Exxon Valdez Oil Spill
Restoration Project Final Report

Coordinating Volunteer Vessels of Opportunity to Collect Oceanographic Data in Kachemak Bay and Lower Cook Inlet

Restoration Project 02671
Draft Final Report

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Study History: This project, *Coordinating Volunteer Vessels of Opportunity to Collect Oceanographic Data in Kachemak Bay and Lower Cook Inlet* (Project 02671) is a new project and therefore has no previous study history with EVOS. This project was specifically conceived of in order to address the potential for utilizing volunteer vessels in collecting oceanographic data. No previous study specifically seeks out potential regional vessels of opportunity and works toward utilizing them in data collection. Neither the project, nor its' resulting database have been published previously. A poster presentation of the drift card study aspect of this project was presented in April, 2002 at the Kachemak Bay Science Conference. A copy of this poster is included as an appendix to this report. Manuscripts of this study are planned but have not yet been submitted to journals. This final report represents the first published results from this study.

Abstract: Cook Inlet Keeper and the Kachemak Bay Research Reserve organized a network database of local community volunteers for the purpose of collecting oceanographic data from regional ships of opportunity. An extensive outreach program was undertaken to identify and construct a database of private and commercial vessels making frequent trips in the Kachemak Bay, lower Cook Inlet and the Gulf of Alaska regions. Future work will utilize this extensive database to identify volunteer boats for collecting time-series of water quality parameters from transects along Kachemak Bay and extending into lower Cook Inlet and the Gulf of Alaska. Drift card studies were conducted in summer and winter and indicate that surface flow into the bay is restricted. Preliminary CTD data indicate important areas of Kachemak Bay for future data collection. Future data collection using volunteer vessels will be used to expand spatial and temporal knowledge of water quality and mixing patterns and their relationship to the dispersal of larvae and pollutants in the region.

Key Words: Cook Inlet, circulation, drift cards, Kachemak Bay, oceanography, ships of opportunity, volunteer vessels

Project Data:

1) CTD transects:

Description of data: Transects of the bay were sampled using an array of instruments including a Seabird SBE 19 CTD, a Wetlabs Wetstar fluorometer, and a Licor cosine PAR sensor. These instruments collectively gave measurements of measuring conductivity(for calculating salinity), temperature, fluorescence and PAR with depth. Post-processed data files were plotted in Matlab and then saved as Powerpoint files. *Format:*There are 7 Powerpoint files, one for each of the following transects: Point Adam to Cape Douglas, Point Pogibshi to Anchor Point, Barabara Point to Bluff Point, Cohen Island to Homer Spit, Peterson Point to Homer Spit, Glacier Spit to Fritz Point, and Bear Cover to Eastland Canyon. *Custodian*: KBRR, *Access limitations*: none.

2) Drift card results:
Description of data: Maps of the deployment transects and retrieval locations for all drift card deployments. *Format:* The files of the 6 drift card deployments and the subsequent retrieval locations have been generated into maps in Microsoft Powerpoint. *Custodian*: KBRR, *Access limitations*: none.

3) CIK Vessel Database
Description of data: A database of regional vessels, their vessel information, approximate routes and timing of these routes. *Format:* This information is contained in an Access database, in a read-only format on a CD prepared for the KBRR by Cook Inlet Keeper. (Appendix B). *Custodian:* KBRR and CIK, *Access limitations:* none.

Citation:

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Executive Summary:

Introduction: Cook Inlet Keeper and the Kachemak Bay Research Reserve received one year of funding from the *Exxon Valdez* Oil Spill Trustees Council through the Ecosystem Synthesis/GEM Transition: Innovative Tools and Strategies to Improve Monitoring. Community volunteers have expressed interest in providing vessels as platforms to collect basic time-series of temperature and salinity in Kachemak Bay and lower Cook Inlet. The spatial and temporal distribution of these and other similar vessels has not been catalogued. This information is integral to establishing a protocol for using volunteer vessels in a long-term oceanographic data collection project. These data are fundamental to understanding mixing dynamics in the Kachemak Bay region.

Objectives: The primary objective of this study was to compile a database of regional vessels which routinely traverse Kachemak Bay, lower Cook Inlet and the greater Gulf of Alaska. Many locally-operated vessels traverse the Kachemak Bay, lower Cook Inlet and Gulf of Alaska region for commercial fishing, charter fishing, transportation (ferries) and for recreational purposes. The spatial and temporal extent of these vessels over this region has not been catalogued. These vessels could be utilized to provide basic information to scientists on regional oceanographic conditions. The purpose of compiling this information is to identify which of these vessels would be willing to participate in future data collection efforts. Volunteer vessels which routinely traverse this study area could provide a low-cost routine mechanism for collecting critically needed oceanographic data. The results of this project, while initially focussed upon the immediate Kachemak Bay regional vessels, are applicable at larger spatial scales including the lower Cook Inlet and the greater Gulf of Alaska region.

The outreach portion of this project was organized under the Cook Inlet Keeper and utilized their staff and extensive network of volunteers and citizen monitors to identify volunteer ships of opportunity, and assist in the design of transects, sampling locations and schedules. The primary goal of this project was utilize the extensive coordinating experience of the Keeper in assembling a database of community vessels by location and seasonal activity, as well as orchestrating an outreach program to identify volunteers and vessels in the region.

Secondary objectives included drift card studies in the Kachemak Bay region to infer seasonal surface circulation, as well as preliminary data collection along transects in order to identify critical regions for future data collection using volunteer vessels. This study worked in conjunction with the existing studies in the region, both those on-going at the Research Reserve as well as within the Cook Inlet Keeper. On-going studies are similarly working to gain and organize a community-based network of volunteers as well as to further the understanding of circulation and mixing in Kachemak Bay. In addition, collaboration between the Keeper's Citizen's Environmental Monitoring Program and the Kachemak Bay Research Reserve's scientific programs allows for greater community involvement and understanding of the regional circulation and water quality.

Methods:

There were two main phases of this project involving input from both the Kachemak Bay Research Reserve (KBRR) and the Cook Inlet Keeper (CIK). These two phases were the KBRR Research and Development program which included a hydrographic data collection effort, and seasonal drift card deployments, and the Cook Inlet Keeper Outreach program for compilation of the vessel database.

Preliminary Hydrographic Data Collection:
Preliminary oceanographic data was collected by the Reserve along representative transects in the Kachemak Bay area. These preliminary data along these transects are being used to further refine regions of importance for future collection of oceanographic data. Transects included along-axis and across axis locations, covering regions of inflowing and outflowing water to the bay. The transects covered the following regions: Point Adam to Cape Douglas, Point Pogibshi to Anchor Point, Barabara Point to Bluff Point, Cohen Island to Homer Spit, Peterson Point to Homer Spit, Glacier Spit to Fritz Point, Bear Cove to Eastland Canyon.

Sampling along these transects was done using a caged array of instruments including a pumped Seabird SBE 19 CTD, a Wetlabs Wetstar fluorometer and a Licor cosine PAR sensor. Profiles of water quality data were taken every kilometer along each transect line. The data from each sensor (for depth, temperature, salinity, fluorescence, and PAR) were filtered, and binned into one meter increments using Seasoft software. These filtered data were then plotted using Matlab.

Drift Card Study:
Drift cards were used as a low-cost means to study and infer regional surface currents. A preliminary knowledge of these currents helps to further refine the relevant regions for future data collection by ships of opportunity. Drift cards were constructed and deployed over two different seasons and for five different locations. Locations for deployment included: Anchor Point, Beluga Slough, Homer Spit, Seldovia and Bear Cove. Each deployment contained 1000 cards, distributed evenly across a transect perpendicular to the shore locations. These locations were also consistent with regional data collection.

Vessel Database:
The Cook Inlet Keeper utilized its expertise in community volunteer involvement to develop an outreach program for identifying regional vessels. This outreach program included local media and regional announcements in order to best identify community volunteers. The primary objective of the Keeper's outreach program was the establishment of a comprehensive database of all regional vessels currently operating in the Kachemak Bay, lower Cook Inlet and, to some extent, the greater Gulf of Alaska region. This database is organized according to the spatial and temporal distribution of these vessels in the region, the owners and operators of the vessels, and the nature of their activity (i.e. charter fishing, recreational charters, transportation/ferry, commercial

fishing). Using community-based workshops, the Keeper further refined the database to delineate which vessels would be interested in participating as a ship of opportunity in a data collection project to begin the following year.

Cook Inlet Keeper implemented an outreach plan consisting of a paid radio public service announcement (PSA), newspaper ads, flyers, a volunteer gathering, and contact with local harbormasters. All Keeper volunteers were informed of the project and offered the opportunity to participate. Online databases such as the Alaska Department of Fish and Game commercial vessel listing were searched and used to import vessel information into the database The Research Reserve, with the cooperation of Keeper staff, organized community workshops that provided prospective volunteers with information about the Vessels of Opportunity project. As a result of this outreach plan, seven vessels were identified as possible volunteer vessels for this project.

Results:

CTD data:

Preliminary data collection was focused upon regions of Kachemak Bay. The purpose of these preliminary data is to refine the important areas for future data collection, the variables necessary for collection by volunteer vessels, and the spatial scales of collection. Of particular importance is the difference between surface sampling of water quality variables and sampling at a range of depths.

Drift card study:

Drift cards deployed outside of the inner region of Kachemak Bay were not transported into the inner bay in either summer or winter deployments. Drift cards deployed inside of the inner bay were either carried out of the bay with the outflowing water and deposited outside of the inner bay, or were entrained within the inner bay circulation and deposited on both sides of the inner bay.

CIK database

Following the extensive outreach program, a listing of regional vessels and their information was compiled by the Cook Inlet Keeper and organized into a database. The Vessel Database is a searchable database of over 7500 private and commercial vessels operating in Kachemak Bay, Lower Cook Inlet, and the Gulf of Alaska. The database includes information about the vessel's owner, operator, skiffs, electronics, physical description, deck, hydraulics, engines, and spatial/temporal information. Six queries are built in to identify vessels with a regular course, volunteer vessels, Kachemak Bay vessels, and other criteria. A vessel report is programmed to list all vessels and the owner information, port of registry, and ADF&G number. All of the queries and the report are printable, savable, and exportable.

Discussion:

CTD data:

The features present in the transects of water quality data show the high variability of water quality parameters within a relatively small spatial area. These features are consistent across some smaller spatial scales but quite different at larger spatial scales. In

doing these profiles of water quality, we were testing the difference between what information would be returned from a surface sensor, such as what could be mounted easily on a vessel of opportunity, and what features would be overlooked in this manner. Temperature and salinity across some spatial scales, could be easily measured using vessels of opportunity, and the data obtained would be useful in describing regional patterns. Other parameters, however, such as fluorescence, a proxy for chlorophyll-a concentration may not be adequately characterized by their surface signature, and require profiles in order to see the vertical distribution of the feature.

Drift Card Study:
Our study hypothesized that in the winter, following extreme mixing and the destruction of intense stratification, that surface waters enter the inner bay from the outer bay. However, both summer and winter outer bay deployments showed no recovery of cards inside the inner bay. Our results concur with previous work that there is a mechanism which is restricting surface flow from the outer to inner bay. Burbank (1977) hypothesized the existence of a large surface gyre in the outer bay which restricted the intrusion of surface waters to the outer bay. Future work examining both the regional surface currents during seasonal as well as sporadic weather events may elucidate the nature of this surface circulation in this region. Future work must also include current profiling in order to fully explore the circulation and missing link between the inner and outer bays.

CIK database:
The database contains information on more than 7500 vessels operating in the greater Gulf of Alaska region. Six vessels have been identified as willing and one may be willing to participate in deploying instruments for the collecting of oceanographic data. This is precisely the type of information that the database was meant to provide. The database should be continually updated for more recent information as well as vessels contacted for future interest in participating as volunteer vessels. Vessel operators should be contacted in the fall of 2002 or the winter of 2003 and given an update on the project. Many of these vessels will be dry-docked or in port and available for outfitting with an instrument. In particular, the Tustumena, a state run ferry, is scheduled to be in Portland, Oregon at the Swan Island Ship Yard from mid Nov. 2002 to April 1, 2003. It will be dry docked sometime in January. This would be the best opportunity to outfit this vessel with an instrument.

Conclusions:
CTD data
The hydrographic data collection was useful in determining both the spatial regions for future data collection as well as the importance of both surface sampling and profiles of hydrographic information. The two most important regions to study are the across axis gradients in Kachemak Bay, for studying the inflow and outflow to the bay, and the along axis region, for studying the estuarine gradients. Both surface data and profiles of data are clearly necessary in order to adequately study the hydrography of this area. Surface instruments, such as thermosalinographs, are relatively inexpensive and easy to maintain

on a volunteer vessel. More sophisticated instruments for obtaining profiles of hydrographic data are possible to use on volunteer vessels, but more expensive and more difficult for volunteers to deploy.

Drift card study

Drift cards provided an inexpensive mechanism for inferring seasonal surface currents. Surface waters are restricted from entering the inner bay in both summer and winter. This supports the hypothesis of a large surface gyre in the outer bay which restricts the intrusion of surface waters into the inner bay. Future work must be done to elucidate the spatial and temporal extent of this circulation.

CIK database

The outreach program designed by the CIK was effective in its intent, and information on 7500 vessels has been entered into an easy-to-operate database. This database can be updated and expanded for more extensive use. The outreach program was also effective in further refining this database to obtain six volunteer vessels who are interested in participating in future projects for collecting oceanographic data in Kachemak Bay and lower Cook Inlet.

Introduction:

Cook Inlet Keeper and the Kachemak Bay Research Reserve received one year of funding from the *Exxon Valdez* Oil Spill Trustees Council through the Ecosystem Synthesis/GEM Transition: Innovative Tools and Strategies to Improve Monitoring. Community volunteers have expressed interest in providing vessels as platforms to collect basic time-series of temperature and salinity in Kachemak Bay and lower Cook Inlet. The spatial and temporal distribution of these and other similar vessels has not been catalogued. This information is integral to establishing a protocol for using volunteer vessels in a long-term oceanographic data collection project. These data are fundamental to understanding mixing dynamics in Kachemak Bay and exchange rates with the Gulf of Alaska.

The physical oceanography of this region has not been well studied and an understanding of the physical environment is critical to understanding the fundamental basis of ecosystem dynamics and habitat distribution, and selection of equipment and routes appropriate to studies in the region. In estuaries such as Kachemak Bay, large gradients can occur at small horizontal and vertical scales due to the effects of precipitation, surface runoff, groundwater flow, and evaporation. Outside Kachemak Bay, the regional circulation is characterized by ocean currents, such as the Alaska Coastal Current in the Gulf of Alaska flowing onto the shelf near the entrance to Cook Inlet. Nutrient rich bottom water is upwelled and mixed with surface water. As these enriched waters stream into Kachemak Bay, fresh water runoff from the surrounding ice fields and watersheds dilute the salinity and increase the sediment load. The inflowing water, therefore, initially supports a marine system while the outflowing water is more turbid and less saline. This difference needs to be quantified to further our understanding of the spatial and temporal patterns of observed changes in this system.

Despite several studies in the late 1960's -1970's, there has been limited work since that time in characterizing the physical oceanographic processes in Kachemak Bay and lower Cook Inlet. Circulation in the greater Cook Inlet is dominated by strong tidal currents. The long, narrow configuration of Cook Inlet produces the world's second highest tidal heights. Tidal heights at the mouth and the head of the inlet are 180 ° out of phase. Thus water in Cook Inlet acts somewhat like a standing wave (Whitney, 1999). The spring to neap tide variation can produce almost a two-fold increase in tidal velocities (SHIO, 1994). Wind is also an important factor affecting the circulation of water in Kachemak Bay and Cook Inlet. In the summer winds are predominantly from the South to Southwest, while in the winter the winds are from the North and Northeast (Wennekens et al., 1975; Whitney, 1999). In addition to the mean wind direction, strong, locally variable winds descend from the surrounding mountains and influence net circulation patterns. Circulation in the region is also strongly influenced by the flow of the Alaska Coastal Current. Water from the ACC becomes entrained into the strong inflow of the bay in the region of Kennedy Entrance.

Previous studies of Kachemak Bay have concluded that the circulation of water in the bay is complex and reflects the combined influences of diurnal and monthly lunar inequalities in tidal forcing, seasonal changes in the tidal regime, meteorological effects and fresh water forcing (Wennekens et al., 1975). Winds have a profound effect on the net circulation of both Kachemak Bay and Cook Inlet. Transient events such as gales may be the most significant factor impacting

the transport and dispersal of planktonic larvae and pollutants (Wennekens et al., 1975). Burbank (1977) proposed the existence of several important gyres and eddies at the entrance to and interior of Kachemak Bay (Figure 1) but no subsequent studies have further elucidated their spatial and temporal extent. The movement of water in this region is critical to understanding ecosystem dynamics such as larval dispersal and habitat distribution as well as for predicting patterns of pollutant (e.g. oil) dispersal. In other regions of Cook Inlet, back eddies such as the one on the north side of the East Forelands have been shown to deposit oil on the beach when the oil is originating from the south along the shoreline (Whitney, 1999). Thus the currents and eddies predicted for the entrance to and interior of Kachemak Bay could be extremely important for localized movement and shoreline deposition of organic matter and pollutants such as oil.

Kachemak Bay is a NOAA National Estuarine Research Reserve (NERR). The NERR system has 26 sites throughout the United States that are dedicated to research and education of the marine/terrestrial interface of estuarine ecosystems. Kachemak Bay is located at the interface between land and ocean waters and thus near the juncture of major oceanographic and land-based processes. Watershed influences on the intertidal and bay habitats range from freshwater input, transport of nutrients, sediments and contaminants to topographic influences on winds and precipitation amounts and rates. Changes in watershed vegetation cover due to urbanization, spruce bark beetle infestation, logging and forest fires will alter transport dynamics and nutrient cycling, and thus the habitat quality and structure of biological communities in the intertidal zone and the bay itself. Oceanographic processes, working from the other end of the ocean-bay-shore continuum, influence nutrient transport, life history dispersal mechanisms of plants, invertebrates and fishes, sediments and contaminants. As part of the NERRs system, the Kachemak Bay Research Reserve has a program to continuously measure seasonal oceanographic water characteristics including nutrients, phytoplankton, temperature and salinity at two stations in the Bay (Homer and Seldovia) as part of the national System Wide Monitoring Program (SWMP). These sensor arrays measure water temperature, conductance, salinity, pH, turbidity, dissolved oxygen, depth, PAR, and fluorescence on a continuous basis. Additionally the National Weather Service, National Data Buoy Center, deployed a long-term data buoy near Kennedy Entrance in June 2001. This data buoy will soon be augmented by a C-MAN station at the Barren Islands.

The primary objectives of this study were to compile a database of regional vessels which routinely traverse Kachemak Bay, lower Cook Inlet and the greater Gulf of Alaska, and to determine the oceanographic conditions that could be monitored using vessels of opportunity. Many locally-operated vessels traverse the Kachemak Bay, lower Cook Inlet and Gulf of Alaska region for commercial fishing, charter fishing, transportation (ferries) and for recreational purposes. The spatial and temporal extent of these vessels over this region has not been catalogued. These vessels could be utilized to provide basic information to scientists on regional oceanographic conditions. The purpose of compiling vessel information is to identify which of these vessels would be willing to participate in future data collection efforts. Volunteer vessels which routinely traverse this study area could provide a low-cost routine mechanism for collecting important oceanographic time series data. The results of this project, while initially focussed upon the immediate Kachemak Bay regional vessels, are applicable at larger spatial scales including the lower Cook Inlet and the greater Gulf of Alaska region.

The outreach portion of this project was organized under the Cook Inlet Keeper and utilized their staff and extensive network of volunteers and citizen monitors to identify volunteer ships of opportunity, and assist in the design of transects, sampling locations and schedules. The primary goal of this project was to utilize the extensive coordinating experience of the Keeper in assembling a database of community vessels by location and seasonal activity, as well as orchestrating an outreach program to identify volunteers and vessels in the region.

Drift card studies and CTD surveys were conducted in the Kachemak Bay region to infer seasonal surface circulation, as well as preliminary data collection along transects in order to identify critical regions for future data collection using volunteer vessels. This study worked in conjunction with the existing studies in the region, both those on-going at the Research Reserve as well as within the Cook Inlet Keeper. On-going studies are similarly working to gain and organize a community-based network of volunteers as well as to further the understanding of circulation and mixing in Kachemak Bay. In addition, collaboration between the Keeper's Citizen's Environmental Monitoring Program and the Kachemak Bay Research Reserve's scientific programs allows for greater community involvement and understanding of the regional circulation and water quality.

Objectives:

Six main objectives were achieved by this study. These objectives were realized through a combination of the Cook Inlet Keeper Outreach program, and the Kachemak Bay Research Reserve Research and Development program.

CIK Outreach program:

1. Organize a network database of regional vessels according to their spatial and temporal distribution in the Kachemak Bay, lower Cook Inlet and Gulf of Alaska.

2. Prepare and execute an extensive outreach program including local workshops in order to identify these vessels and to communicate with potential citizens interested in volunteering their time and vessels for a long-term monitoring project

3. Establish a link between regional research objectives and data collection and an existing successful volunteer monitoring program.

KBRR Research and Development program:

4. Conduct a thorough investigation to compile all of the existing background oceanographic research on the Kachemak Bay and lower Cook Inlet in order to best evaluate which oceanographic variables will be the most relevant for collection in a long-term data set by ships of opportunity. Included in this investigation is an analysis of on-going studies in similar regions as well as the KBRR oceanographic workshop, which

assisted in achieving the goals of this project by combining the expertise of the greater oceanographic community in establishing relevant parameters to be monitored.

5. Collection of important drift card data for inferring regional surface currents. These data are used to infer seasonal surface circulation patterns.

6. Collect preliminary water quality data to evaluate important regions for future data collection with volunteer vessels. This preliminary data will be used to establish a protocol for correlation of future temperature and salinity baseline data sets with existing stationary sensor platforms measuring parameters of temperature, salinity, pH, DO, PAR, turbidity, Chla and nutrients. Data collection could be expanded in later studies by the inclusion of additional instrument sensors for water quality parameters along the same spatial and temporal resolution as designated in the course of this study.

Methods:

There were two main phases of this project involving input from both the Kachemak Bay Research Reserve (KBRR) and the Cook Inlet Keeper (CIK). These two phases were the KBRR Research and Development program, and the Cook Inlet Keeper Outreach program. These two programs occurred concurrently, with some of the objectives detailed for the KBRR program dependent upon the results of the CIK Outreach program and the resulting vessel database.

The KBRR Research and Development program utilized input from the oceanographic community as well as the database of vessels assembled by the Cook Inlet Keeper in defining scientific objectives for an on-going monitoring program. This work involved: preliminary hydrographic measurements to define regions for future study; an on-going drift card study for inferring regional surface currents; an extensive survey into additional instrumentation for volunteer vessels; development of a protocol for data acquisition and processing; an extensive background research survey of existing regional studies and communication with on-going regional programs.

Preliminary Hydrographic Data Collection:
Preliminary oceanographic data was collected by the Reserve along representative transects in the Kachemak Bay area (Figure 2). These preliminary data along these transects are being used to further refine regions of importance for future collection of oceanographic data. Transects included along-axis and across-axis locations, covering regions of inflowing and outflowing water to the bay. The transects covered the following regions (numbered list of transects corresponds to Figure 2 transect numbering):

1) Point Adam to Cape Douglas (Figure 3)
2) Point Pogibshi to Anchor Point (Figure 4)
3) Barabara Point to Bluff Point (Figure 5)
4) Cohen Island to Homer Spit (Figure 6)
5) Peterson Point to Homer Spit (Figure 7)
6) Glacier Spit to Fritz Point (Figure 8)
7) Bear Cover to Eastland Canyon (Figure 9)

Sampling along these transects was accomplished using a caged array of instruments including a pumped Seabird SBE 19 CTD, a Wetlabs Wetstar fluorometer and a Licor cosine PAR sensor. Transect lines as indicated in Figure 2 were followed with profiles of water quality data taken every kilometer along the transect. The data from each sensor (for depth, temperature, salinity, fluorescence, and PAR) were filtered, and binned into one-meter increments using Seasoft software. These filtered data were then plotted using Matlab.

The regions sampled are also consistent with existing stationary NOAA and National Weather Service buoys as well as existing water quality monitoring programs. Data analysis was performed on this preliminary work to refine the data processing protocol to be used in future work, specifically the production of graphs, maps, animations, and other correlation materials to graphically display information on seasonal oceanographic conditions and the relation to regional circulation and mixing processes. Data was analyzed to identify critical regions for future study in other aspects of Kachemak Bay ecosystem dynamics. A particular consideration in examining the results was the comparison of surface signature of water quality parameters compared with the profiles across a given transect.

Drift Card Study:
Drift cards were used as a low-cost means to study and infer regional surface currents. A preliminary knowledge of these currents helps to further refine the relevant regions for future data collection by ships of opportunity. Drift cards were constructed and deployed over two different seasons and for five different locations. Locations for deployment included: Anchor Point, Beluga Slough, Homer Spit, Seldovia and Bear Cove. Each deployment contained 1000 cards, distributed evenly across a transect perpendicular to the shore locations (Figures 10-13). These locations were also consistent with regional data collection.

Drift cards were constructed of painted and varnished wood and labeled with pertinent information for their recovery. Each drifter was color coded by season and location, and labeled with the following:

When found: (date and time)
Where found: (latitude and longitude)
Who found it: (finder's name and address)
Return to: (KBRR address)

Deployments occurred in the Winter (March 15, 2002) and in the Spring/Summer (May 7,16, 29, 2001 and June 9, 2001). Volunteers from the local community were involved in retrieving and tracking the positions of drift cards. Retrieval and tracking was coordinated with the annual beach walk and clean up and involved the participation of the KBRR, Cook Inlet Keeper, the Alaska Center for Coastal Studies and regional volunteers.

Literature Search of Regional Oceanographic Studies
In addition to the work described, a concurrent extensive background search of all previous regional oceanographic work was compiled. An extensive search of published and non-published literature on the Kachemak Bay region was undertaken as part of this project. The published and

unpublished reports that were located as a result of this search have been incorporated into the poster presentation on Circulation Patterns in Kachemak Bay (Appendix A) as well as referenced in the Additional References section of this report. These studies add to the existing known body of research on Kachemak Bay. Listing these references in this report will aid others in the future to locate some of the gray literature studies completed on the region.

Vessel Database:
The Cook Inlet Keeper utilized its expertise in community volunteer involvement to develop an outreach program for identifying regional vessels. This outreach program included local media and regional announcements in order to best identify community volunteers. The primary objective of the Keeper's outreach program was the establishment of a comprehensive database of all regional vessels currently operating in the Kachemak Bay, lower Cook Inlet and, to some extent, the greater Gulf of Alaska region. This database is organized according to the spatial and temporal distribution of these vessels in the region, the owners and operators of the vessels, and the nature of their activity (i.e. charter fishing, recreational charters, transportation/ferry, commercial fishing). Using community-based workshops, the Keeper further refined the database to delineate which vessels would be interested in participating as a ship of opportunity in a data collection project to begin the following year.

Cook Inlet Keeper implemented an outreach plan consisting of a paid radio public service announcement (PSA), newspaper ads, flyers, a volunteer gathering, and contact with local harbormasters. The PSA was played ten times by KBBI public radio in Homer, serving to raise awareness of the project and to recruit volunteers. All Keeper volunteers were informed of the project and offered the opportunity to participate. Online databases such as the Alaska Department of Fish and Game commercial vessel listing were searched and used to import vessel information into the database The Research Reserve, with the cooperation of Keeper staff, organized community workshops that provided prospective volunteers with information about the Vessels of Opportunity project. As a result of this outreach plan, seven vessels were identified as possible volunteer vessels for this project.

Results:

CTD data:
Preliminary data collection was focused upon regions of Kachemak Bay. The purpose of these preliminary data is to define important areas for future data collection, the variables necessary for collection by volunteer vessels, and the spatial scales of collection. Of particular importance is the difference between surface sampling of water quality variables and sampling at a range of depths. These results are intended to show a representation of the type of results (depending on the depth scale) that would be possible to obtain across this area using vessels of opportunity.

The Point Adam to Cape Douglas transect is representative of the inflowing water to the Kachemak Bay region (Figure 3). Water tends to be well-mixed and colder. Point Pogibshi to Anchor Point (Figure 4) water exiting the bay (to the north) is warmer and less saline, having become more estuarine while mixing with Kachemak Bay waters. There is a noticeable

fluorescence peak (Figure 4C) centered at approximately 20 meters depth that surface sampling would miss.

Moving further into the bay, the Barabara Point to Bluff Point transect shows more distinct features (Figure 5). Here again waters leaving the bay are warmer and more saline. The flourescence feature is also present, here across a much wider area, but also concentrated at approximately 20 meters depth.

Cohen Island to Homer Spit (Figure 6) shows sharply defined depth gradients in both temperature and salinity, with a shallow warm, less saline layer overlying colder, more saline waters. The fluorescence feature is more widespread and closer to the surface. Peterson Point to Homer spit, the lateral extension of the previous transect, shows similar gradients across the width of the entrance to the inner bay (Figure 7).

Inside the inner bay, Glacier Spit to Fritz Point (Figure 8) and Bear Cove to Eastland Canyon (Figure 9) the average depth is more shallow and the water is more stratified. This is consistent with observations by Abookire et al. (2000). Warmer, less saline waters are on the surface, with the estuarine waters to the north and colder waters to the south, indicating the gyral circulation within the bay. The fluorescence feature is again present and concentrated at 20 meters depth.

Drift card study

Drift cards were deployed in five different location over two different seasons (Figures 10, 11, 12). The Summer deployments took place in May, 2001 (May 7, 16, 29) and early June 2001 (June 9). These summer deployments occurred in both the inner bay (Figure 10) and outer bay (Figure 11). As the locations of the recovered drift cards show, for the deployments which occurred outside of the inner bay, no cards were recovered within the bay (Figure 11). Cards deployed to the north side, outside of the inner bay, were all recovered north of the bay in Cook Inlet (Figure 11B). Drift cards deployed south of the inner bay, near Seldovia and Kennedy entrance (Figure 11C), were recovered outside of the inner bay, both on the ocean side of the Homer Spit, as well as further north in Cook Inlet. The Summer cards deployed inside of the inner bay were recovered on both sides of the inner bay, as well as along the spit and to the north of the bay in Cook Inlet (Figure 10A,B). In the Winter deployment, on March 15, 2002, cards were deployed from Seldovia, outside and to the south of the inner bay (Figure 12). These cards were recovered in regions similar to those for the Summer deployment (Figure 11A). No cards from this deployment were recovered inside the inner bay. The percent recovery from the summer deployment was 38%, while the Winter deployment had a lower recovery of only 1%. The lower winter recovery rate is to be expected as there are fewer people walking beaches during that period and hence a lower chance of cards being spotted and retrieved.

CIK database

Following the extensive outreach program outlined in the Methods section, a listing of regional vessels and their information was compiled by the Cook Inlet Keeper and organized into a database. The Vessel Database is a searchable database of over 7500 private and commercial vessels operating in Kachemak Bay, Lower Cook Inlet, and the Gulf of Alaska. The database includes information about the vessel's owner, operator, skiffs, electronics, physical description, deck, hydraulics, engines, and spatial/temporal information (Figure 13). Six queries are built in

to identify vessels with a regular course, volunteer vessels, Kachemak Bay vessels, and other criteria (Figure 13B). A vessel report is programmed to list all vessels and the owner information, port of registry, and ADF&G number (Figure 13C). All of the queries and the report are printable, savable, and exportable.

Discussion:

CTD data:

The features present in the transects of water quality data show the high variability of water quality parameters within a relatively small spatial area. These features are consistent at small spatial scales but are quite different at larger spatial scales. In doing these profiles of water quality, we were testing the difference between what information would be returned from a surface sensor, such as what could be mounted easily on a vessel of opportunity, and what features would be overlooked in this manner. Temperature and salinity across some spatial scales, could be easily measured using vessels of opportunity, and the data obtained would be useful in describing regional patterns. Other parameters however, such as fluorescence, a proxy for chlorophyll-a concentration may not be adequately characterized by their surface signature, and require profiles in order to see the vertical distribution of the feature.

In designing a study using vessels of opportunity, our preliminary data collection survey indicates that a combination of instrumentation would be the most useful in characterizing nested spatial scales of water quality parameters. Surface instruments such as thermosalinographs, that are the easy to install can provide useful information about the lateral variability of hydrographic properties, but the interpretation of data from such systems must consider the possibility of vertical stratification of the water column. Systems that allow vertical profiling would provide the needed water column detail, however these sophisticated instruments are not easily deployed from a moving vessel of opportunity. Plans to instrument vessels of opportunity must be made as simple as possible for the vessel owner to operate while providing quality data.

Drift card study:

The recovery locations from the drift card deployments in both Winter and Summer concur with previous work by Burbank (1977) on the regional surface circulation. All drift cards deployed in the outer bay (both to the north and south of the entrance to the inner bay) remain outside of the inner bay, sometimes landing to the outside of the Homer spit, or continuing further north in the east side of Cook Inlet. Cards deployed inside of the bay are either swept along the northern edge of the inner bay and deposited or entrained into water leaving the bay and moving towards the north along the Homer spit. Some cards are also found to the south of their deployment indicating either a back-eddy or the entrainment into the larger inner bay gyre and then deposition again on the southward edge of the gyre.

Our study hypothesized that in the winter, following extreme mixing and the destruction of intense stratification, that surface waters enter the inner bay from the outer bay. However, both summer and winter outer bay deployments showed no recovery of cards inside the inner bay. Our results concur with previous work that there is a mechanism which is restricting surface flow from the outer to inner bay. Burbank (1977) hypothesized the existence of a large surface gyre in the outer bay which restricted the intrusion of surface waters to the outer bay. Future work

examining both the regional surface currents during seasonal as well as sporadic weather events may elucidate the nature of this surface circulation in this region. Future work must also include current profiling in order to fully explore the circulation and missing link between the inner and outer bays.

CIK database:
The database contains information on more than 7500 vessels operating in the greater Gulf of Alaska region. Personnel at the Cook Inlet Keeper were able to utilize the information from the database they compiled to identify six (possibly seven) vessels which would be interested in participating in future work to collect oceanographic data. This is precisely the type of information that the database was meant to provide. Six vessels have been identified as willing and one may be willing to participate in deploying instruments for the collecting of oceanographic data. Vessel operators should be contacted in the fall of 2002 or the winter of 2003 and given an update on the project. Many of these vessels will be dry-docked or in port and available for outfitting with an instrument. In particular, the Tustumena, a state run ferry, is scheduled to be in Portland, Oregon at the Swan Island Ship Yard from mid Nov. 2002 to April 1, 2003. It will be dry docked sometime in January. This would be the best opportunity to outfit this vessel with an instrument.

If funding is available and other vessels are needed the database could be utilized to search for other vessels. This database should be updated for more recent information as it is utilized as well for additional vessels interested in participating as volunteer vessels.

Conclusions:
CTD data
The hydrographic data collection was useful in determining the spatial regions for future data collection as well as the importance of both surface sampling and profiles of hydrographic information. The two most important regions to study are the across-axis gradients Kachemak Bay, for studying the inflow and outflow to the bay, and the along-axis region, for studying the estuarine gradients. Both surface data and profiles of data are clearly necessary in order to adequately study the hydrography of this area. Surface instruments, such as thermosalinographs, are relatively inexpensive and easy to maintain on a volunteer vessel. More sophisticated instruments for obtaining profiles of hydrographic data are possible to use on volunteer vessels, but more difficult to deploy, and more expensive.

Drift card study
Drift cards provided an inexpensive mechanism for inferring seasonal surface currents. Surface waters are restricted from entering the inner bay in both summer and winter. This supports the hypothesis of a large surface gyre in the outer bay which restricts the intrusion of surface waters into the inner bay. Future work must be done to elucidate the spatial and temporal extent of this circulation.

CIK database
The outreach program designed by the CIK was effective in its intent and information on 7500 vessels has been entered into an easy-to-operate database. This database can be updated and expanded for more extensive use. The outreach program was also effective in further refining

this database to obtain six volunteer vessels who are interested in participating in future projects for collecting oceanographic data in Kachemak Bay and lower Cook Inlet.

Acknowledgements:
We gratefully acknowledge the hard work of Joel Cooper and Dale Banks from the Cook Inlet Keeper in their outreach program and database development. We would also like to thank Heloise Chenelot, Dara Rhyder and Carmen Field for their work in the construction and deployment of the drift cards, and Scott Pegau for his review and commentary on this report..

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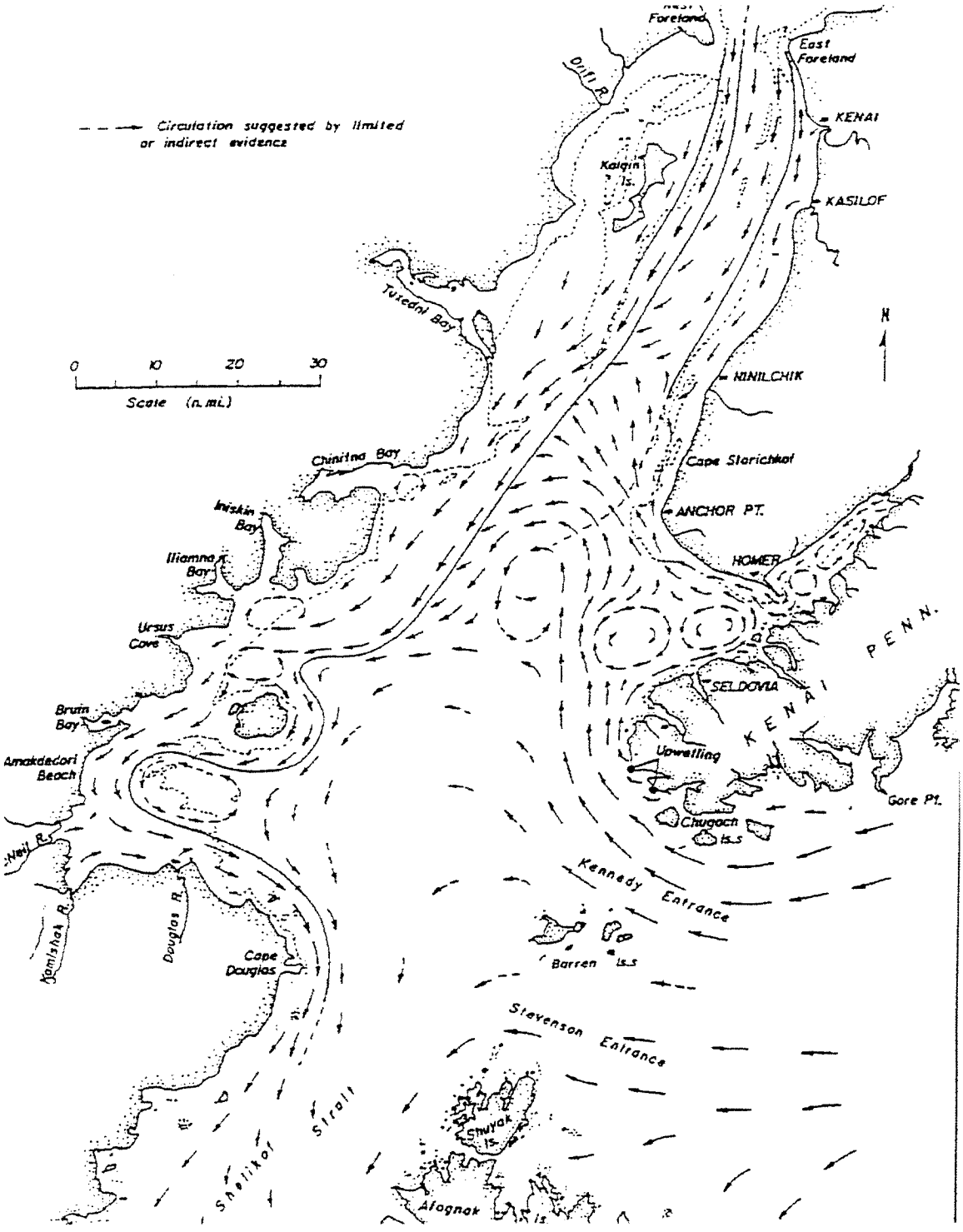


Figure 1: Net surface circulation in Kachemak Bay and lower Cook Inlet (Burbank, 1977)

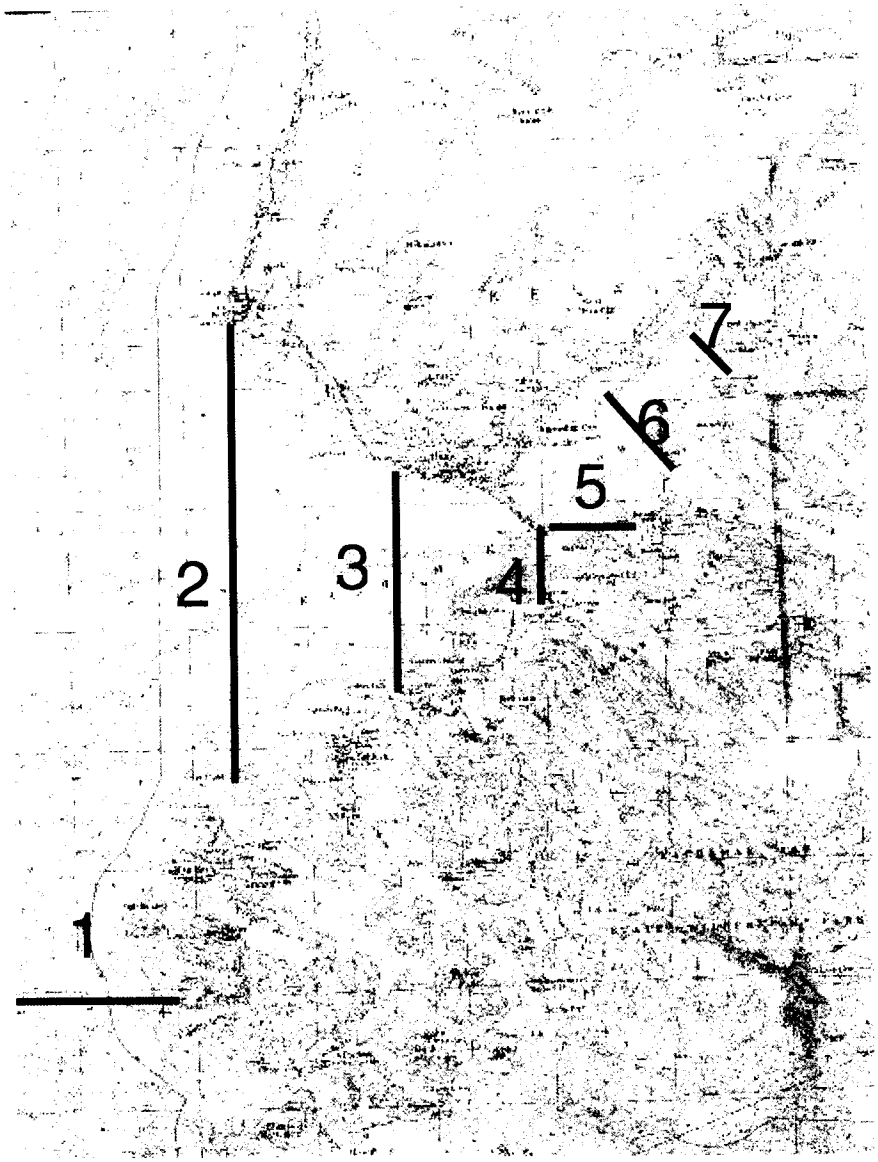


Figure 2: Map of transects for summer water quality data collection. Numbers correspond to transect descriptions in the text.

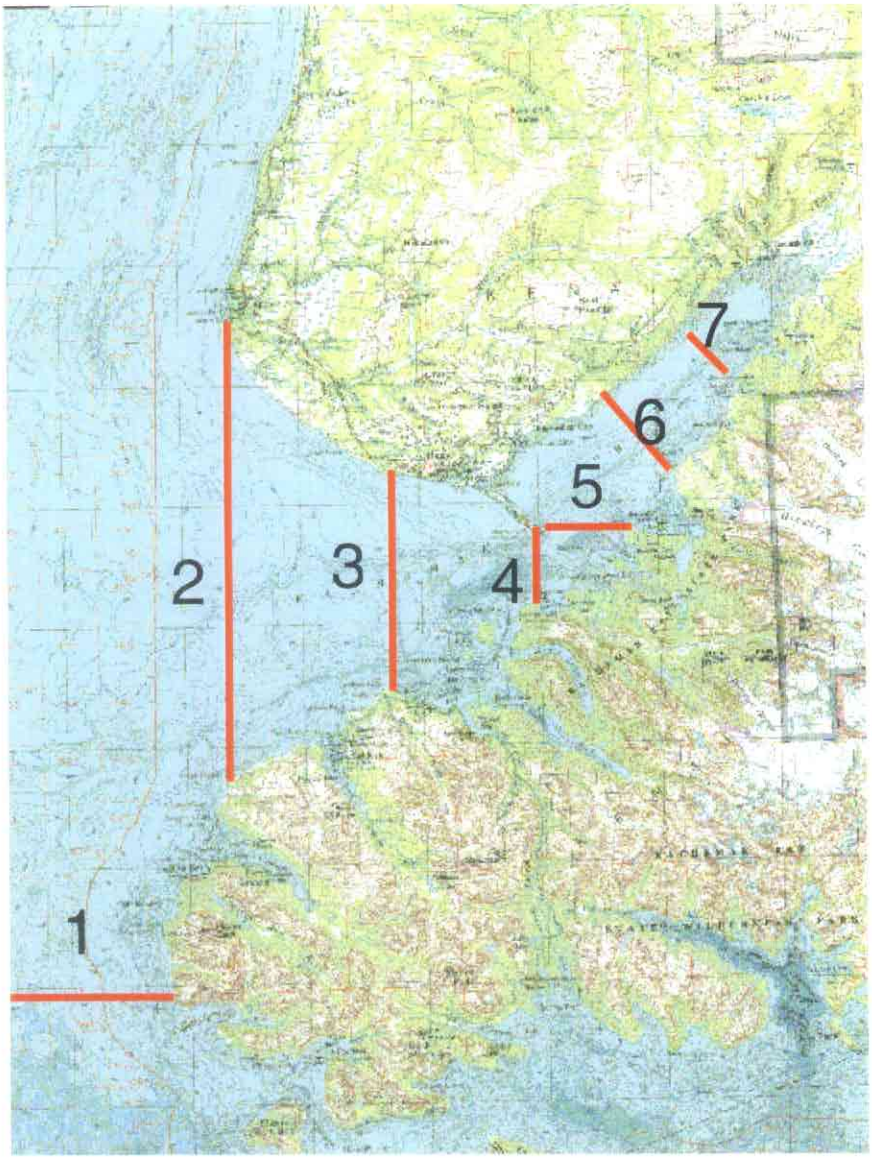


Figure 2: Map of transects for summer water quality data collection. Numbers correspond to transect descriptions in the text.

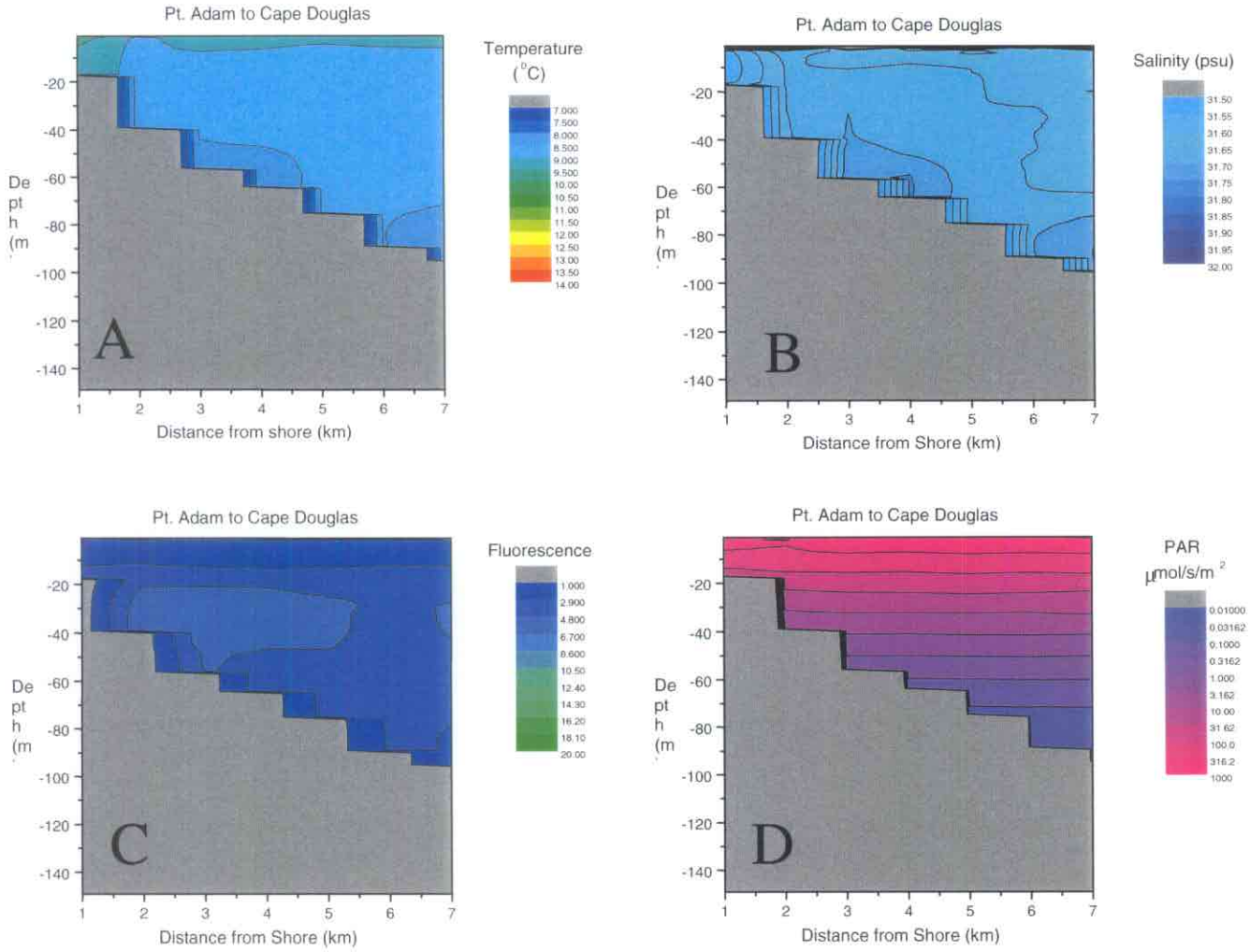


Figure 3: Point Adam to Cape Douglas
A) Temperature
B) Salinity
C) Fluorescence
D) PAR

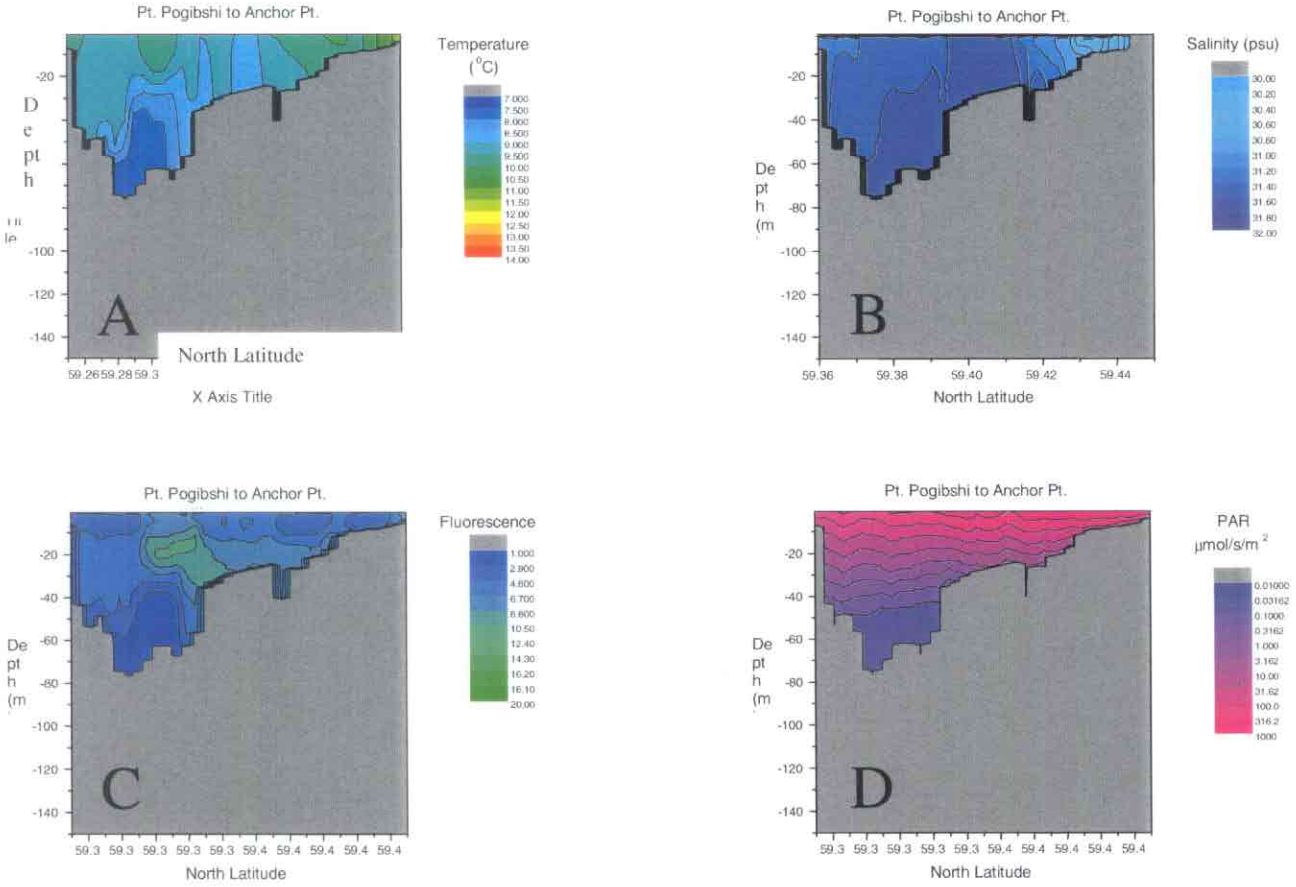
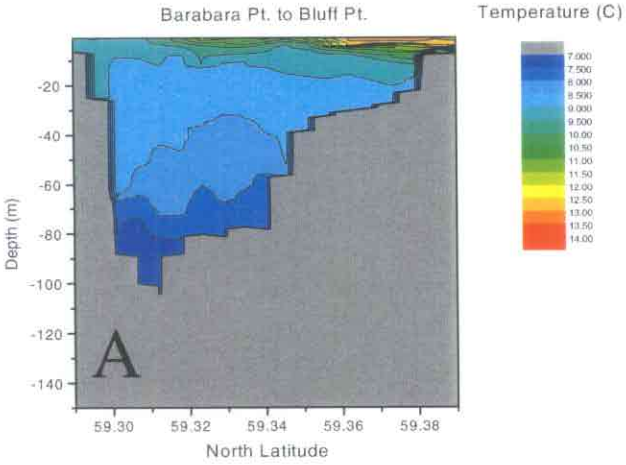
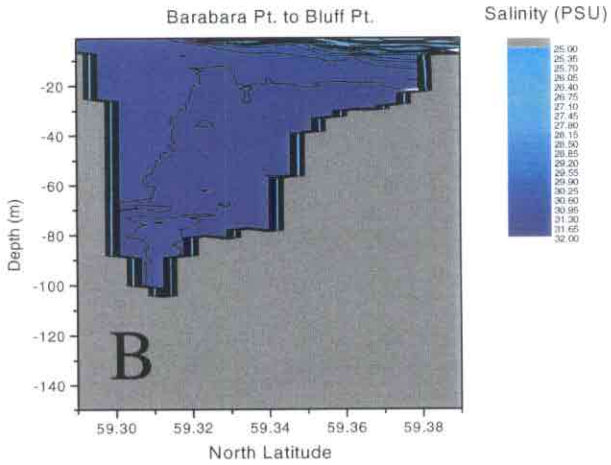
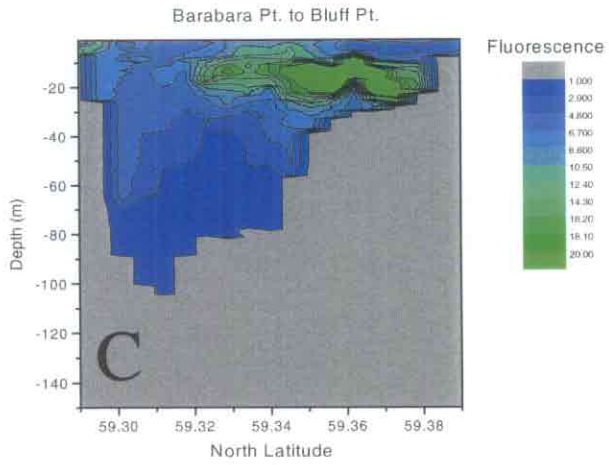


Figure 4: PointPogibshi to Anchor Point
A) Temperature
B) Salinity
C) Fluorescence
D) PAR







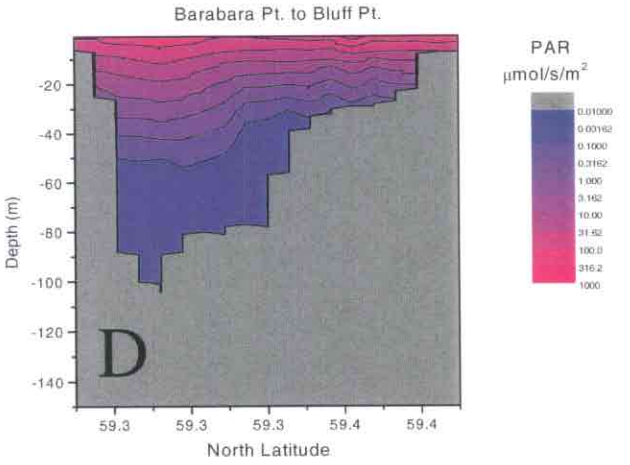
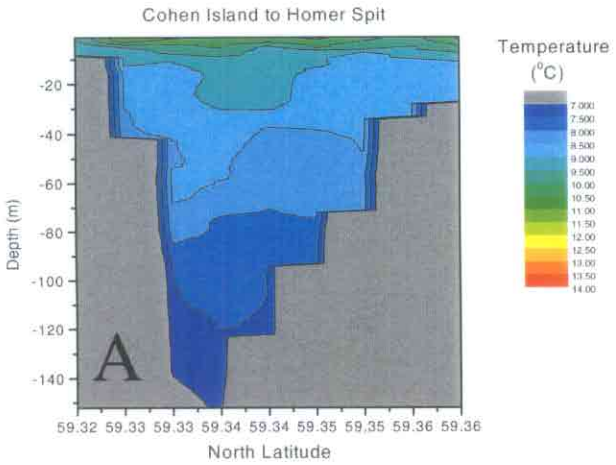
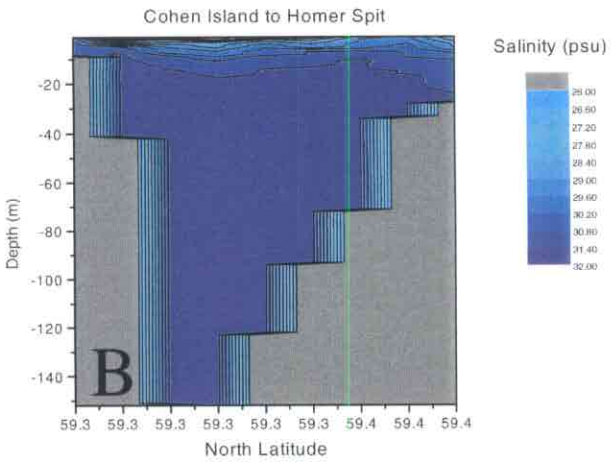
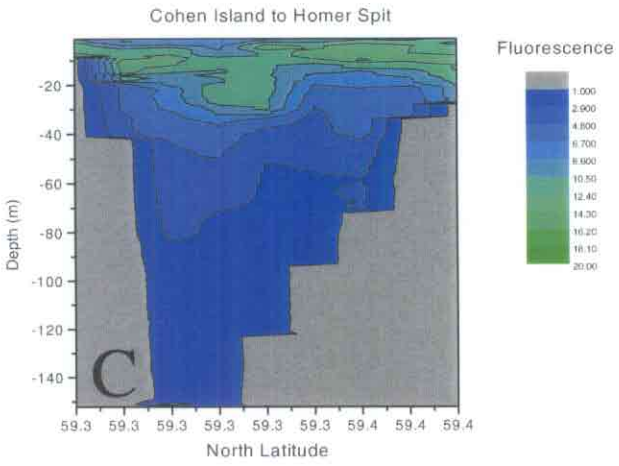


Figure 5: Barabara Point to Bluff Point
A) Temperature
B) Salinity
C) Fluorescence
D) PAR







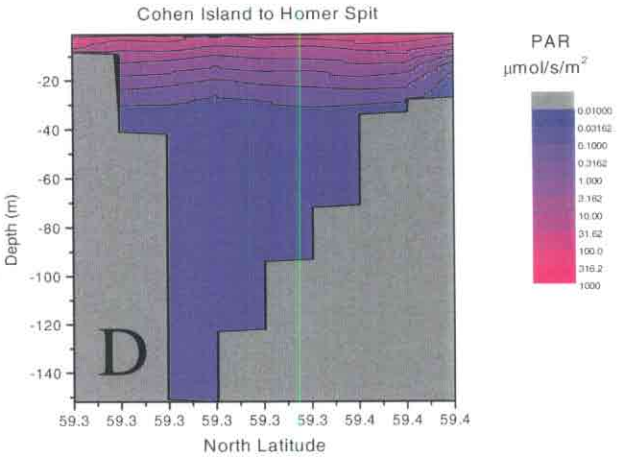
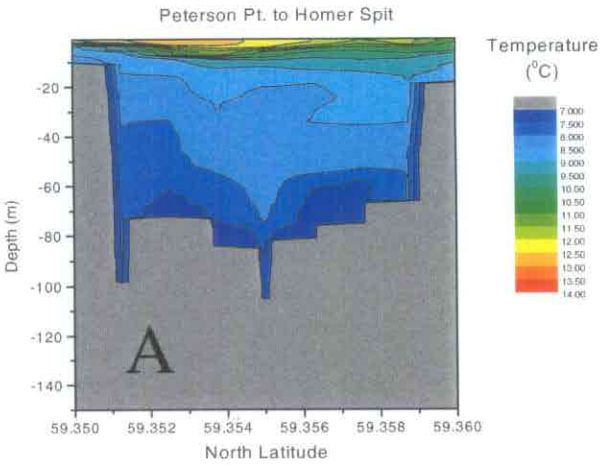
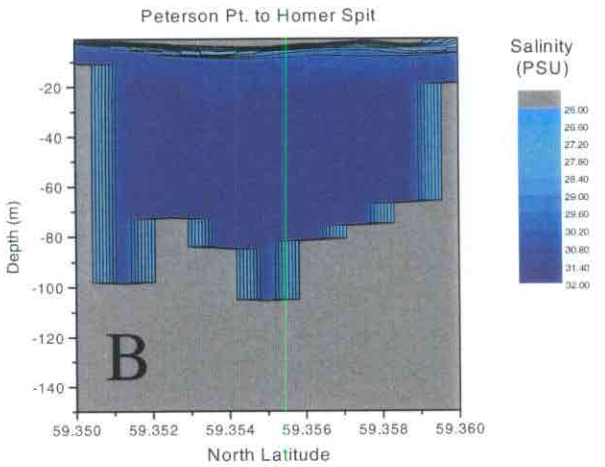
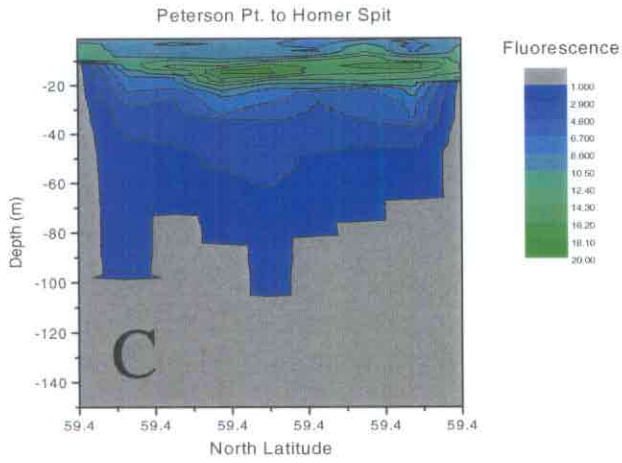


Figure 6: Cohen Island to Homer Spit
A) Temperature
B) Salinity
C) Fluorescence
D) PAR







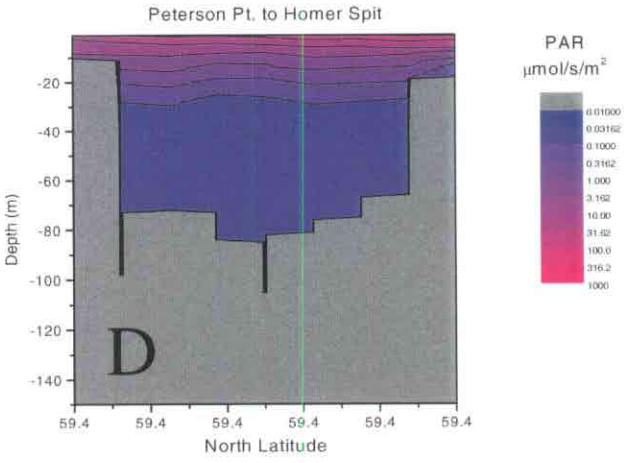
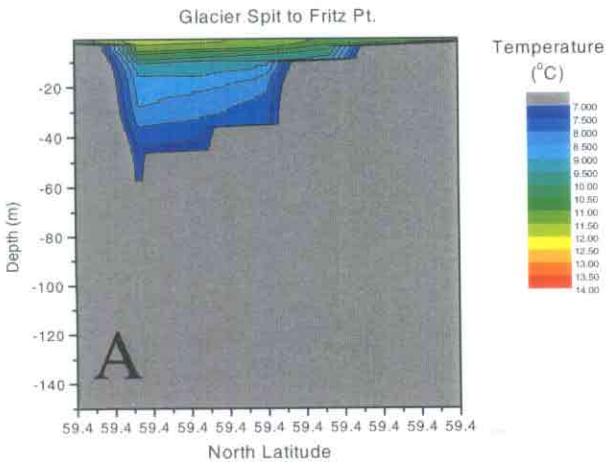
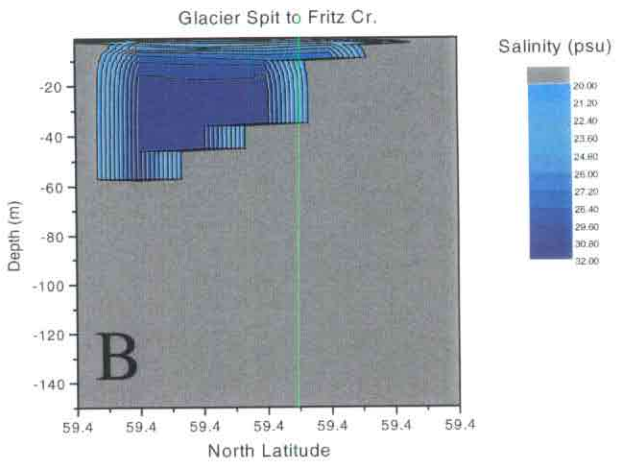
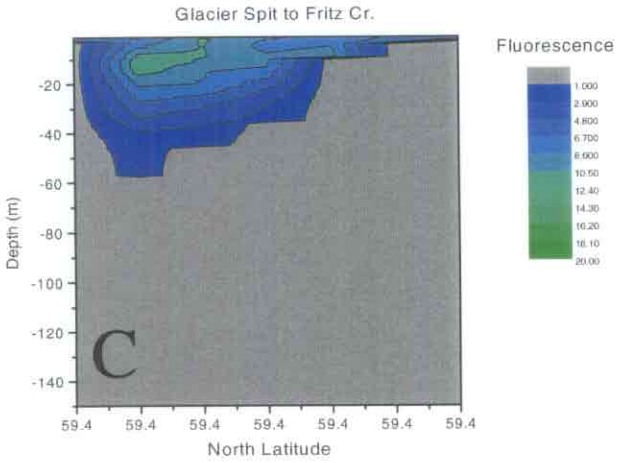


Figure 7: Peterson Point to Homer Spit
A) Temperature
B) Salinity
C) Fluorescence
D) PAR







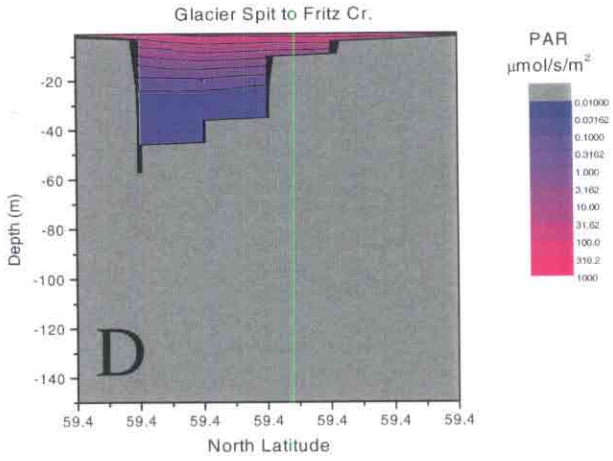
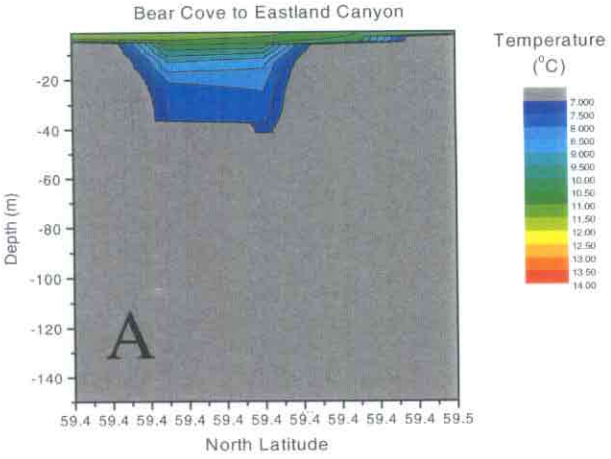
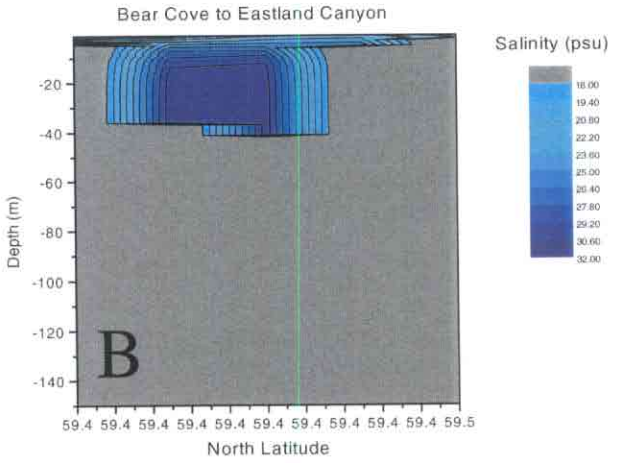
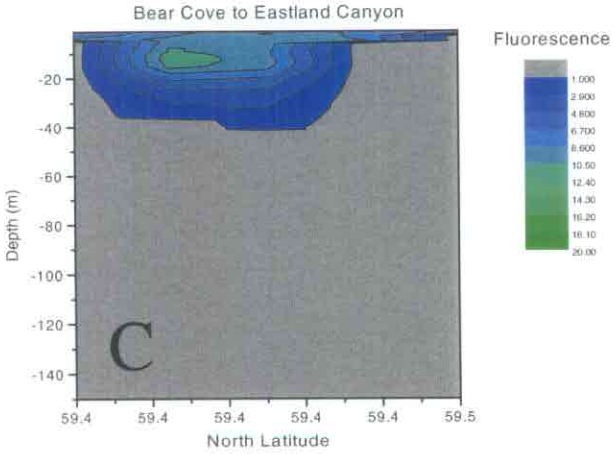


Figure 8: Glacier Spit to Fritz Point
A) Temperature
B) Salinity
C) Fluorescence
D) PAR







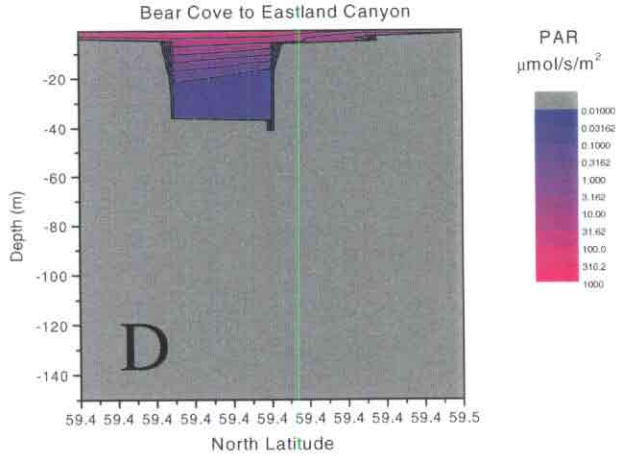


Figure 9: Bear Cove to Eastland Canyon
A) Temperature
B) Salinity
C) Fluorescence
D) PAR

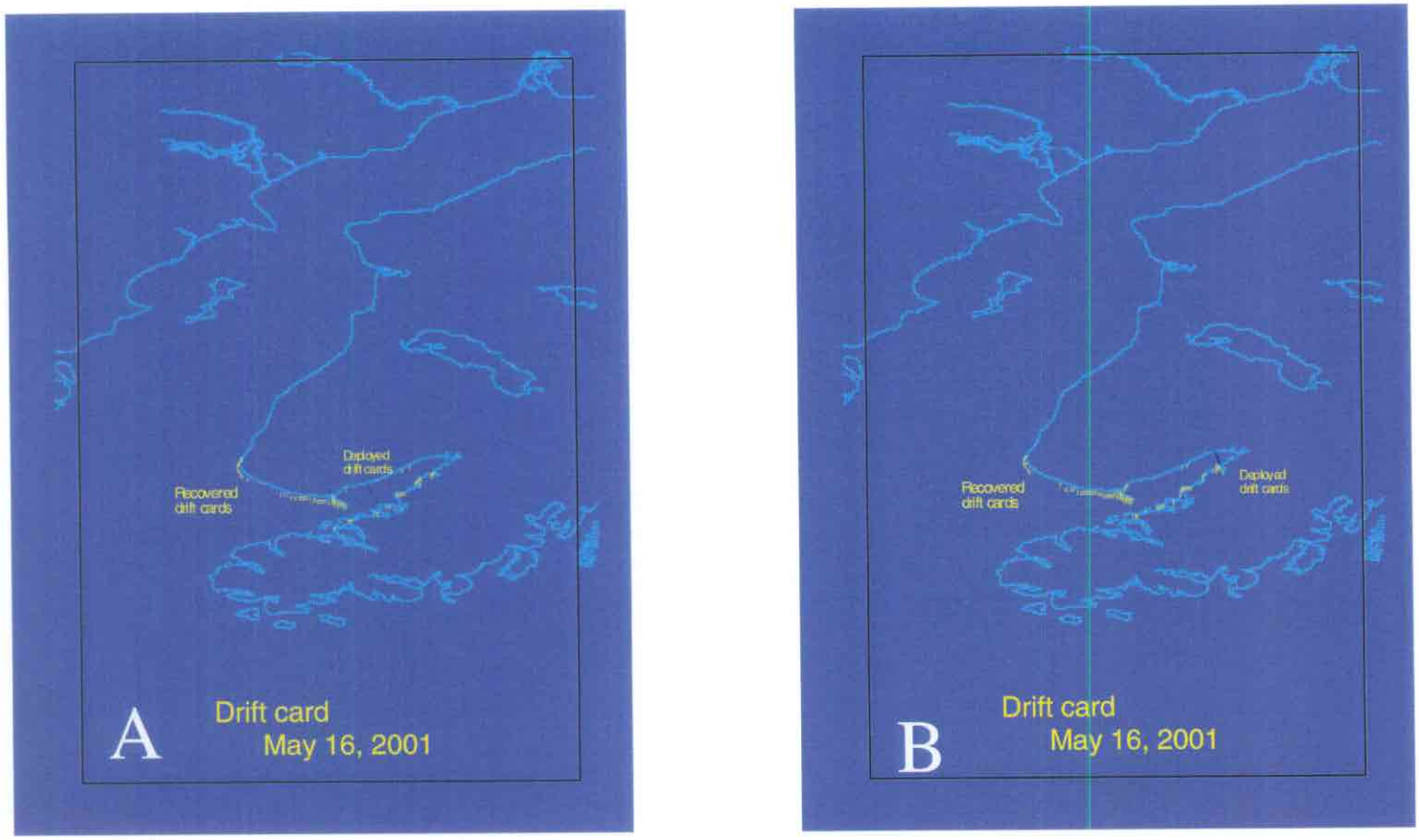


Figure 10: Summer drift card deployments Inner bay
A) Deployment near Homer Spit
B) Deployment near Bear Cove

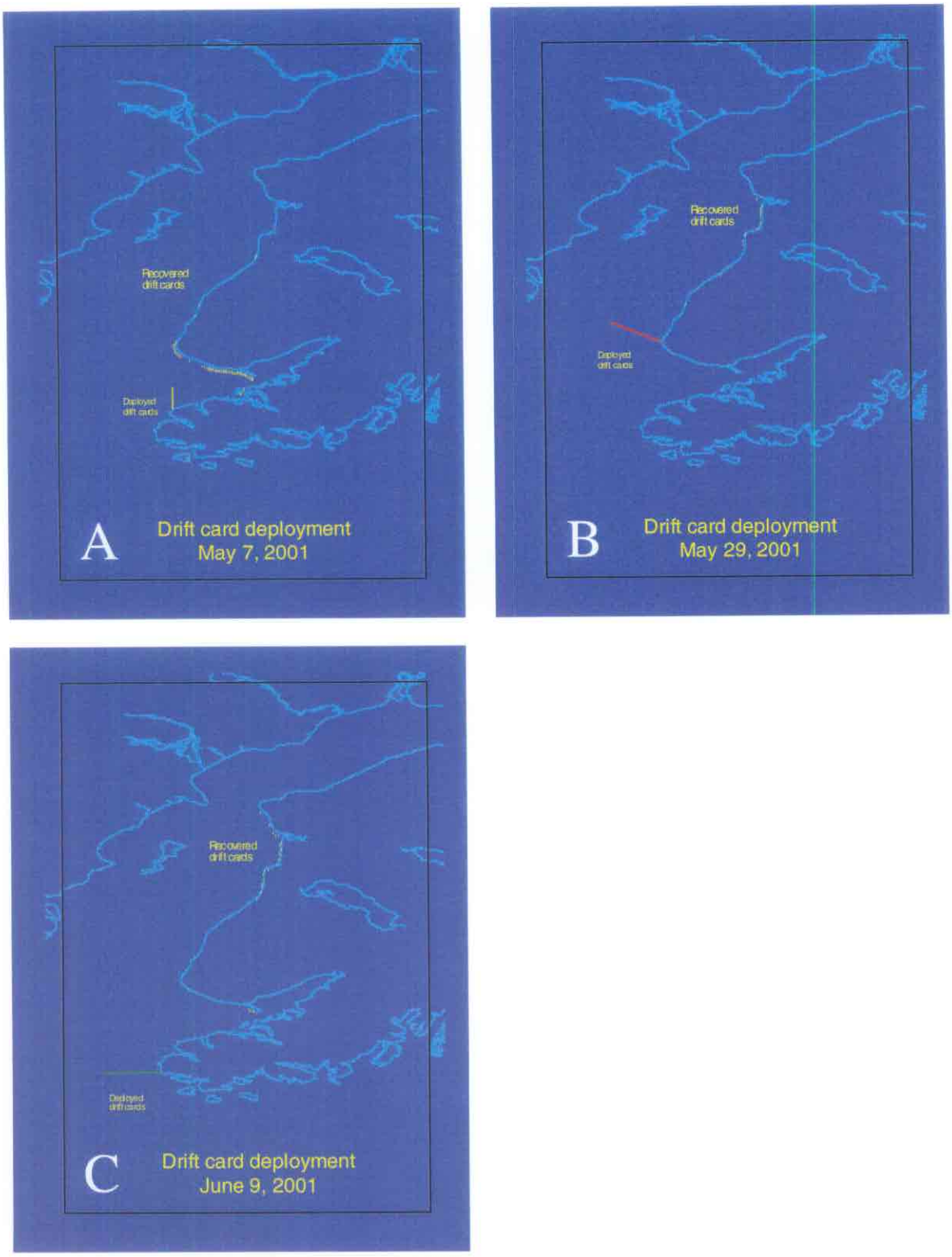


Figure 11: Summer drift card deployment Outer bay.
A) Deployment near Seldovia
B) Deployment near Anchor Point
C) Deployment near Kennedy Entrance

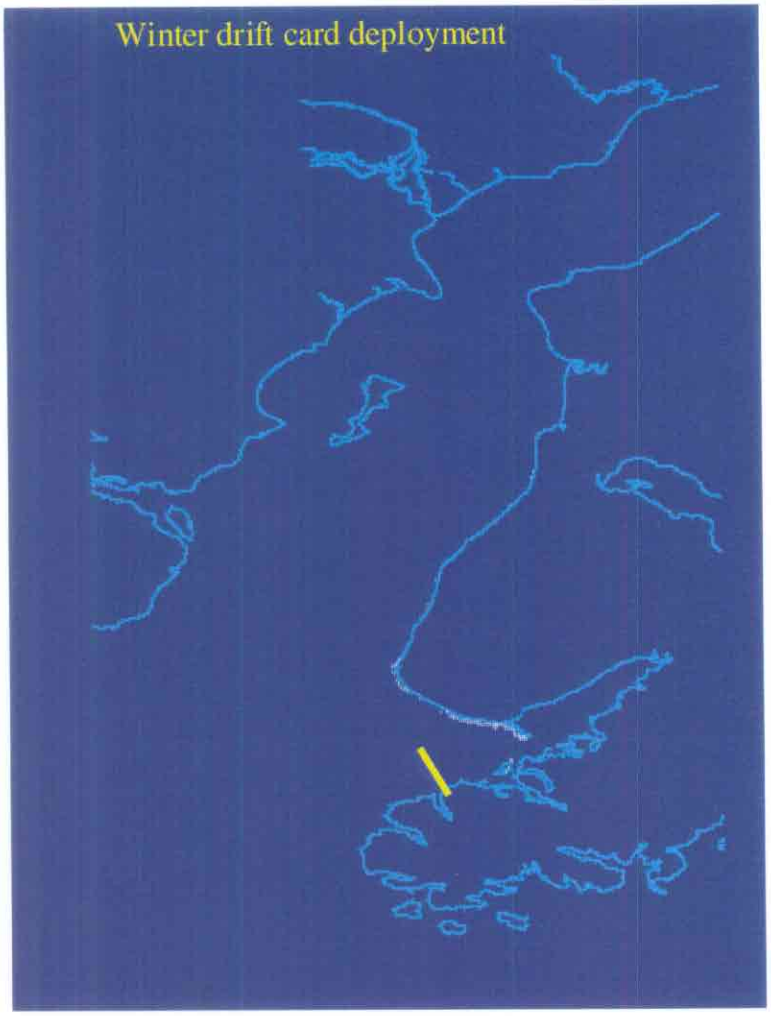
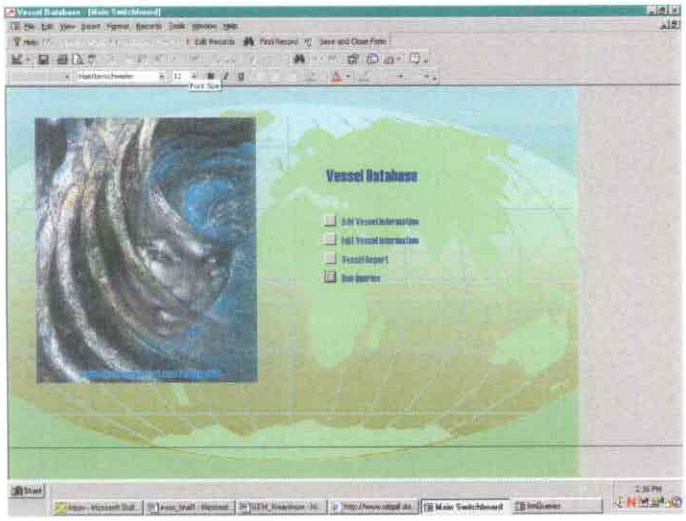
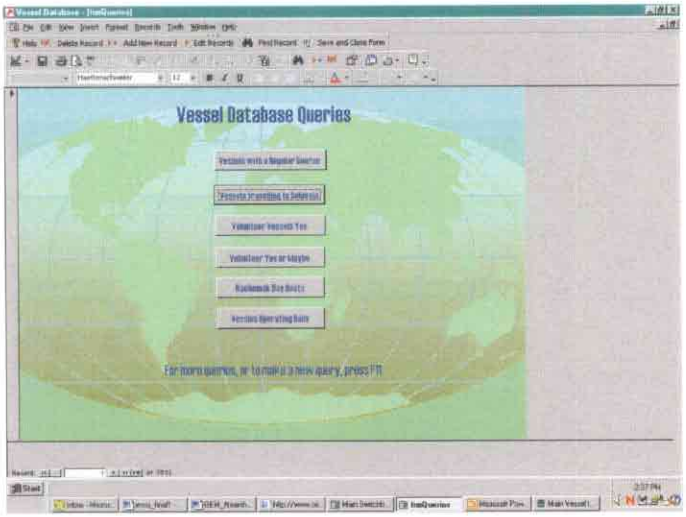


Figure 12
Winter drift card deployment transect and the resultant retrieval locations.
Note that none of the cards from this deployment were retrived inside of the inner bay.

A



B



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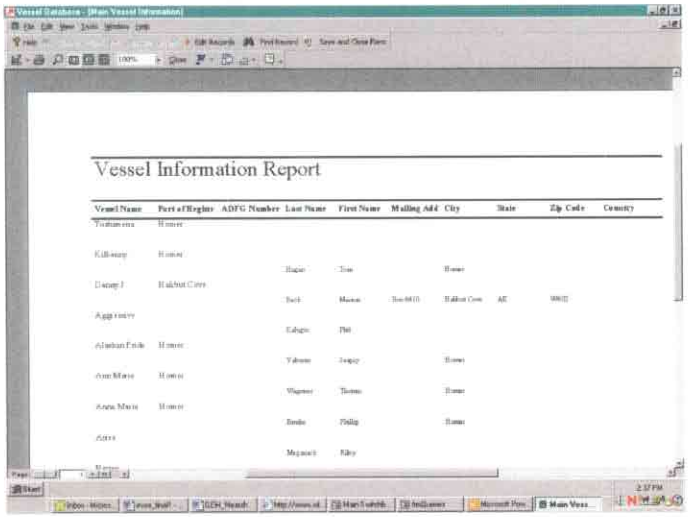

Figure 13: Screen Shots of Access Database of Volunteer Vessels
A) Opening screen to database: Chose objective
B) Vessel Database Queries
C) Example of Vessel Database Report