look more like delta smelt with much lighter body pigmentation and a broad silvery band on the side. This indicates that the wakasagi phenotype is also strongly influenced by the environmental conditions found in the estuary.

Conclusion

To achieve accurate fish identification the fish biologist must use all resources available. In this case the biologist had to work with the geneticist to verify identification, because morphological characteristics proved inadequate to separate these two closely related species. During this study we cooperated with researchers at the University of California, Davis for allozyme analysis (May 1996).

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A Comparison of Fall Stockton Ship Channel Dissolved Oxygen Levels in Years with Low, Moderate, and High Inflows

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Introduction

Since 1968, Bay-Delta and Monitoring Section staff and supporting IEP staff have measured dissolved oxygen levels in the Stockton Ship Channel in late summer and early fall. Dissolved oxygen is monitored to determine if placement of the Old River closure is necessary and to monitor conditions during and after placement. This article compares the monitoring results obtained during years with low (1994), moderate (1997), and high (1998) fall inflows into the channel to determine if high inflows significantly improve dissolved oxygen levels within the channel.

Dissolved oxygen monitoring was conducted twice a month by vessel (the *San Carlos*) from August through November of each year. During each of the monitoring runs, 14 sites were sampled from Prisoner's Point in the central Delta (Station 1) to the Stockton Turning Basin (Station 14) (Figure 1). Dissolved oxygen and water temperature data were collected for each site at the top and bottom of the water column during ebb slack tide using traditional discrete (Van Dorn sampler and Winkler titration) and continuous monitoring (Hydrolab model DS-3 multiparameter surveyor) instrumentation.

Typically, dissolved oxygen levels in the eastern Stockton Ship Channel drop below 6.0 mg/L during the late summer and early fall because of low San Joaquin River inflows, warm water temperatures, high BOD, reduced tidal circulation, intermittent reverse flow conditions, and other factors. These low dissolved oxygen levels have been known to cause physiological stress to fish and block upstream migration of salmon in the San Joaquin River. Despite the distinctly different inflows into the eastern channel during the fall of 1994, 1997, and 1998, these conditions persisted. A brief description of the findings for different inflow conditions of each year follows.

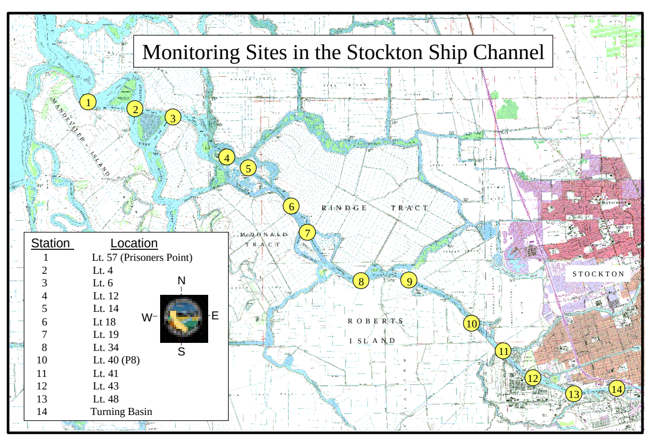

Figure 1 Dissolved oxygen monitoring sites in the Stockton Ship Channel

1994: A DRY YEAR WITH LOW FALL SAN JOAQUIN RIVER FLOWS

In 1994, average daily flows in the San Joaquin River past Vernalis approached 1,000 cfs in August and September and 1,300 cfs in October and November. Because of the low late summer and early fall San Joaquin River flows, the Old River closure was in place from September 7 through November 30. However, reverse flow conditions in the San Joaquin River past Stockton persisted throughout the late summer and early fall, as average net daily flows past Stockton ranged from –717 cfs to +168 cfs in August and September, and –308 to +301 cfs in October and November. These conditions apparently reduced any improvements attributable to placement of the closure.

Because of low inflows into the eastern channel, warm late summer water temperatures (24 to 28 °C), persistent reverse flow conditions past Stockton, and other factors, a dissolved oxygen sag (an area within the channel where levels were 5.0 mg/L or less) developed in the eastern channel in and immediately west of Rough and Ready Island (the Station 9 to 13 area) in August and persisted through early October (Figure 2). The lowest surface and bottom dissolved oxygen levels of 4.0 mg/L and 3.8 mg/L, respectively, were measured at the eastern end of Rough and Ready Island (Station 13) on August 22.

Cooler water temperatures in the channel on October 18 (16 to 19 °C) and November 18 (10 to 12 °C) and slightly improved flow conditions eliminated the sag area by October 18. Dissolved oxygen levels in the eastern channel fully recovered to levels similar to those in the western channel by November 15.

1997: A WET YEAR WITH MODERATE FALL SAN JOAQUIN RIVER FLOWS

In 1997, average daily flows in the San Joaquin River past Vernalis approached 2,000 cfs in August and September and exceeded 2,000 cfs in October and November. Because of the relatively high average daily flows, the Old River closure was not installed due to overtopping, bank erosion, and other concerns. In spite of the relatively high flows in the San Joaquin River, average daily net flows past Stockton ranged from –466 cfs to +198 cfs in August and September, and reverse flows were not eliminated until early October when flood control related reservoir releases within the drainage basin of the San Joaquin River were initiated.

Because of the relatively low inflows into the eastern channel, warm late summer and early fall water temperatures (22 to 27 °C), late summer and early fall reverse flow conditions past Stockton, and other factors, a dissolved oxygen sag also developed in the eastern channel in and immediately west of the Rough and Ready Island area (Stations 8 through 13) in August and persisted through early October (Figure 3). The lowest surface (3.1 mg/L) and bottom (2.6 mg/L) levels were measured at Buckley Cove (Station 10) on October 1, 1997.

Cooler water temperatures in the channel on October 15 (17 to 19 °C) and in November (14 to 18 °C), improved fall flow conditions in the San Joaquin River (the average daily flows past Vernalis briefly exceeded 3,000 cfs in mid-October). The elimination of reverse flow conditions past Stockton on October 10 displaced the sag area westward on October 15 and gradually eliminated it in November. The lack of late fall rain in the San Joaquin River drainage basin delayed the full recovery of dissolved oxygen levels in the eastern channel to those historically measured in the western channel during November in previous years.

1998: A WET YEAR WITH HIGH FALL SAN JOAQUIN RIVER FLOWS

In 1998, average daily flows in the San Joaquin River past Vernalis ranged from 4,753 to 6,708 cfs from August through October and average daily flows past Vernalis ranged from 1,020 to 2,011 cfs due to the exceptionally wet winter of 1997–1998 and the following cool, wet spring. Because of the exceptionally high flows and the absence of reverse flow conditions past Stockton, a closure across the mouth of Old River was not constructed in fall 1998.

In spite of exceptionally high San Joaquin River inflows into the eastern Stockton Ship Channel, a dissolved oxygen depression occurred in the central channel from Columbia Cut (Station 5) to Fourteen Mile Slough (Station 9) in August and early September (Figure 4). This area of depression is considerably west of the Rough and Ready Island area in the eastern channel where the sag area has historically occurred.

Relatively warm late summer water temperatures measured within the channel in August and early September (22 to 26 °C) appear to have contributed to the establishment of the dissolved oxygen depression in the channel in the late summer of 1998. However, at the range of water temperature values experienced in the late summer of 1998, dissolved oxygen levels have been lower (less than 5.0 mg/L) in the eastern channel in previous years.

The high San Joaquin River inflows into the eastern channel immediately east of Rough and Ready Island appear to have been sufficient to push the area of depressed dissolved oxygen levels westward from the historical sag area in the eastern channel to the central portion of the channel. Tidal fluctuations and greater water column mixing within the central portion of the channel may have contributed to the improved dissolved oxygen levels.

By September 18, 1998, the late summer dissolved oxygen depression in the channel was eliminated and by October 20, 1998, full recovery of dissolved oxygen levels to greater than 8.0 mg/L was accomplished throughout the channel due to cooler water temperatures (15 to 18 °C in October) and sustained high San Joaquin River inflows into the channel.

CONCLUSIONS

From August through October of 1998, average daily San Joaquin River flows past Vernalis (approximately 6,000 cfs) were six times the flows past Vernalis during the same period in 1994, and three times the flow past Vernalis during the same period in 1997. The significantly higher flows in 1998 did eliminate the dissolved oxygen sag normally present in the eastern channel. However, a dissolved oxygen depression developed within the Stockton Ship Channel in August and early September, when water temperatures were warmest, in spite of the significantly higher flows in 1998. Thus, the 1998 flow conditions apparently contributed to only partial improvement in late summer dissolved oxygen conditions within the channel.

Based on the 1998 dissolved oxygen monitoring results, placement of the closure at the head of Old River may produce marginal results in years with low to moderate fall San Joaquin River inflows. At no time during years with low to average fall flows in the San Joaquin River (such as 1994 and 1997, respectively) would placement of the Old River closure have improved flows sufficiently to duplicate the flow conditions and partial improvement on channel dissolved oxygen levels achieved in fall 1998.

POSTSCRIPT: THE STOCKTON TURNING BASIN IN 1994, 1997, AND 1998

Exceptionally high surface and low bottom dissolved oxygen levels were periodically measured in the Stockton Turning Basin throughout the fall in 1994, 1997, and 1998. During these periods, surface dissolved oxygen levels ranged from 9.6 to 15.4 mg/L and bottom dissolved oxygen levels ranged from 1.5 to 5.6 mg/L. Occasionally, the distinct dissolved oxygen stratification subsided, and surface and bottom dissolved oxygen levels became similar (within 2 to 3 mg/L of each other). These results are typical of all years.

The highly stratified dissolved oxygen conditions periodically detected in the basin during the late summer and early fall of each year appear to be the result of localized biological and water quality conditions occurring in the basin. The basin is at the eastern dead-end terminus of the channel and is subject to reduced tidal activity, restricted water circulation, and increased residence times when compared to the remainder of the channel. As a result, water quality and biological conditions within the basin have historically differed from those within the main channel downstream, and have led to extensive late summer and fall algal blooms and dieoffs. Usually a series of intense algal blooms composed primarily of cryto-monads, diatoms, flagellates, and blue-green and green algae are detected. Stratified dissolved oxygen conditions appear to be produced in the water column of the basin by blooms in the following manner: (1) high algal productivity at the surface of the basin produces elevated surface dissolved oxygen levels and (2) dead or dying bloom algae settle out of the water column and sink to the bottom to contribute to high BOD. Bottom dissolved oxygen levels in the basin are further degraded by additional BOD loadings in the area such as regulated discharges into the San Joaquin River and from recreational activities adjacent to the basin. When bloom activity subsides, the dissolved oxygen stratification is reduced, and basin surface and bottom dissolved oxygen levels become less diverse.

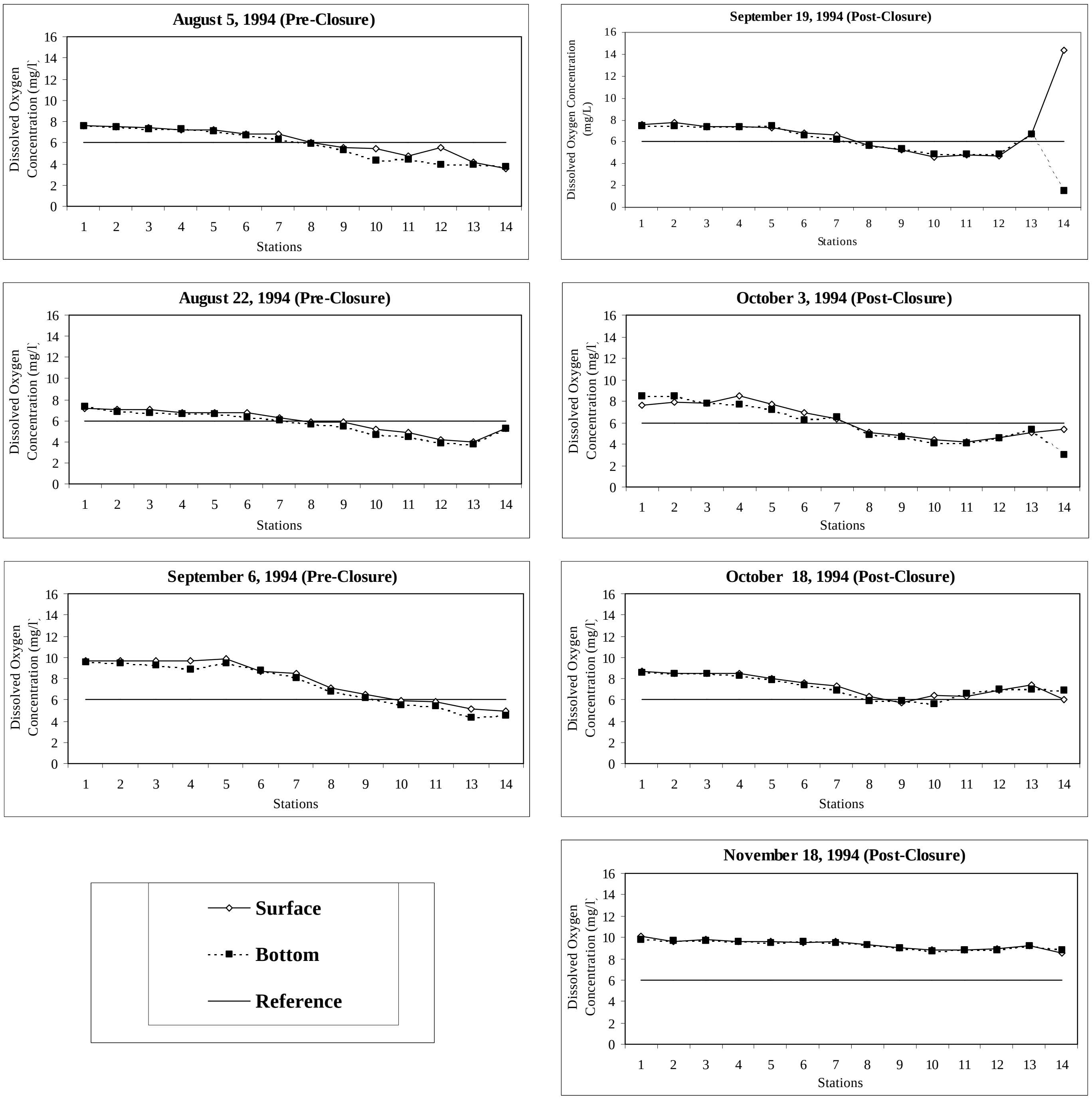

Figure 2 Dissolved oxygen concentrations in the Stockton Ship Channel in 1994

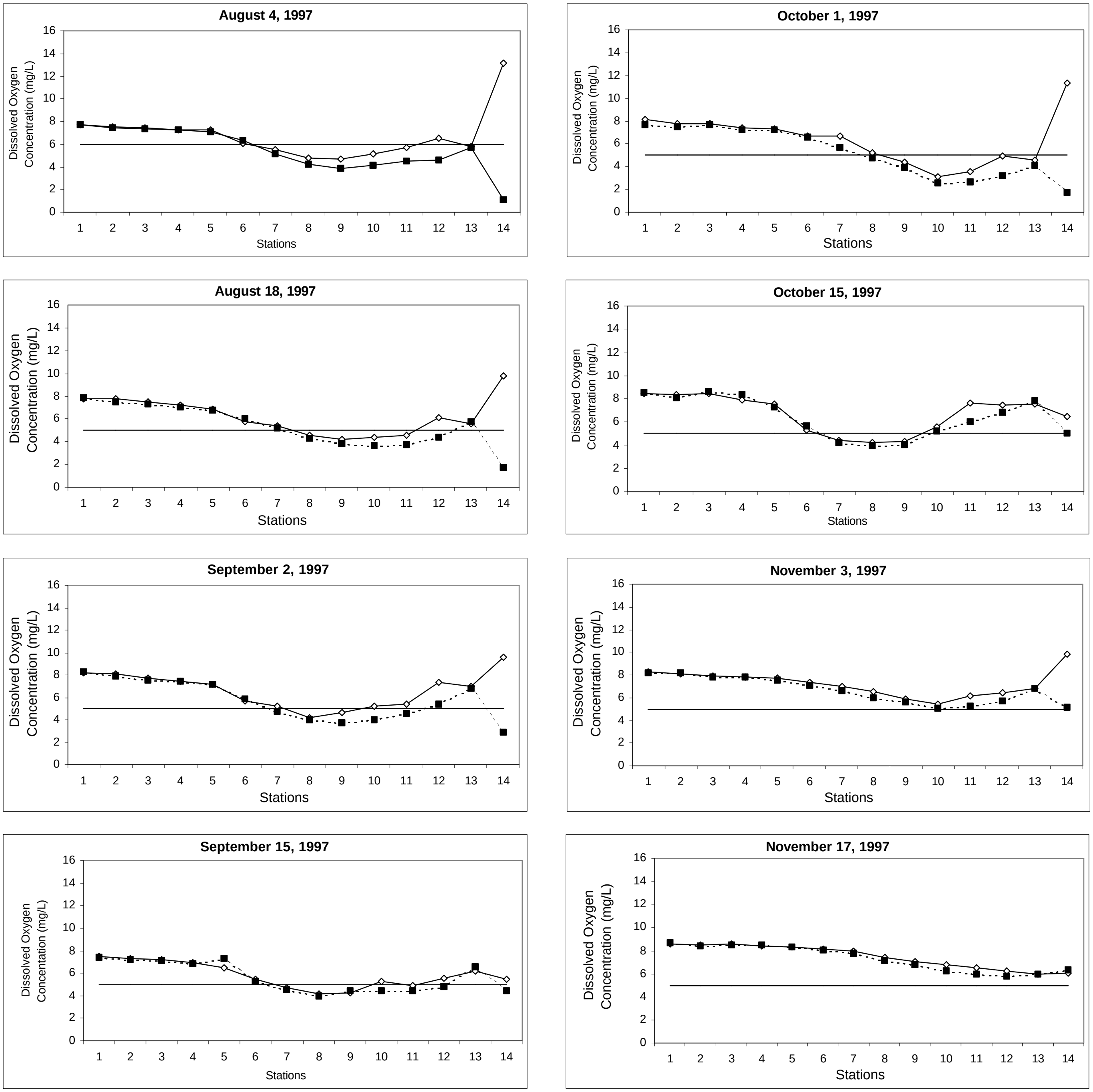

Figure 3 Dissolved oxygen concentrations in the Stockton Ship Channel in 1997

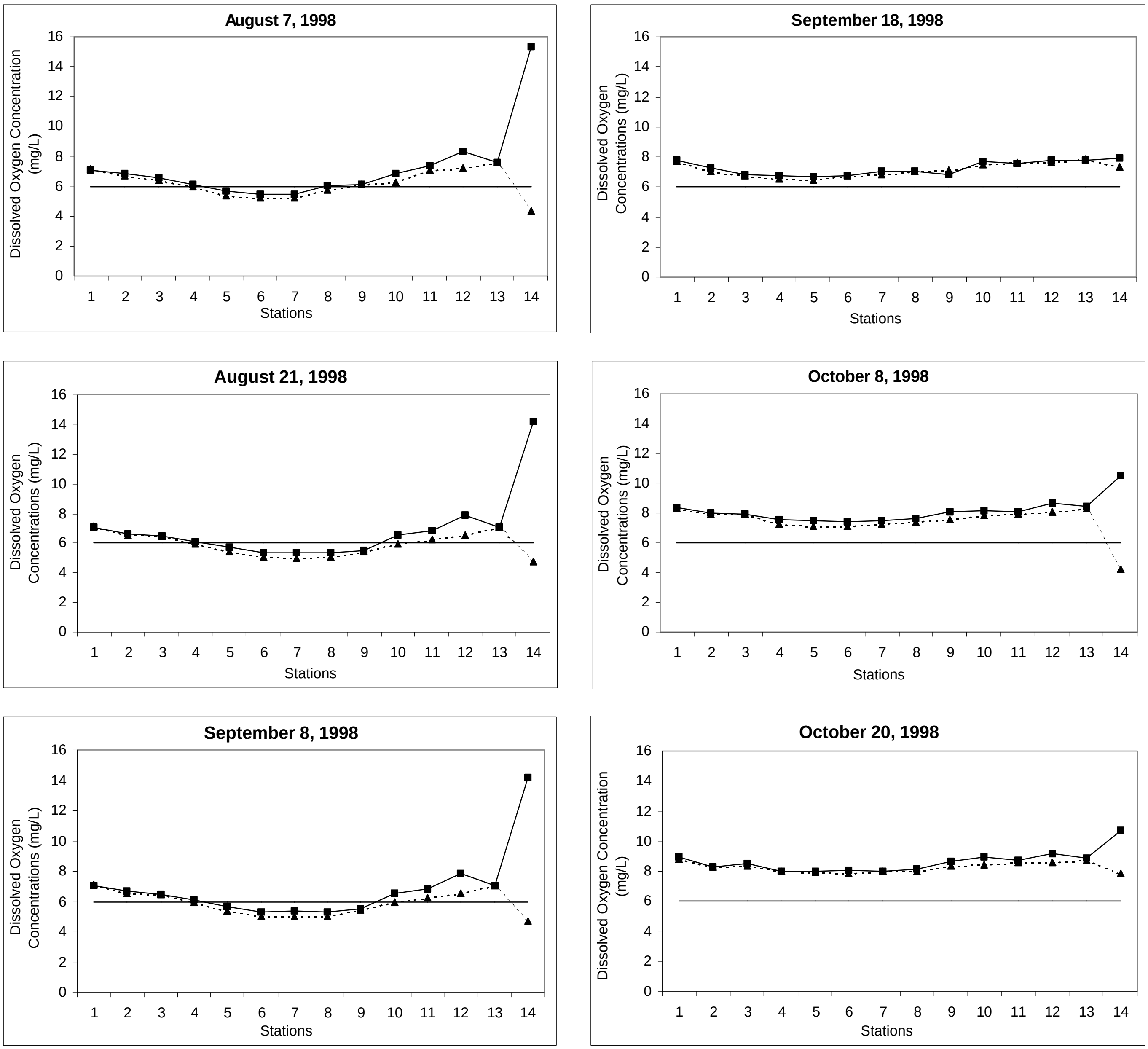

Figure 4 Dissolved oxygen concentrations in the Stockton Ship Channel in 1998