinity (1.6 PPT).

After the sandbar formed in late October 1995 the salinity of the lagoon quickly dropped, and upper water column salinities in Butano Marsh (D3,6) and East Delta Marsh (G1-2) were quite fresh (1.8-2.1 PPT) (Table 2). Salinities jumped again after the sandbar opened in December, reaching 15.3 PPT at D3 and 4.0 PPT at D6 in Butano Marsh and 11.8-13.3 PPT near and at the entrance to East Delta Marsh on 20 December. East Butano Marsh (D8) remained fresh (0.7 PPT).

Mid-January 1996 storm runoff freshened the marshes along Butano Creek. Salinities in Butano Marsh and East Delta Marsh were generally 0.4 - 0.8 PPT on 19 January and 0.1 - 0.8 PPT on 24 February (Table 2). The exceptions were the ponds, potholes and backwater ditches. The pond near the opening between Middle and East Butano Marsh (D5) is only connected to the lagoon at high water (about 5.0 feet), and it remained somewhat saltier through January and March (1.5-2.3 PPT). A backwater ditch (D1) and saltpan pothole (D2) in North Butano Marsh had salinities of 2.4- 2.6 PPT in February, and reached 5.4-6.6 PPT on 25 March. The pothole near the entrance to East Delta Marsh (G1) traps saline water on its bottom and was 2.4-5.6 PPT in the upper 0.5 m in January through March.

After high runoff through Butano Creek and Marsh ceased, salinities substantially increased. On 15 June high tide salinity reached 17.3 PPT at the east edge of North Butano Marsh (D3) and 10.8 PPT at the eastern edge of Middle Butano Marsh (D6) (Table 2). The station on East Butano Marsh (D8) remained fresh (0.1 PPT). The entrance to East Delta Marsh (G2) reached 3.7 PPT on 15 June and 7.2 PPT on 26 July. Two small ponds in Butano Marsh (D5 and S4) remained fresh (0.6-1.2 PPT) all summer.

After the sandbar formed in August, salinities were relatively low throughout Butano (D3,5,6,8) and East Delta (G1-2) marshes (0.4-3.6 PPT on 31 August and 17 September).

Red-legged Frogs

The 1995 sampling for frogs did not begin until summer and was primarily confined to North Marsh and associated channels. In June adult red-legged frogs were common in the two sag ponds (S1- 2) (14+ frogs) and in the ditch on the north side of the marsh (F1) (5+ frogs). Several were also present in the pond adjacent to the channel to North Pond (C4). The ditch on the south side of the marsh (E1-3) was already saline and nearly dry, and lacked frogs, as did the edges of the tidal channel to North Pond (C1- 3). No frogs were seen during water quality sampling in Butano Marsh.

By August 1995 the number of frogs in the sag ponds had declined, and sightings of adults were only in S2, the less saline pond; 4 adults were present in August (@ 5.9 PPT), and apparently only 2 were present in September (@ 7.8 PPT). In August there were more than 20 adult frogs

near and in the culvert at the north side of North Marsh (F1) (@ 7.2 PPT), but none were present on 2 September (@ 12.1 PPT).

No frog larvae were captured by dipnet in the North Marsh ponds (S1-2 or C4) in 1995, but 1 juvenile was present in S1 in August. Scarce larvae were captured in the north ditch (F1,5) in August, but none were present in September, when salinity reached 12.1 PPT.

The apparent scarcity of red-legged frogs in summer 1995, and the loss of almost all of their habitat to high salinity and/or drying by late summer, suggested that the population might be quite low. However, 1996 results demonstrated that this cryptic species is both resilient and common at Pescadero Marsh.

In Winter and early spring 1996 the entire Pescadero Marsh was searched for red-legged frog egg masses (Figure 2). Early efforts were concentrated in North Marsh and spread outward from there during the sampling period. All lowland egg masses were found in North Marsh or in the pond adjacent to the channel to North Pond (C4). The highest concentrations were along the north ditch (F1,5) and in the western portion (E1-2) of the south ditch. A few egg masses were also found towards the center of the marsh, but none were found in the sag ponds (S1-2) or in the ditch at the east end of the marsh (H). A single egg mass was found in Trout Pond 4, although adults were seen and heard in both Trout Pond 2 and 4 (the two ponds with dense cattails). The lack of discovery of egg masses elsewhere may be partially due to the relatively later searches in East Delta and Butano marshes.

Larval distribution and abundance generally matched that of egg distribution (Figure 3). Larvae were abundant in the north ditch of North Marsh (F1,5) and common in the south ditch (E1-3), including further east than egg masses were found. They were also common in pond C4 and surprisingly common in the open water of North Marsh. They were not collected in the ditch on the east end of North Marsh (H), a result similar to that of Jennings and Hayes (1990). Their failure to use this freshwater ditch is puzzling, but might be due to the relatively heavy shading and scarcity of algae as larval food.

Larvae were absent from North Butano Marsh and most of Middle Butano Marshes, which matches the lack of egg mass discoveries there (Figures 2,3). However, larvae were present, and even abundant in some samples, in East Butano Marsh and East Delta Marsh, despite the failure to find egg masses there earlier in the winter. Larvae were also common in the small pond at the junction of Middle and East Butano marshes (D5). Larvae were common in Trout Pond 4, where the single egg mass was found, and were also present in Trout Pond 2.

Although many of the habitats with larvae dried up early or were quite saline by August 1996 (Tables 1 and 2), many red-legged frogs were able to metamorphose prior to the decline in habitat conditions. Young-of-the-year red-legged frogs were present, often in abundance, in late summer at all sites with larvae (Figures 3 and 4). In addition, they were common to abundant in the North Marsh sag ponds (S1-2), Trout Pond 3, and upper Butano Creek, locations were no larvae were collected. In East Butano and East Delta marshes summer drying and salinity

appeared to have the greatest impact on larval survival, as relatively few juveniles were observed compared to larval abundance. However, monitoring of larval survival was stopped when the red-legged frog was listed as threatened.

Adult red-legged frogs were observed at all the locations with larvae (Figures 5A,B), but also showed a more widespread distribution. However, few adults were seen in areas which had even seasonally high salinities, such as North Pond, the main lagoon embayment, lower Butano Creek, or the North and Middle Butano marshes. Adults were commonly seen in the north (F1,5) and south (E1-3) ditches and sag ponds (S1-2) of North Marsh. These sites offered deep water and/or dense emergent vegetation as escape habitat. They were also common in the northern part of East Delta Marsh, in the trout ponds, and along the western portion of East Butano Marsh. Near North Butano Marsh red-legged frogs were abundant in a small pond (S4), where larvae and juveniles were never observed. Adult frogs were common to abundant in the upper portion of Butano Creek and near the banks of Pescadero Creek, areas which offered good cover and potential foraging, but were unsuitable for breeding. Single adult frogs were observed in North Butano Marsh, the east ditch at North Marsh (H), and near the west shore of the main lagoon embayment. During surveys conducted in the breeding season up to 37 adults were seen in a single night in the north ditch of North Marsh and 55 in the south ditch.

Bullfrogs

No bullfrogs were observed in North Marsh in 1995, which was probably due to the lack of habitat in the south ditch (E1). In 1996 bullfrogs began to appear in May in the south ditch (Figure 6), but by then salinities were already increasing (3.5 PPT) (Table 1) and water levels were low. By mid June salinity in the ditch (E1) or in North Marsh (F1,2) was too high for egg survival (4.3-5.0 PPT). No calling was heard at the ditch, and apparently no breeding occurred in 1996. The source of the bullfrogs is unknown. They may be from upstream on Pescadero Creek or may be holdovers from years when conditions in North Marsh allowed bullfrog breeding and larval metamorphosis.

Adult bullfrogs were also seen in summer 1996 in the trout ponds, in East Butano Marsh and in and near the channel to East Delta Marsh (Figure 6). No calling was heard, and no bullfrog egg masses were found at those sites. Breeding apparently did not occur, although sampling for larvae in late summer could not be conducted because of the federal listing of red-legged frogs.

Bullfrog larvae and juveniles were found in late spring in Butano Creek near Pescadero Road (Figure 6). Adults in Butano Creek were first seen upstream, and then appeared to move down the Butano Creek channel and enter East Butano Marsh through a levee opening at the northwest corner of the marsh. The presence of bullfrogs in the channel to East Delta Marsh (G4) also appears to have been from movements down the Butano Creek channel. Bullfrogs are present in farm ponds upstream on Butano Creek; those ponds may be a continual source of adults and larvae to the habitats at Pescadero Marsh.

Red-legged frogs at Pescadero Marsh were able to breed in winter and metamorphose larvae before the habitats dried or became saline in summer 1996 (Figure 5). The summer drying that occurred at Pescadero Marsh in 1995, 1996, and earlier in 1989, 1990 and 1993, may not provide the best environment for red- legged frogs, but it has apparently has not drastically affected their abundance. However, these periodic harsh summer conditions appear to be a major factor in preventing bullfrog success in the marsh. In many years, as in 1996, bullfrogs would be unable to breed in portions of the the marsh, due to drying or salty conditions during the mid-summer breeding period. Stable, freshwater habitats suitable for the 1 year larval development usual for bullfrogs are scarce. The trout ponds, without supplemental water from Pescadero Creek, dry each summer. East Butano Marsh and Butano Creek are rinsed by floods in many winters and can dry or be salty in late summer. In years when the sandbar forms early and the lagoon and marshes are converted to relatively fresh conditions for the summer, bullfrogs may breed and become more abundant in Pescadero Marsh. However, populations should fall again in years like 1995 and 1996. Any restoration efforts that produce permanent freshwater habitats would probably benefit mostly bullfrogs, a major predator and competitor of red-legged frogs.

Treefrogs

Pacific treefrogs (Hyla regilla) used all of the habitats used by the red-legged frogs (Figure 7), but also heavily used the more open portions of North Marsh (F3-4) and the ditch on its eastern edge (H) for breeding. They were the only frog that used the pond (S5) on the west side of Highway 1, and were able to successfully breed there, despite its seasonal nature. Like the red-legged frog, they were not observed in areas of even seasonally high salinity.

San Francisco Garter Snakes

Despite the large amount of time spent in the marsh in 1995 through 1996, very few confirmed San Francisco garter snakes were observed. However, the observations of garter snakes were made during water quality or frog sampling, and we had no permit to capture or harass possible San Francisco garter snakes. If a snake quickly sought cover, it was not pursued and its identity remained unknown. Santa Cruz garter snakes (Thamnophis atratus atratus), a subspecies of aquatic garter snake, and the coast garter snake (T. elegans terrestris), a subspecies of western terrestrial garter snake, were also present. Both appeared to be much more abundant than San Francisco garter snakes.

All sightings of San Francisco garter snakes were in areas of high adult and larval frog abundance, including the north (F1,5) and south (E1-3) ditches and sag ponds (S1-2) of North Marsh and at the boundary of Middle and East Butano marshes (D5,6).

Tidewater Goby

In summer 1995 no tidewater gobies were seen or captured in North Pond or the channel leading to it (C1-3) or in the north (F1,5) and south ditches (E1) of North Marsh. North Pond and the channel to it were strongly tidal, with the pond nearly drained at low tide and with fast currents in the channel on incoming and outgoing tides. Sampling with seine or dipnet was difficult, because of the very soft bottom muds. The water was clear, and habitats were also visually inspected unsuccessfully for gobies. Both of the ditches of North Marsh were reduced to shallow puddles, also with soft bottoms. The remaining habitat at the north ditch (F5) appeared sufficient for gobies, but none were captured by difficult sampling.

In November 1995 North Marsh was re-flooded, and tidewater gobies were regularly captured by seine in the open water and in north ditch in spring 1996. Apparently, gobies survived in the north ditch in 1995, and their population rapidly grow and expanded over the winter and spring. Tidewater gobies were also regularly captured in marshy habitats of Butano and East Delta marshes in spring 1996, while sampling for red-legged frog larvae.

In August 1996 the non-marshy portions of the lagoon were sampled by seine for tidewater goby, but relatively few were captured. None were captured at two sites in the main embayment, but 3 were captured between the neck of the embayment and the lower portion of Pescadero Creek. None were captured on the lower portion of Butano Creek, but a total of 5 were captured from 4 sites above and below station P1 on Pescadero Creek, including over gravelly substrate. On Butano Creek near the mouth of the channel from East Delta Marsh at least 12 tidewater gobies were captured within dense sea lettuce (Ulva); this was the only one of the 10 main channel sample sites where the gobies might have been common. Young-of-year prickly sculpins (Cottus asper) were commonly taken during the sampling, but no yellowfin gobies were captured.

In previous sampling at Pescadero Marsh (Smith 1990) tidewater gobies were always quite rare in channels or open water with substantial tidal movement, but were usually abundant after the sandbar had formed, creating a calm lagoon. The pattern in 1996 appeared to be the same; the sandbar failed to form until late August, and prior to that gobies were common only in the calm, marshy portions of Pescadero Marsh, and rare in the stream channels and lagoon embayment. The failure of the sandbar to close in 1995 until late October may also have been a factor in the low 1996 abundance. Overall tidewater goby abundance in Pescadero Marsh in 1996 was probably rather low compared to the much smaller, but closed, lagoons of Santa Cruz and San Mateo counties (including Arroyo de los Frijoles and Laguna, Baldwin, Wilder and Moore's creeks) (Smith, unpublished). Thirty to 300 gobies per seine haul were often captured in those lagoons.

Western Pond Turtles

Pond turtles were frequently observed, and a limited trapping effort was mounted for them in

summer 1996. They were most commonly observed in the upstream portion of Pescadero Creek, where salinities were lower and where logs provided basking habitat and escape cover. They were also captured in the channel to East Delta Marsh (G1,4) and in the north ditch of North Marsh (F5).

Pond turtles were relatively common in the south ditch of North Marsh (E1-3) in winter, but vacated as the water level dropped and salinities increased in late spring and summer of 1995 and 1996. Pescadero Creek turtles probably regularly overwinter in the ditch, just as many Waddell Creek lagoon turtles use the adjacent pond for overwintering (Smith, Abel and Davis 1997).

Many of the turtles, especially in Pescadero Creek, were quite large, compared to those present at Waddell Creek (Smith, Abel and Davis 1997). Shell growth ridges of Pescadero Creek turtles indicated very fast growth; growth of those near East Delta Marsh was more like that of Waddell Creek.

Juvenile turtles (75-125 mm shell length) were frequently sighted, and were apparently common. Pond turtles prefer to nest in warmer, open grasslands with finer soils, and tend to avoid sandy soils or shady riparian or upland sites (Galen Rathbun, Biological Resources Division, U.S. Geological Survey, pers. comm.; Smith, Abel and Davis 1997). Potential upland nest sites appear plentiful and include open, south-facing levee banks and the cattle pasture east of Pescadero Creek.

EVALUATION OF RESTORATION EFFORTS AND MANAGEMENT RECOMMENDATIONS

Effects of Completed Restoration Efforts

Opening the levees between the 3 segments of the Butano Marsh has allowed easier flood water movement through the marshes (freshening them in winter and early spring) and easier tidal movement (making them more salty in late spring and summer). The marshes function more naturally now, but North and Middle Butano marshes apparently do not now provide habitat for red-legged frogs or for San Francisco garter snakes, which depend upon frogs for food.

The restoration of tidal action to North Pond, and the channel leading to it, has probably reduced the value of the habitat for tidewater goby in most years. Prior to restoration, gobies were common in both eutrophic North Pond and in the portion of North Marsh that lies west of the new low levee (Smith 1990). In 1995 when the more natural habitats were tidal no tidewater gobies were found. In 1996 tidewater gobies were rare in other portions of the lagoon system that were strongly tidal. In years of earlier sandbar formation gobies at Pescadero Marsh would be much more abundant and widespread in summer, including in North Pond. Prior to removal of the levee, North Pond was persistently too saline for use by breeding red-legged frogs, so the

restoration of tidal conditions did not adversely affect conditions for frogs.

The low levee between North Marsh and the channel to North Pond is too low (+4.7 feet) to prevent overflow, including of very saline water, after sandbar formation. To overcome this potential problem, the 6 large culverts at station B have been kept closed more often than originally intended. Incidents of overflow have also caused some erosion in the low points of the levee.

The sag ponds (S1-2), which were constructed in the southwest portion of North Marsh, have worked relatively well. They fill in winter from water in North Marsh and from seepage through the low levee from the channel to North Pond. In 1995 and 1996 they retained significant water later into the summer than most of the other marsh habitats, and were used by by red-legged frogs and San Francisco garter snakes. The western pond (S2) is deeper and usually had lower salinities than the eastern pond.

Management Recommendations

Recommendation 1. The low levee should be raised to +5.5 to 6.0 feet to prevent spills of saline water over the levee into North Marsh. The surface of the levee should be revegetated or otherwise protected against erosion when overtopped. The raised levee will store more water in North Marsh and delay drying of the marsh and will also allow the regular resumption of tidal flow to North Pond (with open culverts at station B).

Recommendation 2. The large culverts at Station B and at the north (C3) and south (C1) ends of the low levee should be regularly maintained so that they do not leak and can be opened and closed as needed.

Recommendation 3. The 2 small culverts at station B should be periodically checked to see that they are not clogged. The slide gates on the small culverts do not work. A slide gate should be installed and maintained on the culvert from station B to E1, so that it might be occasionally closed to regulate salinity or height of water in North Marsh.

Recommendation 4. Proposed future restoration actions include the opening of the levee at the upstream end of East Delta Marsh. This would increase flood flows through the marsh and might freshen the marsh in winter and early spring. However, the levee opening might also increase use of the marsh by bullfrogs, which in 1996 appeared to approach the marsh from the downstream opening (G2) from their apparent source upstream on Butano Creek. If the levee opening is at a high enough elevation so that a portion of flood flows, but not late spring and summer streamflows, passed through the break fewer bullfrogs might enter East Delta Marsh. The present inoperable tide gate at East Delta Marsh could be modified rather than removed. This might keep the marsh wetter and fresher longer in summer, and improve red-legged frog larval survival.

Recommendation 5. The Trout Ponds should be maintained as seasonal ponds and not converted to permanent freshwater habitats by heavy diversion of water from Pescadero Creek; permanent water would result in the establishment of a reproducing bullfrog population.

Recommendation 6. The water right on Pescadero Creek could be used to augment the water level of the Trout Ponds in spring and early summer of dry years, so that red-legged frogs could metamorphose before the pond dried. The diversion could also be used to augment and freshen the water in the south ditch (E1-3) of North Marsh in dry years.

Recommendation 7. Continue to monitor water quality and tidewater goby and red-legged frog populations, especially in years when the sandbar forms early and conditions are different from those observed in 1995-96. Water quality stations that should be monitored are: B, C1 or C3, C4, D3,5,6, E1-3, F1-2, G1- 2, H and S1-2. Monitoring of larval or juvenile frogs is probably most useful.

Recommendation 8. Movements of red-legged frogs and bullfrogs are not known, but are apparently important to the biology of both species. Red-legged frogs could be radio-tracked in late summer to see what habitats provide refuges when the marshes dry or become salty. Bullfrogs could be radio-tracked to determine seasonal movements and potential sources within the watershed.

Recommendation 9. San Francisco garter snake numbers and seasonal movements are not known. They could be trapped with drift fences and funnel traps, PIT tagged to identify individuals, and radio-tracked to determine movements and habitat use.

Recommendation 10. If bullfrogs become abundant at Pescadero Marsh a management plan to reduce them may be needed. Possible management actions might include periodically managing for salinity and water levels, like those seen in 1995 and 1996, and attempts to reduce bullfrog populations at major sources in the watershed.

ACKNOWLEDGMENTS

Sampling techniques and understanding of red-legged frog biology benefited greatly from discussions with Mark Jennings by phone or in chest waders, after dark, in North Marsh. Department of Parks and Recreation rangers David Augustine and Michael Grant assisted with access and historical information. Jae Abel directed the surveying of levee and staff gage elevations. The field work was assisted by an army of volunteers, especially Jae Abel, Caroline Davis, Diane Kodama, Kathy Korotaj, Pat Peterson, Dan Reis, Ruth Sundermeyer and Casey Yturralde. Other volunteers included: Jerry Abel, John Cruz, Robin Dakin, Tiffany Hernandez, Beth Morris, Melanie Nead, Fran Peters, the other Jerry Smith (Dawn's father), Mike Westphal, Ben Winkler and Jerry Welch.

LITERATURE CITED

Jennings, M. R. and M. P. Hayes. 1990. Status of the California Red-legged Frog Rana aurora draytonii in the Pescadero Marsh Natural Preserve. Report to the California Department of Parks and Recreation.

Smith, J. J. 1990. The effects of sandbar formation and inflow on aquatic habitat and fish utilization in Pescadero, San Gregorio, Waddell and Pomponio Creek estuary/lagoon systems. 21985-1989. Report to the California Department of Parks and Recreation.

Smith, J. J., J. Abel and Caroline Davis. 1997. Management plan for Waddell Creek Lagoon and surrounding habitats. Report to the California Department of Parks and Recreation.

Table 1. Mean salinity (PPT) in the upper 0.5 m (or mean upper 0.25 m / 0.5 m value) for stations in North Pond and North Marsh and associated channels north of Pescadero Creek. (on dates with * the sandbar was closed)

	Station										
Date	C1	C3	C4	E1	E3	F1	F2	F5	S1	S2	H
21Nov93				4.6			5.1				
7Jan94*	5.0/ 8.0			11.3			11.3				
9Mar94	23.6			6.6			8.5		8.3/ 8.6		
30May94*	2.1/ 3.6			4.4/ 5.6					7.0		
3Dec94	27.0			6.5/ 16.8			6.6				
22Jun95	18.4		4.4	22.6		4.4	4.6		4.7	3.6	
1Aug95	20.2		5.9	31.8		7.2	8.0		8.3	5.6	
2Sep95	16.0		6.7	34.2	dry	12.9	dry		10.0/ 11.0	7.8	dry
26Nov95*	4.2	5.9	3.4/ 4.5	2.1	2.1	5.0	5.0		4.1/ 4.5	4.8/ 7.1	2.0
20Dec95	5.9	5.6/ 5.0	3.9/ 4.5	4.0	1.8/ 7.1	4.1/ 4.4	4.0		3.8	4.4/ 6.9	1.6/ 3.1
28Jan96	5.1	4.9/ 6.4	3.3	3.1	2.0/ 6.7	3.6	3.4		3.2	3.2/ 3.6	0.3/ 1.8
24Feb96	2.9	2.8/ 3.2	2.5	2.3	1.4/ 5.2	2.7	2.4	2.3	2.5	2.2	0.3/ 2.2
15Mar96	3.3		2.5	2.1					2.3	2.0	
18May96	24.9			3.5	2.9/ 6.1		3.4	3.5			1.8/ 2.3
15Jun96		28.8	4.9	4.3		4.3	5.0		3.6	3.6	2.3
26Jul96	14.8/ 17.3	15.0		6.9	7.6	6.8	11.0		6.0	4.6	
31Aug96*	6.7		6.3	9.3				8.6	8.4	5.6	2.4

Table 1 (Continued)

Date	Station										
	C1	C3	C4	E1	E3	F1	F2	F5	S1	S2	H
17Sep96*	5.9/ 7.0	8.0		1.4		7.5	3.4		4.6/ 6.3	5.0/ 5.7	
11Oct96*	2.5/ 4.2	2.2/ 3.9	4.2/ 4.9	1.3	1.2	4.0			4.4	4.7/ 5.0	
8Dec96	14.0/ 17.2	7.8	3.0/ 3.4	2.4	1.9/ 5.7	2.6	2.3		2.4	2.1	

Table 2. Salinity (PPT) in the upper 0.5 m for stations in Pescadero Creek and in marshes of Butano Creek. (on dates with * the sandbar was closed)

Date	Station										
	B	P1	D1	D2	D3	S4	D5	D6	D8	G1	G2
2Sep95	16.0				9.4		1.6	5.3			
12Nov95*	2.7				3.3		2.7	2.3			
26Nov95*	1.9	0.8			1.9		2.0	1.8		1.9	2.1
10Dec95									2.3	3.5	
20Dec95	16.0	5.6			15.3		3.3	4.0	0.7	11.8	13.3
15Jan96	8.0	1.0			5.6		3.7	6.1	1.3		
19Jan96	0.8				0.6		2.2	0.7	0.4	2.9	0.6
24Feb96	2.4		2.6	2.4	0.3		1.5	0.1	0.1	5.6	0.8
25Mar96	3.1		6.6	5.4	0.9	0.4	2.3	0.8		2.4	
17May96	0.9									5.5	1.5
15Jun96	19.6				17.3	0.6	1.2	10.8	0.1	2.8	3.7
26Jul96	19.0	12.2			8.1		1.0	5.8	0.7	10.6	7.2
2Aug96	17.3	10.1			7.1			3.1		3.1	
31Aug96*	4.0	0.7			2.3	0.6	0.7	1.0	0.4	3.6	0.4
17Sep96*	1.0				2.3			1.8		3.5	2.2
8Dec96	12.0	9.9			6.1		0.7	0.5			6.0

FIGURE 1.

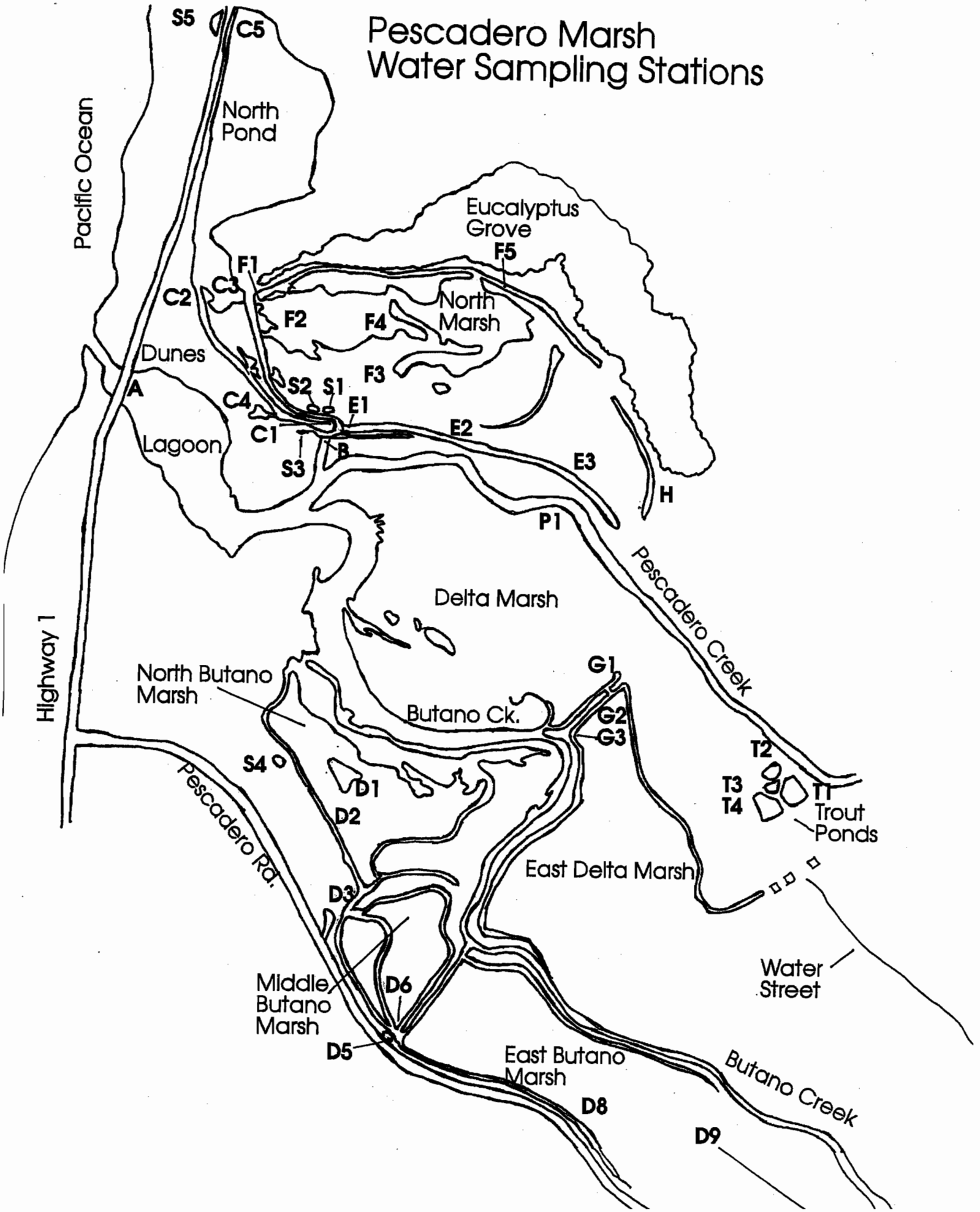
Pescadero Marsh
Water Sampling Stations
Pacific Ocean
Highway 1
North Pond
Eucalyptus Grove
North Marsh
Dunes
Lagoon
Delta Marsh
North Butano Marsh
Butano Ck.
Pescadero Creek
Pescadero Rd.
East Delta Marsh
Trout Ponds
Water Street
Middle Butano Marsh
East Butano Marsh
Butano Creek
S5
C5
F1
C3
C2
F2
F4
F5
F3
S2
S1
E1
C4
C1
E2
A
B
S3
E3
H
P1
G1
G2
G3
T2
T3
T4
T1
S4
D1
D2
D3
D6
D5
D8
D9

FIGURE 2 1996 Red-legged Frog Egg Mass Distribution In Pescadero Marsh

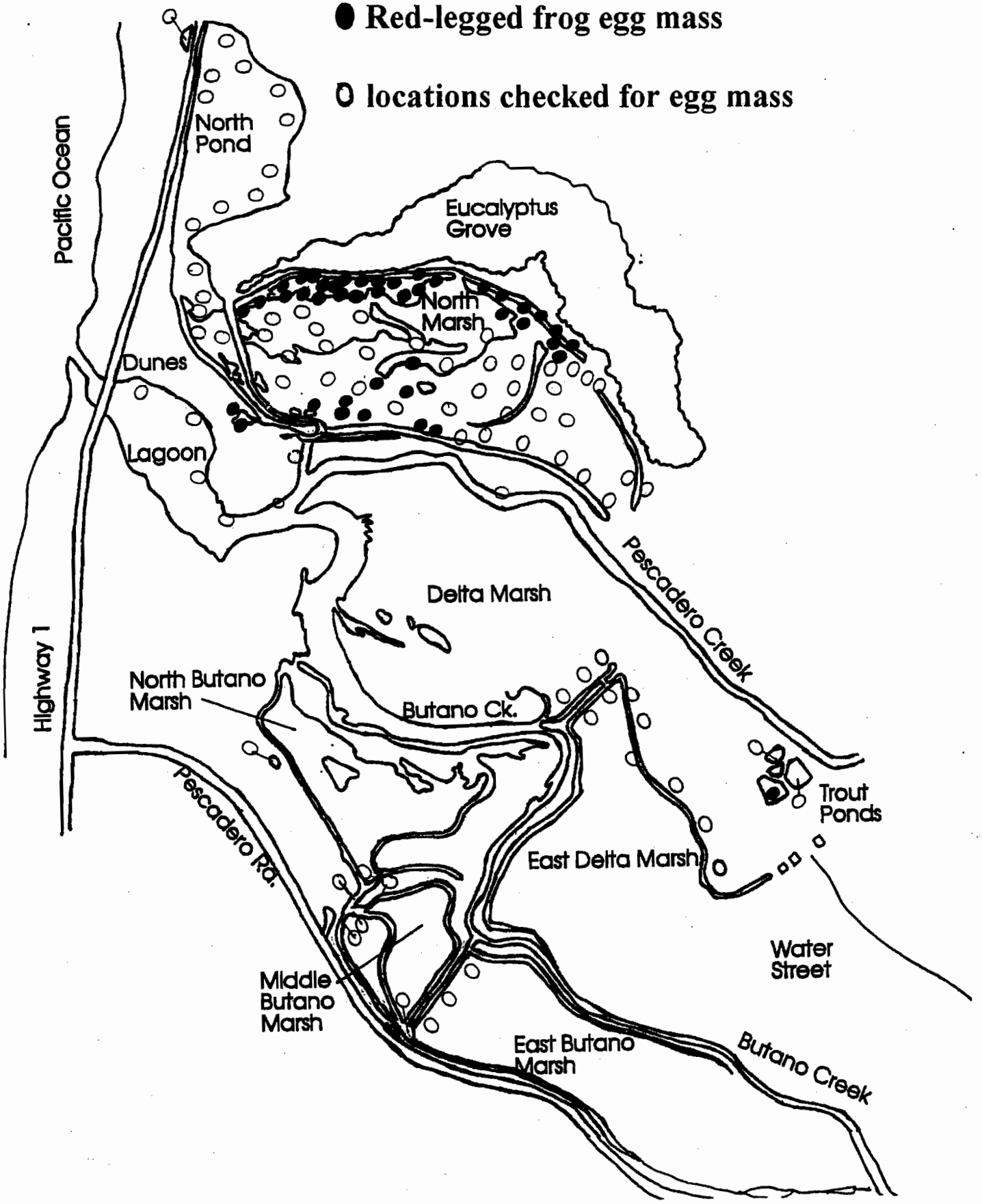

FIGURE 3 1996 Red-legged Frog Larvae Distribution In Pescadero Mars

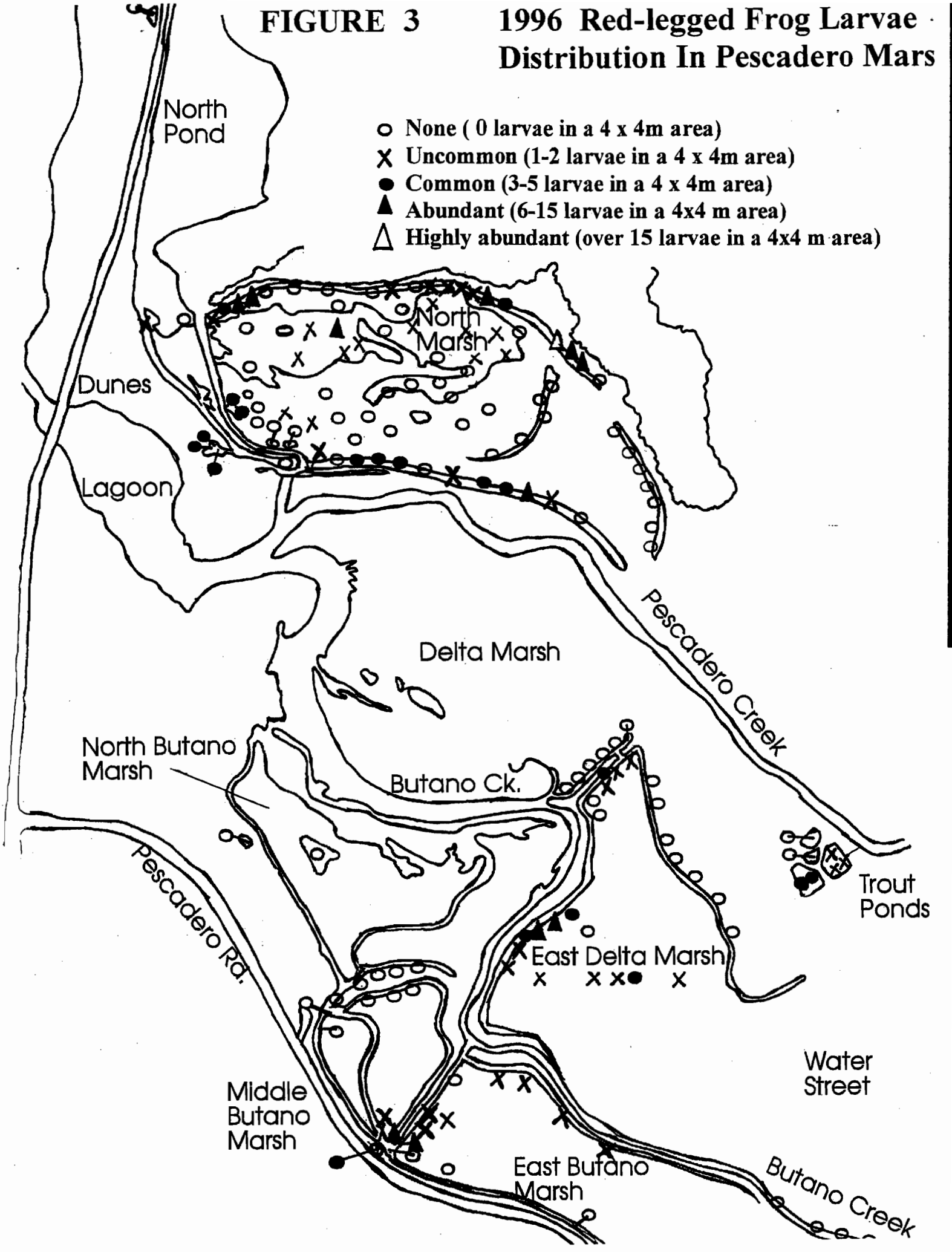

FIGURE 4 1996 Red-legged Frog Young Of The Year Distribution In Pescadero Marsh

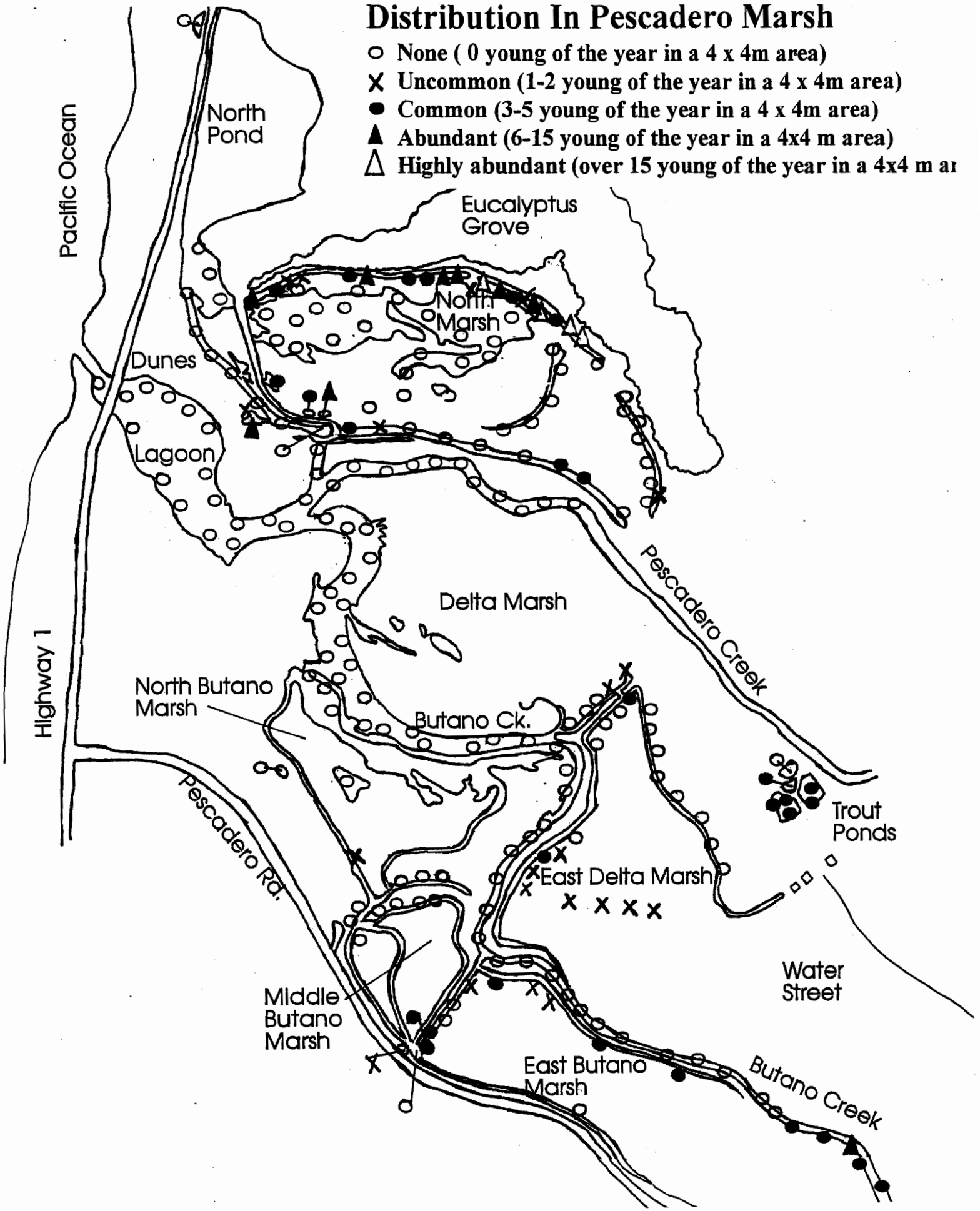

FIGURE 5A 1996 Adult Red-legged Frog Distribution In Pescadero Marsh

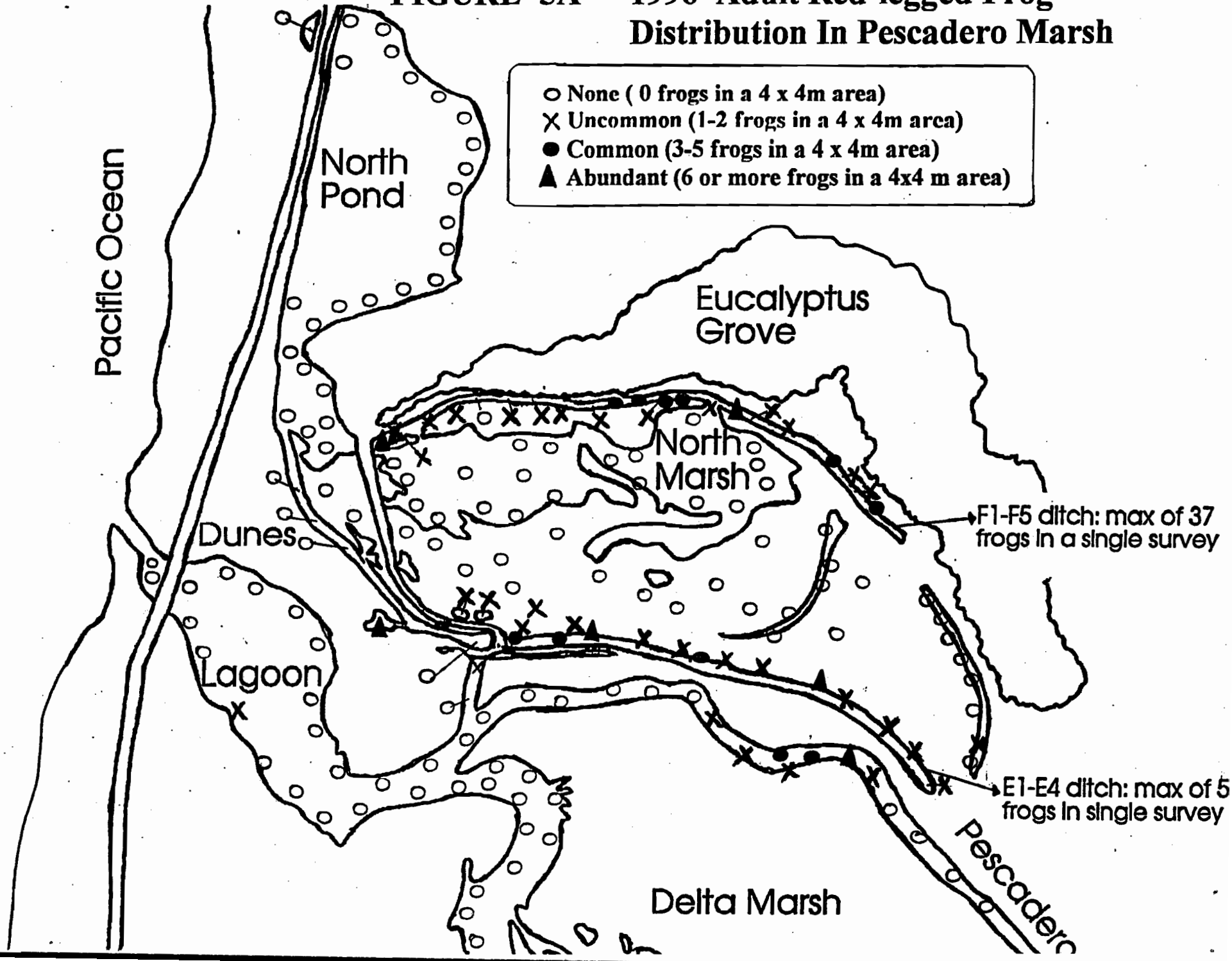

FIGURE 5B **1996 Adult Red-legged Frog Distribution In Pescadero Marsh**

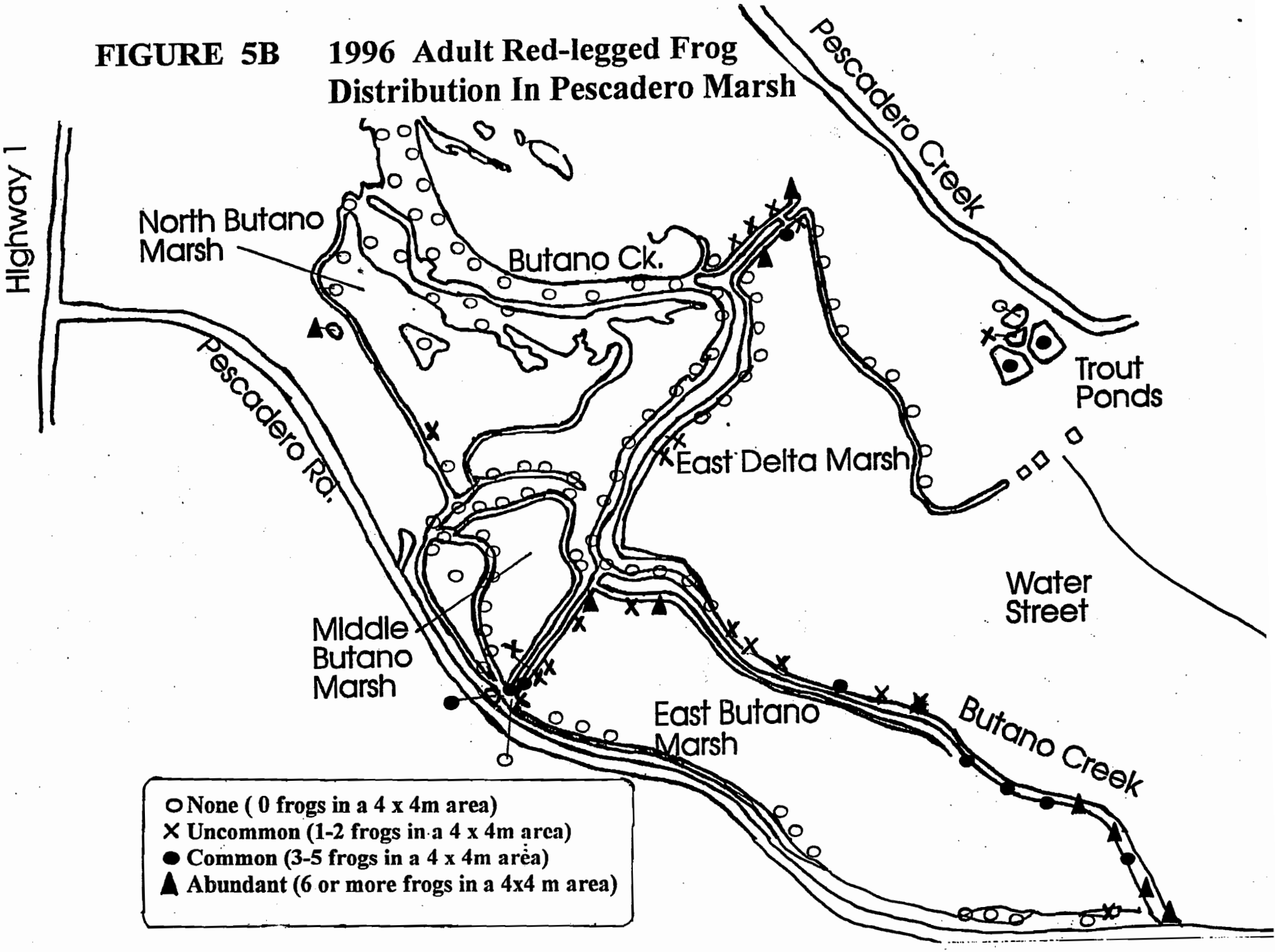

FIGURE 6 1996 Bullfrog Distribution In Pescadero Marsh

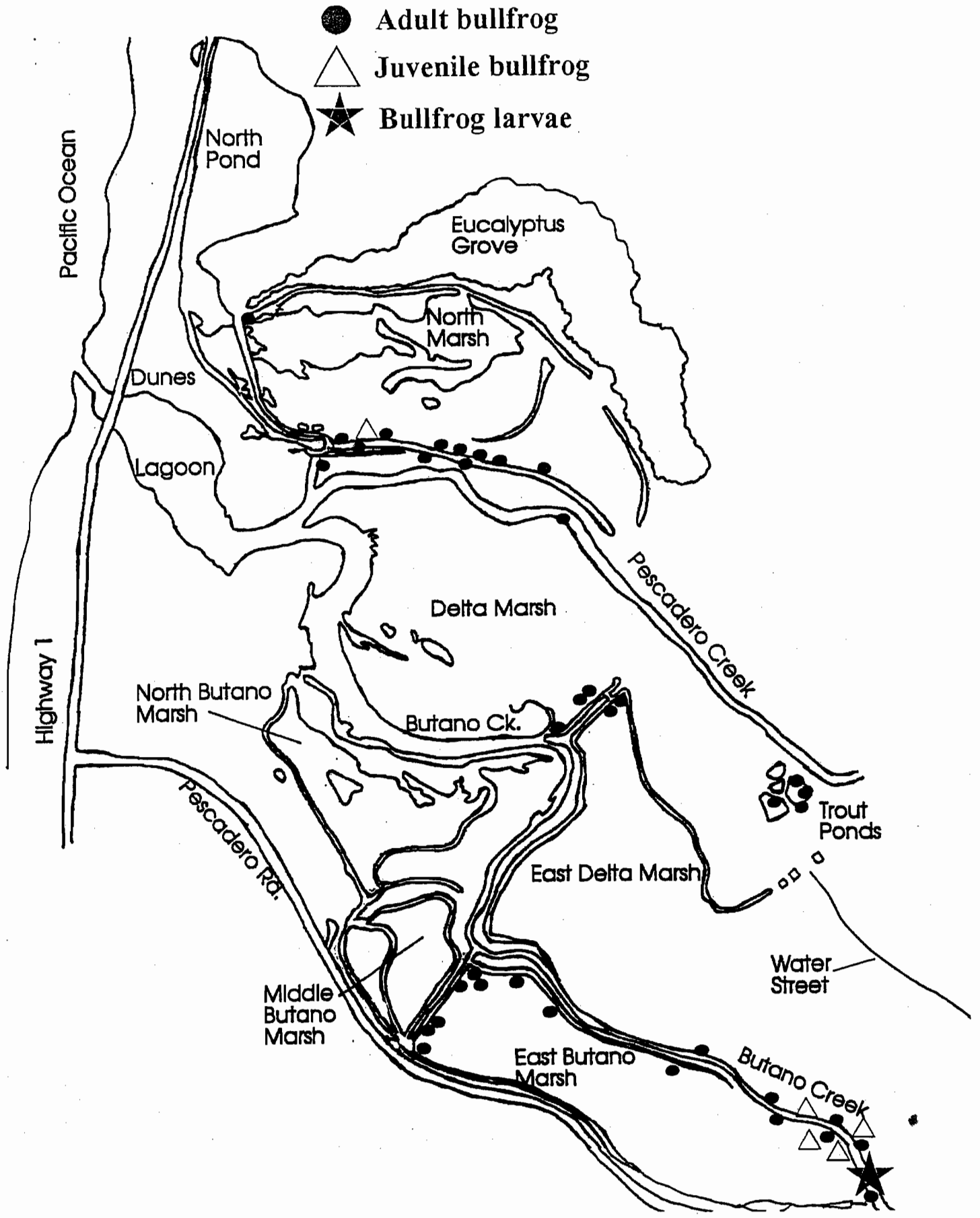

FIGURE 7 1996 Pacific Tree Frog Distribution In Pescadero Marsh