BIB

Special Studies for Sand Mining Discharges of the Tidewater Sand and Gravel Company

December 8, 1993

MEC ANALYTICAL SYSTEMS, INC.

Special Studies for Sand Mining Discharges of the Tidewater Sand and Gravel Company

Agenda for Discussion on December 8, 1993

EFFLUENT QUALITY

METHODS

- The effluent discharge was sampled monthly and was characterized for toxic constituents. The survey dates were as follows:
  - Survey 1- 2 June 1993
  - Survey 2- 30 June and 1 July 1993
  - Survey 3- 19 and 20 August 1993
  - Survey 4- 3 September 1993 (bioassay only)

- Sampling took place at two areas:
  - Presidio Shoal
  - Point Knox Shoal

- All samples were split and were analyzed as whole effluent (unfiltered) and filtered subsamples.

- (4 surveys x 2 areas x 2 subsamples)

Bioassay Test Methods

- The 48 hour critical lifestage bioassay was conducted using the Pacific oyster (*Crassostrea gigas*).

- Criteria used to determine test acceptability were the following:
  - Survival in control must be at least 70%.
  - Abnormal development in the control must be less than 10%.

Chemical Analyses

- Filtered and unfiltered effluent samples were analyzed for the following parameters:
  - Total suspended solids
  - Metals
  - Arsenic
  - Total organic carbon
  - Total sulfides
  - Ammonia
  - Polynuclear aromatic hydrocarbons (PAHs)

RESULTS

- Bioassay effluent test results are summarized in Table 1-1, and results of chemical analyses are presented in Tables 1-2 through 1-4.

Survey 1

Bioassay Tests

- Test controls did not meet passing criteria of at least 70% survival.

Chemical Analyses

- Total PAHs were low in unfiltered samples and not detected in filtered samples.
- In unfiltered samples, concentrations of arsenic, copper, chromium, mercury, lead, nickel, and zinc exceeded water quality objectives (WQO) for municipal waters; concentrations were reduced to values below WQO after filtering.
- Total ammonia was detected in all samples. Values were within water quality criteria.

Survey 2

Bioassay Tests

- Toxicity was observed in both the unfiltered and filtered effluent from Presidio Shoal and Point Knox Shoal (LC25 < 6.25%). *Note that for this survey, the results may have been biased toward toxicity. Test organisms were more sensitive to the reference toxicant, and test results were only narrowly statistically significant compared to control values.
- Effluent concentrations of 100% failed to produce any sublethal effects for samples taken at either station (IC25 > 100%).

Chemical Analyses

- Total PAHs were very low in the unfiltered samples, and not detected in filtered samples from Presidio Shoal.
- Metal concentrations were less than the WQO for all values.
- Total sulfides and total organic carbon were not detected.
- Total ammonia was detected in all samples. Values were within water quality criteria.

Survey 3

Bioassay Tests

- Toxicity (LC25) was not observed in either the filtered or unfiltered samples from either area.
- No sublethal effects were displayed.

Chemical Analyses

- Total PAHs were very low or not detected.
- In the unfiltered Presidio Shoal sample, arsenic exceeded the WQO. Ammonia levels were slightly higher in this sample as well.
- Filtering reduced metal concentrations, as in Surveys 1 and 2.

Survey 4

Bioassay Tests

- No statistically significant toxicity was observed in any sample.
- No sublethal effects were observed in any sample.

Chemical Analyses

- No chemical analyses were performed for this survey.

CONCLUSIONS

- Toxicity was displayed for effluent samples in Survey 2, although results may have been biased toward toxicity. Chemistry data from Survey 2 did not indicate a causal relationship between measured contaminant concentrations and effluent toxicity.
- Sublethal effects did not occur in any sample.
- Concentrations of PAHs were either not detected or extremely low for all samples.
- Moderate concentrations of most metals were detected in unfiltered samples; however, concentrations were greatly reduced with filtration, indicating that these constituents were probably not bioavailable.
- Low levels of ammonia were detected in most samples. Values were within U.S. EPA water quality criteria.

Table 1-1. Summary of Results for Bioassay Effluent Tests for *Crassostrea gigas* (bivalve larvae).

Sample Collection June 30 - July 1, 1993 (Survey 2) / Testing July 1 - 3, 1993

Concentration (%)	Mean Total Larvae/mL	% Treatment Mortality	LCp (%)		% Abnormal	ICp (%)		NOEC (%)	TUc
Control	30.6	NA			2.0				
PS Unfiltered									
6.25	19.1*	37.6	**LC50**	59.9 (48.0 - 76.4)	18.8*	**IC50**	>100	< 6.25	> 16.0
12.5	21.7*	29.1	**LC40**	39.9 (31.7 - 49.2)	10.9	**IC40**	>100		
25	23.1*	24.5	**LC25**	< 6.25	17.8*	**IC25**	>100		
50	16.1*	47.4	**LC15**	< 6.25	8.1	**IC15**	>100		
100	11.8*	61.4	**LC10**	< 6.25	14.3	**IC10**	< 6.25		
Concentration (%)	**Mean Total Larvae/mL**	**% Treatment Mortality**	**LCp (%)**		**% Abnormal**	**ICp (%)**		**NOEC (%)**	**TUc**
PS Filtered									
6.25	16.7*	45.4	**LC50**	>100	2.8	**IC50**	>100	< 6.25	> 16.0
12.5	20.5*	33.0	**LC40**	>100	1.6	**IC40**	>100		
25	22.7*	25.8	**LC25**	< 6.25	0.9	**IC25**	>100		
50	19.9*	35.0	**LC15**	< 6.25	3.2	**IC15**	>100		
100	19.7*	35.6	**LC10**	< 6.25	3.7	**IC10**	>100		
Concentration (%)	**Mean Total Larvae/mL**	**% Treatment Mortality**	**LCp (%)**		**% Abnormal**	**ICp (%)**		**NOEC (%)**	**TUc**
PK Unfiltered									
6.25	24.0*	21.6	**LC50**	33.8 (24.9 - 48.9)	7.3*	**IC50**	>100	< 6.25	>16.0
12.5	17.7*	42.2	**LC40**	16.9 (11.3 - 23.1)	7.6*	**IC40**	>100		
25	15.8*	48.4	**LC25**	< 6.25	8.8*	**IC25**	>100		
50	14.1*	53.9	**LC15**	< 6.25	9.8*	**IC15**	>100		
100	11.0*	64.1	**LC10**	< 6.25	9.9*	**IC10**	>100		
Concentration (%)	**Mean Total Larvae/mL**	**% Treatment Mortality**	**LCp (%)**		**% Abnormal**	**ICp (%)**		**NOEC (%)**	**TUc**
PK Filtered									
6.25	19.9 *	35.0	**LC50**	>100	5.0 *	**IC50**	>100	< 6.25	>16.0
12.5	21.3 *	30.4	**LC40**	>100	3.1	**IC40**	>100		
25	20.6 *	32.7	**LC25**	< 6.25	4.8 *	**IC25**	>100		
50	20.5 *	33.0	**LC15**	< 6.25	16.0 *	**IC15**	>100		
100	25.8 *	15.7	**LC10**	< 6.25	15.4 *	**IC10**	41.0 (37.0 - 66.2)		

PS: Presidio Shoal
PK: Point Knox Shoal
* Statistically significant.
LC/ICp: Lethal/Inhibition Concentration for p% of the organisms.
NOEC: No Observable Effect Concentration.
TUc: 100%/LC-IC25.
( ): 95% Confidence Limits.

Table 1-1. Continued.

Sample Collection August 19 - 20, 1993 (Survey 3) / Testing August 20 - 22, 1993

Concentration (%)	Mean Total Larvae/mL	% Treatment Mortality	LCp (%)		% Abnormal	ICp (%)		NOEC-a (%)	TUc
Control	18.3	NA			5.0				
PS Unfiltered									
6.25	20.0	0.0	LC50	>100	5.4	IC50	>100	25/100	<1.0
12.5	19.7	0.0	LC40	>100	5.4	IC40	>100		
25	20.6	0.0	LC25	>100	6.0	IC25	>100		
50	19.5	0.0	LC15	>100	9.9*	IC15	>100		
100	16.9	7.7	LC10	84.6	7.6	IC10	>100		

Concentration (%)	Mean Total Larvae/mL	% Treatment Mortality	LCp (%)		% Abnormal	ICp (%)		NOEC (%)	TUc
PS Filtered									
6.25	20.3	0.0	LC50	>100	4.1	IC50	>100	100	<1.0
12.5	18.5	0.0	LC40	>100	1.3	IC40	>100		
25	18.9	0.0	LC25	>100	1.0	IC25	>100		
50	20.5	0.0	LC15	>100	3.4	IC15	>100		
100	20.1	0.0	LC10	>100	2.0	IC10	>100		

Concentration (%)	Mean Total Larvae/mL	% Treatment Mortality	LCp (%)		% Abnormal	ICp (%)		NOEC (%)	TUc
PK Unfiltered									
6.25	26.5	0.0	LC50	>100	2.5	IC50	>100	100	<1.0
12.5	30.1	0.0	LC40	>100	4.2	IC40	>100		
25	19.0	0.0	LC25	>100	1.8	IC25	>100		
50	21.6	0.0	LC15	24.9	2.0	IC15	>100		
100	22.9	0.0	LC10	20.8	4.8	IC10	>100		

Concentration (%)	Mean Total Larvae/mL	% Treatment Mortality	LCp (%)		% Abnormal	ICp (%)		NOEC (%)	TUc
PK Filtered									
6.25	18.9	0.0	LC50	>100	3.5	IC50	>100	100	<1.0
12.5	16.8	8.2	LC40	>100	4.3	IC40	>100		
25	16.6	9.3	LC25	>100	3.3	IC25	>100		
50	19.7	0.0	LC15	>100	3.6	IC15	>100		
100	16.9	7.7	LC10	>100	2.8	IC10	>100		

PS: Presidio Shoal
PK: Point Knox Shoal
* Statistically significant.
LC/ICp: Lethal/Inhibition Concentration for p% of the organisms.
NOEC: No Observable Effect Concentration.
TUc: 100%/LC-IC25.
-a: Based on an intermittent dose response.

Table 1-1. Continued.

Sample Collection September 3, 1993 (Survey 4) / Testing September 3 - 5, 1993

Concentration (%)	Mean Total Larvae/mL	% Treatment Mortality	LCp (%)	% Abnormal	ICp (%)	NOEC (%)	TUc
Control	41.2	NA		7.0			
PS Unfiltered							
6.25	49.8	0.0	**LC50** >100	5.1	**IC50** >100	100	1.2
12.5	46.3	0.0	**LC40** >100	12.8	**IC40** >100		
25	45.5	0.0	**LC25** 86.9	11.7	**IC25** >100		
50	44.7	0.0	**LC15** 70.6 (54.1 - 86.5)	12.4	**IC15** >100		
100	30.7	25.5	**LC10** 62.4 (11.4 - 74.3)	9.0	**IC10** >100		

Concentration (%)	Mean Total Larvae/mL	% Treatment Mortality	LCp (%)	% Abnormal	ICp (%)	NOEC (%)	TUc
PS Filtered							
6.25	38.3	7.0	**LC50** >100	1.9	**IC50** >100	100	<1.0
12.5	35.1	14.8	**LC40** >100	2.1	**IC40** >100		
25	38.5	6.6	**LC25** >100	3.4	**IC25** >100		
50	40.5	1.7	**LC15** >100	1.7	**IC15** >100		
100	41.5	0.0	**LC10** >100	4.5	**IC10** >100		

Concentration (%)	Mean Total Larvae/mL	% Treatment Mortality	LCp (%)	% Abnormal	ICp (%)	NOEC (%)	TUc
PK Unfiltered							
6.25	33.5	18.7	**LC50** >100	4.4	**IC50** >100	100	<1.0
12.5	37.9	8.0	**LC40** >100	6.7	**IC40** >100		
25	37.3	9.5	**LC25** >100	4.4	**IC25** >100		
50	35.1	14.8	**LC15** >100	4.1	**IC15** >100		
100	40.9	0.7	**LC10** < 6.25	5.4	**IC10** >100		

Concentration (%)	Mean Total Larvae/mL	% Treatment Mortality	LCp (%)	% Abnormal	ICp (%)	NOEC (%)	TUc
PK Filtered							
6.25	49.3	0.0	**LC50** >100	6.2	**IC50** >100	100	<1.0
12.5	49.9	0.0	**LC40** >100	10.7	**IC40** >100		
25	57.1	0.0	**LC25** >100	9.2	**IC25** >100		
50	57.1	0.0	**LC15** 99.0	9.1	**IC15** >100		
100	43.1	0.0	**LC10** 82.7	6.3	**IC10** >100		

PS: Presidio Shoal
PK: Point Knox Shoal
* Statistically significant.
LC/ICp: Lethal/Inhibition Concentration for p% of the organisms.
NOEC: No Observable Effect Concentration.
TUc: 100%/LC-IC25.
( ): 95% Confidence Limits

Table 1-2. Effluent Concentrations of Ammonia, Total Suspended Solids, Total Sulfides, and Total Organic Carbon. Values are mg/L (ppm).

	Presidio Shoal		Point Knox Shoal		MRL	EPA Method
	Unfiltered	Filtered	Unfiltered	Filtered		
Survey 1 (June 2)						
Ammonia	0.67	0.57	0.20	0.18	0.05	350.3
Total Suspended Solids	10,800	ND	484	ND	5	160.2
Total Sulfides	0.12	ND	ND	ND	0.05	9030
Total Organic Carbon	110	1.5	1.0	ND	0.5	415.1
Survey 2 (June 30 - July 1)						
Ammonia	0.30	0.29	0.17	NS	0.05	350.3
Total Suspended Solids	541	27	173	NS	5	160.2
Total Sulfides	ND	ND	ND	NS	0.05	9030
Total Organic Carbon	<1.0*	<0.5	1.5	NS	0.5	415.1
Survey 3 (August 19 - 20)						
Ammonia	1.63	1.33	0.17	0.22	0.05	350.3
Total Suspended Solids	1,350	ND	493	5	5	160.2
Total Sulfides	0.11	ND	ND	ND	0.05	9030
Total Organic Carbon	1.2	1.1	0.8	1.2	0.5	415.1

NS = not sampled
ND = not detected
*Detection Limit Elevated Due to Matrix Interference

Table 1-3. Effluent Concentrations of Priority Pollutant Metals. Values are µg/L (ppb).

	Presidio Shoal		Point Knox Shoal		MRL	EPA Method
	Unfiltered	Filtered	Unfiltered	Filtered		
Survey 1 (June 2)						
Arsenic	121	2.7	6.4	1.5	5	200.8M
Cadmium	3.2	0.04	0.35	0.07	0.2	200.8M
Chromium	127	0.2	13.5	0.4	2	200.8M
Copper	232	0.5	21.8	0.9	1	200.8M
Lead	214	0.23	23.2	0.18	0.2	200.8M
Mercury	2.9	ND	0.1	ND	0.1	7470
Nickel	250	1.6	20.2	1.6	2	200.8M
Selenium	6	0.6	0.7	0.7	4	200.8M
Silver	ND	ND	0.11	ND	0.5	200.8M
Zinc	593	9	66	5	10	200.8M
Survey 2 (June 30 - July 1)						
Arsenic	12.1	1.7	2.9	NS	5	200.8M
Cadmium	0.23	0.18	0.16	NS	0.2	200.8M
Chromuim	14.1	0.2	5.6	NS	2	200.8M
Copper	20.2	1.7	5.6	NS	1	200.8M
Lead	16.4	0.41	2.42	NS	0.2	200.8M
Mercury	0.2	ND	ND	NS	0.1	7470
Nickel	19.2	4.9	6.7	NS	2	200.8M
Selenium	ND	ND	ND	NS	4	200.8M
Silver	0.11	ND	0.02	NS	0.5	200.8M
Zinc	36	7	10	NS	10	200.8M
Survey 3 (August 19 - 20)						
Arsenic	77.3	4.1	2.0	1.7	0.5	200.8M
Cadmium	0.43	0.05	0.53	0.12	0.02	200.8M
Chromium	25.8	0.2	0.4	0.6	0.2	200.8M
Copper	32.5	0.6	1.8	1.1	0.1	200.8M
Lead	43.8	0.25	0.75	0.31	0.02	200.8M
Mercury	0.4	0.6	0.2	ND	0.1	7470
Nickel	35.0	1.1	1.2	1.7	0.2	200.8M
Selenium	<1	0.6	ND	ND	0.5	200.8M
Silver	0.15	ND	ND	ND	0.02	200.8M
Zinc	51	9	14	17	1	200.8M

NS = not sampled
ND = not detected

Table 1-4. Effluent Concentrations of Polynuclear Aromatic Hydrocarbons. Values are µg/L (ppb). EPA Method 3510 in Combination with GC/MS SIM Method.

	Presidio Shoal		Point Knox Shoal		MRL
	Unfiltered	Filtered	Unfiltered	Filtered	
SURVEY 1 (June 2)					
Naphthalene	ND	ND	ND	ND	0.1
2-Methylnaphthalene	ND	ND	ND	ND	0.1
Acenaphthylene	ND	ND	ND	ND	0.1
Dibenzofuran	ND	ND	ND	ND	0.1
Acenaphthene	ND	ND	ND	ND	0.1
Fluorene	ND	ND	ND	ND	0.1
Phenanthrene	0.4	ND	0.1	ND	0.1
Anthracene	ND	ND	ND	ND	0.1
Fluoranthene	0.5	ND	0.2	ND	0.1
Pyrene	0.5	ND	0.3	ND	0.1
Benz(a)anthracene	0.2	ND	ND	ND	0.1
Chrysene	0.2	ND	0.1	ND	0.1
Benzo(b+k)fluoranthene	0.4	ND	0.3	ND	0.1
Benzo(a)pyrene	0.3	ND	0.2	ND	0.1
Indeno(1,2,3-cd) pyrene	0.2	ND	0.2	ND	0.1
Dibenzo(a,h)anthracene	ND	ND	ND	ND	0.1
Benzo(g,h,i)perylene	0.3	ND	0.2	ND	0.1
SURVEY 2 (June 30 - July 1)					
Naphthalene	ND	ND	ND	NS	0.1
2-Methylnaphthalene	ND	ND	ND	NS	0.1
Acenaphthylene	ND	ND	ND	NS	0.1
Dibenzofuran	ND	ND	ND	NS	0.1
Acenaphthene	ND	ND	ND	NS	0.1
Fluorene	ND	ND	ND	NS	0.1
Phenanthrene	ND	ND	ND	NS	0.1
Anthracene	ND	ND	ND	NS	0.1
Fluoranthene	0.1	ND	ND	NS	0.1
Pyrene	0.1	ND	ND	NS	0.1
Benz(a)anthracene	ND	ND	ND	NS	0.1
Chrysene	ND	ND	ND	NS	0.1
Benzo(b+k)fluoranthene	ND	ND	ND	NS	0.1
Benzo(a)pyrene	ND	ND	ND	NS	0.1
Indeno(1,2,3-cd) pyrene	ND	ND	ND	NS	0.1
Dibenzo(a,h)anthracene	ND	ND	ND	NS	0.1
Benzo(g,h,i)perylene	ND	ND	ND	NS	0.1

Table 1-4. Continued.

	Presidio Shoal		Point Knox Shoal		MRL
	Unfiltered	Filtered	Unfiltered	Filtered	
SURVEY 3 (August 19 - 20)					
Naphthalene	ND	ND	ND	ND	0.1
2-Methylnaphthalene	ND	ND	ND	ND	0.1
Acenaphthylene	ND	ND	ND	ND	0.1
Dibenzofuran	ND	ND	ND	ND	0.1
Acenaphthene	ND	ND	ND	ND	0.1
Fluorene	ND	ND	ND	ND	0.1
Phenanthrene	ND	ND	ND	ND	0.1
Anthracene	ND	ND	ND	ND	0.1
Fluoranthene	ND	ND	ND	ND	0.1
Pyrene	ND	ND	ND	ND	0.1
Benz(a)anthracene	ND	ND	ND	ND	0.1
Chrysene	ND	ND	ND	ND	0.1
Benzo(b+k)fluoranthene	ND	ND	0.1	ND	0.1
Benzo(a)pyrene	ND	ND	ND	ND	0.1
Indeno(1,2,3-cd) pyrene	ND	ND	ND	ND	0.1
Dibenzo(a,h)anthracene	ND	ND	ND	ND	0.1
Benzo(g,h,i)perylene	ND	ND	ND	ND	0.1

ND = not detected
NS = not sampled

RECEIVING WATER QUALITY

METHODS

- Water quality depth profiles and water samples for chemical analysis were taken within and outside the effluent plume on a monthly basis for three months. The survey dates were as follows:
  - Survey 1- 2 June 1993
  - Survey 2- 30 June and 1 July 1993
  - Survey 3- 19 and 20 August 1993

- Sampling took place at two stations:
  - Presidio Shoal
  - Point Knox Shoal

- At each station, four locations were sampled:
  - **Upstream (ambient)**- At a point upstream/up current or along side of the effluent plume and not under the influence of discharge, but representative of ambient conditions.
  - **30 m downstream (plume)**- Within 30m downstream of the point of discharge.
  - **Midpoint (plume)**- At a point midpoint in the plume.
  - **Downstream (ambient)**- At a downstream/downcurrent location outside the effluent plume.

- (3 surveys x 2 stations x 4 locations)

Water Quality Depth Profiles

- Water quality measurements were collected at 1m intervals for the following parameters:
  - Temperature
  - Salinity
  - Dissolved oxygen
  - pH
  - Percent transmittance

Chemical Analyses

- Discrete water samples were taken at two depths: one meter below the water surface (surface) and two meters above the bottom (bottom), at both stations at each of the four locations. Water samples were analyzed for the following parameters:
  - Total suspended solids
  - Metals
  - Arsenic
  - Total organic carbon
  - Total sulfides
  - Ammonia

RESULTS

Water Quality Depth Profiles

- Water quality profiles for the four locations sampled at Presidio Shoal and Point Knox Shoal are presented in Figures 2-1 to 2-10.

- Depth ranged from 19 to 27m at Presidio Shoal and from 16 to 24m at Point Knox Shoal.

- Temperatures were slightly higher at surface (13.88 to 17.49°C) compared to bottom waters (12.44 to 17.18°C). Temperatures were similar at the two stations and four locations (within and outside of the plume).

- Salinity values generally were lower at the surface (27.32 to 30.40 ppt) than in bottom waters (29.02 to 31.60 ppt). Salinity was similar at the two stations and four locations.

- Dissolved oxygen tended to be variable at all station locations. In general surface values (7.4 to 9.5 mg/L) were slightly higher than bottom values (7.2 to 9.3 mg/L). **No effluent effects were found. All dissolved oxygen concentrations were greater than the 5.0 mg/L minimum.**

- Values for pH tended to be stable (7.78 to 8.14) throughout the water column at all locations. **No effluent effects were detected. Variation between ambient and plume values did not exceed 0.2 pH units.**

- Percent transmittance generally was higher at the surface (22.09 to 41.48%) than in bottom waters (0.53 to 19.46%) at ambient locations. At plume locations, an initial low percent transmittance value was followed by an abrupt increase in transmissivity and then a general decline toward the bottom of the water column.

Chemical Analyses

- Most ammonia concentrations were slightly higher in surface waters (0.07 to 0.18 mg/L) compared to bottom waters (0.06 to 0.17 mg/L) (Table 2-1). Ammonia concentrations were similar at the two stations and four locations.

- Total suspended solids concentrations generally were lower in surface waters (6 to 38 mg/L) compared to bottom waters (7 to 78 mg/L) (Table 2-2). Values were higher at Presidio Shoal (6 to 78 mg/L) than at Point Knox Shoal (ND to 19 mg/L). Concentrations were similar for the four locations.

- Sulfides were not detected at the method reporting limit (0.05 mg/L).

- Total organic carbon concentrations were variable (Table 2-3), but were similar within and outside of the plume.

- Values for arsenic, cadmium, chromium, copper, lead, nickel, and zinc showed only slight differences for the two stations and four locations (within and outside of the effluent plume). Mercury, selenium, and silver were found only in very low concentrations or were not detected. These values are found in Table 2-4.

CONCLUSIONS

- Water quality parameters, including temperature, salinity, dissolved oxygen, and pH, showed no patterns related to station or location relative to the plume.

- Percent transmittance did show slight plume-related trends. Outside the plume, percent transmittance values generally were higher at surface compared to bottom waters. Within the plume, values were low at the surface, increased below the surface, and then decreased in bottom waters.

- No plume-related differences were seen for total suspended solids or metals.

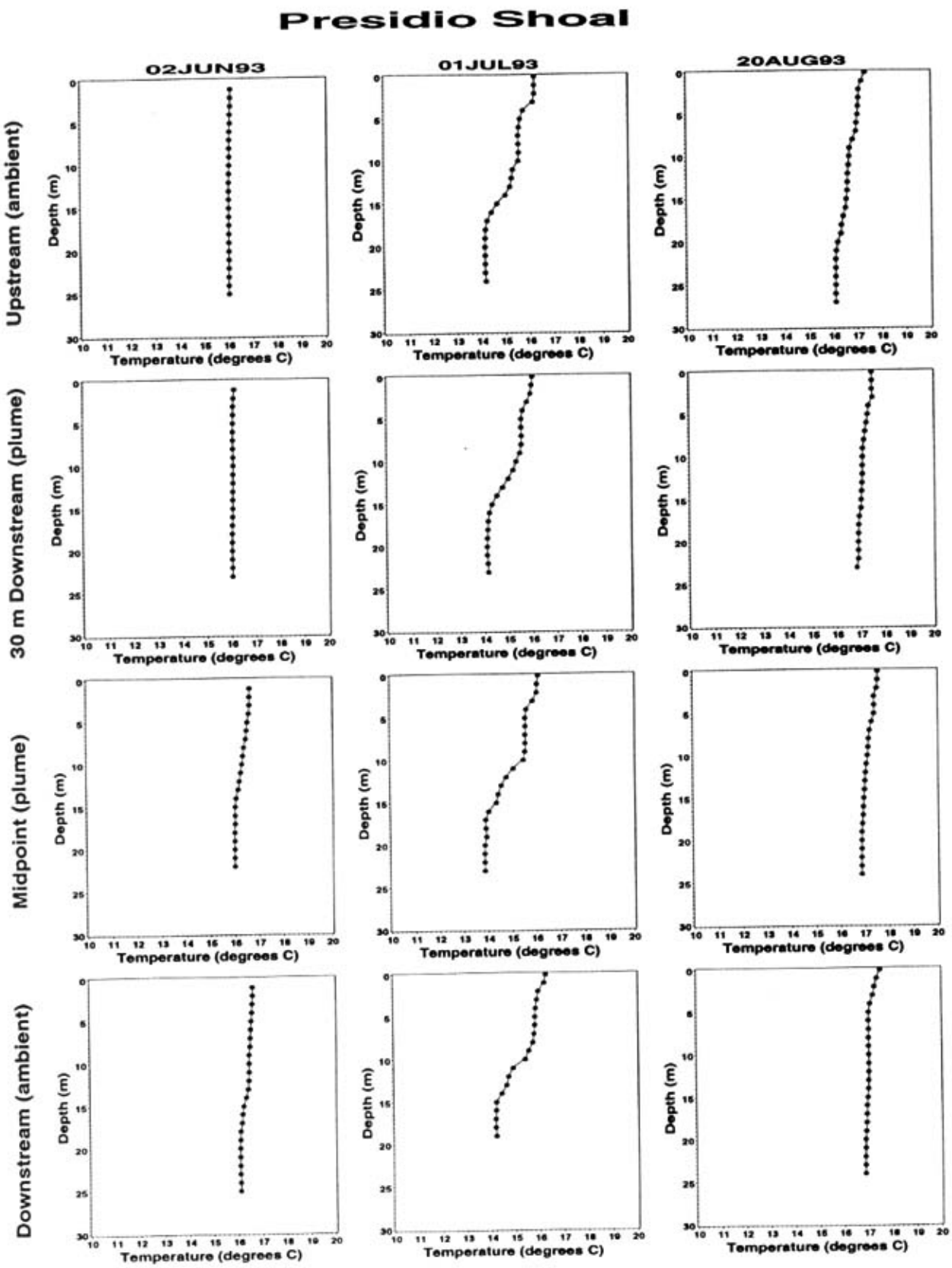

Figure 2-1. Depth Profiles for Temperature at Presidio Shoal.

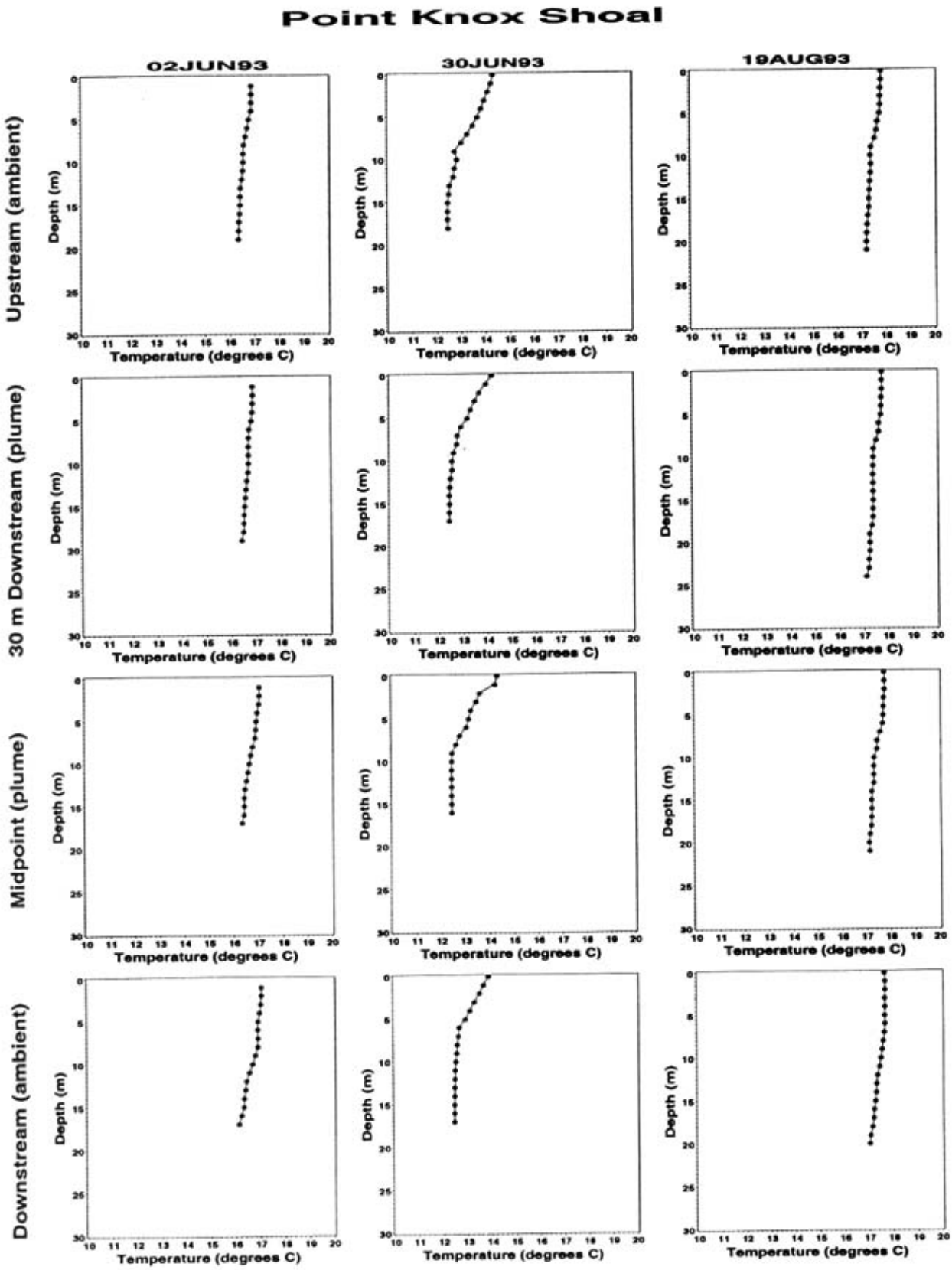

Figure 2-2. Depth Profiles for Temperature at Point Knox Shoal.

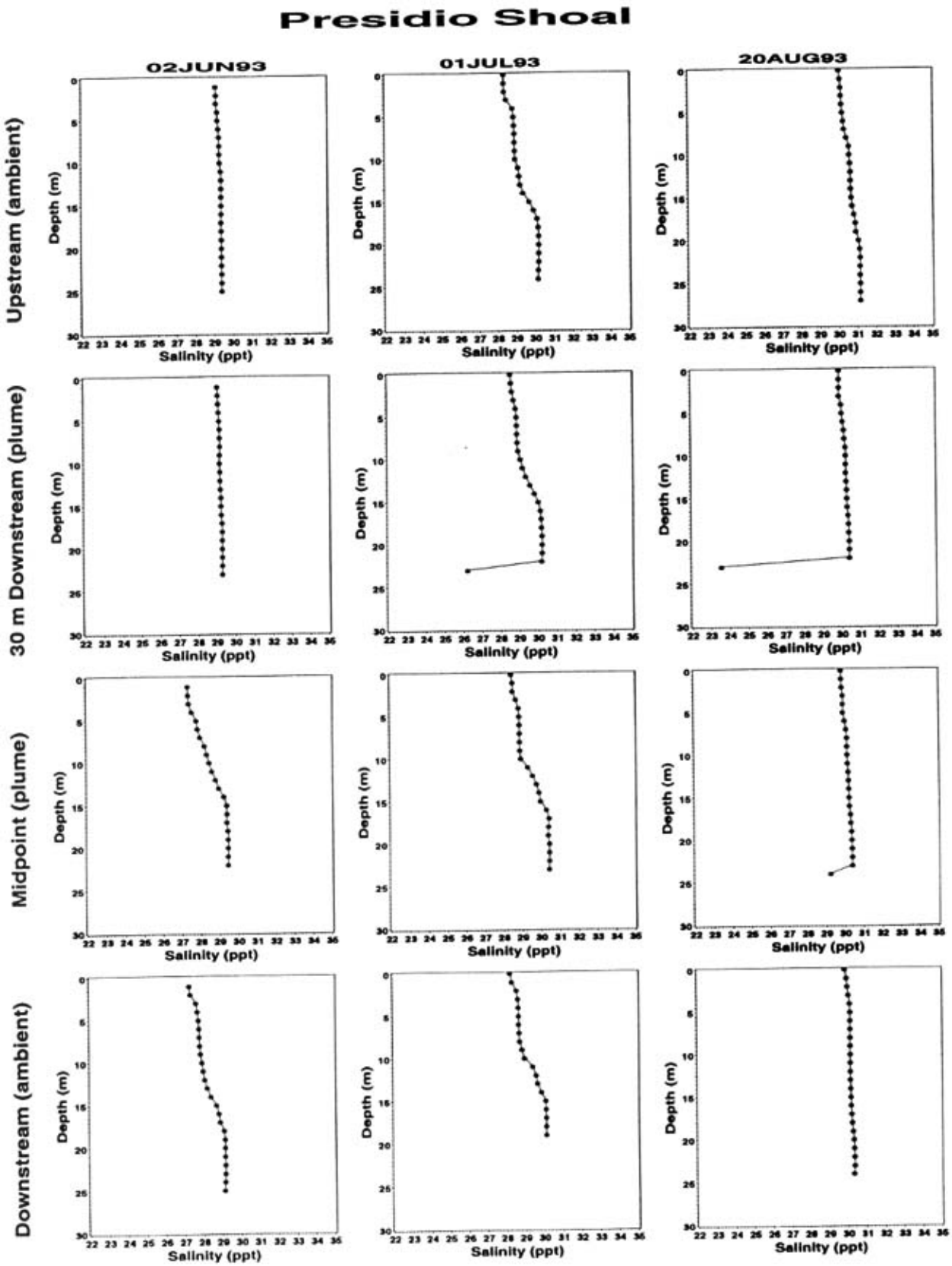

Figure 2-3. Depth Profiles for Salinity at Presidio Shoal.

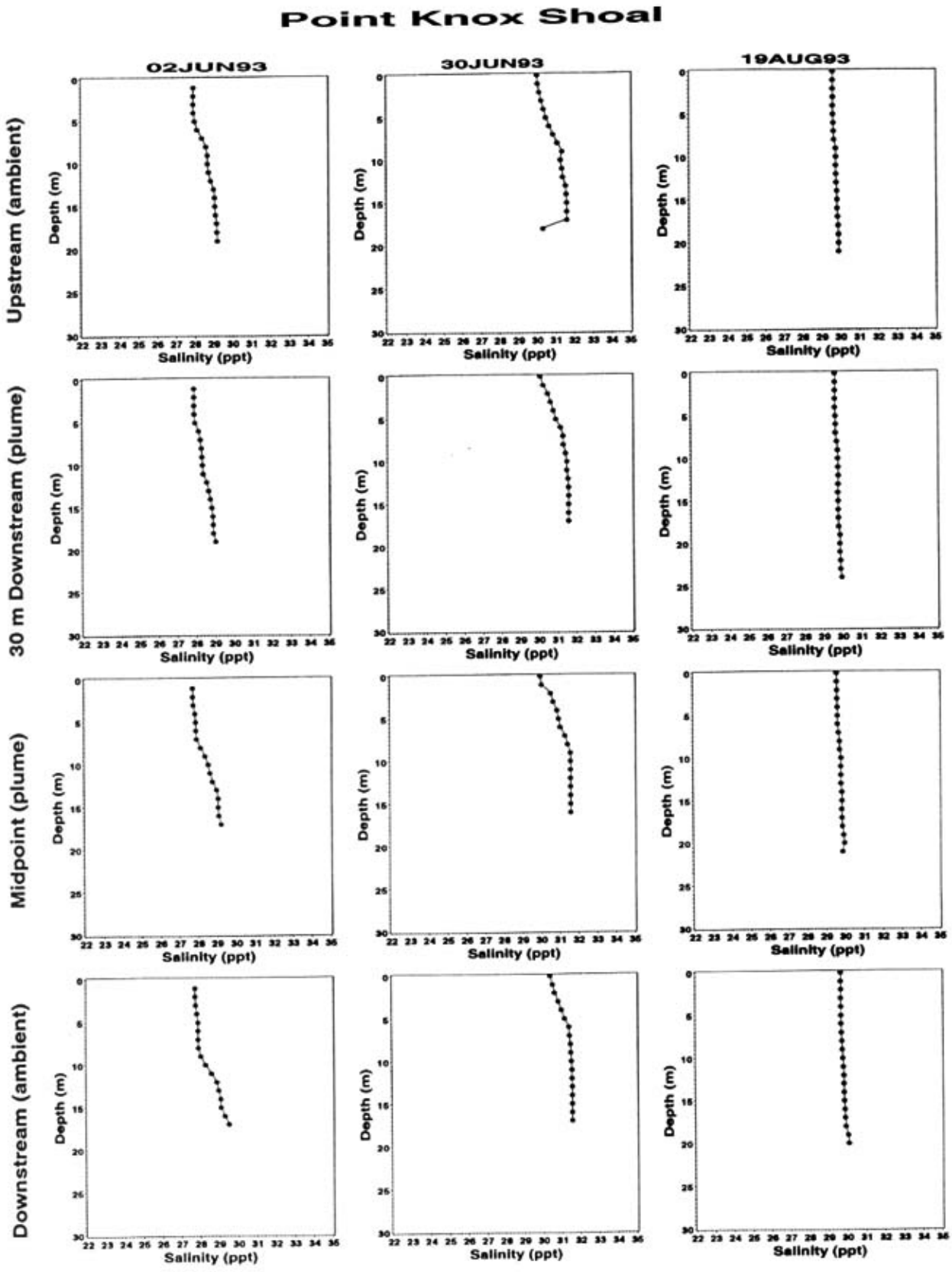

Figure 2-4. Depth Profiles for Salinity at Point Knox Shoal.

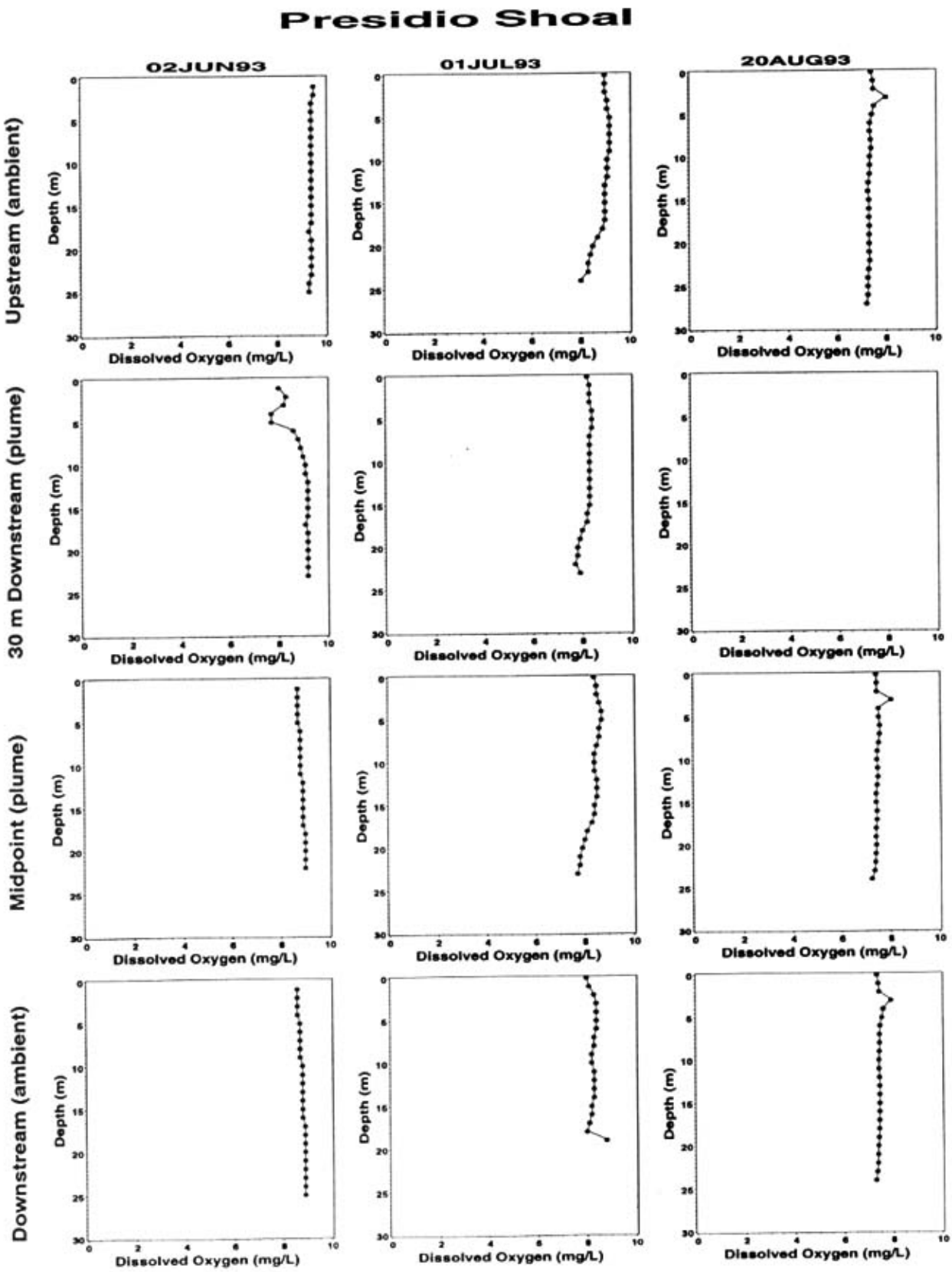

Figure 2-5. Depth Profiles for Dissolved Oxygen at Presidio Shoal.

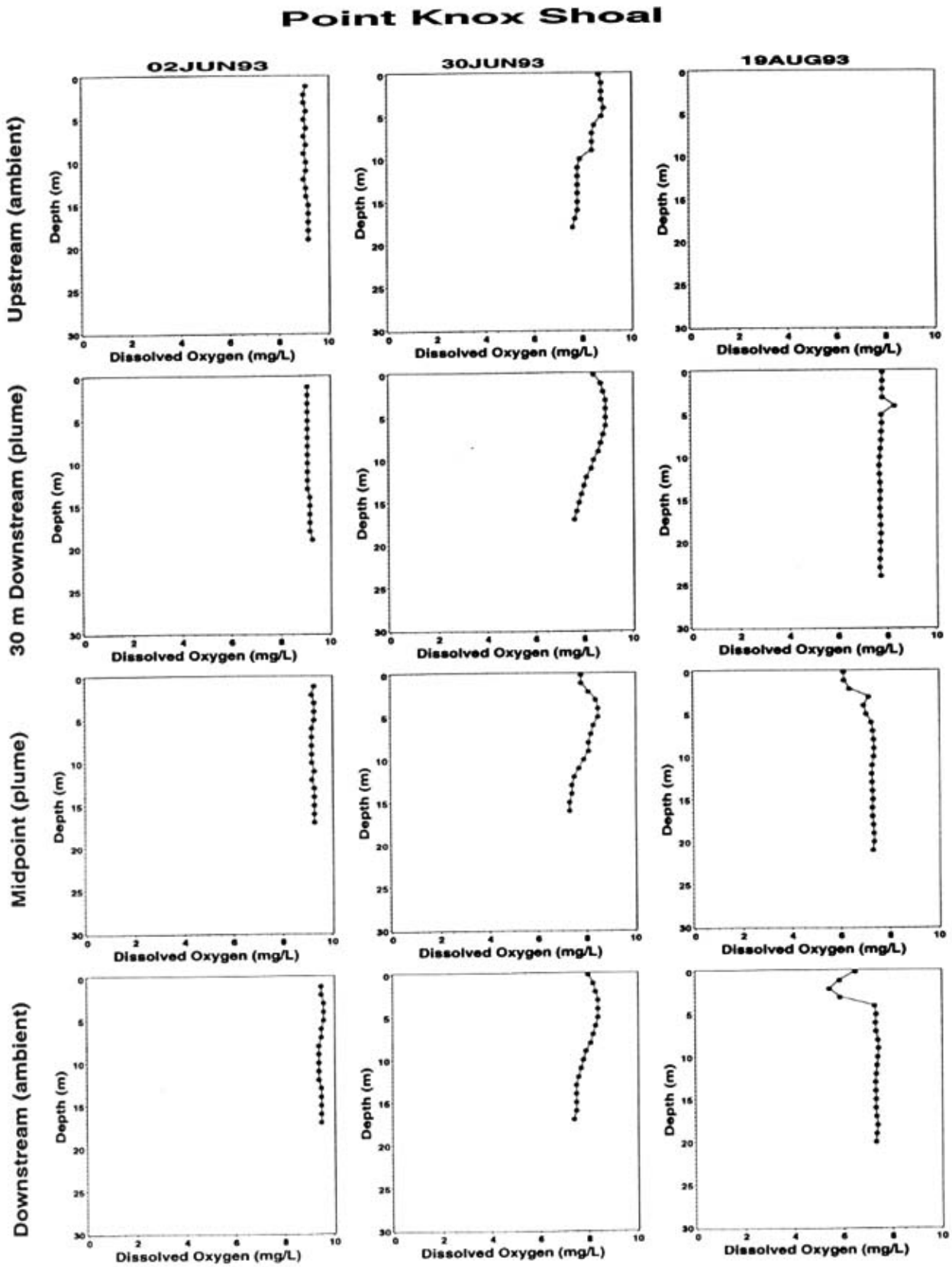

Figure 2-6. Depth Profiles for Dissolved Oxygen at Point Knox Shoal.

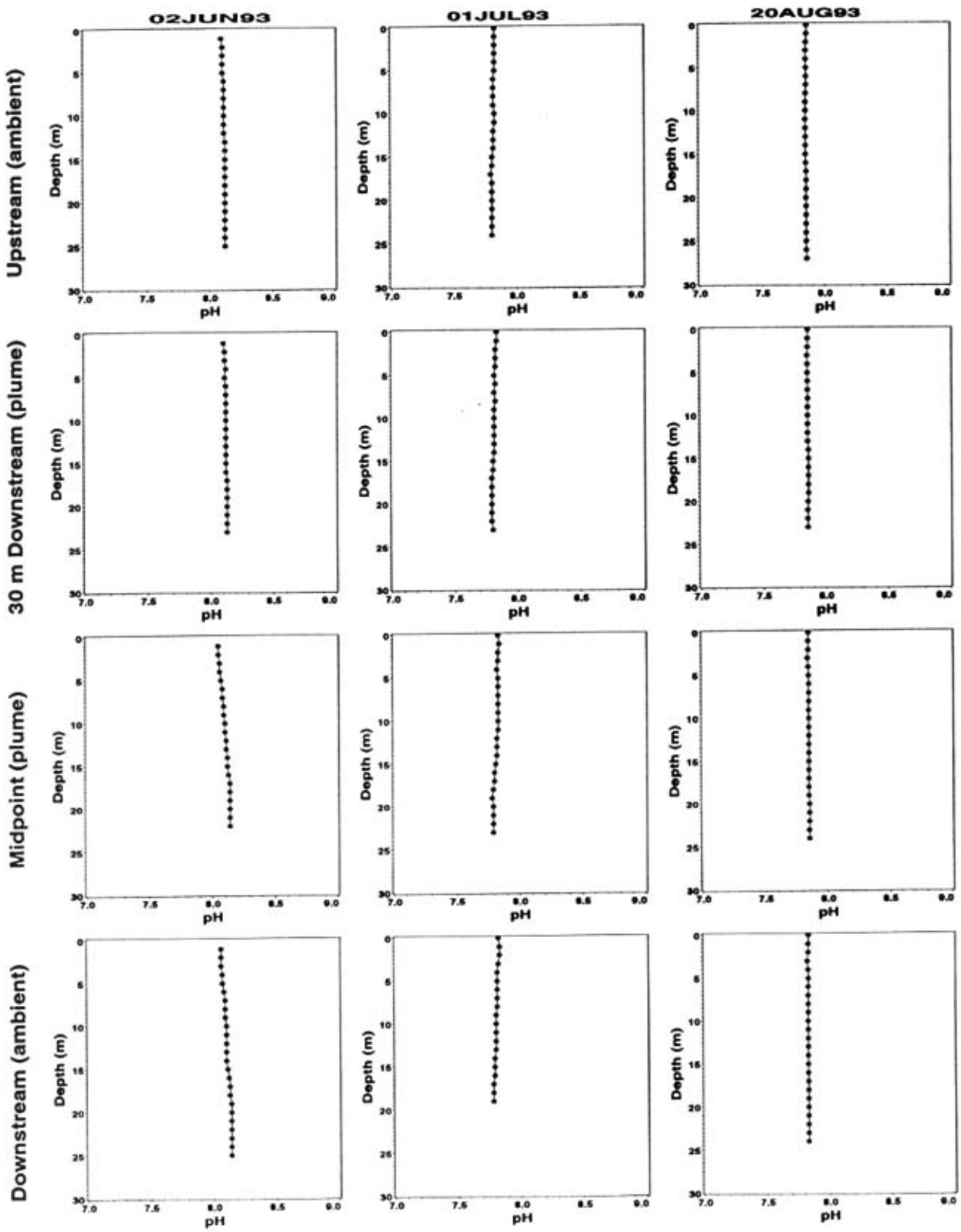

Figure 2-7. Depth Profiles for pH at Presidio Shoal.

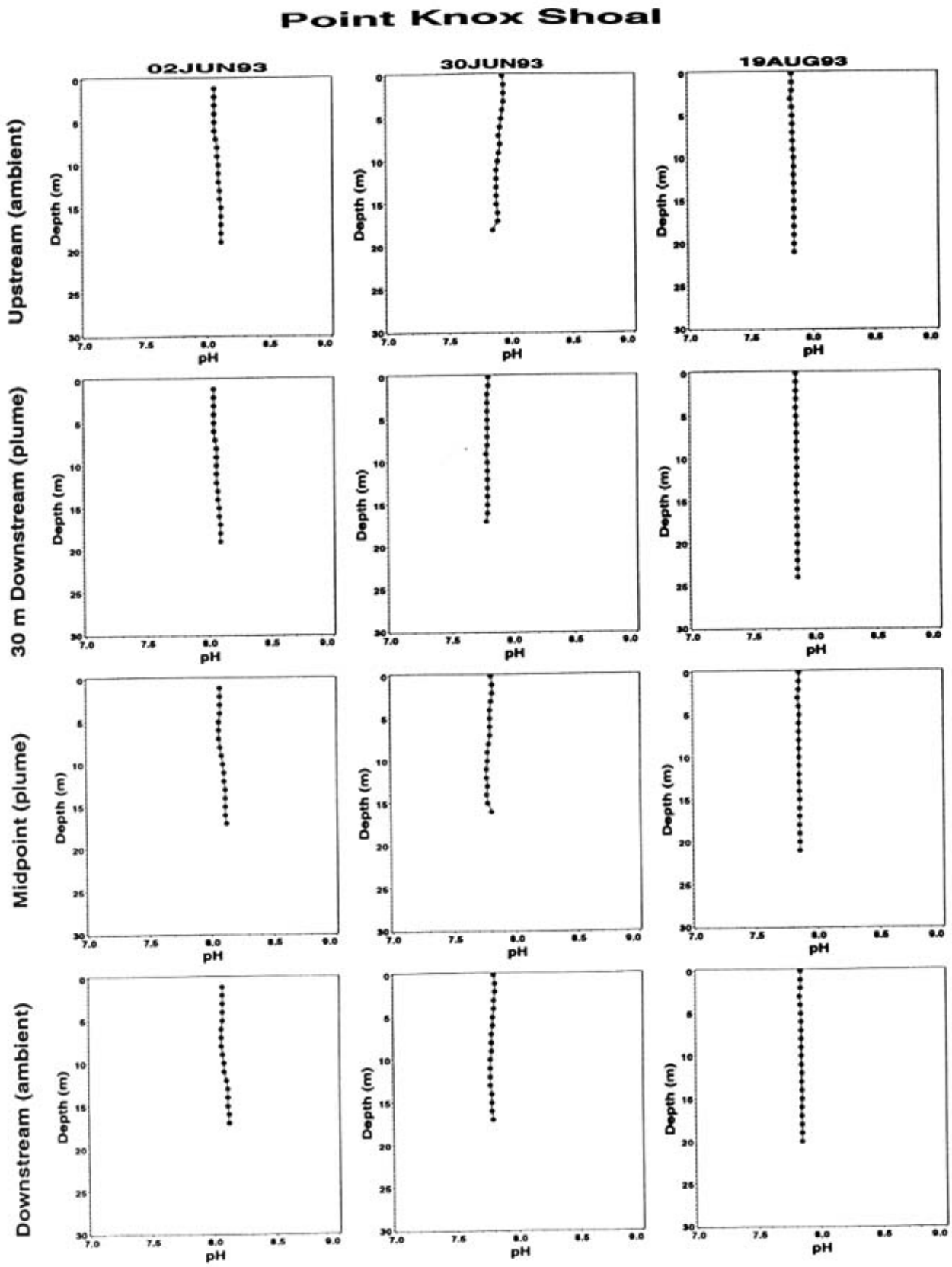

Figure 2-8. Depth Profiles for pH at Point Knox Shoal.

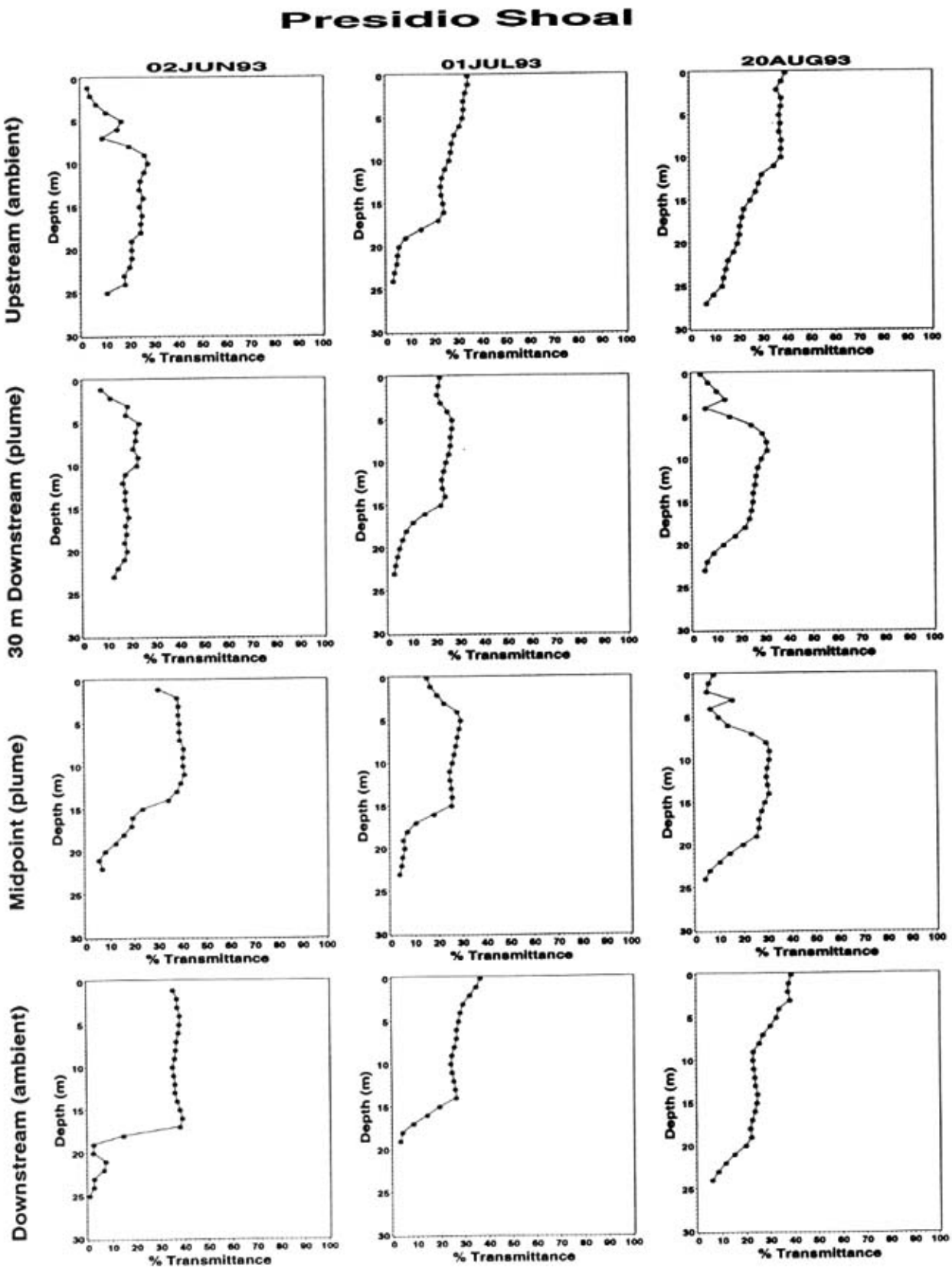

Figure 2-9. Depth Profiles for Transmittance at Presidio Shoal.

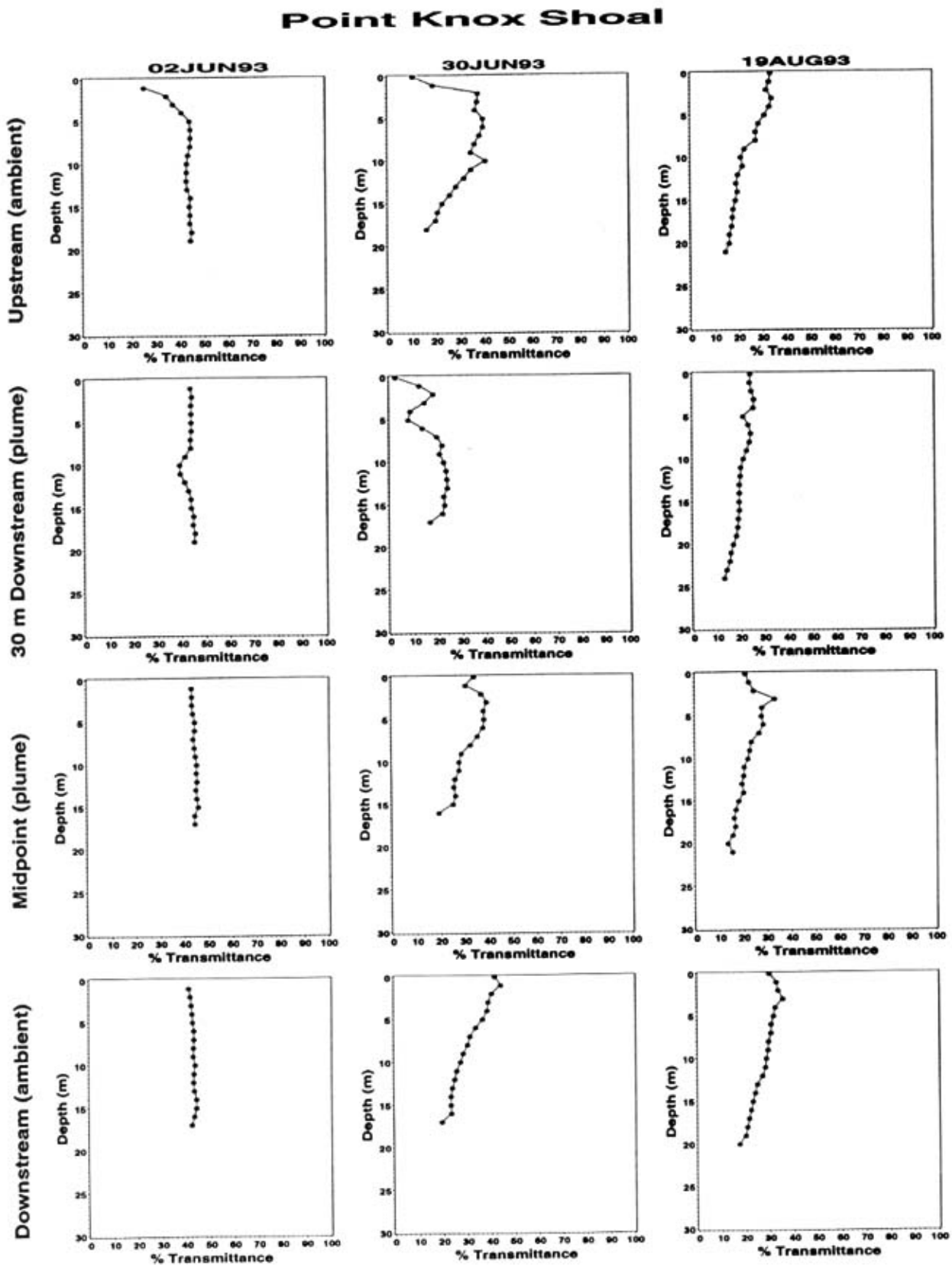

Figure 2-10. Depth Profiles for Transmittance at Point Knox Shoal.

Table 2-1. Concentrations of Ammonia as Nitrogen in mg/L (ppm) in Receiving Waters.

Location	Depth	STATION	
		Presidio Shoal	Point Knox Shoal
Survey 1 (June 2)			
Upstream (Ambient)	Surface	0.10	0.09
	Bottom	0.09	0.08
30 m Downstream (Plume)	Surface	0.08	0.10
	Bottom	0.08	0.08
Midpoint (Plume)	Surface	0.10	0.09
	Bottom	0.09	0.08
Downstream (Ambient)	Surface	0.12	0.08
	Bottom	0.08	0.09
Survey 2 (June 30 - July)			
Upstream (Ambient)	Surface	0.09	0.09
	Bottom	0.07	0.07
30 m Downstream (Plume)	Surface	0.09	0.07
	Bottom	0.07	0.06
Midpoint (Plume)	Surface	0.08	0.07
	Bottom	0.10	0.06
Downstream (Ambient)	Surface	0.14	0.07
	Bottom	0.08	0.11
Survey 3 (August 19 - 20)			
Upstream (Ambient)	Surface	0.17	0.16
	Bottom	0.14	0.16
30 m Downstream (Plume)	Surface	0.15	0.16
	Bottom	0.17	0.24
Midpoint (Plume)	Surface	0.18	0.16
	Bottom	0.14	0.16
Downstream (Ambient)	Surface	0.12	0.18
	Bottom	0.12	0.14

EPA Method: 350.3
MRL (Method Reporting Limit): 0.05
ND = None Detected at or above the Method Reporting Limit

Table 2-2. Concentrations of Total Suspended Solids (TSS) in mg/L (ppm) in Receiving Waters.

Location	Depth	STATION	
		Presidio Shoal	Point Knox Shoal
Survey 1 (June 2)			
Upstream (Ambient)	Surface	29	12
	Bottom	29	12
30 m Downstream (Plume)	Surface	24	10
	Bottom	29	7
Midpoint (Plume)	Surface	9	6
	Bottom	72	10
Downstream (Ambient)	Surface	7	9
	Bottom	38	8
Survey 2 (June 30 - July 1)			
Upstream (Ambient)	Surface	34	9
	Bottom	78	13
30 m Downstream (Plume)	Surface	17	12
	Bottom	28	19
Midpoint (Plume)	Surface	34	16
	Bottom	67	18
Downstream (Ambient)	Surface	38	8
	Bottom	70	14
Survey 3 (August 18 - 19)			
Upstream (Ambient)	Surface	8	8
	Bottom	36	12
30 m Downstream (Plume)	Surface	18	5
	Bottom	39	12
Midpoint (Plume)	Surface	12	12
	Bottom	38	14
Downstream (Ambient)	Surface	6	ND
	Bottom	17	16

EPA Method: 160.2
MRL (Method Reporting Limit): 5
ND = None Detected at or above the Method Reporting Limit

Table 2-3. Concentrations of Total Organic Carbon (TOC) in mg/L (ppm) in Receiving Waters.

Location	Depth	STATION	
		Presidio Shoal	Point Knox Shoal
Survey 1 (June 2)			
Upstream (Ambient)	Surface	0.8	0.9
	Bottom	0.7	0.8
30 m Downstream (Plume)	Surface	0.8	0.8
	Bottom	0.7	0.8
Midpoint (Plume)	Surface	0.8	0.8
	Bottom	0.7	0.7
Downstream (Ambient)	Surface	0.7	0.8
	Bottom	0.8	0.7
Survey 2 (June 30 - July 1)			
Upstream (Ambient)	Surface	0.7	0.5
	Bottom	1.7	ND
30 m Downstream (Plume)	Surface	1.1	ND
	Bottom	0.6	ND
Midpoint (Plume)	Surface	0.6	ND
	Bottom	0.5	ND
Downstream (Ambient)	Surface	0.7	ND
	Bottom	ND	ND
Survey 3 (August 19 - 20)			
Upstream (Ambient)	Surface	0.5	0.7
	Bottom	ND	0.7
30 m Downstream (Plume)	Surface	0.6	0.7
	Bottom	0.5	0.6
Midpoint (Plume)	Surface	0.6	0.7
	Bottom	ND	0.7
Downstream (Ambient)	Surface	0.5	0.7
	Bottom	ND	0.6

EPA Method: 415.1
MRL (Method Reporting Limit): 0.5
ND = None Detected at or above the Method Reporting Limit

Table 2-4a. Values for Total Metals in µg/L (ppb) in Upstream Ambient Waters.

Metal	Depth	Presidio Shoal	Point Knox Shoal	MRL	EPA Method
Survey 1 (June 2)					
Arsenic	Surface	1.8	1.4	0.5	200.8M
	Bottom	1.5	1.3		
Cadmium	Surface	0.11	0.05	0.02	200.8M
	Bottom	0.08	0.04		
Chromium	Surface	1.0	1.0	0.2	200.8M
	Bottom	1.2	0.3		
Copper	Surface	1.9	1.4	0.1	200.8M
	Bottom	1.6	0.8		
Lead	Surface	11.3	3.13	0.02	200.8M
	Bottom	7.96	0.91		
Mercury	Surface	ND	ND	0.1	7470
	Bottom	ND	ND		
Nickel	Surface	1.4	1.2	0.2	200.8M
	Bottom	1.7	0.4		
Selenium	Surface	ND	0.5	0.4	200.8M
	Bottom	ND	0.7		
Silver	Surface	ND	ND	0.02	200.8M
	Bottom	ND	ND		
Zinc	Surface	28	20	1.0	200.8M
	Bottom	8	4		
Survey 2					
Arsenic	Surface	1.5	1.3	0.5	200.8M
	Bottom	1.9	1.1		
Cadmium	Surface	0.51	0.10	0.02	200.8M
	Bottom	0.13	0.08		
Chromium	Surface	0.4	0.3	0.2	200.8M
	Bottom	1.6	0.5		
Copper	Surface	1.2	1.2	0.1	200.8M
	Bottom	2.2	1.1		
Lead	Surface	0.65	0.65	0.02	200.8M
	Bottom	1.22	0.76		
Mercury	Surface	ND	ND	0.1	7470
	Bottom	ND	ND		
Nickel	Surface	1.1	1.2	0.02	200.8M
	Bottom	2.4	0.6		
Selenium	Surface	ND	ND	0.4	200.8M
	Bottom	ND	ND		
Silver	Surface	ND	ND	0.02	200.8M
	Bottom	ND	ND		
Zinc	Surface	5	14	1.0	200.8M
	Bottom	7	4		

Table 2-4a. Continued.

Metal	Depth	Presidio Shoal	Point Knox Shoal	MRL	EPA Method
Survey 3					
Arsenic	Surface	1.5	4.0	0.5	200.8M
	Bottom	1.8	1.8		
Cadmium	Surface	0.08	0.21	0.02	200.8M
	Bottom	0.07	0.12		
Chromium	Surface	0.5	12.4	0.2	200.8M
	Bottom	2.1	0.7		
Copper	Surface	1.4	15.2	0.1	200.8M
	Bottom	2.1	1.6		
Lead	Surface	0.65	12.9	0.02	200.8M
	Bottom	1.16	0.55		
Mercury	Surface	ND	ND	0.1	7470
	Bottom	0.6	ND		
Nickel	Surface	1.0	16.9	0.2	200.8M
	Bottom	2.7	1.6		
Selenium	Surface	ND	0.5	0.4	200.8M
	Bottom	ND	ND		
Silver	Surface	0.02	0.05	0.02	200.8M
	Bottom	ND	ND		
Zinc	Surface	4	26	1.0	200.8M
	Bottom	6	7		

M = Modified
MRL = Method Reporting Limit
ND = Not detected at or above the Method Reporting Limit

Table 2-4b. Values for Total Metals in µg/L (ppb) in 30m Downstream (Plume) Waters.

Metal	Depth	Presidio Shoal	Point Knox Shoal	MRL	EPA Method
Survey 1 (June 2)					
Arsenic	Surface	1.7	1.4	0.5	200.8M
	Bottom	1.3	1.4		
Cadmium	Surface	0.06	0.05	0.02	200.8M
	Bottom	0.13	0.04		
Chromium	Surface	0.9	0.8	0.2	200.8M
	Bottom	1.2	0.4		
Copper	Surface	1.4	1.5	0.1	200.8M
	Bottom	1.8	1.0		
Lead	Surface	3.71	1.86	0.02	200.8M
	Bottom	16.7	3.41		
Mercury	Surface	ND	ND	0.1	7470
	Bottom	ND	ND		
Nickel	Surface	1.2	1.0	0.2	200.8M
	Bottom	1.7	0.7		
Selenium	Surface	ND	0.5	0.4	200.8M
	Bottom	0.4	0.5		
Silver	Surface	ND	ND	0.02	200.8M
	Bottom	ND	ND		
Zinc	Surface	28	87	1.0	200.8M
	Bottom	26	6		
Survey 2 (June 30-July 1)					
Arsenic	Surface	1.9	1.4	0.5	200.8M
	Bottom	1.7	1.2		
Cadmium	Surface	0.09	0.08	0.02	200.8M
	Bottom	0.08	0.06		
Chromium	Surface	0.7	0.4	0.2	200.8M
	Bottom	1.1	0.8		
Copper	Surface	1.5	1.2	0.1	200.8M
	Bottom	1.5	1.2		
Lead	Surface	0.67	0.89	0.02	200.8M
	Bottom	0.72	1.48		
Mercury	Surface	ND	ND	0.1	7470
	Bottom	ND	ND		
Nickel	Surface	1.7	0.7	0.2	200.8M
	Bottom	1.7	0.7		
Selenium	Surface	ND	ND	0.4	200.8M
	Bottom	ND	ND		
Silver	Surface	ND	ND	0.02	200.8M
	Bottom	ND	ND		
Zinc	Surface	3	39	1.0	200.8M
	Bottom	5	4		

Table 2-4b. Continued.

Metal	Depth	Presidio Shoal	Point Knox Shoal	MRL	EPA Method
Survey 3 (August 19-20)					
Arsenic	Surface	1.9	1.9	0.5	200.8M
	Bottom	1.9	1.9		
Cadmium	Surface	0.08	0.11	0.02	200.8M
	Bottom	0.17	0.08		
Chromium	Surface	0.9	0.7	0.2	200.8M
	Bottom	2.0	0.6		
Copper	Surface	1.5	1.5	0.1	200.8M
	Bottom	2.4	1.4		
Lead	Surface	0.63	0.42	0.02	200.8M
	Bottom	1.32	0.52		
Mercury	Surface	0.5	ND	0.1	7470
	Bottom	ND	ND		
Nickel	Surface	1.3	1.5	0.2	200.8M
	Bottom	2.3	1.1		
Selenium	Surface	ND	ND	0.4	200.8M
	Bottom	ND	ND		
Silver	Surface	ND	ND	0.02	200.8M
	Bottom	ND	ND		
Zinc	Surface	28	6	1.0	200.8M
	Bottom	11	34		

M = Modified
MRL = Method Reporting Limit
ND = Not detected at or above the Method Reporting Limit

Table 2-4c. Values for Total Metals in µg/L (ppb) in Midpoint (Plume) Waters.

Metal	Depth	Presidio Shoal	Point Knox Shoal	MRL	EPA Method
Survey 1 (June 2)					
Arsenic	Surface	1.2	1.6	0.5	200.8M
	Bottom	2.1	1.5		
Cadmium	Surface	0.16	0.05	0.02	200.8M
	Bottom	0.18	0.06		
Chromium	Surface	0.4	0.3	0.2	200.8M
	Bottom	3.3	0.4		
Copper	Surface	1.3	1.1	0.1	200.8M
	Bottom	3.6	0.9		
Lead	Surface	24.1	1.46	0.02	200.8M
	Bottom	7.16	0.91		
Mercury	Surface	ND	ND	0.1	7470
	Bottom	ND	ND		
Nickel	Surface	1.2	0.8	0.2	200.8M
	Bottom	3.3	0.8		
Selenium	Surface	0.5	0.5	0.4	200.8M
	Bottom	0.5	0.6		
Silver	Surface	ND	ND	0.02	200.8M
	Bottom	ND	0.02		
Zinc	Surface	13	22	1.0	200.8M
	Bottom	40	11		
Survey 2 (June 30-July 1)					
Arsenic	Surface	1.7	1.4	0.5	200.8M
	Bottom	1.7	1.0		
Cadmium	Surface	0.08	0.08	0.02	200.8M
	Bottom	0.10	0.06		
Chromium	Surface	0.9	0.6	0.2	200.8M
	Bottom	1.1	0.5		
Copper	Surface	1.5	1.2	0.1	200.8M
	Bottom	1.4	0.7		
Lead	Surface	0.84	0.66	0.02	200.8M
	Bottom	0.80	0.49		
Mercury	Surface	ND	ND	0.1	7470
	Bottom	ND	ND		
Nickel	Surface	1.5	1.3	0.2	200.8M
	Bottom	1.7	0.9		
Selenium	Surface	ND	ND	0.4	200.8M
	Bottom	ND	ND		
Silver	Surface	ND	ND	0.02	200.8M
	Bottom	ND	ND		
Zinc	Surface	7	3	1.0	200.8M
	Bottom	4	2		

Table 2-4c. Continued.

Metal	Depth	Presidio Shoal	Point Knox Shoal	MRL	EPA Method
Survey 3 (August 19-20)					
Arsenic	Surface	1.8	1.9	0.5	200.8M
	Bottom	1.6	1.8		
Cadmium	Surface	0.09	0.09	0.02	200.8M
	Bottom	0.07	0.07		
Chromium	Surface	0.9	0.9	0.2	200.8M
	Bottom	1.7	0.8		
Copper	Surface	1.5	1.6	0.1	200.8M
	Bottom	1.9	1.5		
Lead	Surface	0.85	1.23	0.02	200.8M
	Bottom	2.29	2.16		
Mercury	Surface	ND	ND	0.1	7470
	Bottom	ND	ND		
Nickel	Surface	1.4	1.2	0.2	200.8M
	Bottom	1.8	1.3		
Selenium	Surface	ND	ND	0.4	200.8M
	Bottom	ND	ND		
Silver	Surface	ND	ND	0.02	200.8M
	Bottom	ND	ND		
Zinc	Surface	20	8	1.0	200.8M
	Bottom	13	13		

M = Modified
MRL = Method Reporting Limit
ND = Not detected at or above the Method Reporting Limit

Table 2-4d. Values for Total Metals in µg/L (ppb) in Downstream (Ambient) Waters.

Metal	Depth	Presidio Shoal	Point Knox Shoal	MRL	EPA Method
Survey 1 (June 2)					
Arsenic	Surface	1.6	1.4	0.5	200.8M
	Bottom	1.7	1.3		
Cadmium	Surface	0.09	0.05	0.02	200.8M
	Bottom	0.06	0.04		
Chromium	Surface	0.5	0.3	0.2	200.8M
	Bottom	1.6	0.4		
Copper	Surface	1.6	1.2	0.1	200.8M
	Bottom	2.1	1.0		
Lead	Surface	4.12	0.20	0.02	200.8M
	Bottom	4.31	1.39		
Mercury	Surface	ND	ND	0.1	7470
	Bottom	ND	ND		
Nickel	Surface	1.2	0.8	0.2	200.8M
	Bottom	1.7	0.8		
Selenium	Surface	0.5	0.5	0.4	200.8M
	Bottom	0.7	0.4		
Silver	Surface	ND	ND	0.02	200.8M
	Bottom	ND	ND		
Zinc	Surface	85	22	1.0	200.8M
	Bottom	37	7		
Survey 2					
Arsenic	Surface	1.7	1.0	0.5	200.8M
	Bottom	1.6	1.2		
Cadmium	Surface	0.15	0.06	0.02	200.8M
	Bottom	0.08	0.06		
Chromium	Surface	0.3	0.4	0.2	200.8M
	Bottom	1.5	0.7		
Copper	Surface	1.1	0.7	0.1	200.8M
	Bottom	1.6	0.9		
Lead	Surface	0.39	0.39	0.02	200.8M
	Bottom	1.14	0.69		
Mercury	Surface	ND	ND	0.1	7470
	Bottom	ND	ND		
Nickel	Surface	0.3	0.6	0.2	200.8M
	Bottom	1.8	0.8		
Selenium	Surface	ND	ND	0.4	200.8M
	Bottom	ND	ND		
Silver	Surface	ND	ND	0.02	200.8M
	Bottom	ND	ND		
Zinc	Surface	5	3	1.0	200.8M
	Bottom	4	3		

Table 2-4d. Continued.

Metal	Depth	Presidio Shoal	Point Knox Shoal	MRL	EPA Method
Survey 3					
Arsenic	Surface	1.6	1.7	0.5	200.8M
	Bottom	1.6	1.7		
Cadmium	Surface	0.08	0.06	0.02	200.8M
	Bottom	0.05	0.06		
Chromium	Surface	0.5	0.4	0.2	200.8M
	Bottom	0.9	0.8		
Copper	Surface	1.2	1.2	0.1	200.8M
	Bottom	1.2	1.3		
Lead	Surface	0.63	1.96	0.02	200.8M
	Bottom	0.47	0.80		
Mercury	Surface	ND	ND	0.1	7470
	Bottom	ND	ND		
Nickel	Surface	0.9	0.9	0.2	200.8M
	Bottom	1.2	1.2		
Selenium	Surface	ND	ND	0.4	200.8M
	Bottom	ND	ND		
Silver	Surface	ND	ND	0.02	200.8M
	Bottom	ND	ND		
Zinc	Surface	5	6	1.0	200.8M
	Bottom	3	5		

M = Modified
MRL = Method Reporting Limit
ND = Not detected at or above the Method Reporting Limit

FISHERIES

METHODS

- Beam trawl surveys were conducted biweekly from June 2 to July 27, 1993.
- For each survey, three transects were taken at each of three areas - Presidio Shoal, Point Knox Shoal, and a reference site east of Angel Island.
- (5 surveys x 3 areas x 3 transects)

RESULTS

- A complete species list is provided in Table 3.1.

Fish

- The most abundant fish species were:
  - Speckled sanddab (*Citharichthys stigmaeus*)
  - California tonguefish (*Symphurus atricauda*)
  - English sole (*Pleuronectes vetulus*)
  - Yellowfin goby (*Acanthogobius flavimanus*)
  - Rockfish (*Sebastes* spp.)
- Both the **density** of fish and the **number of fish species** were significantly greater at Presidio Shoal and the reference area compared to Point Knox Shoal.
- Because the density and number of fish species were similar at Presidio Shoal and the reference site, **no dredging effect is indicated.**

Crustaceans

- Densities of all shrimp and crabs are presented in Table 3-2.
- Four species of Bay shrimp were found:
  - Northern Bay shrimp (*Crangon alaskensis*)
  - California Bay shrimp (*Crangon franciscorum*)
  - Blacktail Bay shrimp (*Crangon nigricauda*)
  - Bay shrimp (*Crangon stylirostris*)
- Northern Bay shrimp was the most abundant.
- Densities of Northern Bay shrimp and Blacktail Bay shrimp are shown in Figure 3-1. At Presidio Shoal and the reference area, the Northern Bay shrimp (*Crangon alaskensis*) increased in abundance during June, with peak abundance in the middle of July. The Blacktail Bay shrimp (*Crangon nigricauda*) was found in the first three surveys, then disappeared in mid and late July.

- For the Northern Bay shrimp (*Crangon alaskensis*), Presidio Shoal and the reference area had significantly higher abundances than Point Knox Shoal.

- For Blacktail Bay shrimp (*Crangon nigricauda*), no differences were seen among the three areas.

- Because abundances of these shrimp are similar at the Presidio Shoal (or Presidio and Point Knox Shoals) and the reference area, *no dredging effect is indicated.*

- Seven species of *Cancer* crabs were identified. These are:
  - *Cancer anthonyi*
  - *Cancer antennarius*
  - *Cancer productus*
  - *Cancer jordoni*
  - *Cancer gracilis*
  - *Cancer branneri*
  - *Cancer magister*

- Densities of *Cancer gracilis* and *Cancer* spp. are shown in Figure 3.2.

- Number of *Cancer gracilis* were almost twice as high at the reference area compared to Presidio Shoal and were substantially higher (more than 25 times) compared to Point Knox Shoal.

- Juvenile *Cancer* spp. (probably *Cancer gracilis*) were significantly more abundant at the reference station compared to Presidio Shoal and Point Knox Shoal.

- Only two specimens of the commercially important Dungeness Crab, *Cancer magister*, were found.

CONCLUSIONS

- Four species of Bay Shrimp were found in the study area. Of these, the Northern Bay Shrimp was the most abundant.

- Differences in abundances of this shrimp were likely due to environmental factors and are not related to dredging, as numbers were similar at Presidio Shoal and the reference area.

- Shrimp were widespread throughout the study area, and effects of the sand mining operation were not apparent.

- Only two specimens of the commercially important Dungeness Crab were found during the two-month study period.

Table 3-1. Invertebrate and Fish Species Found at Presidio Shoal, Point Knox Shoal, and the Reference Area During the Five Trawl Surveys.

	Presidio Shoal	Point Knox Shoal	Reference
Crustaceans			
Amphipoda	X	X	X
Anomura			X
Cancer antennarius	X		X
Cancer anthonyi	X		X
Cancer branneri	X		X
Cancer gracilis	X	X	X
Cancer jordani			X
Cancer magister		X	X
Cancer productus		X	X
Cancer sp.	X	X	X
Caprellidea	X		X
Cirripedia		X	X
Crangon alaskensis	X	X	X
Crangon franciscorum	X	X	X
Crangon nigracauda	X	X	X
Crangon stylirostris	X	X	X
Cumacea	X	X	X
Heptacarpus stimpsoni	X	X	X
Isopoda	X	X	X
Lophopanopeus sp.	X		X
Mysida	X	X	X
Ogyrides sp.	X		
Ostracoda	X		
Paguridae		X	
Pagurus sp.			X
Pinnixa sp.	X		X
Pycnogonida	X		
Pycnogonum rickettsi	X		X
Pyromaia tuberculata	X	X	X
Molluscs			
Acanthodoris rhodoceras			X
Acanthodoris sp.			X
Aeolidia sp.	X		
Alia carinata	X	X	X
Amphissa sp.			X
Asperiscala sp.			X
Bullomorpha	X		X
Calliostoma annulata			X
Clinocardium sp.	X	X	X
Cooperella subdiaphana	X		

Table 3-1. Continues...

Table 3-1. Continued.

	Presidio Shoal	Point Knox Shoal	Reference
Coryphella sp.	X	X	X
Cryptomya californica	X		X
Cylichnella sp.	X		
Dendronotus sp.			X
Dendronotus venustus	X		
Donacidae		X	
Hiatella arctica			X
Leptopecten latiauratus			X
Macoma sp.	X		
Mactridae	X		X
Mya arenaria	X		X
Nassarius mendicus	X		X
Nassarius sp.	X		X
Neverita recluziana			X
Neverita sp.			X
Nitidiscala indianorum			X
Nucella sp.		X	
Nudibranchia		X	
Odostomia sp.			X
Olivella biplicata		X	
Olivella pycna	X	X	X
Philine quadrata	X		
Potamocorbula amurensis	X		X
Protothaca sp.	X		
Semele sp.	X		
Siliqua patula	X	X	X
Solen sicarius	X		
Tellina sp.	X	X	
Theora lubrica	X		X
Transenella tantilla	X	X	X
Triopha sp.			X
Turbonilla sp.			X
Venerupis phillipinarum	X		X
Cnidarians			
Abietinaria sp. (colonial)	X		
Aglaophenia sp. (colonial)	X	X	X
Bougainvilliidae (colonial)	X	X	X
Calycella syringa	X		
Campanularia sp. (colonial)		X	
Campanulariidae (colonial)	X	X	X
Corynactis californica		X	

Table 3-1. Continues...

Table 3-1. Continued.

	Presidio Shoal	Point Knox Shoal	Reference
Diadumene leucolena			X
Epiactis prolifera	X		X
Gonionemus vertens			X
Hydrallmania distans		X	
Obelia bidentata	X	X	X
Obelia dichotoma	X	X	X
Obelia sp. (colonial)	X	X	X
Plumularia alicia		X	
Plumularia sp.		X	
Sagartia catalinensis			X
Sagartia sp.			X
Sertulariidae	X		
Stylatula elongata	X		
Stylatula sp. A (MEC)	X		
Platyhelminthes			
Stylochus sp.	X		X
Nematodes			
Nematoda	X		
Annelids			
Ampharetidae	X		X
Aphroditidae			X
Capitellidae	X		
Glyceridae	X		
Hirudinea	X		X
Nereidae	X	X	X
Orbiniidae			X
Pectinaria sp.			X
Pectinariidae			X
Polychaeta	X	X	X
Polynoidae			X
Sabellidae			X
Spionidae			X
Ectoprocts			
Alcyonidium sp. (colonial)			X
Anguinella palmatum (colonial)	X		X
Aplousina filum (colonial)			X
Celleporella hyalina (colonial)	X	X	X
Cheilopora praelonga (colonial)			X
Crisia sp. (colonial)	X	X	X
Ctenostomata		X	X
Ectoprocta (colonial)	X	X	
Filicrisia sp. (colonial)	X		

Table 3-1. Continues...

Table 3-1. Continued.

	Presidio Shoal	Point Knox Shoal	Reference
Scrupocellaria sp. (colonial)	X		X
Tricellaria sp. (colonial)		X	
Watersipora cucullata (colonial)	X	X	X
Brachiopods			
Glottidia albida	X		
Echinoderms			
Amphiodia digitata			X
Amphiodia sp.	X	X	X
Dendraster excentricus	X		
Dendraster sp.	X		
Ophiothrix spiculata	X		X
Ophiuroidea	X		X
Patiria minuta		X	
Pisaster brevispinus	X		X
Urochordates			
Perophora sp.		X	
Urochordata	X		X
Fish			
Acanthogobius flavimanus	X	X	X
Citharichthys stigmaeus	X	X	X
Genyonemus lineatus	X		X
Gobiesocidae		X	
Gobiidae			X
Ilypnus gilberti			X
Leptocottus armatus	X	X	X
Paralichthys californicus	X		
Pleuronectes vetulus	X	X	X
Pleuronichthys decurrens		X	
Porichthys notatus	X	X	X
Psettichthys melanostictus		X	X
Sciaenidae	X		
Sebastes sp.	X	X	X
Spirinchus thaleichthys	X	X	
Symphurus atricauda	X	X	X
Syngnathus leptorhynchus		X	

Table 3-2. Mean density and biomass (per 100m^2) for crabs and shrimp.

Species/Station	Density (#/100 m^2)			Biomass (g/100 m^2)		
	Presidio Shoal	Point Knox Shoal	Reference	Presidio Shoal	Point Knox Shoal	Reference
Survey 1 (June 2)						
Heptacarpus stimpsoni	17.25	0.27	149.06	1.83	0.01	8.97
Crangon nigracauda	2.80	0.00	7.65	0.10	0.00	0.65
Crangon alaskensis	147.88	2.89	157.90	28.62	1.46	29.45
Crangon stylirostris	10.62	0.07	2.66	0.37	0.00	0.08
Crangon franciscorum	0.59	0.40	1.76	0.36	0.22	1.73
Pyromaia tuberculata	1.25	0.07	2.08	0.30	0.02	1.20
Cancer sp. juvenile	2.58	0.14	14.30	0.07	0.01	0.51
Cancer productus	0.00	0.07	0.99	0.00	0.01	0.23
Cancer branneri	0.00	0.00	0.35	0.00	0.00	0.46
Cancer magister	0.00	0.00	0.09	0.00	0.00	0.02
Cancer gracilis	1.51	0.33	5.37	1.13	0.23	2.98
Cancer anthonyi	0.15	0.00	0.19	23.54	0.00	0.03
Lophopanopeus sp.	0.00	0.00	0.22	0.00	0.00	0.02
Pinnixa sp.	0.50	0.00	0.00	0.02	0.00	0.00
Survey 2 (June 10)						
Heptacarpus stimpsoni	0.93	0.00	0.00	0.10	0.00	0.00
Crangon nigracauda	3.02	0.00	0.00	0.21	0.00	0.00
Crangon alaskensis	36.15	0.00	0.00	7.92	0.00	0.00
Crangon stylirostris	1.27	0.00	0.00	0.04	0.00	0.00
Pyromaia tuberculata	0.58	0.00	0.00	0.16	0.00	0.00
Cancer sp. juvenile	0.53	0.00	0.00	0.04	0.00	0.00
Cancer gracilis	0.10	0.00	0.00	0.42	0.00	0.00
Survey 3 (June 30 - July 1)						
Ogyrides sp.	0.09	0.00	0.00	0.00	0.00	0.00
Heptacarpus stimpsoni	22.68	0.24	108.20	2.06	0.01	8.49
Crangon nigracauda	3.94	2.57	2.77	0.30	0.70	0.04
Crangon alaskensis	241.62	20.86	379.62	21.59	10.48	27.99
Crangon stylirostris	3.57	0.18	1.86	0.14	0.01	0.06
Crangon franciscorum	0.26	0.97	0.78	0.34	1.38	0.80
Anomura	0.00	0.00	0.00	0.00	0.00	0.00
Pyromaia tuberculata	0.94	0.00	1.93	0.74	0.00	1.65
Cancer sp. juvenile	1.88	0.07	11.29	0.08	0.00	0.43
Cancer productus	0.00	0.00	0.55	0.00	0.00	0.08
Cancer antennarius	0.09	0.00	0.00	12.01	0.00	0.00
Cancer branneri	0.17	0.00	0.13	0.05	0.00	0.04
Cancer magister	0.00	0.07	0.00	0.00	0.23	0.00
Cancer gracilis	1.37	0.04	4.15	3.50	0.00	4.02

Table 3-2. Continues...

Table 3-2. Continued.

Species/Station	Density (#/100 m²)			Biomass (g/100 m²)		
	Presidio Shoal	Point Knox Shoal	Reference	Presidio Shoal	Point Knox Shoal	Reference
Cancer anthonyi	0.08	0.00	0.28	14.84	0.00	0.07
Cancer jordani	0.00	0.00	0.07	0.00	0.00	0.05
Lophopanopeus sp.	0.26	0.00	0.28	0.01	0.00	0.19
Pinnixa sp.	0.86	0.00	0.18	0.02	0.00	0.01
Survey 4 (July 13)						
Heptacarpus stimpsoni	6.06	0.63	164.13	0.39	0.06	12.16
Crangon alaskensis	505.73	38.23	725.12	90.11	16.80	165.78
Crangon stylirostris	129.10	18.00	0.30	8.63	1.21	0.00
Crangon franciscorum	0.60	1.63	5.48	0.80	2.26	6.34
Anomura	0.00	0.00	0.00	0.00	0.00	0.00
Paguridae	0.00	0.00	0.00	0.00	0.00	0.00
Pagurus sp.	0.00	0.00	0.45	0.00	0.00	0.25
Pyromaia tuberculata	0.60	0.00	2.51	0.99	0.00	2.55
Cancer sp. juvenile	0.30	0.00	3.23	0.01	0.00	0.08
Cancer productus	0.00	0.12	0.56	0.00	1.55	0.32
Cancer antennarius	0.30	0.00	0.00	66.89	0.00	0.00
Cancer branneri	0.00	0.00	0.75	0.00	0.00	0.19
Cancer gracilis	8.09	0.29	13.11	144.80	6.04	36.04
Lophopanopeus sp.	0.00	0.00	0.51	0.00	0.00	0.72
Survey 5 (July 27)						
Heptacarpus stimpsoni	28.87	0.80	107.23	2.02	0.04	8.28
Crangon alaskensis	402.15	85.85	396.19	76.22	34.17	53.33
Crangon stylirostris	64.68	34.16	1.80	4.97	3.28	0.18
Crangon franciscorum	1.08	3.40	1.10	2.09	5.04	1.35
Paguridae	0.00	0.00	0.00	0.00	0.00	0.00
Pagurus sp.	0.00	0.00	0.54	0.00	0.00	0.24
Pyromaia tuberculata	0.28	0.00	1.14	0.15	0.00	0.63
Cancer sp. juvenile	6.81	0.26	4.74	0.22	0.01	0.15
Cancer productus	0.00	0.00	1.08	0.00	0.00	0.74
Cancer antennarius	0.36	0.00	0.36	27.45	0.00	0.94
Cancer branneri	0.72	0.00	0.18	0.23	0.00	0.05
Cancer gracilis	2.35	0.30	3.96	45.11	7.00	6.29
Pinnixa sp.	2.16	0.00	0.00	0.10	0.00	0.00

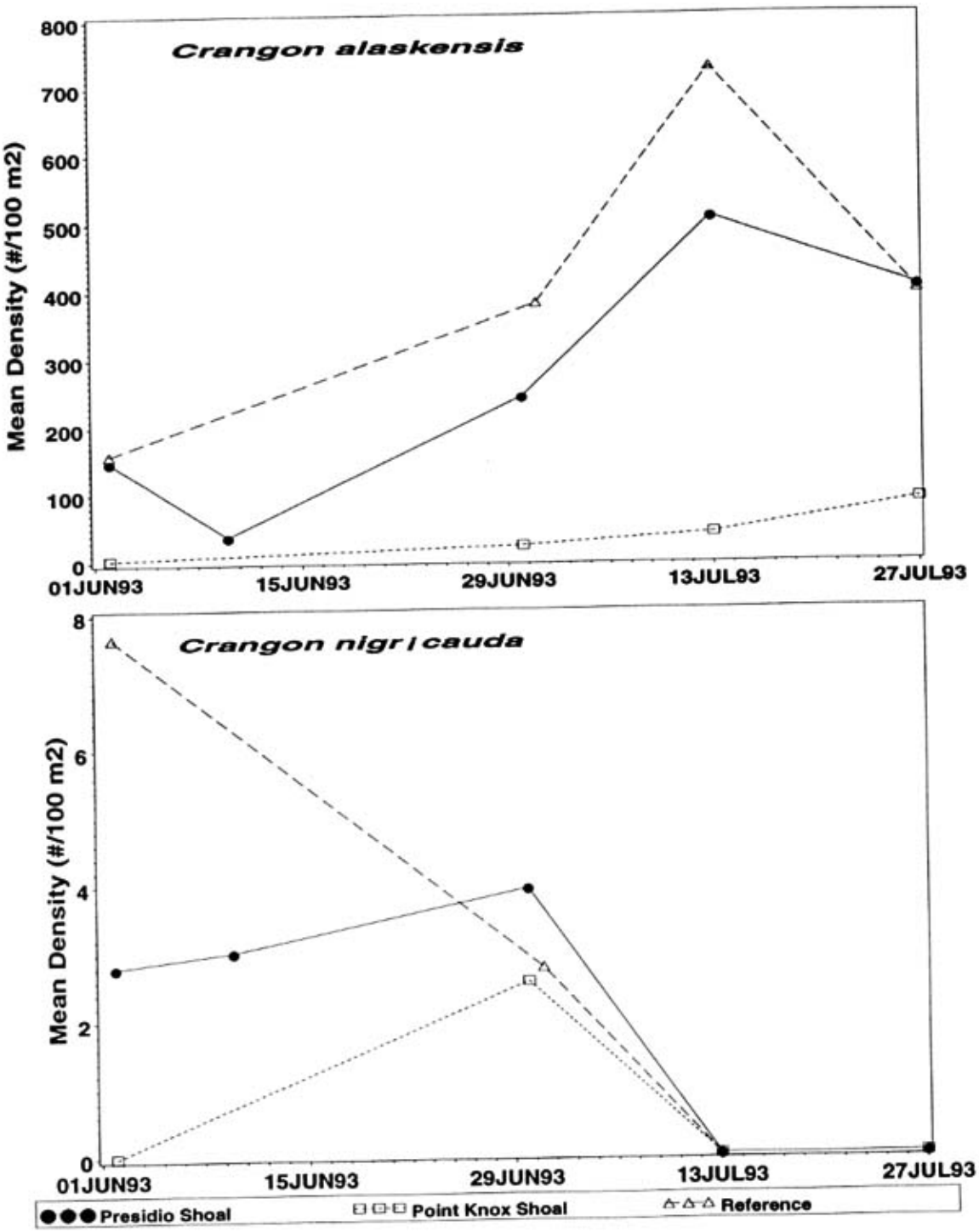

Figure 3-1. Mean Density (per 100 m^2) of Two Abundant Species of Bay Shrimp at the Three Areas.

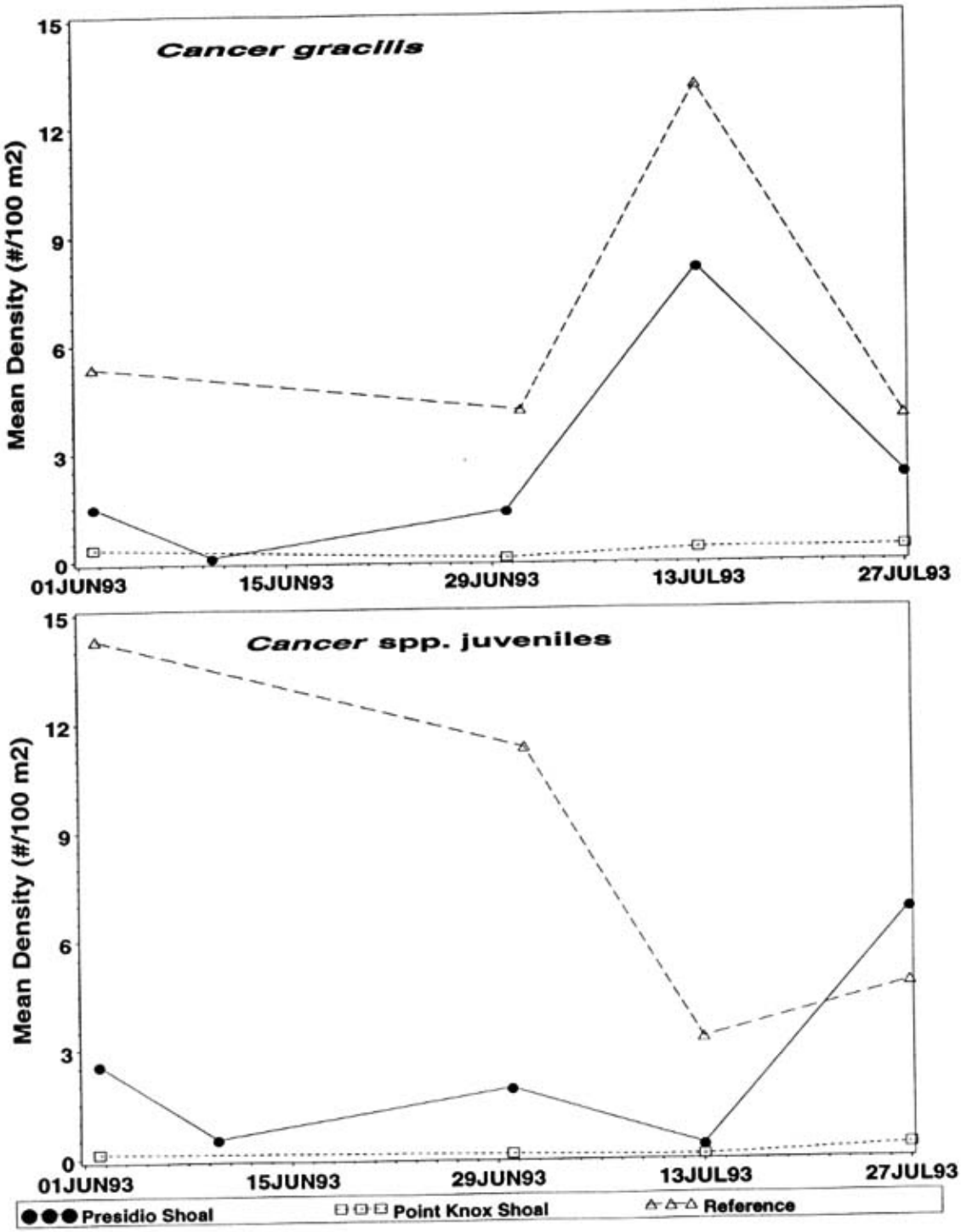

Figure 3-2. Mean Density (per 100 m^2) of the Crabs *Cancer gracilis* and *Cancer* spp. Juveniles at the Three Areas.