Entergy Nuclear Generation Company

Study of Winter Flounder Transport in Coastal Cape Cod Bay and Entrainment at Pilgrim Nuclear Power Station

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1.0 INTRODUCTION

Winter flounder (*Pseudopleuronectes americanus*) are commercially important in Cape Cod Bay and are a dominant species collected in entrainment monitoring at Pilgrim Nuclear Power Station (PNPS). The objective of this study is to evaluate the impact of winter flounder larvae entrainment at PNPS through direct field measurements. An approach was applied whereby field measurements were collected to determine the relative amount of net volumetric flow and winter flounder larvae entrained into the PNPS cooling water system compared to the net volumetric flow and amount of winter flounder larvae passing PNPS in offshore Cape Cod Bay waters.

The field program was designed to collect sufficient measurements to determine the flux of winter flounder larvae moving along the Plymouth coast and the flux of winter flounder entering the PNPS. To determine larvae flux, larvae concentration and volumetric flowrate of water are required. The field program featured collection of larvae concentration measurements and water velocity measurements along the Plymouth coast in Cape Cod Bay and collection of larvae concentration measurements at the PNPS cooling water system.

The field program was conducted over a four-week period and consisted of the following three elements:

- Field sampling of four stages of winter flounder larvae at five stations along a Plymouth coast transect in Cape Cod Bay.
- Water velocity measurements at three stations along a Plymouth coast transect in Cape Cod Bay, using bottom mounted Acoustic Doppler Current Profiler (ADCP) units.
- Sampling of four stages of winter flounder larvae entrained into the PNPS cooling water flow.

Larvae and water velocity measurements were collected concurrently throughout May 2000 to support determination of larvae flux. Larvae sampling was conducted along the Plymouth coast and at the PNPS system during four surveys - once per week – during the month of May 2000. For each survey, larvae samples were obtained four times – twice during the day, and twice during the night - during a one-day period. Water velocity measurements were collected continuously during the month of May 2000.

The field larvae data were combined with the current measurements to determine the flux of larvae along the coast of Cape Cod Bay, for each of the four daily measurement periods. These values were then compared to the amount of larvae entrained into the PNPS cooling system, as determined from the entrainment study, during the same four daily measurement periods.

Section 2 of this report describes the field sampling program. Section 3 provides the field study results. Section 4 provides an analysis of the study results. Section 5 provides the study conclusion and an overall assessment of the entrainment impact of PNPS on winter flounder larvae in Cape Cod Bay based on the study results.

2.0 FIELD SAMPLING PROGRAM

2.1 Winter Flounder Larvae Sampling

Larval winter flounder were collected at five stations along a single transect located in Cape Cod Bay (Figure 2-1). Stations are defined as segments located along the transect line which began at Rocky Point and projected perpendicular to the shoreline to the 120' contour line of Cape Cod Bay. The total transect length was approximately five nautical miles. The same transect line was used for the hydrodynamic measurements described below. The close proximity of the larvae sampling stations to the hydrodynamic measurements facilitated correlation of the acquired hydrodynamic data with biological sample data to formulate an estimate of the population of winter flounder contained in Cape Cod Bay coastal waters flowing towards and past PNPS.

The five sampling stations were identified as Stations A through E in order of increasing distance from the shore, with each station having a segment length of approximately one-half nautical mile. The ranges of water depths along the station segment lengths were approximately as follows: Station A: 25'- 37'; Station B: 43' - 60'; Station C: 75' - 100'; Station D: 105' - 115'; Station E: 118' - 125'. As shown on Figure 2-1, the stations were positioned such that the inshore stations were more closely spaced than the offshore stations. Tow duration for each sample was approximately six to eight minutes, which provided sample volumes ranging from 85 to 150 cubic meters and an overall average of 120 cubic meters.

Four weekly field surveys (cruises) were completed during the month of May 2000 – May 8, 9, May 15, 16, May 22, 23, and May 30, 31. Each survey was structured to capture the ebb and flood tides of two tidal cycles on each sampling day (4 sampling events per survey, 2 during the day and 2 during the night). Sampling was conducted at each station using 60-cm diameter "bongo" nets rigged with 0.202-mm and 0.333-mm nylon mesh plankton nets.

At all five stations, A, B, C, D, and E, stratified oblique tows were performed, by partitioning the water column into three equal-depth layers and completing one oblique tow in each layer so that samples were obtained from surface, mid-depth and bottom layer. Stations were initially located using GPS bearings during deployment of the ADCP units. At that time for each station Loran C coordinates were determined and used to locate each station for subsequent tows. Filtration volumes were determined using General Oceanics 2030R flow meters installed in the mouth of the plankton net.

After the completion of each sample tow, the net was washed down from the outside and the contents were transferred to one-liter bottles containing sufficient formalin to produce a 10% solution with seawater. A waterproof tag listing the station, date, start and end time of the collection, the flow-meter readings, and the net was placed into each sample container. Samples were then delivered to the lab for microscopic analysis where all winter flounder larvae were identified and counted within four developmental stages. Only the 0.202-mm mesh samples were analyzed; the 0.333-mm mesh samples were archive. Due to the abundance of zooplankton some samples were split in half using a plankton splitter patterned after (Motoda 1959, see also VanGuelpin et al. 1982). Counts were converted to numbers per 100 cubic meters of water based on the flow-meter readings.

2.2 Entrainment Monitoring

In conjunction with each offshore sampling series, ichthyoplankton samples were also taken from the PNPS cooling water discharge. Sampling was conducted near the center of the discharge canal approximately 30 meters downstream from the headwall to assess the impacts of entrainment on winter flounder populations. Samples were collected using a 60-cm diameter plankton net constructed of 0.202-mm nylon mesh. On each of the four May occasions 2 day and 2 night samples were taken approximately centered in time on each of the offshore sampling series for a total of 4 per survey. Each collection was made by streaming the net for 10 to 30 minutes depending on tide stage, longer sampling intervals being required to collect samples near high water. Exact filtration volumes were determined using a General Oceanics 2030R2 flowmeter mounted in the mouth of the net.

After sample collection, the net was rinsed from the outside using seawater to wash all plankton into the cod end of the net. The sample was then transferred into a 1-liter wide mouth bottle and preserved using sufficient buffered Formalin to obtain a 10% solution. A waterproof tag listing the station, date, time of collection, and the flow-meter readings was placed into each sample container. Samples were returned to the laboratory and processed as described above for the offshore samples.

2.3 Hydrodynamic Measurements

The hydrodynamic measurement component of the field program was designed to support determination of the total volumetric flux of water along the Plymouth coast. The hydrodynamic surveys were scheduled concurrently with winter flounder larvae sampling surveys to support determination of winter flounder larval flux along the Plymouth coast.

As shown in Figure 2-2, hydrodynamic measurements were collected along an east-west transect extending from Rocky Point in Plymouth to a depth of 130 feet, approximately 5 nautical miles offshore. The location of this transect was selected to capture dominant longshore currents flowing in a north-south direction. The hydrodynamic field program consisted of two components, a long-term survey and a synoptic survey. The long-term survey featured deployment of hydrodynamic instruments and continuous collection of measurements at three locations (designated locations #1, #2, and #3 in Figure 2-2) along the Rocky Point transect for a period of one month. The synoptic survey featured collection of hydrodynamic measurements from a boat transiting the entire Rocky Point transect. The long-term and synoptic surveys were successfully collected the data required to support the impact assessment and are described below.

2.3.1 Long-term Hydrodynamic Survey

Hydrodynamic measurements were continuously collected at three locations (denoted #1, #2, and #3) along the Rocky Point transect (Figure 2-2). At each hydrodynamic sampling location, the following measurements were collected for a period of one month.

- Water velocity measurements throughout the water column using a bottom-based acoustic Doppler current profiler (ADCP). ADCP measurements were acquired at one-meter intervals throughout the full depth of the water column. The ADCP measures the magnitude and direction of water movement through transmission of acoustic signals and interpretation of Doppler frequency shifts in acoustic returns.
- Water level of the sea surface using a tide gauge.

The long-term hydrodynamic field data collection program achieved 100% data recovery, as planned. A description of long-term survey deployments, equipment, and data collection is provided below for each location.

<u>Location #1: Data Collection Summary</u>

Deployment Information:

- Instrument deployment coordinates: 41° 57.366'N, 70° 34.616'W
- Instrument deployment depth: 44 feet of water
- Deployment date/time: 06 May 2000 at 1254
- Recovery date/time: 09 June 2000 at 1730
- Deployment duration: 34-days, 4 hours

Equipment and Data Collection Configuration:

- Water velocity meter specification: RD Instruments, Workhorse Sentinel ADCP, 600kHz frequency (serial #0633).
- Water velocity data collection: ADCP measurements collected and recorded every 10 minutes throughout the water column.
- Tide gauge specification: Coastal Macrowave Non-directional Wave Gauge (serial #10209).
- Tide gauge data collection: Water level measurements collected and recorded every 10 minutes.

Location #2: Data Collection Summary

Deployment Information:

- Instrument deployment coordinates: 41° 57.761'N, 70° 32.305'W
- Instrument deployment depth: 98 feet of water
- Deployment date/time: 06 May 2000 at 1331
- Recovery date/time: 09 June 2000 at 1243
- Deployment duration: 33-days, 23 hours

Equipment and Data Collection Configuration:

- Water velocity meter specification: RD Instruments, Workhorse Sentinel ADCP, 300kHz frequency (serial #0880).
- Water velocity data collection: Measurements collected and recorded every 10 minutes throughout the water column.
- Tide gauge specification: Coastal Macrowave Non-directional Wave Gauge (serial #10603).
- Tide gauge data collection: Water level measurements collected and recorded every 10 minutes.

Location #3: Data Collection Summary

Deployment Information:

- Instrument deployment coordinates: 41° 58.370'N, 70° 29.108'W
- Instrument deployment depth: 129 feet of water
- Deployment date/time: 06 May 2000 at 1408
- Recovery date/time: 09 June 2000 at 1136
- Deployment duration: 33-days, 21 hours

Equipment and Data Collection Configuration:

- Water velocity meter specification: RD Instruments, Workhorse Sentinel ADCP, 300kHz frequency (serial #0896).

- Water velocity data collection: Measurements collected and recorded every 10 minutes throughout the water column.
- Tide gauge specification: Coastal Macrowave Non-directional Wave Gauge (serial #10301).
- Tide gauge data collection: Water level measurements collected and recorded every 10 minutes.

All instruments were successfully recovered and 100% of data was achieved, as planned. Processing, analysis and application of the long-term hydrodynamic measurement data is described in Section 3.

2.3.2 Synoptic Hydrodynamic Survey

Synoptic boat-based water velocity measurements were collected using an ADCP instrument on 09 June 2000. The boat-based ADCP survey featured measurement of water velocities (direction and magnitude) at one meter intervals throughout the water column. Two transits of the Rocky Point transect were performed, once each during ebb and flood tide. The ADCP unit was rigidly mounted in a frame suspended over the side of the survey vessel. The synoptic survey transits were perfomed at the times indicated below:

- Ebb tide survey date/time: 09 June 2000 from 10:12 to 11:20
- Flood tide survey date/time: 09 June 2000 from 14:34 to 15:44

The synoptic survey achieved the 100% data collection goal. Processing, analysis and application of synoptic hydrodynamic measurement data is described in Section 3.

2.4 Water Column Monitoring

Measurements of temperature (± 0.1° C), salinity (± 0.1 o/oo), and dissolved oxygen (± 0.1 ppm) were recorded at each station immediately preceding the surface tow using a Hydrolab Quanta instrument. Readings were recorded at surface, mid-depth and at a depth within 1-meter of the bottom.

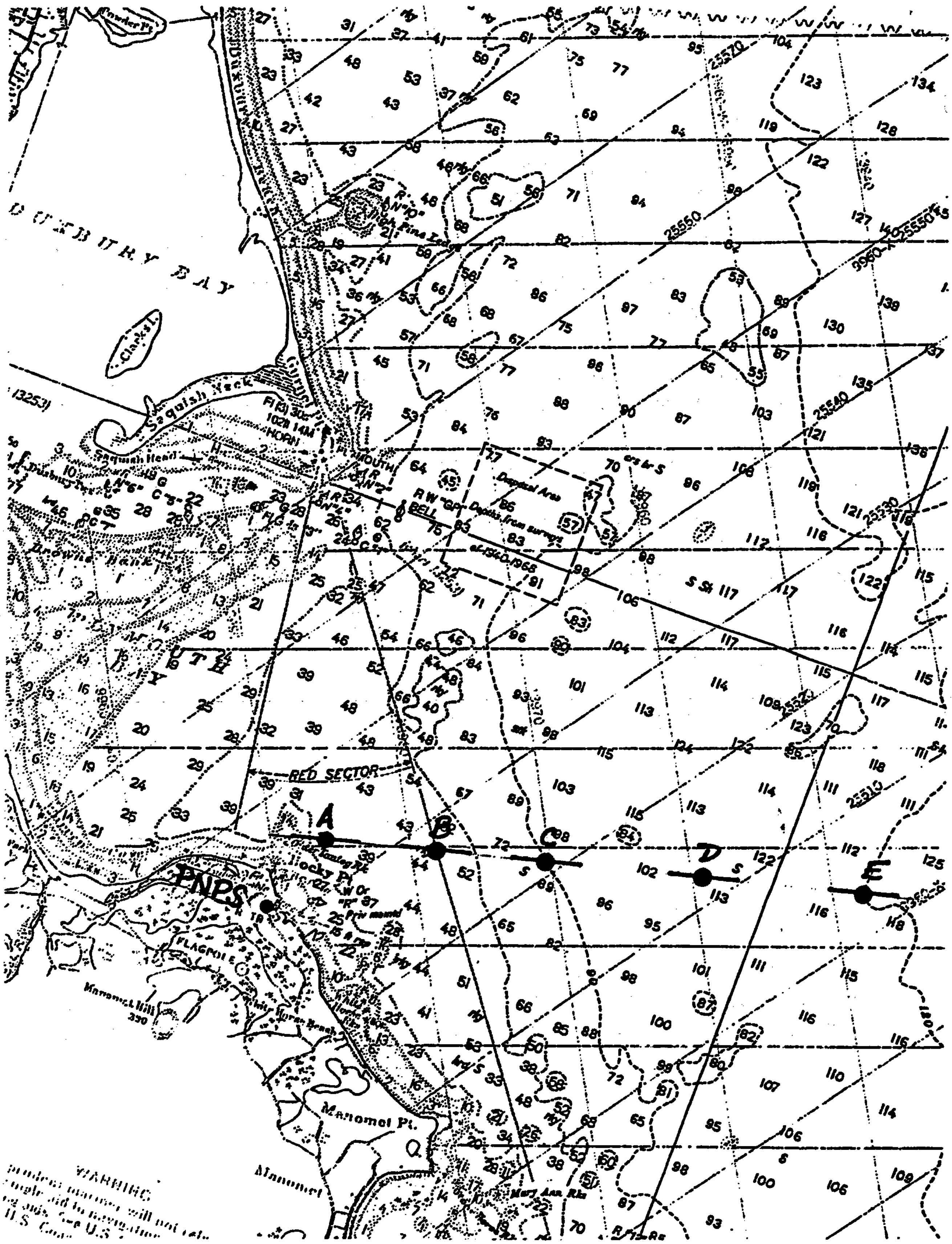


Figure 2-1
Station Transects for the Collection of Winter Flounder Larvae Samples

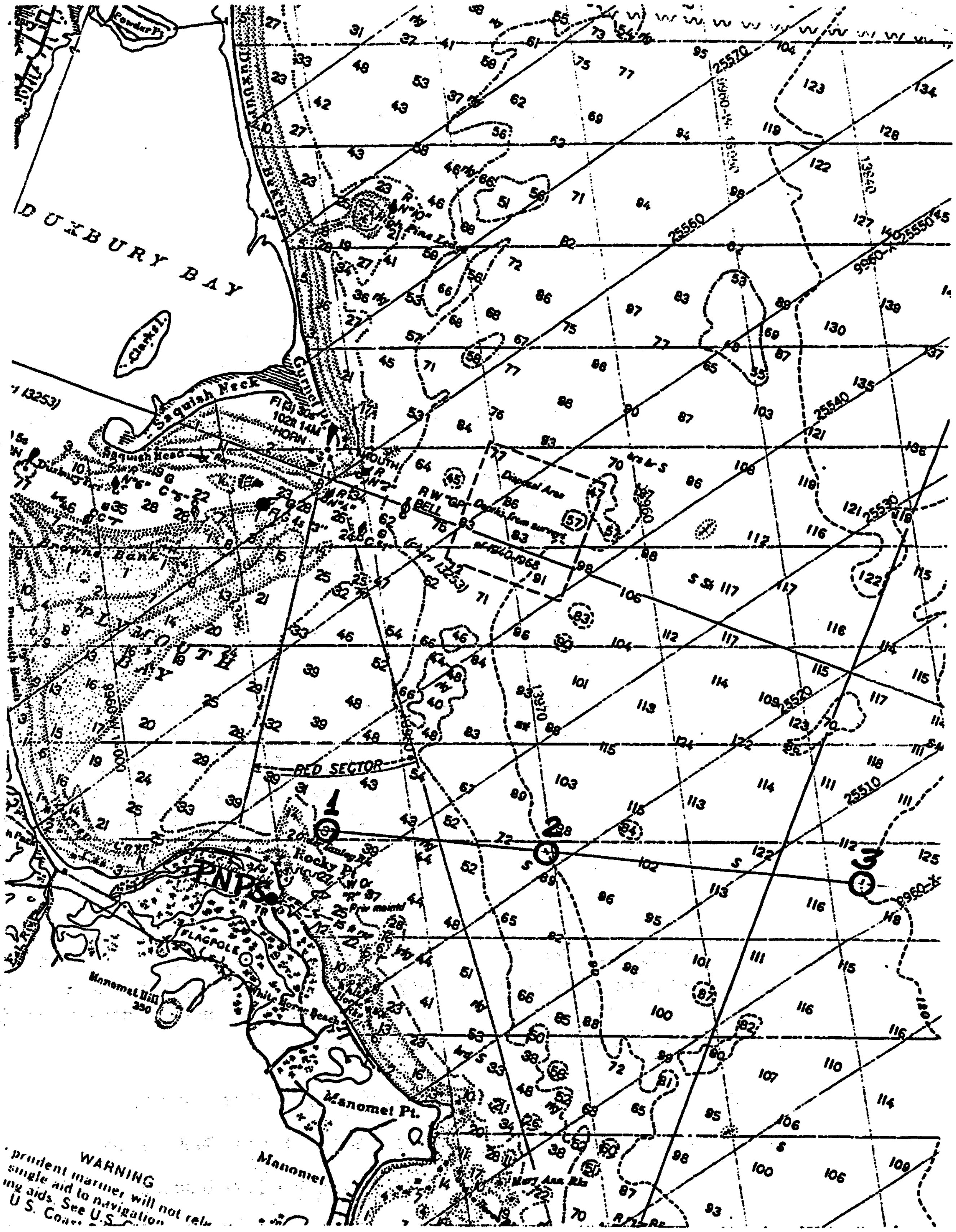


Figure 2-2
Deployment Sites for ADCP/Tide Gauge Instrumentation Packages

3.0 STUDY RESULTS

3.1 Larvae and Entrainment Sampling Results

Densities of larval flounder per 100 m^3 of water by developmental stage for each sample appear in Appendix A. Larval flounder were present on each sampling occasion. Averaged over all samples taken within each of the four cruises, larvae were most abundant during the May 22, 23 series, least abundant during the May 30, 31 series, and found in nearly equal numbers during the first two series. Overall mean densities were 22.1, 22.2, 35.5, and 11.5 per 100 m^3 of water, respectively. Stage 1, yolk-sac larvae accounted for 34 and 35% of the total during the first two cruises then declined to 17% and 1% of the total during the third and fourth cruises, respectively. Stage 2 and 3 larvae clearly accounted for the majority of flounder collected; together they accounted for between 65 and 98% of the total. Older Stage 4 larvae, those nearing metamorphosis, were relatively uncommon, being absent during the first and second cruises, accounting for less than 1% on the third and fourth cruises.

3.2 Hydrodynamic Monitoring Results

3.2.1 Long-term Hydrodynamic Survey

Data from each of the three locations was inspected, processed, and exported for further analyses using RD Instruments WinADCP software. Figure 3-1 through 3-3 contain WinADCP plots of the ADCP time series of North velocities at each of the three stations, for May 8 and 9, the time of the first larvae sampling event. Since the study transect is along an East-West line, the North component of velocity gives the flow perpendicular to the study transect. The conversion of the water velocity vectors (magnitude and direction) to North velocity means that all velocities and water fluxes are reported such that positive values are flowing North, and negative values are flowing South.

The ADCP data shows that flood tides are associated with southerly water flow across the study transect. Ebb tides are associated with either northerly water flow, or southerly water flow of reduced speed, across the study transect. Over the duration of the ADCP deployment, observed velocities perpendicular to the study transect ranged, in meters per second:

- from 0.342 (North) to -0.396 (South) with an average of -0.017 at Station 1,
- from 0.531 (North) to -0.540 (South) with an average of -0.047 at Station 2, and
- from 0.491 (North) to -0.764 (South) with an average of -0.035 at Station 3

RD Instruments SURFACE software was used to process the ADCP data to determine the height of the water surface above the bottom. These heights were used to determine the depths and areas in the water and larval flux calculations presented in Section 4. Hydrodynamic data are provided in Appendix C.

3.2.2 Synoptic Hydrodynamic Survey

Data from the two boat-based ADCP tows was inspected using RD Instruments WinRiver software. The ADCP transect tows of June 9, 2000 are presented in Figures 3-4 (10:12-11:20) and 3-5 (14:34-15:44). These figures again show the North component of velocity, perpendicular to the study transect.

The results of the synoptic surveys show that the current profiles vary smoothly across the transect, validating the choice of the three long-term ADCP stations. The two tows occurred under different current scenarios, the earlier flowing North and the later flowing South, yet show consistent results in terms of smooth transitions of velocity across the transect.

3.3 Water Column Monitoring Results

Water temperature, salinity, and dissolved oxygen data recorded at each station are tabulated in Appendix B for each of the four cruises. Based on average readings across station for each cruise, surface water temperatures (Figure 3-6) ranged from 9.8° C on the first cruise to 12.8° C on the fourth. Bottom readings (Figure 3-6) ranged from 6.5° C on the first to 7.9° C on the fourth however bottom readings actually averaged somewhat higher (8.1° C) on the second cruise. Along the sampling transect both surface and bottom water averaged higher at inshore Station A then further offshore, the difference between location being more pronounced in bottom water due to the increasing depth along the transect.

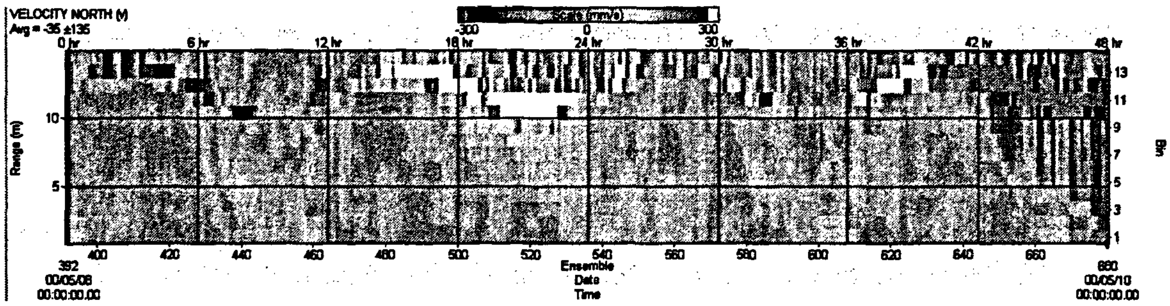


Figure 3-1 ADCP at Station 1 May 8-9, 2000

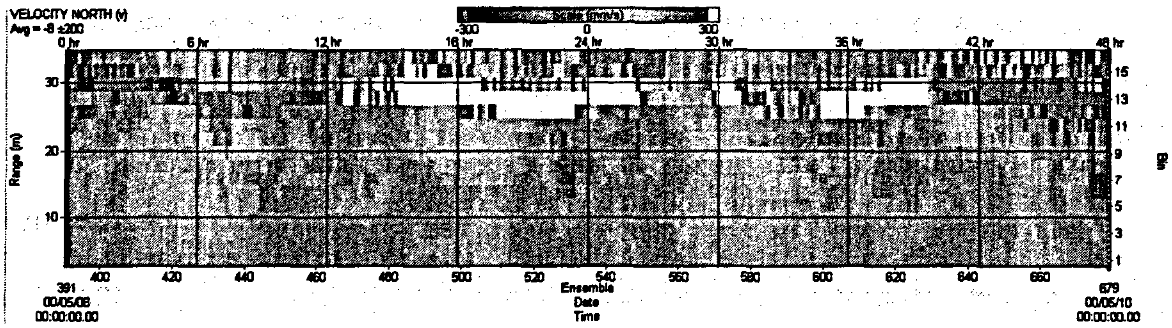


Figure 3-2 ADCP at Station 2 may 8-9, 2000

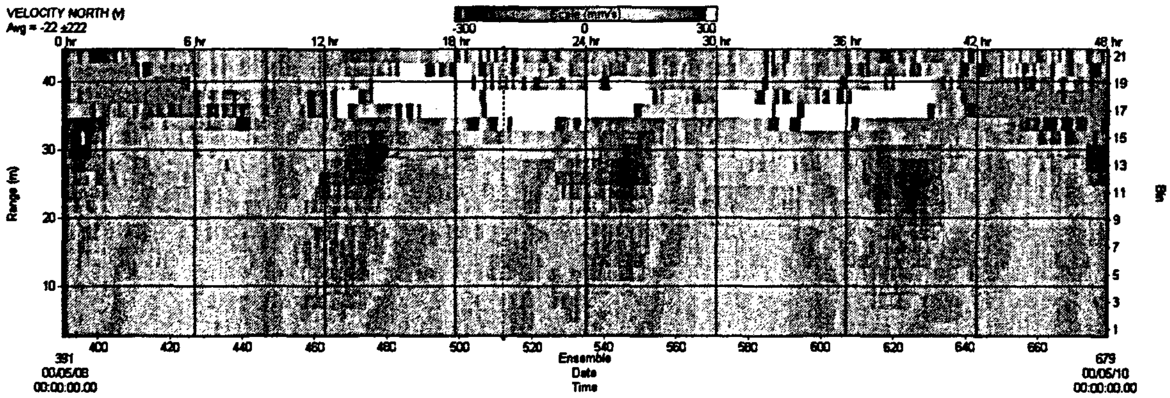


Figure 3-3 ADCP at Station 3 May 8-9, 2000

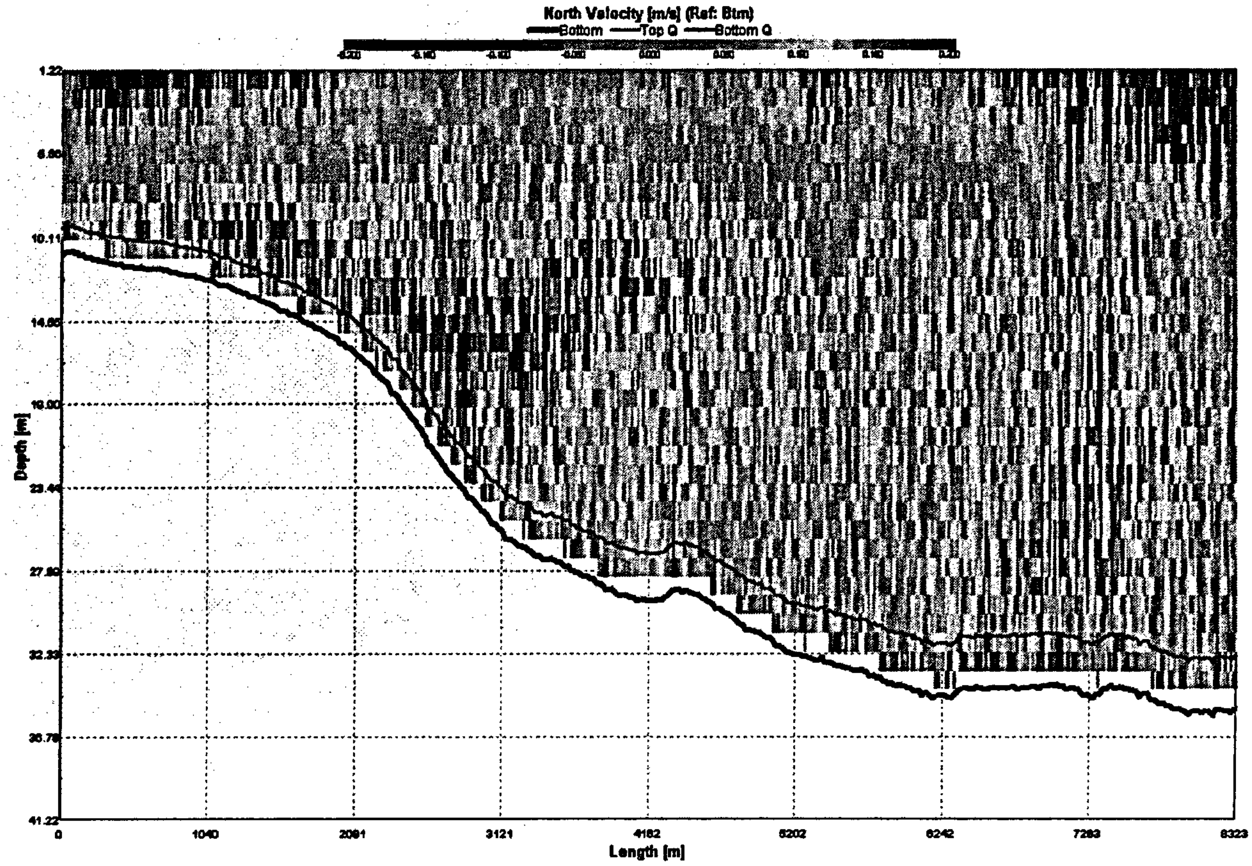


Figure 3-4 Towed ADCP Data June 9, 2000 10:12-11:20

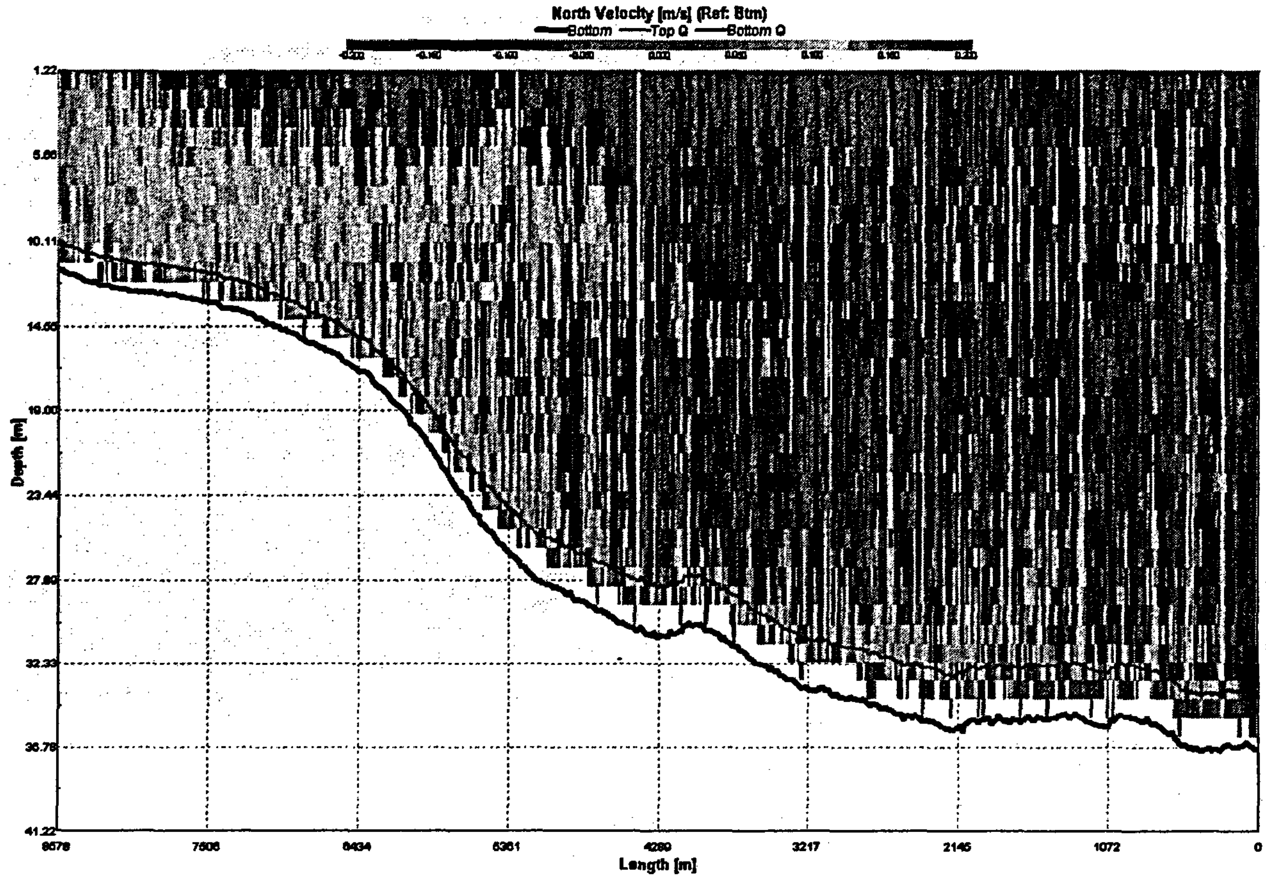
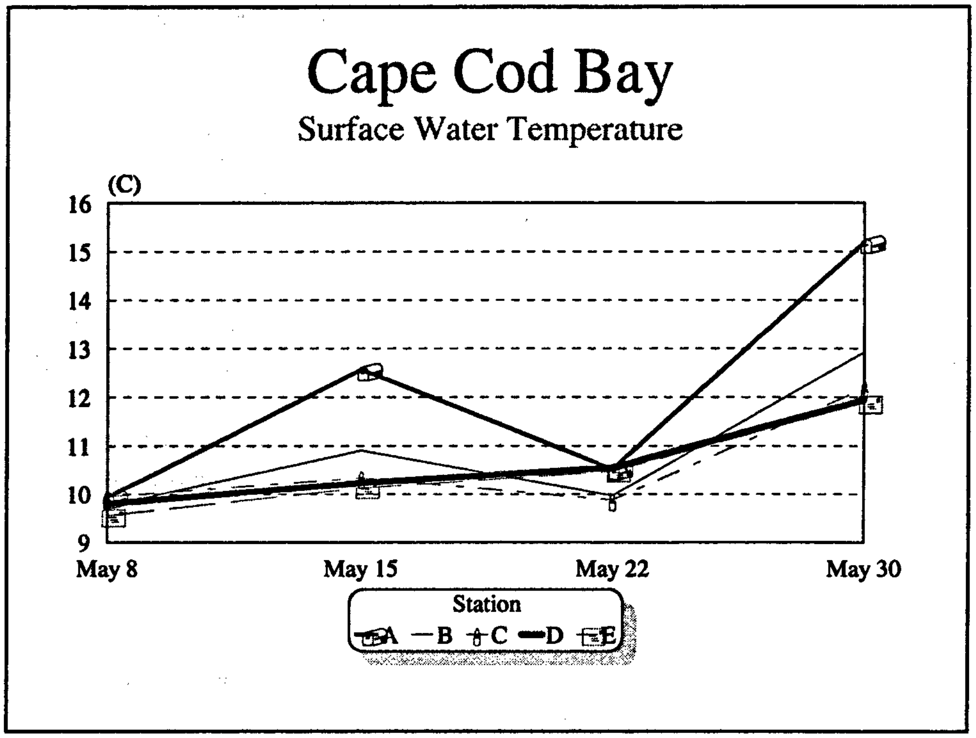


Figure 3-5 Towed ADCP Data June 9, 2000 14:34-15:44



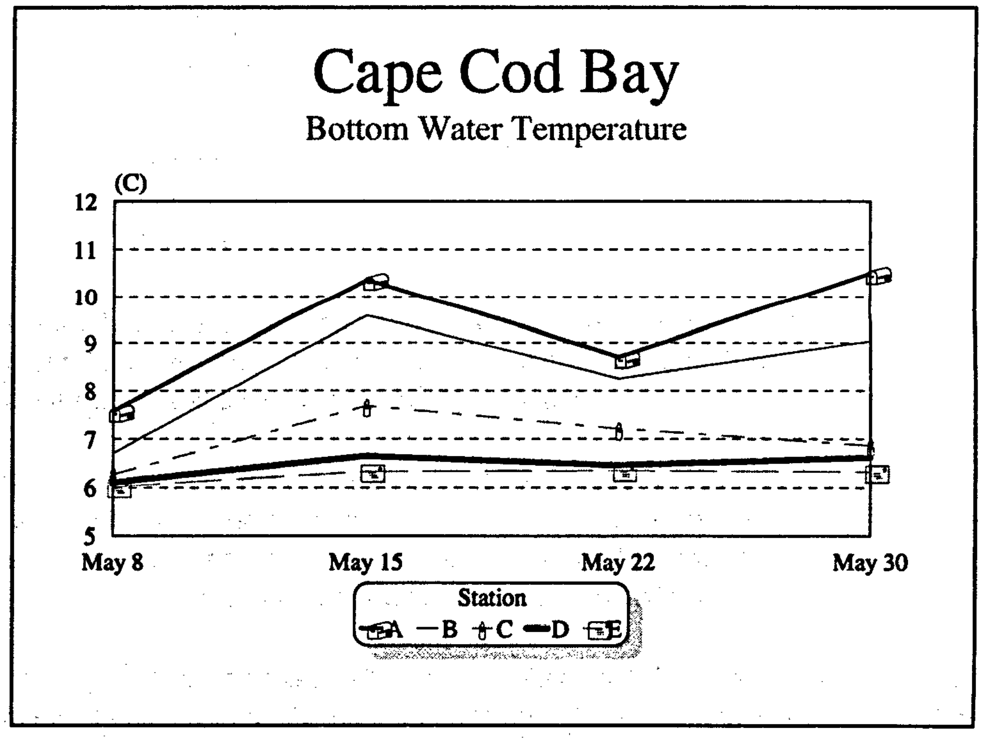


Figure 3-6 Mean Surface (top) and Bottom Water Temperatures Recorded at Each of Five Stations in Cape Cod Bay During Four May Cruises

4.0 DATA ANALYSIS AND ASSESSMENT

The data discussed above were analyzed to allow a determination of (1) the percentage of net volumetric flow in nearby coastal Cape Cod Bay waters withdrawn by PNPS and (2) the percentage of winter flounder larvae in the net coastal flow entrained by PNPS. This allows an evaluation of the overall effect of winter flounder larvae entrainment at PNPS.

A separate calculation of the percentage of coastal flow withdrawn and larvae entrained by PNPS was performed for each of the four sampling events, for which the sampling study was conducted. In addition, the volumetric flow analysis was performed over the entire monthly period that the hydrodynamic measurements were conducted. The larval analysis was performed for each of the four winter flounder larvae life stages and for total larvae. Details of the analysis procedures and results are discussed below.

4.1 Volumetric Flux Analysis

In order to correlate the three continuous-depth ADCP stations with the five discrete-depth larvae sampling stations, the ADCP water velocity data was processed in the following manner:

- At each ADCP station, the velocity values were segmented into thirds based on total depth at the time of the reading. The North component of the velocity was averaged over the ADCP data in each third of the water column, for each 10-minute ensemble of data.
- Since two of the larvae sampling stations (B and D) were between ADCP stations (A and C, and C and D, respectively), the North velocities were estimated by the average of the North velocities at the adjacent stations (*i.e.*, B is average of A and C).

Figure 4-1 contains plots of water depth and the average North velocities for the three depth intervals at each ADCP station during each larvae sampling period. The results of this process are 15 time series of North velocity (3 depths by 5 stations) to characterize the flow across the study transect.

The flux of water from North to South was then calculated by multiplying each of the 15 North velocity series by the estimated cross-sectional area of the transect represented by that value. The cross-sectional areas were determined for each segment by multiplying one-third of the water depth at the station by one-half of the combined distance to the two adjacent stations.

In order to correlate the ADCP time series with the discrete larvae sampling events, the ADCP-based water flux data was averaged over the duration of each tidal phase. The tidal phase was defined as the time between the maximum and minimum tide heights at the station. The sum of the fluxes during the four tidal phases also was the basis for daily estimates of water flux across the study transect. Table 4-1 compares the daily water fluxes during the sampling events with the average daily water flux during the study period, May 8-31, 2000. The percentage of the volumetric flow withdrawn by PNPS (assuming full pump operation) was determined to range from 0.08% to 0.59% for the four larvae sampling days, and to be 0.21% for the entire monthly study period (see Table 4-1).

4.2 Larval Entrainment and Flux Analysis

4.2.1 Larval Transport Analysis

The flux or transport of winter flounder larvae flowing along the coast was determined for each of the four study days using larvae density and hydrodynamic measurements. This approach integrated current velocity, water depth and larval stage density over the cross-sectional area of the transect over the time of each tidal phase. The calculation was performed for each of the four winter flounder larval stages and the total winter flounder larvae concentration at each of the 4 time series that constituted one 24-hour period. For each study day, the net larval flux was determined by taking the sum of the net larval flux over each tidal period.

The net larval flux over a given 6 hours tidal period was determined by multiplying the concentration of larvae (larvae/m^3) times the flux of water (m^3/s) to yield larvae/second over a 6 hour period. All the larvae data in each series (except for series 3 and 4 on May 30-31) were collected across an ebb and flood cycle. Therefore, to obtain consistent results the following averaging method was used for the larval data:

- The tidal phase corresponding to the time of collection of the first larvae sample of the first series for each round was used as the tidal phase for the whole series. If station A, series 1, was collected first and this was during the flood period then the rest of the series was considered a flood. The second series would then be an ebb, the third a flood, the fourth an ebb.
- Within each data series each station A-E was determined to have been sampled during the Ebb or Flood by checking the sampling period against the ADCP tidal record.
- If the pre-determined series tidal phase matched the actual tidal phase of the discrete sample in a given series, then the larvae concentration used was the discrete number given (no average taken). If the two phases did not match, then the larvae concentration used was determined by averaging the discrete number in the given series with the corresponding larvae concentration as found in the series preceding the one in question. If the series was the first series in a date then the concentration would be averaged with the appropriate sample for the series following it. This analysis is appropriate because, as shown in Section 4.3, the larvae vertical distribution does not vary with tidal stage.

The larval flux during each tide phase was summed to provide an estimate of the number of larvae passing the study transect during each 24-hour period covered by the sampling round. These values are presented in Table 4-2.

4.2.2 Larval Entrainment Analysis

The number of winter flounder larvae entrained by PNPS during each of the four sampling events was determined from the station flow rate and the four larval entrainment samples collected during the day specifically for this study. The calculation was performed for each of the four winter flounder larval stages, by multiplying the number of larvae for each stage entrained by the station by the station flow rate for the 6hour tidal cycle over which the ambient flounder samples were collected. The sum of each of the 6 hour periods became the total entrainment per day.

The percentage of each larval stage entrained was determined by dividing the number of larvae entrained during the day by the number of larvae carried past the station in the net longshore current (and then multiplying by 100 to obtain a percentage). The larval entrainment results are presented in Table 4-2.

In general, the results in Table 4-2 indicate that PNPS entrains a very small percentage of the winter flounder larvae in the coastal flow of Cape Cod Bay. On the first 3 sampling days, the percentage of total (all larval stages) winter flounder larvae entrained ranged from 0.07% to 0.21%. Stage 1 and 2 larvae entrained ranged from 0.02% to 0.16%. Stage 3 larvae entrained ranged from 0.13% to 0.27%. No Stage 4 larvae were entrained during this period. For the fourth sampling day, No Stage 1 larvae were entrained. Stage 2 and 3 larvae entrained were 0.29% and 1.24%, respectively. Stage 4 larvae were entrained at 5.1%. It is possible that this value is anomalously high due to sampling gear inefficiency; i.e. the inability of the plankton trawls to sample many of the Stage 4 larvae in the bay which are likely located at or near the bottom. The total larvae entrained for the fourth sampling period was 1.05%, which is also potentially skewed high due to the Stage 4 value.

In summary, the percentage of larvae entrained by PNPS was generally much less than 1%. On one out of the four sampling days, one of the four larval life stages was entrained at a rate greater than 1%, and this value may be suspect due to inherent sampling inefficiency. Based on this analysis, it is concluded that the percentage of winter flounder larvae transported in coastal Cape Cod Bay waters that is entrained by PNPS may be conservatively estimated at less than 1%.

4.3 Statistical Analysis of Larval Variability

Two statistical analyses of winter flounder larvae variability were performed:

1. The variation in the vertical larval distribution throughout the tidal cycle was examined to evaluate the potential for larvae to use the vertical distribution as a retention mechanism.

2. The effect of wind speed and direction on the distribution of larval densities was evaluated.

4.3.1 Variation in Vertical Distribution of Larval Densities

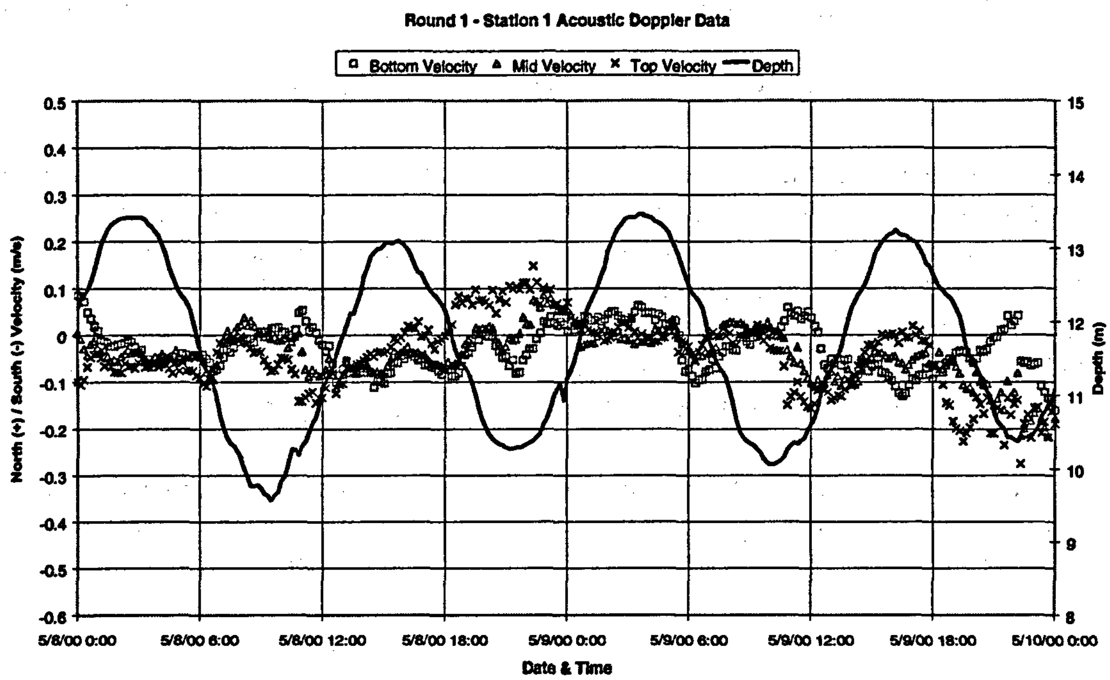
The possibility exists that winter flounder larvae can maintain their position within a localized region of Cape Cod Bay by using one of two retention mechanisms. One of the potential mechanisms is transport within localized gyres; however, there is no evidence that such gyres exist in Cape Cod Bay. The other potential retention mechanism is the control by larvae of their vertical location in the water column during various tidal phases (flood versus ebb) in order to preferentially control their transport and maintain a position within a localized area. If larvae are using such a mechanism, their vertical distribution in the water column would vary throughout the tidal cycle.

In order to evaluate whether the vertical distribution of winter flounder larvae varies throughout the tidal cycle, an ANOVA (analysis of variance) test was performed on the vertical distribution of larval densities during flood and ebb tides collected during this study. The test was performed as follows:

- Discrete larvae concentrations were sorted for their location in an ebb or flood tidal phase and their location as a surface or bottom sample.
- A ratio between the surface larvae concentrations and the bottom total larvae concentrations was calculated for the ebb samples and the flood samples.
- A one-way ANOVA test was performed on the ratio of the surface to bottom values for the ebb and flood tides. The results (shown on Table 4-3) indicate that there is no difference between the means of the data set given. This indicates that winter flounder larvae do not vary their location in the water column with tidal phase or use such a mechanism to control their transport.

4.3.2 Effect of Wind Speed and Direction on Larval Density Distribution

There is a potential that localized winds may control the larval density distribution by transporting water to or from shore depending on whether the wind is onshore or offshore. In order to evaluate the relationship between wind speed and direction and larval density distribution, a correlation analysis was performed by plotting winter flounder larval densities versus wind speed (with offshore winds specified as positive and onshore winds as negative) for the larvae sampling stations that were the nearest to and furthest from the shore. If a correlation between winds and larvae distribution existed, it would be expected that nearshore densities would decrease for an offshore wind and increase for an onshore wind, with the opposite effect for the furthest offshore station. The results of the analysis (shown on Figure 4-2) indicate that there is essentially no correlation between winds and the larval density distribution.



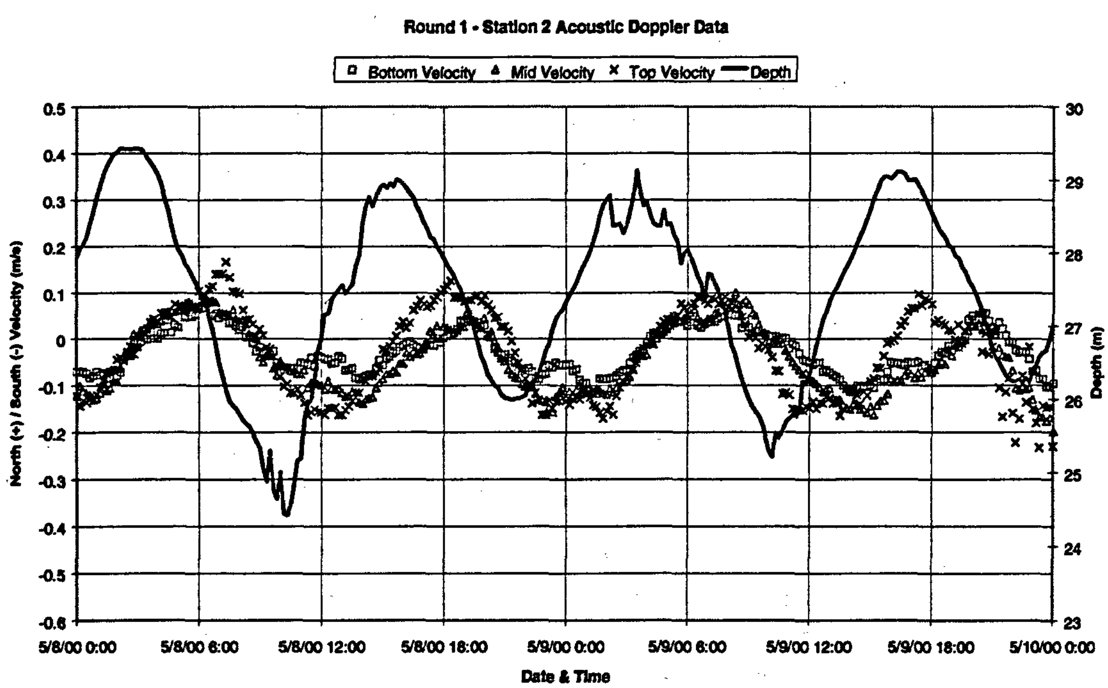
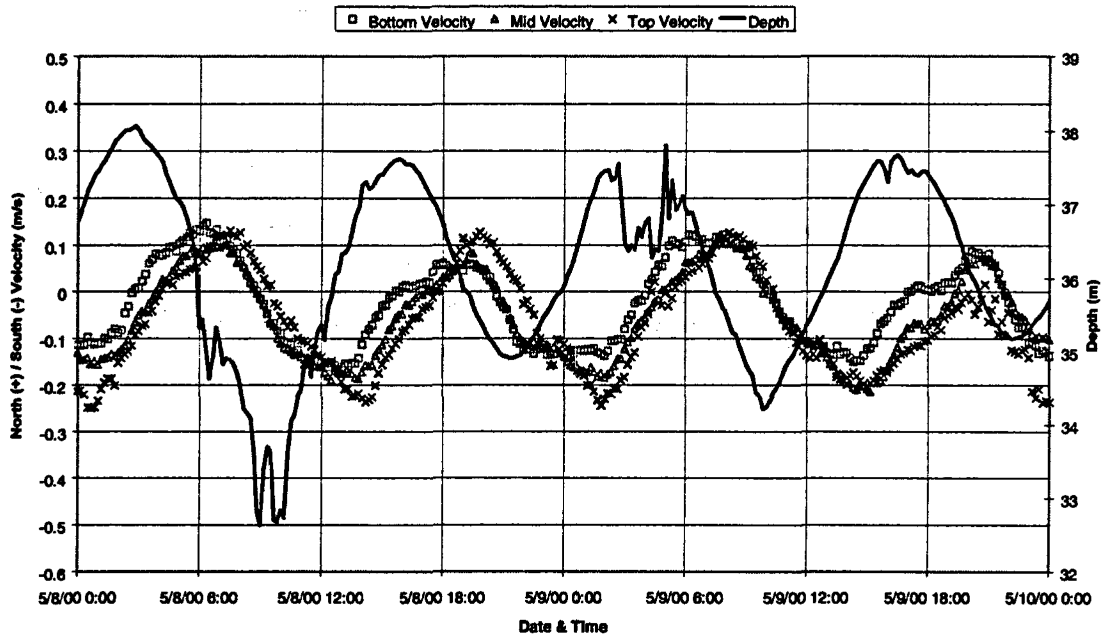


Figure 4-1 Surface, Mid, and Bottom North Velocity and Water Depth

Round 1 - Station 3 Acoustic Doppler Data



Round 2 - Station 1 Acoustic Doppler Data

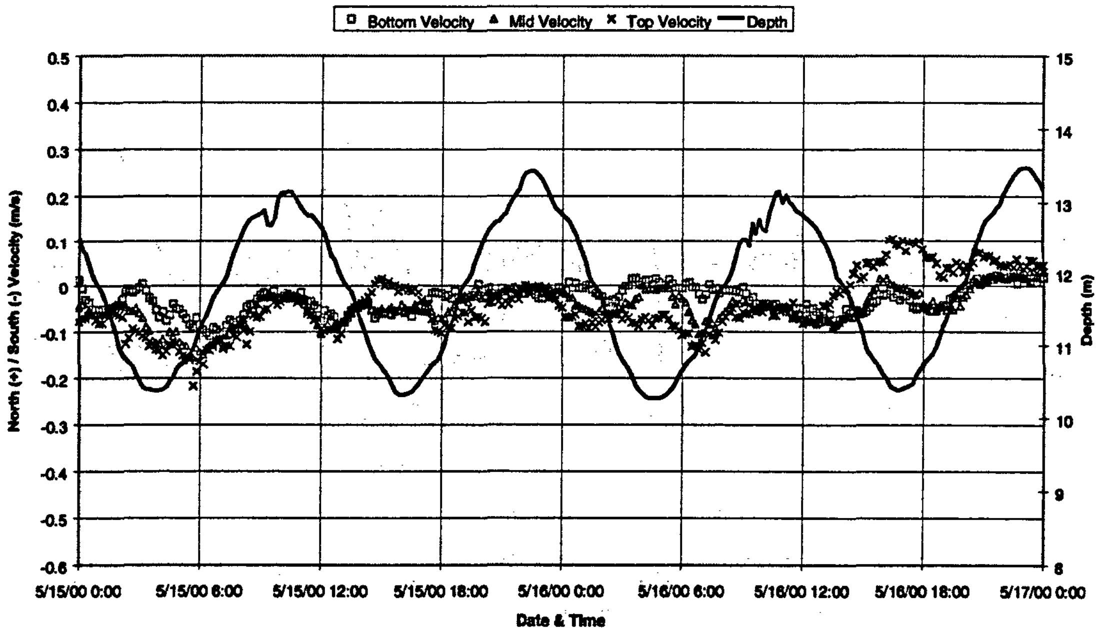
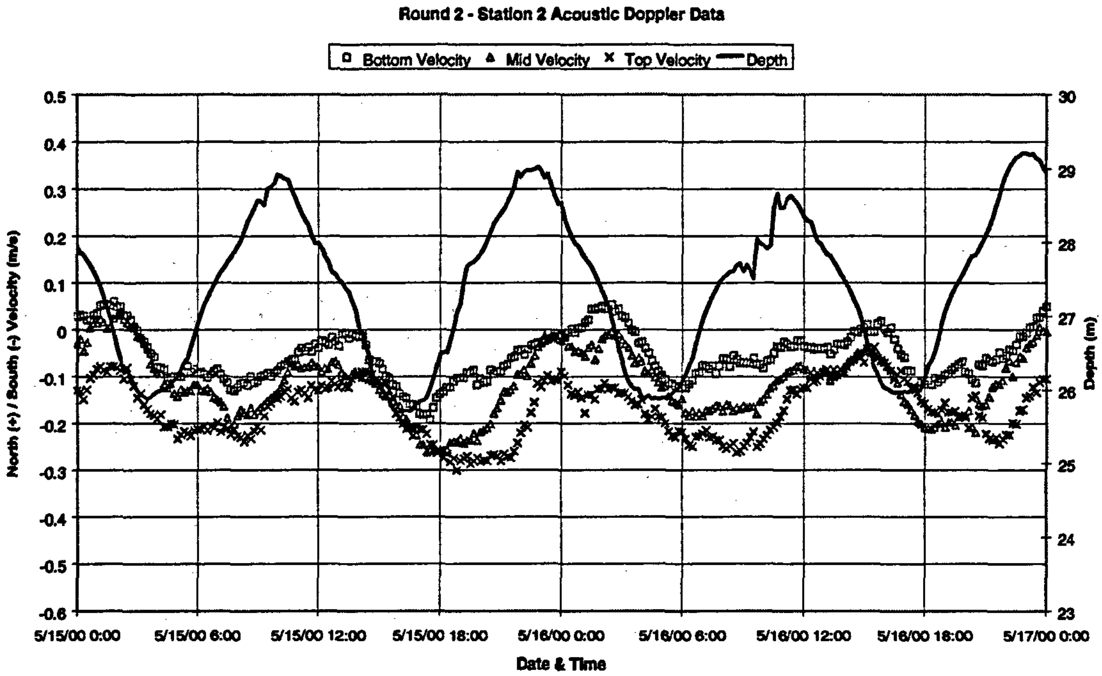


Figure 4-1 Surface, Mid, and Bottom North Velocity and Water Depth (continued)



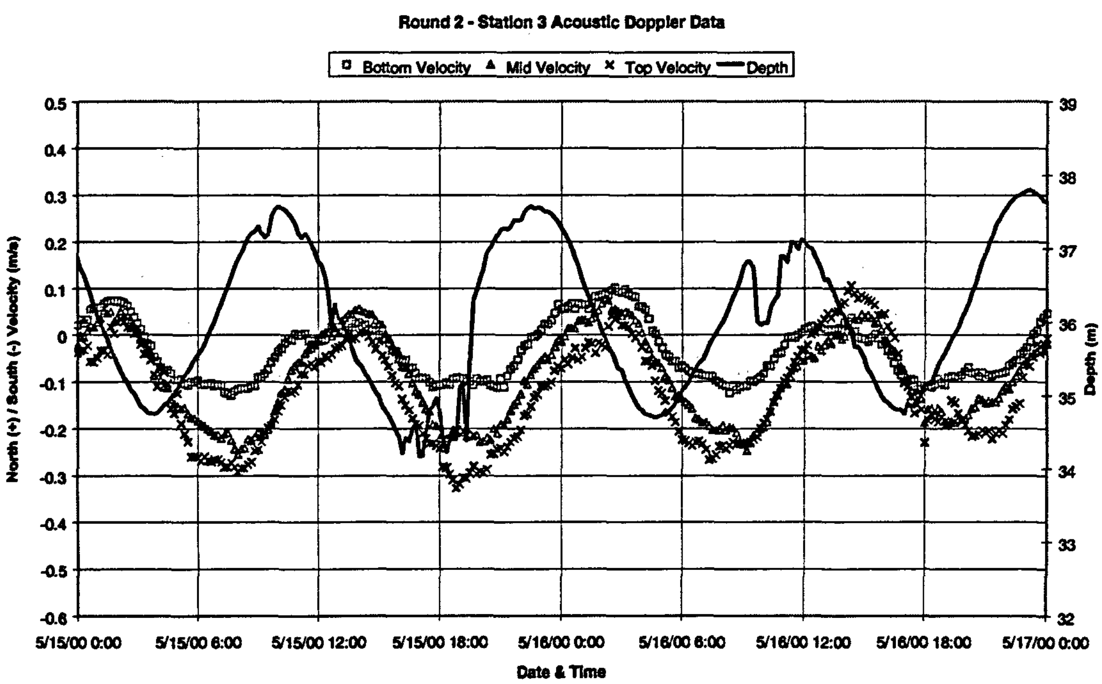
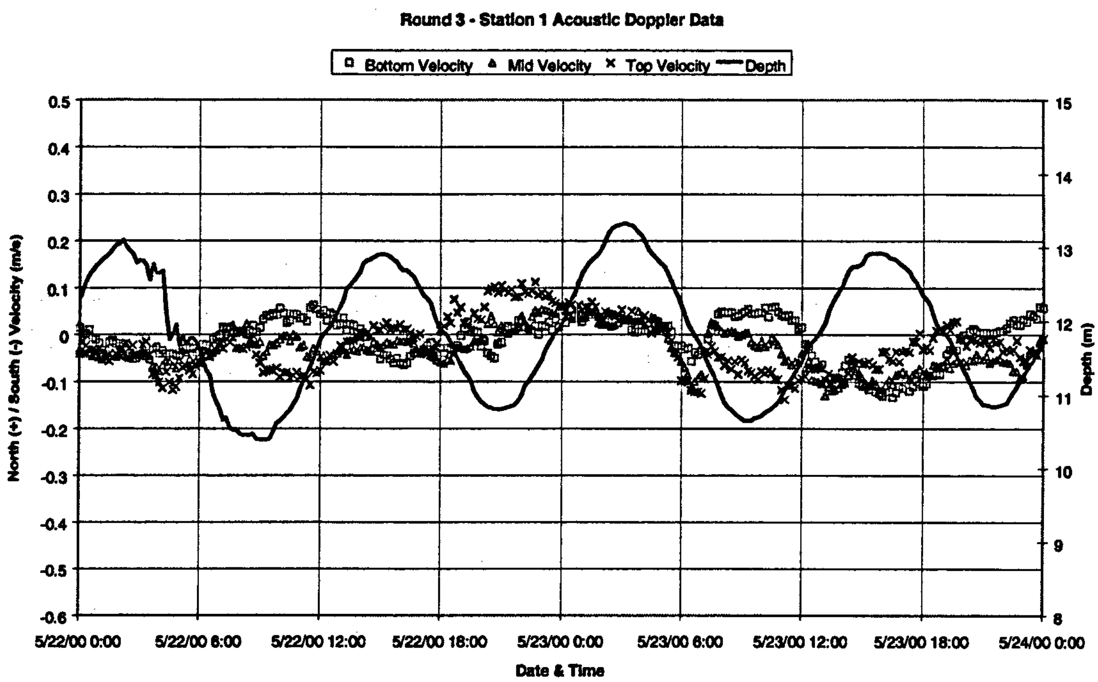


Figure 4-1 Surface, Mid, and Bottom North Velocity and Water Depth (continued)



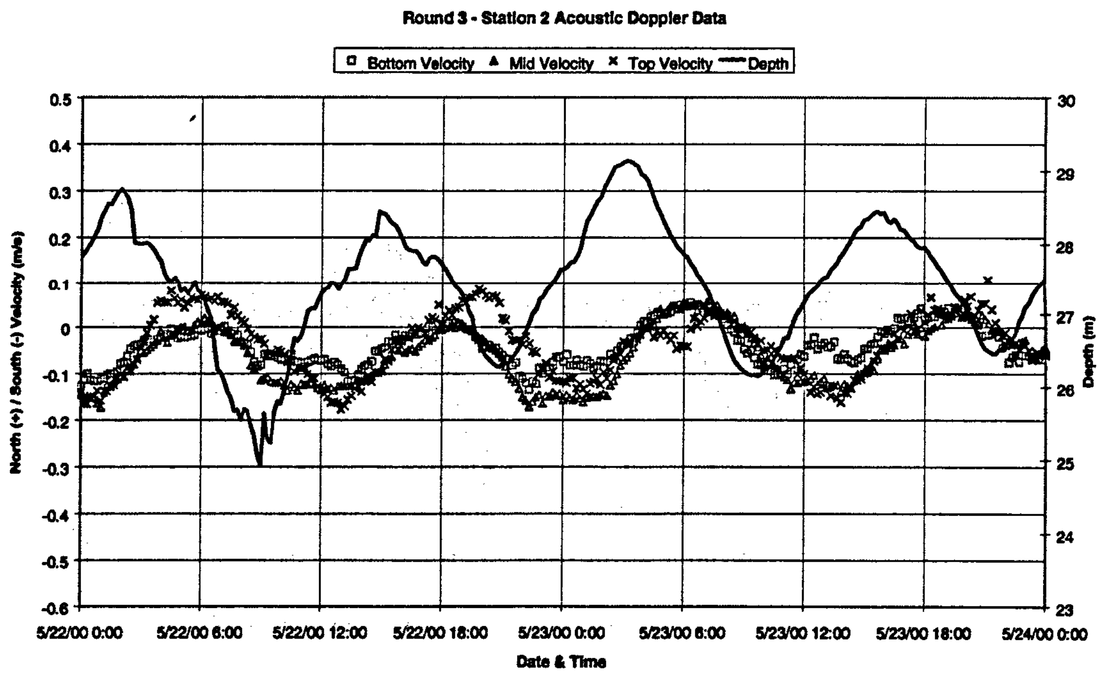
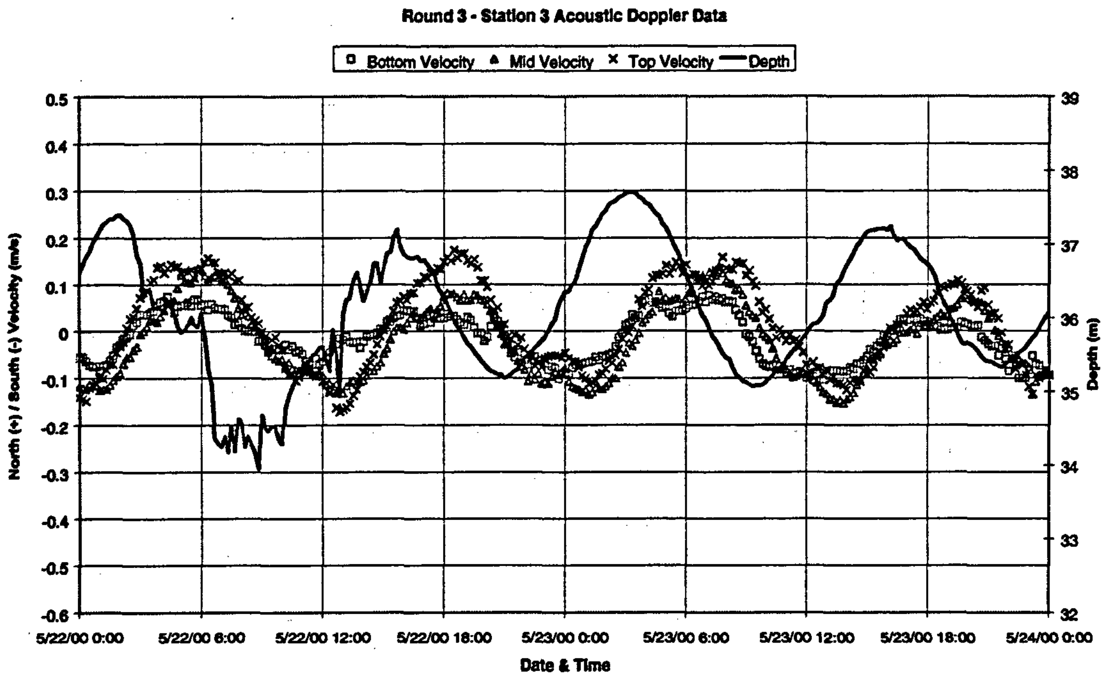


Figure 4-1 Surface, Mid, and Bottom North Velocity and Water Depth (continued)



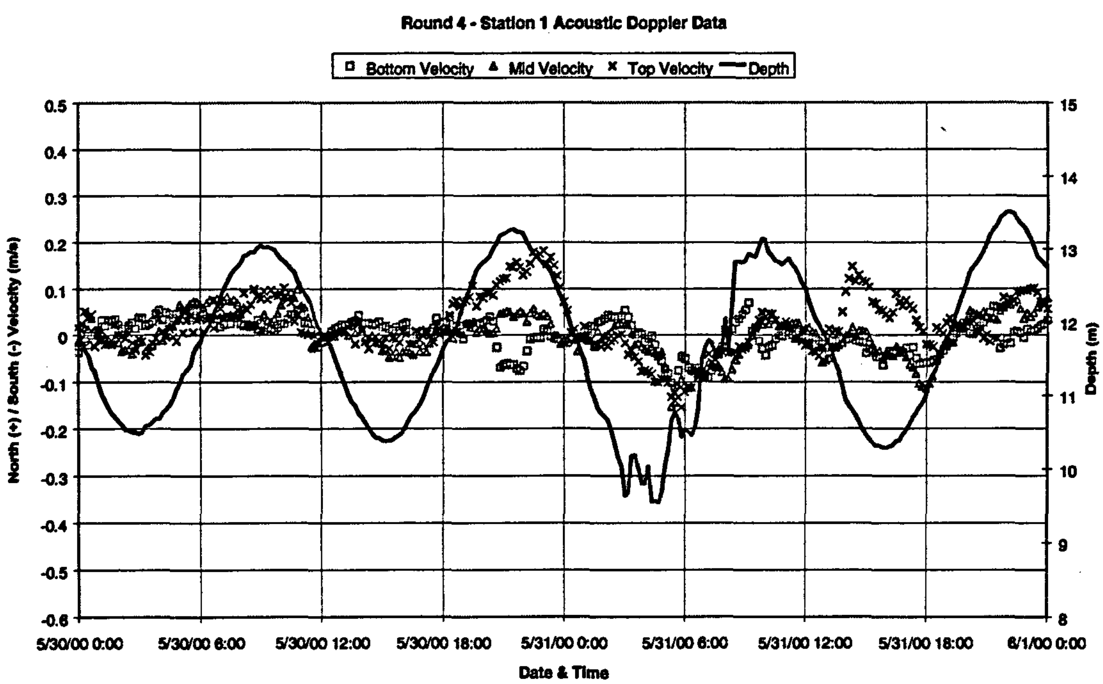
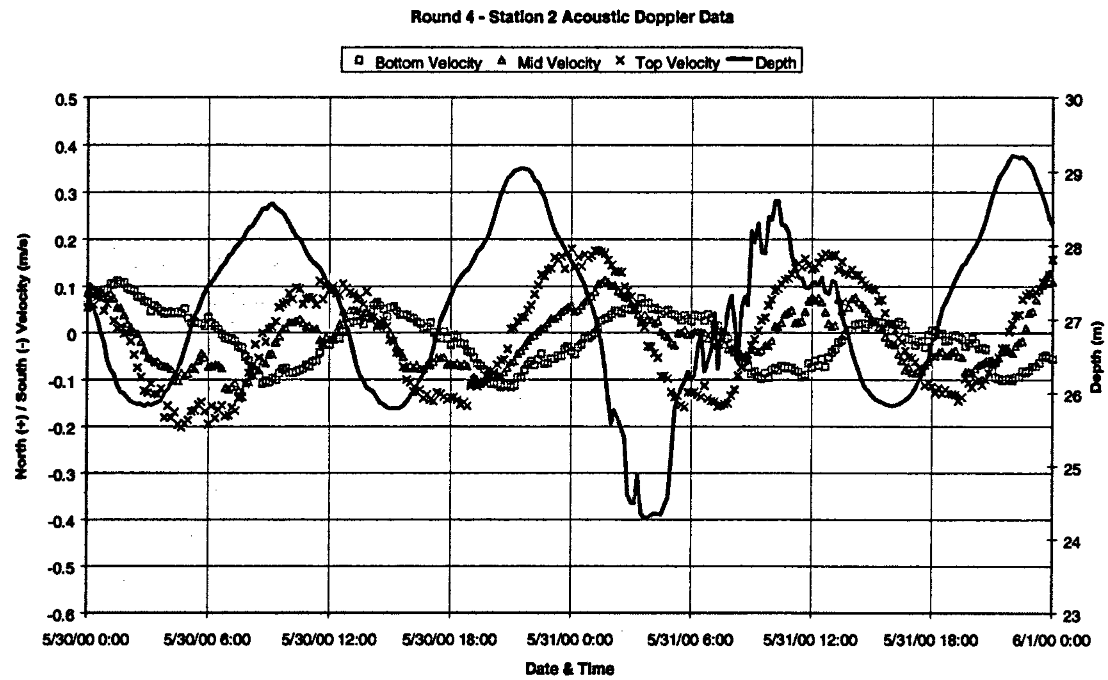


Figure 4-1 Surface, Mid, and Bottom North Velocity and Water Depth (continued)



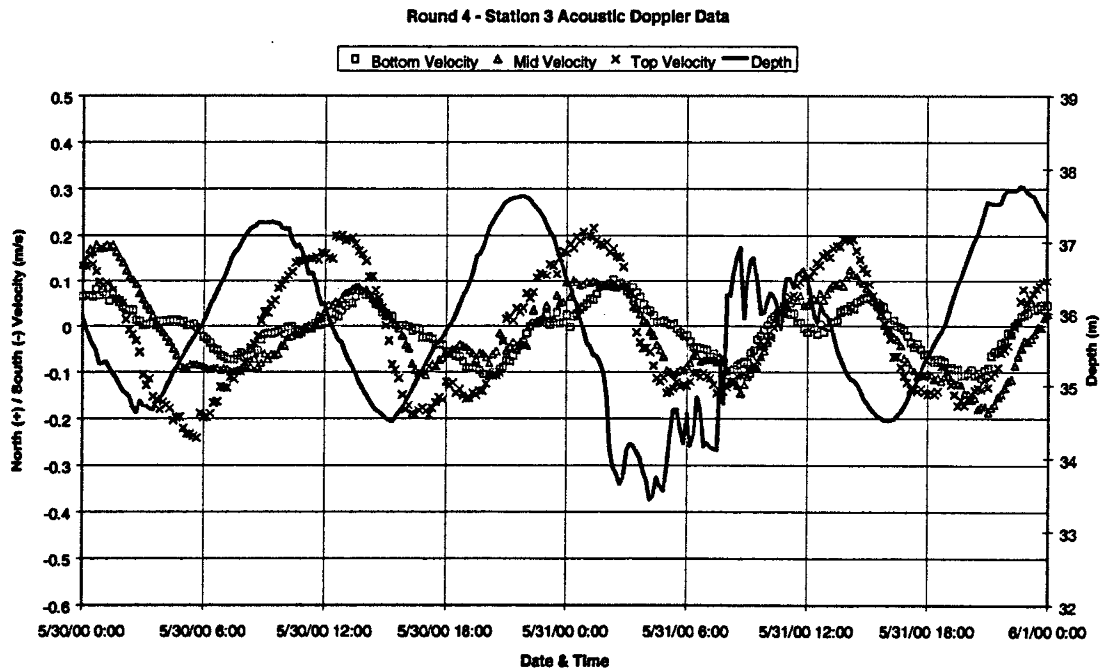


Figure 4-1 Surface, Mid, and Bottom North Velocity and Water Depth (continued)

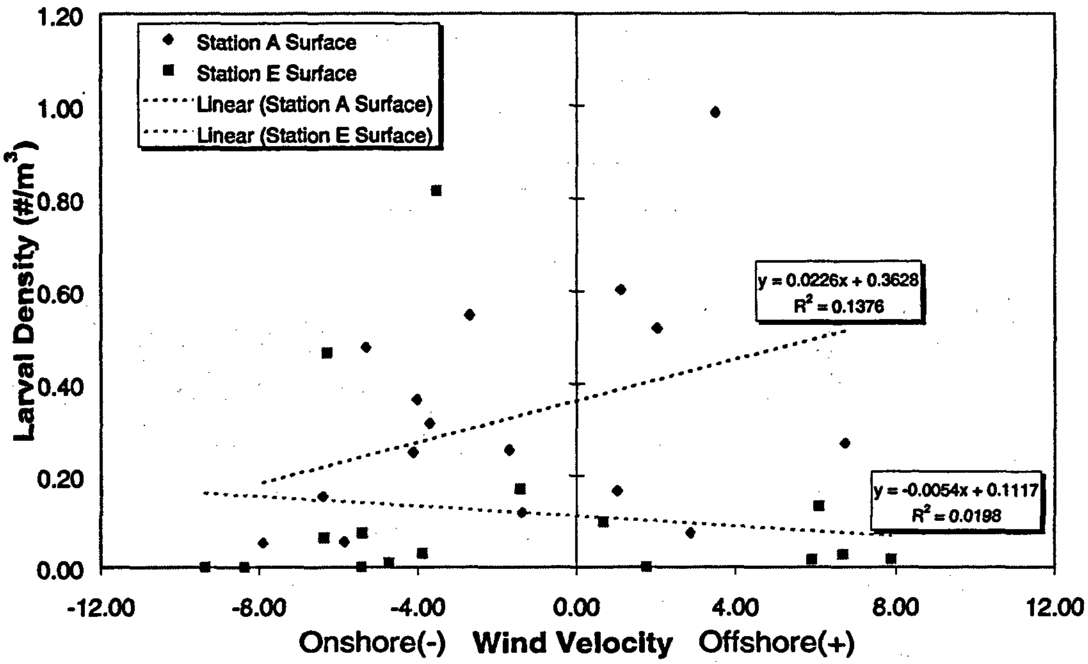


Figure 4-2 Wind Effects on Flounder Larval Densities

Table 4-1 Analysis of Volumetric Flow in Bay Study Area Compared to PNPS Withdrawal

	May 8-9	May 15-16	May 22-23	May 30-31	Study Duration
Net Volumetric Flow (m^3) in Bay Study Area for 1 Day	-8.75E+08	-2.21E+09	-5.35E+08	-2.88E+08	-8.21E+08
% of Volumetric Flow in Bay Study Area Withdrawn by PNPS* in 1 Day	0.19	0.08	0.32	0.59	0.21
* Assuming full pump operation at PNPS (19.56 m3/s)					

Table 4-2 Analysis of Larval Transport in Bay Study Area Compared to PNPS Entrainment

Day1 (May 8-9/2000)	Stage 1	Stage 2	Stage 3	Stage 4	Total
Net Larval Count in Bay Study Area	1.14E+07	4.05E+07	2.54E+07	0.00E+00	7.73E+07
Larval Entrainment at PNPS*	1.80E+04	5.22E+04	3.23E+04	0.00E+00	1.03E+05
% of Net Larval Flux Entrained by PNPS*	0.16	0.13	0.13	NA	0.13
Day2 (May 15-16/2000)					
Net Larval Count in Bay Study Area	8.51E+07	2.18E+08	2.95E+07	0.00E+00	3.33E+08
Larval Entrainment at PNPS*	1.33E+05	3.42E+05	2.12E+05	0.00E+00	6.87E+05
% of Net Larval Flux Entrained by PNPS*	0.16	0.16	0.72	NA	0.21
Day3 (May 22-23/2000)					
Net Larval Count in Bay Study Area	1.37E+07	1.73E+08	4.20E+07	4.50E+03	2.28E+08
Larval Entrainment at PNPS*	2.36E+03	3.91E+04	1.14E+05	0.00E+00	1.56E+05
% of Net Larval Flux Entrained by PNPS*	0.02	0.02	0.27	0.00	0.07
Day4 (May 30-31/2000)					
Net Larval Count in Bay Study Area	2.40E+05	6.17E+06	1.26E+07	6.21E+05	1.97E+07
Larval Entrainment at PNPS*	0.00E+00	1.76E+04	1.57E+05	3.17E+04	2.07E+05
% of Net Larval Flux Entrained by PNPS*	0.00	0.29	1.24	5.10	1.05
* Assuming full pump operation at PNPS (19.56 m3/s)					

Table 4-3 ANOVA for Flood and Ebb Larvae Concentrations

Alpha = 0.05
Null Hypothesis = The means of the two data sets are equal.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Ratio: Flood Surface to Bottom (larvae/m^3)	35	93.75	2.68	10.87
Ratio: Ebb Surface to Bottom (larvae/m^3)	38	88.02	2.32	10.73

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.39	1	2.39	0.22	0.64	3.98
Within Groups	766.66	71	10.80			
Total	769.05	72				

Since P-Value is > alpha, fail to reject the null hypothesis.
The means of the two data sets are equal.

5.0 CONCLUSIONS

The study results show that:

- There is a consistent net flow of water to the south along coastal Cape Cod Bay in the vicinity of PNPS.
- PNPS withdraws a relatively small percentage of the net flow – an average of approximately 0. 2%.
- Transport of winter flounder larvae follow a similar trend - there is consistently a net transport of larvae to the south.
- The amount winter flounder larvae entrained by PNPS is a relatively small percentage of the net larval transport – conservatively estimated at less than 1%.
- Winter flounder larvae do not appear to be using vertical transport in the water column as a retention mechanism to maintain position in a localized portion of Cape Cod Bay.
- Winds do not appear to have a significant influence on the density distribution of winter flounder larvae.

These results confirm the conclusion in the March 2000 316 Demonstration Report that entrainment at PNPS has not had any adverse impacts on the integrity of the winter flounder population. In fact, based on these results, the potential impact to the winter flounder population (less than 1%) is less than that stated in the 316 Demonstration (less than 5%).

6.0 REFERENCES

Motoda, S. 1959. Devices of simple plankton apparatus. Memoirs of the Faculty of Fisheries, Hokkaido University 7: 73-94.

Van Guelpen, L., D.F. Markle, and D.J. Duggan. 1982. An evaluation of accuracy, precision, and speed of several zooplankton subsampling techniques. International Council for the Exploration of the Sea 40: 226-236.

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