EVOS Annual Progress Report

Project Number: # 070817

Project Title: Physical Oceanographic Factors Affecting Productivity in Juvenile Pacific Herring
Nursery Habitats

PI Name: Shelton Gay - PWSSC

Time Period Covered by Report: June - August 2008

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Work Performed: The results of the previous year of this study were summarized in a synthesis report sent to the Exxon Valdez Oil Spill Trustee Council (EVOSTC) in May, 2008, titled Physical Oceanographic Processes in Relation to Productivity of Pacific Herring (Gay 2008). The present report, therefore, addresses work accomplished mainly during final quarter of the project over the summer of 2008 and various problems encountered during that time. A table of all activities (including collaborative work) performed during the entire 2008 field season is given in Appendix A. Please note that this report is a summary of work accomplished and a more thorough report of the results from 2008 will be presented during the October 2008 meeting to be held in Anchorage.

Over the summer of 2008 the following field work was performed: 1) installation and downloading of meteorological data from a buoy and a shore based weather station in Whale Bay and one shore based station in Simpson Bay; 2) three intensive hydrography/ADCP cruises to Whale Bay and two cruises to Simpson Bay to supplement last year's data; 3) one thermosalinograph (TSG) cruise measuring hydrography, i.e. temperature/salinity/fluorescence/turbidity (T/S/F/Tb), over PWS and within Eaglek Bay and Whale Bay; and 4) deployment and retrieval of two oceanographic moorings within Whale. Some of Simpson's station maintenance and downloading of weather data was done during trips to Simpson using the PI's skiff. These sessions represent additional work not scheduled in the original DPD. On two occasions, intensive hydrography/ADCP cruises in Simpson also supported collaborators from Texas A&M University at Galveston (TAMUG) collecting ancillary measurements of deep currents, turbidity (sediment size distribution) and temperature, salinity and dissolved oxygen. Each of the other major project segments is addressed below.

Intensive Hydrography Cruises. Three intensive hydrography cruises around PWS were undertaken from June 4th to the 7th, July 31st to August 3rd and August 23rd to the 27th. These included continuous recording of current profiles collected with an acoustic Doppler current profiler (ADCP) and water column hydrography (T/S) collected continuously with an undulating sled and repeatedly at CTD stations (T/S/F/Tb) located throughout both Whale and Simpson. Most of the initial results of the 2007 intensive hydrography cruises and mooring data from Simpson were described in the synthesis report. The cruises to Simpson Bay performed n

2008 showed patterns in flow and T/S properties similar to observations made during the previous year (Gay 2008). However, some variation in surface currents and hydrography were seen reflecting a marked change in weather conditions between years. These measurements along with the ancillary weather data will be quite valuable in explaining the combined forcing mechanisms that affect water exchange into the main basin and into the northern (inner) basin.

Both currents and hydrography at Whale were highly influenced by inflow of glacial water emanating from Icy Bay, a neighboring tidewater glacial fjord. These observations confirmed those made during the surveys of Whale made during the Sound Ecosystem Assessment (SEA) project. However, just as Simpson exhibited variation in physical oceanographic characteristics between 2007 and 2008, so also did Whale. In the latter case, this appears to have been an attribute of high snow accumulation over the winter and its gradual release over the summer due to below average air temperatures, which caused an estuarine outflow from the fjord. This is a marked contrast to conditions observed in the 1990s in which the inner basins were warmer and saltier than the outer basin. Hopefully, the high resolution CTD data collected during the second and third cruises will show how this outflow interacted with glacial water from Icy Bay entering Whale during ebb tides. Analysis of the currents and hydrograpy may also reveal how flows in the upper 100 m affect transport into the Southern Arm of the fjord. Note that the latter region of the fjord is primarily where age 0 juvenile herring were observed during the SEA program. One caveat here is that the highly detailed structure of the currents provided by the 600 kHz ADCP within Simpson was not available at Whale. This was due to the considerably deeper basin depths (100-300m) at Whale which required using a lower frequency 150 kHz ADCP in order to achieve bottom tracking.

TSG Cruise. This cruise was sponsored in part by OSRI and in part by my project. It was accomplished on two separate legs; one between July 18th and 21st and one on July 26th. The surveys included measurements of the temperature (T), salinity (S), fluorescence (F), and turbidity (Tb) of the nearsurface water throughout Prince William Sound (PWS) and within the two of the fjords studied during the SEA project. Also, within Whale a 600 kHz ADCP was towed to determine the feasibility of using GPS as a reference for absolute currents. This attempt had mixed success and from these trials it was concluded that only the use of the 150 kHz ADCP would suffice to survey Whale.

In addition to the TSG data, full water column T/S/F/Tb profiles were collected at various oceanographic stations distributed over the cruise area (*see the revised detailed project description (DPD), July 2007*). Lines of stations were also occupied, spanning across the inlets near the Alaska Ocean Observing System (AOOS) mooring sites in Hinchinbrook Entrance and Montague Strait. The hydrography data collected during the TSG cruise should provide a comparison of physical conditions within PWS and the four nursery habitats in mid summer of 2008. Unfortunately, budget constraints limited other TSG cruises in 2008 to surveys made in mid to late winter (Feb. and March).

Moorings at Whale Bay. The two moorings at Whale were successfully deployed and retrieved, and with the exception of the loss of the anti-foulant cells on one of the nearsurface CTs all the instruments collected data throughout the deployment. It is hoped that these data will show if exchange of deep water below 100 m (and hence nutrients from PWS) that enters into the

Whale's outer basin also enters into the Southern (inner) basin. The mooring retrieval represents the last portion of the 2008 field season directly undertaken by this project. Any additional data collected next fall and late winter will be done by collaborative projects.

Future Work: Future research objectives were addressed in detail in the revised DPD submitted in July 2007. Various logistical and budget constraints encountered during the early stages of the study were also outlined in the 2007 progress report. Here I will describe how these were specifically addressed during the 2008 field season.

The original objectives in 2008 called for focusing the intensive hydrographic cruises on Whale Bay, a fjord located in a region influenced by freshwater discharge from tidewater glaciers. Fieldwork in this fjord was still a major objective. However, because of vessel availability in 2008 intensive surveys of Simpson were again accomplished in mid to late summer. Unfortunately, there were further problems with the undulating CTD system involving cabling and sensor failures, and this limited data collection with the SB9 CTD to Whale only.

The objectives and methodology used in 2008 remained the same, but the scheduling changed slightly. For example, intensively surveying two fjords during each cruise reduced the overall time spent within each location to about 15 hr. This permitted collecting quasi-synoptical data in both fjords under the same interannual climate, which was preferable in comparing the response of these fjords to local climatic forcing. As aforementioned in the 2007 progress report, it is becoming more apparent that interannual climatic variation is increasing. For example, in just four years the summer climate of PWS and elsewhere in Alaska went from a warm anomaly in 2004 to a cool anomaly in 2008. How this may be related to either a shift in the Pacific Decadal Oscillation (PDO) or to background global warming is uncertain. The affects of the former will only be revealed by a time series with a sufficiently long fundamental frequency (i.e. inter-decadal).

Coordination/Collaboration: The coordination and collaboration with other projects was successful for the most part in 2008 (see Appendix A). These data included hydrographic (T/S) profiles collected during both the afore-mentioned TSG cruise and the EVOS sponsored cruises conducted by R. Thorne (Trends in adult and juvenile herring distribution and abundance in PWS). One final data set should be available following a cruise scheduled for Thorne's project in November 2008. In addition to the above work, coordination with research being conducted in Simpson Bay by personnel from TAMUG was accomplished. A key researcher at TAMUG is Dr. Antonietta Quigg who is studying primary productivity (i.e. phytoplankton dynamics). Dr. Quigg is analyzing chlorophyll and nutrient samples collected in 2008.

Due to budget constraints only one synoptic TSG cruise was conducted in the summer of 2008. At present, it is uncertain whether the money for these cruises will be included in the AOOS budget for next year (2009). However, if such funds were to become available it would behoove the herring restoration program to include money through my project to include hydrography measurements in the four SEA fjords next year.

Community Involvement/TEK & Resource Management Applications:

During the 2008 field season, community involvement was limited to contracting or renting vessels for use in the intensive physical surveys of the four SEA fjords. Resource management applications are not applicable at this time.

Information Transfer: No publications or presentations were scheduled during the 2008 summer field season. However, presentation of the second year's results are planned for the Ocean Sciences meeting in January 2009 in Anchorage sponsored by the EVOSTC. In addition, I will be analyzing the data for inclusion in my PhD dissertation, which will be written in part over the 2009 budget year. The dissertation will serve as a final report for this project in 2010.

Budget: A detailed explanation of the budget changes requested for next year will be submitted along with a revised DPD later once I have reached Texas A&M. For now I will state that I am requesting an additional $4K to cover the equipment problems and the TSG cruise incurred in 2008 and (possibly) an additional $6K to cover fjord hydrography during TSG cruises in 2009 (if these occur). Finally, I have revised the original amount requested for salary in 2009 from 3 months to 5. I feel this is justified in that I may not return to TAMU in the fall that year, but may instead remain in Cordova to complete writing my dissertation. As such, I will require more financial support to accomplish this.

Signature of PI: ____

APPENDIX A Table of research tasks and collaborative activities performed during the 2008 field season for project # 070817: Physical Oceanographic Factors Affecting Productivity in Juvenile Pacific Herring Nursery Habitats.

Month	*Dates*	*Cruise Type & Locations*	*Types Data Collected or Service Performed*
Feb	?	TSG cruise (AOOS/OSRI) - A. Craig	Collect tsg data over PWS & and ctd data at select stations
March	16-23	Juvenile Herring Cruise - D. Thorne	Broad scale hydrography; CTDs at 6 stations in each fjord
March	?	TSG cruise (AOOS/OSRI) - A. Craig	Full tsg/ctd cruise & ctd data over PWS & at MS/HE
May	12-28?	Zooplankton Cruise - T. Kline	Hydrography (Hydrobios CTDF) at discrete depths in above fjords
June	3-7	Cruise to all SEA fjords - Auklet	CTD Moorings deployed at WB; Intensive ADCP/ Hyrography transects at WB; CTDs elsewhere
June	21	Trip to Simpson - Scott Pegau	Upload met data at Simpson
Jul	18-21,26	TSG cruise (OSRI) - A. Craig	Collect tsg data over PWS & and ctd data at select stations; Upload met data at Simpson and Whale
July/Aug	31-3	Cruise to all SEA fjords - Auklet	CTD Moorings retrieved at WB; Intensive ADCP/ Hyrography transects; CTDs elsewhere
Sept	?	Zooplankton Cruise - T. Kline	Hydrography (Hydrobios CTDF) at discrete depths in above fjords
Nov	?	Juvenile Herring Cruise - D. Thorne	Broad scale hydrography; CTDs at 6 stations in each fjord

Physical Oceanographic Processes in Relation to the Early Life History Stages of Pacific Herring (*Clupea pallasi*) in Prince William Sound Alaska

Shelton M. Gay III
Prince William Sound Science Center and Texas A&M University

INTRODUCTION

A central hypothesis investigated during the Sound Ecosystem Assessment (SEA) program is that the major fish taxa in PWS, including Pacific herring (*Clupea pallasi*), walleye pollock (*Theragra chalcogramma*), and pink salmon (*Oncorhynchus gorbuscha*), all interact ecologically at various life history stages, and that survival of juvenile herring and salmon is highly dependent on the availability of macro-zooplankton consumed by all three species (Cooney et al., 2001; Willette et al., 2001). In this regard, the interannual variation in secondary production the zooplankton food base can moderate the survival of both pink salmon and herring in their early life stages by causing either prey sheltering or facultative predation on the young by the adults (Willette et al., 2001; Norcross et al., 2001). Productivity of zooplankton within Prince William Sound, Alaska (PWS) is affected by a number of physical processes including interannual variation in climate, hydrography, circulation and water exchange with the Gulf of Alaska (GOA) (Niebauer et al., 1994; Vaughan et al., 2001). These processes also influence productivity to some degree within small nursery fjords in PWS (Gay and Vaughan, 2001). This occurs both indirectly by exchange of water masses from the GOA containing allochthonous sources (or subsidies) of nutrients and plankton, and directly through effects of local climate, hydrology and the physical oceanography, such as tidal and wind driven circulation.

The consensus among researchers is that larval herring are advected from broadcast spawning sites within PWS by the general circulation and ultimately enter into nursery fjords, where they develop into sub-adults. Indeed during the subsequent years of the SEA program juvenile herring were observed consistently occupying these habitats by Stokesbury et al. (2000) and in more recent years by Thomas and Thorne (2001; 2003) and Thorne (2008). Furthermore, herring juveniles appear to reside in various nurseries for approximately 3 years before recruiting as adults (Norcross et al., 2001; Stokesbury et al., 2000). Therefore, production and advection of zooplankton within these basins should markedly influence growth and survival, particularly during the critical early life stages such as the first winter (Paul and Paul, 1998; Stokesbury et al. 1999; Foy and Paul, 2000; Foy and Norcross 2001). Simulations of larval drift based on a Princeton Ocean Model (Wang et al., 2001; Norcross et al., 2002) also suggest a general dispersal from spawning sites to nursery habitats, but detailed knowledge of the specific mechanisms that operate in advection and retention of larvae into fjord basins is very limited. In addition, the relative importance of allochhtonous vs. autochthonous sources of nutrients and plankton to productivity within these small basins has been inferred mainly from research of stable isotope ratios of juvenile herring and a qualitative description of available forage based on items in their diets, but this question still remains an open subject of research.

This paper is intended to be a general review of the important physical oceanographic processes that influence survival of Pacific herring during their early life history stages in PWS; i.e. processes affecting phytoplankton dynamics and secondary production of zooplankton, and processes influencing larval drift into nurseries. It covers examples of both the broad (macroscale) processes within PWS as well as the fine (mesoscale) processes that occur within one nursery habitat, Simpson Bay, which was studied intensively over the summer of 2007. The final section addresses work to be completed during the 2008 field season and recommendations for physical observations that could support future studies of herring restoration solicited by the Exxon Valdez Oil Spill Trustee Council (EVOS).

BASIN SCALE PROCESSES

The seasonal hydrography and circulation within PWS (Fig.1) exhibit considerable interannual variation (Niebauer *et al.*, 1994; Vaughan *et al.*, 2001), which in turn causes a range of affects on nutrient cycling and biological productivity within the Sound (Eslinger *et al.*, 2001). The annual emergence of large *Neocalanus* spp. within the upper euphotic zone is markedly affected by the climate in late winter to early spring. This either promotes a rapid phytoplankton bloom of high biomass through early and persistent density stratification or a slower protracted bloom over the spring due to intermittent disturbance of stratification by storms (Eslinger et al., 2001). Nutrient availability also plays an important role in the timing of the annual phytoplankton bloom, and Eslinger et al. (2001) state that from 1993 to 1997 availability of nitrates was highly dependent on shoaling of the mixed layer depth, which introduces nutrients into the upper euphotic zone. This shoaling is ultimately tied to the cessation of strong convective mixing by cold katabatic winds, or the transition from a net heat loss from the upper layer to a net gain and hence the onset of stratification. Temperature thus plays an initial role in stabilizing the water column, but later in the spring and early summer freshwater input becomes the dominant agent of density stratification (Vaughan *et al.*, 2001).

Nutrients within PWS are also indirectly linked to large-scale advective processes (Eslinger et al., 2001) such as water exchange from the GOA in the upper 100m during the winter and intermediate to deep water (100 to 300m) during the summer and fall (Schmidt 1977; Niebauer *et.al.* 1994; Vaughan *et al.*, 2001). The GOA water masses contain remineralized nutrients that have either been vertically mixed within the upper water column over the winter or have been upwelled along the coast during the summer (Schmidt,1977; Niebauer et.al.,1994; GLOBEC??). In addition, they contain oceanic species of macrozooplankton, hence inflow of these water masses is associated with nutrient renewal and potential reseeding of both Euphausiids (Thorne personal comm.) and *Neocalanus spp*. These macrozooplankton are found extensively outside the GOA continental shelf but they also overwinter in deep (>700m) basins of PWS (Cooney *et al*, 2001; Kline, 1999). Studies of PWS fjord systems (Gay and Vaughan, 1998; 2001) have shown that these sources of nutrients and plankton can also reach many of the smaller secondary and tertiary basins by both surface and deep water circulation. The following sections describe each of these processes individually.

Circulation within PWS and water exchange with the GOA. Circulation within PWS (Figs. 3 and 4) is strongly moderated on a seasonal basis by prevailing winds, coastal downwelling vs. upwelling (Bakun, 1973), and the strength of the Alaska Coastal Current (ACC). The ACC flows westward along the coast as a baroclinic-geostrophic current driven mainly by a line source of freshwater input from runoff of stored precipitation, generated by extreme precipitation (2-5m annually) (Royer, 1979, 1982). Runoff either occurs directly into watersheds from rainfall or is stored over the winter as snow and glacial ice (Royer et al., 2001). Just eastward of PWS, however, the ACC is driven by high discharge from the Copper River (Fig. 1b). When prevailing winds are easterly the ACC is constrained close to shore but when winds are westerly this flow may disperse southward over the continental shelf. Figure 1b shows southward deflection of the ACC by Kyak Island in August 2004 and lateral dispersal of the Copper River plume as it moves westward towards PWS.

The regional climate is mostly influenced by the strength and position of the Aleutian Low (Wilson and Overland, 1986). This system generates strong geostrophic (southeasterly) winds over the northern GOA from fall through spring and effects of this pressure field is reflected as seasonal increases in both dynamic heights and the strength of the ACC, which ranges from $0.25m\ s^{-1}$ in the winter to $1.5m\ s^{-1}$ in the fall (Johnson et al., 1989). The dynamics of the Aleutian Low have also been implicated in affecting variability in the GOA zooplankton community on seasonal to decadal time scales (Brodeur and Ware, 1992).

Early studies of PWS (Niebauer et al. 1994) concluded that the general circulation is defined by inflow of the ACC at Hinchinbrook Entrance (HE) with a corresponding outflow at Montague Strait (MS) (Fig. 1b). This is the predominant flow pattern from late fall through winter, but during the summer and early fall ACC water can become entrained into a cyclonic gyre that develops within the central basin. Studies of PWS circulation during the SEA program (Vaughan et al., 2001) also show the through-flow pattern occurring in December 1996 (Fig. 2d), but also revealed considerable decadal variation in the flow patterns in comparison to the 1970's and 1980's. The upper layer circulation is highly dependent on the prevailing wind directions, tides, as well as dynamic heights (Fig. 2). Figure 3 gives examples of horizontal ADCP vectors showing that the central cyclonic gyre was well developed in September 1994 and 1995, begins as early as July in 2002, and there is a hint of this circulation in Jun 2001. Note, however, that in April 1995 an anticyclonic eddy developed in the northern portion of this basin. This feature of circulation possibly occurred following a period of prevailing northwesterly winds. Since stratification in April is minimal the internal rossby radius appears to be on the O(5-10km) which is in the range of 5 km given for this time of year by Niebauer et al. (1994). In contrast to the dispersing and upwelling effects of the cyclonic gyres in the fall, this type of eddy could potentially suppress nutrient renewal in the upper layer and trap *Neocalanus* zooplankton and larval herring within the central basin.

A more recent study of circulation within PWS in 2004 using WOCE drifters (Cox et al., 2005) indicates that the timing of the central gyre in PWS is also strongly mediated by interannual variation in summer climate. For example, 2004 was an anomalously warm and dry summer (Royer, pers. comm.) and early forcing of the central gyre was relegated to various forms of glacial runoff both within PWS and along the GOA coast. The latter influence this major eddy via intrusions of the ACC, flowing into the eastern side of HE and into the eastern main basin. Such conditions occurred in 2004 and hence a cyclonic gyre was well developed within the central Sound by late July (Fig. 3e). This trend may be on the rise as inferred by an analysis of T/S anomalies in the Northern GOA near Resurrection Bay by Royer and Grosch (2006).

Deep Water Exchange. Prince William Sound has basin depths over 700 m but is considered to be a deep silled (180 m) fjord-like system. Exchange of deep water (below 100m) occurs annually during the summer and fall when dense isopycnals in the GOA rise above sill depth in response to changes in wind forcing (Bakin, 1973; Muench and Heggie, 1978). This large scale advective process involves exchanges of both intermediate water in the sound with GOA derived water at 100 to 200 m depth and, deep advective inflows (>200 m) through Hinchinbrook Entrance (HE) (Schmidt,1977; Niebauer et.al.,1994). Circulation of the intermediate water within PWS has been described by Schmidt (1977) in the form of advective intrusions (boluses) of GOA water with higher salinity and nutrients (NO_3), centered around very fine temperature and *NO* maxima (Broekner, 1974).

Niebauer et al. (1994) estimated transports from current meter moorings in HE and MS in 1977 and 1978. These data indicate that from May to September ~ 40% of PWS is flushed by inflow at HE. The estimated volume flushed during winter increased to nearly 200%. The inflow during the summer/fall period was predominately in the deep water (250 m. to depth), and the upper layers exhibited varied amounts of inflow and outflow during the same period. However, transport estimates in June 1978 indicated that 100% of the deep water below 250m was flushed in one month which explains why none of the deep waters in PWS have been shown to become anoxic over time (Muench and Heggie, 1978). A current meter (ADCP) mooring placed in HE during SEA in 1995, 1996 and 1997 (Vaughan et al., 2001) showed similar seasonal transport patterns, but the values during periods of maximum inflow (October to December) were 50% lower than the estimates given by Niebauer et al.(1994). An example of these data for the summer of 1995 is shown in Figure 4. This time series was filtered to remove tidal effects and shows periods of both deep inflow (+ values) in July and outflow (- values) in September. The latter correspond with increased onshore transport due to strong easterly winds during storms. Figure 5 shows ADCP data averaged over pairs of repeated ebb and flood tide transects collected during OSRI sponsored cruises in 2001 to 2002. These observations indicate that deep inflow possibly began as early as June in 2000, and by July 2002 most of the water column below 100m has an inflow. Note also that in December 2000 practically the entire water column shows inflow, which is consistent with water exchange expected during this season. In 2005, a pair of ADCP moorings were deployed by the author at HE as part of the Alaska Ocean Observing System (AOOS). The raw data from June to September are shown in Figure 6 for the down-looking mooring located on the west side of HE. Even without filtering out the tides, periods of deep baroclinic flow as strong as 0.75 to 1 mps can be seen in the data (Fig 6) possibly indicating that deep water exchange occurred early in the summer of 2005.

Evidence of Transport of GOA Water into PWS Fjords from Stable Isotopes and Circulation. One of the hypotheses generated by SEA is that survival of age-0 herring through the first winter is a key factor determining recruitment (Norcross and Brown, 2001), and that survival of this age class is contingent upon forage availability during the first year. In this regard, Kline (1999, 2001) has found from trophic structure analysis using stable isotope abundance that the relative contribution of oceanic subsidies to the zooplankton population plays a major role in interannual variation in age-0 survival and recruitment. For example, in 1995 a large influx of GOA derived carbon within PWS was indicated by strongly depleted $\delta^{13}C$ values in juvenile herring within four nursery fjords studied during SEA. Interestingly, this pulse of oceanic carbon also occurred in juvenile Pollock and many other forage taxa, including diapausing *Neocalanus spp.* in the deep regions of PWS (Kline, 1999) pointing to the relative importance of advective processes, such as deep water exchange, in determining forage quality as opposed to merely quantity. Kline (1999) postulated that physical processes transported the GOA carbon to the four SEA fjords in 1995. This hypothesis is plausible, as shown by various studies of water exchange described above (Schmidt, 1977; Niebauer et al., 1994; Vaughan et al. 2001), modeling of the general circulation (Wang et al., 1997) and passive transport of larval herring from spawning areas to nearshore sites (Norcross et al., 2002).

SMALL SCALE PROCESSES

Transport of zooplankton and larval herring into nursery sites is highly dependent on local factors influencing circulation within each fjord (Gay and Vaughan, 2001). In addition, age 0 herring are predominately found in the inner basins of fjords during their first year (Stokesbury et al., 2000) indicating that advective processes markedly affect their dispersal. Details of an advective mechanism for Simpson Bay, a small nursery fjord located near Cordova with a history of consistently containing over-wintering schools of juvenile herring were determined by the author in 2007. These are addressed in the following section.

Water exchange in Simpson Bay. In the summer of 2007, the currents and hydrography (profiles of temperature and salinity – T/S) were measured repeatedly within Simpson Bay (Fig. 1c) over diurnal (26 hr) tidal periods during three cruises. In addition, two sets of moorings and weather stations were also deployed (Fig. 7). The methods used during this study were outlined in an interim report submitted to EVOS last summer (Gay 2007).

Simpson Bay has a relatively large watershed (170 km^2), and runoff is fed by meltwater from an alpine glacial ice field (Fig. 1c). The fjord also has a relative high watershed to the basin surface area (=6), so that when runoff is enhanced by both rain and glacial melting in the early fall, it can exhibit high surface freshwater concentrations with salinities as low as 10-13. Simpson is generally shallow in bathymetry with depths ranging from 50 to 60m., but there are two regions where the basin depths reach 80m or greater. One region is located on the east side of the mouth (> 100m) and extends into the southeastern arm (80-90m). The other deep region (80m) is located just inside a shallow reef that separates the northern and southern basins (Fig. 1c).

The dominant mechanism causing water exchange (and hence potentially plankton and larval fish) into Simpson Bay is driven by interaction of tides and bathymetry (Figs. 8 and 1c). The most prominent feature of this mechanism is a northeastward jet (0.25-0.3 m/s) generated by flow across the shallow shelf on the western side of the mouth (Fig. 8a,b,c,f). A secondary hydrodynamic response to this forcing is a southward flow along the eastern shoreline. This outflow ultimately re-circulates water at the mouth via an anticyclonic eddy. During ebb tides (Fig. 8e-f) the cross-channel flow field is reversed and water exits Simpson along the western side of the fjord. This current is initially generated by acceleration of an estuarine outflow from the northern arm through a channel on the western side of the reef. However, the imbalance in cross-channel flow created by this current eventually generates an anticyclonic eddy around the reef forcing exchange of water from Orca Bay into the northern arm through a channel 40m in depth located on the eastern side of the reef. The currents in the northern arm exhibit a three layered system that rapidly diminishes in magnitude between the upper 10m and deeper layers (30 cm s^{-1} to < 10 cm s^{-1}). The subsurface water exhibits possibly two reversals in direction with respect to the surface tide currents (Fig. 11).

Along with tides, an important secondary mechanism in water exchange is forcing by SW winds. These wind events are shown in Figure 9 as sustained periods of high speeds with low variability, indicated wherever the red (low pass filter) line closely follows the high speeds in the blue (raw data) line). The SW winds turn into the fjord in part due to vorticity created by velocity shear of the steep headlands and also possibly due to sea-breeze effects. The only set of transects that co-occurred with one of these wind events was made during the first flood tide in July (Fig. 8a). Note that the surface inflow tends to follow more closely to the wind direction as opposed to 45^o to the right. This phenomenon is associated with wave action or Stoke's drift, which is a forcing of surface flow by an imbalance in upper and lower rotation of wave orbitals for short (deep-water) waves (Pond and Pikard, 1993).The wind effects are also interrupted just north of the mouth due to the action of the anticyclonic eddy, which can be seen to affect the water column to at least 10m depth (Fig. 8b).

The affects of winds were also inferred from an analysis of the moored instruments. For example, the near-surface (2-3m) T/S properties in both the main and inner basins (Fig. 10a,b) exhibited a high coherency at frequencies of 0.17 cycles per day (cpd) and a lesser coherence at the semidiurnal tidal frequencies ranging from 0.1 to 0.08 cpd. The highest coherence is centered around a 4 to 5 hr period coinciding with the strong afternoon SW winds. This indicates that a frequent wind –driven surface water exchange occurs in the summer between the lower basin and northern arm. By contrast, the deep 70m water column (Fig. 10c) exhibits a gradual warming and freshening with a much less coherency in low frequency cycles observed in the surface CTs or the deep CT deployed near the mouth (Fig. 10d). Although the differences in time series suggest an isolation of the deep water inside the northern arm, there are coherencies at frequencies less than day^{-1} which indicate that some deep advection may be occurring into this basin. This is also suggested in the turbidity data which are described below.

In the early June 2007 the physical properties (Fig. 12) were relatively cool and salty (Fig 12a,b), and 20 days later both thermal and haline stratification still remain relatively shallow. Deep stratification doesn't appear until mid July, and although subsurface isotherms and isohalines generally increase uniformly over time within the fjord there are regions of compression and extension that may be due to internal waves in the lower basin. Early surface stratification within the northern arm appears consistently high from freshwater input. How this influences phytoplankton concentrations is uncertain, however, since the maximum biomass , which occurs by late June (Fig. 13c) is distributed over the entire upper 20m layer by late June (Fig. 13c). This layer becomes a subsurface maxima in mid July (Fig. 13e), but by mid August the phytoplankton biomass is quite depleted (Fig. 13g). Each month the main distribution of chlorophyll appears to be distributed above the base of the pycnocline which gradually deepens over time, but changes in horizontal distribution within the northern arm and lower basin appear to be influenced by water exchange. For example, the peak biomass in mid June appears over the lower basin, and this is probably transferred into the northern arm by winds and tides. By July the main concentration was primarily inside this inner basin.

Another peculiar characteristic of the northern arm is a gradual increase in turbidity of the deep layer over the summer (Fig. 13b,d,f,h). It would be logical to presume the source of this water is from a re-suspension of sediments in the northern arm, but the deep currents don't necessarily corroborate this (Fig. 11). It is also unlikely the source of the turbidity is from freshwater input at the head of the fjord. First of all, alpine glacial runoff was very limited over the summer due to low rainfall, and second, all freshwater input at the head from meltwater appears to remain at the surface (Fig. 12). The process involved in increasing turbidity may actually be a re-suspension of sediments around the reef channels in the upper main basin where turbulence from velocity shear is likely to occur. For example, note that the turbidity in both late June and mid July is relatively high at the bottom of station 5, which is located just south of the reef. The T/S properties of the 40m CT at the mouth exhibit numerous periods of freshening ranging from 30.25 to 30.75 over cycles of 6 to 7 days. This water is gradually advected by the flood tides towards the northeast side of the reef. If this water were to become turbid due to sediment re-suspension it could very well become dense enough to settle into the deep portion of the northern arm. This fresh water would naturally diffuse upward by eddy viscosity over time leaving a suspended turbid layer at depth, moved about by the tides.

SUMMARY AND CONCLUSIONS

The physical oceanography of the GOA and PWS exhibit high interannual variation that closely follows the regional meteorology and its effects on subregional winds, heat and freshwater input. The large basin-scale processes that are important to the annual ocean climate involve deep convective cooling and mixing in winter, onshore transport and advection of nutrient rich water into PWS, deep water exchange over the summer and fall, and shoaling of the mixed layer depth in the spring. The later is an important factor, indicating a transition of weather patterns from those causing convective heat loss in winter to those causing surface heat gain in the spring. All of the above influence to some degree the timing and extent of the phytoplankton bloom and also the macro-zooplankton bloom that provides both food items and prey sheltering for larval and juvenile herring.

The basin-scale meteorology and wind-driven circulation in the spring are also important factors mediating egg loss by wave action and drift of the larvae. For example, if upon hatching the winds create an anticyclonic circulation in the central Sound, then many of the larvae may end up caught within a downwelling eddy with low food availability. On the other hand if the cyclonic circulation begins early in the season this could provide a pathway to disperse larvae around the periphery of the central basin and hence prevent large groups from entering any given nursery. In this regard the conditions influencing circulation and forage availability upon hatching may form a critical juncture in the survival of a given cohort. This is why the basin-scale physical oceanography must be continually monitored each year, and hopefully AOOS will provide this service.

I address this further in my recommendations below. However, one thing that would help immensely would be to re-deploy a buoy like the Communication-Linked Automated Buoy (CLAB) in central PWS to provide a time series of the weather conditions, water physical properties and chlorophyll associated with the temporal characteristics annual phytoplankton blooms in central PWS.

As for Simpson Bay in 2007, the frequent westerly winds in Orca Bay in early summer (June) were probably more conducive to larval drift towards this fjord as opposed to summers with more frequent winds from the east and southeast. All of the factors described affecting the circulation within this fjord explain how larval herring, if advected from spawning locations into Orca Bay, may ultimately reach Simpson's inner basin and how they may be retained there. During the SEA project in the 1990's this basin exhibited relatively high abundance of age 0 herring believed to be tied to higher biological productivity. In mid summer of 2007 phytoplankton growth in the northern arm may have been just keeping pace with grazing pressure, but there does seem to be some relationship between summer biomass in the inner basin to surface water exchange from the lower basin (Fig. 8). This process appears to commence in June when the peak phytoplankton concentration occurred in the main lower basin (Fig. 13c), and by July the peak concentration of phytoplankton was within the northern arm (Fig. 13e). Samples of zooplankton net tows showed a relatively higher abundance there as well, and all of the oceanographic characteristics described above for this basin may therefore explain why this region of the fjord is a preferred habitat of juvenile herring over the summer.

WORK PLANNED FOR 2008

Plans for research in 2008 include re-visiting Simpson Bay in order to obtain measurements of high resolution hydrography (that were lacking in 2007) along with ADCP data, and to obtain additional samples of nutrients, chlorophyll and zooplankton. A lower frequency 150 kHz ADCP will also be deployed to measure currents in the deep regions of the fjord (Fig. 1b), and to provide data on meteorology a shore weather station will be set-up again on the site used in 2007 (Fig. 7f). At least two cruises are planned for obtaining the same type of data at Whale Bay, located in southwest PWS (Fig. 1). This fjord differs in from Simpson in two important characteristics. First the bathymetry of the main fjord basin is much deeper (300m) and it lacks an entrance sill. The southern (inner) basin does have a sill but it is relatively deep (60m) in comparison to Simpson (10m), and all of these differences suggest that Whale is potentially open to advection in both the upper and deep layers. The second characteristic is that Whale is directly influenced by glacial water advected from Icy Bay, a fjord containing two tidewater glaciers. Fronts of this water tend to restrict outflow in the upper 50m of Whale during ebb tides, whereas flood tide currents tend to penetrate far into the southern arm (Gay and Vaughan 2001).

The advective mechanism at Simpson is tied to both a flood tidal jet that develops over the outer sill at the mouth and a cyclonic eddy that develops during the ebb tides around the shallow reef at the entrance to the northern arm. The counterclockwise flow around this structure, however, is caused by the pair of channels located on either side. This appears to be due more to changes in vorticity as opposed to lateral fluctuations in hydrography. At Whale an entirely different advective mechanism may be in place, one that involves an imbalance in the flood and ebb currents into the southern arm. This is caused in part by a restriction of surface outflow during the ebb due to the presence of a lateral glacial front in the lower main basin (Gay and Vaughan, 2001). This front was observed as well in both the late winter (March) and fall (October) of 1996 (Gay, *unpublished data*), and in both cases the reversed water density in the main basin was due to glacial water still present at the mouth, albeit in late winter it was highly reduced. The only likely source of this subsurface water was Icy Bay.

In addition to the intensive surveys of the above two fjords the cruises in 2008 will obtain TS profiles within all four nursery fjords to continue the time series re-commenced last year. Time has not allowed a full analysis of these data as of yet, but this is one of the tasks I hope to fulfill this summer and next year with my dissertation analysis.

RECOMMENDATIONS (for Future Research)

The recent PWS Herring Restoration Plan (draft issued in Jan. 2008) lists seven research and monitoring efforts currently in progress. Those that relate closely with interannual variation in physical oceanographic processes include: 1) development and refinement of a quantitative model of the PWS herring population; 2) tracking spawning strength and geographic distribution; 3) modeling larval dispersion and 4) documenting oceanographic conditions, plankton abundance and juvenile herring energy content in larval rearing areas. The other efforts all have some indirect relationship to the physics and include monitoring the abundance of juveniles, documenting the presence of predators and modeling predation losses, and monitoring the ongoing effects of herring diseases. Progress in monitoring and describing the physical oceanography important to early life stages of herring within a nursery has been met in part by the program the author began in 2007, and this effort will continue with work planned for this year. However, there are significant gaps in linking the current biological and physical research programs.

First of all, there are insufficient systematic ancillary physical data being collected during most of the biological surveys to properly link and interpret the relationship of any physical data obtained to actual processes. For example, there are far too many high to moderate frequency meteorological and physical events within PWS that produce short-lived phenomena that interact with seasonal heat and freshwater flux, such as fronts, internal waves, wind driven currents and turbulent dissipation. All of these can lead to misinterpretation of T/S measurements collected at a few stations or in discrete depth layers when attempting to elucidate their effects on biology. At minimum CTD data should be collected in some systematic spatial grid along with net-tows to compare the structure of the water column to biological data. Future research should therefore require a collaborative effort in the form of combined cruises to make the synoptic collection of these data more meaningful.

Second of all, a highly valuable forecasting tool might be developed if, through hind-casts, a correlation between general oceanographic conditions in PWS and herring recruitment strength might be synthesized. What is necessary to make this linkage are physical oceanographic model hind-casts of the broad-scale circulation patterns and ocean climate that existed during specific spawn years to be compared with survival in later years. My program's analysis of the thermosalinograph (TSG) and CTD data from OSRI should provide a start in this direction. Moreover, I highly recommend future incorporation of the Regional Ocean Model (ROM) and Regional Atmospheric Model (RAM) sponsored by Oil Spill Recovery Institute (OSRI) as part of AOOS. Using data from NOAA buoys, TSG cruises and the AOOS moorings these models could help provide a better understanding of which physical processes (such as surface water exchange in winter and deep water exchange in the summer to fall) were important in driving plankton production and possibly how circulation influenced larval transport of age 0 herring within PWS. Without all of these tools we are basically guessing about the origins (i.e. spawn locations) of any age 0 herring found within given fjords instead of testing hypotheses of possible advection schemes.

Lastly, since a full census of the relative population structure of age 0 herring is practically impossible due to their wide-spread distribution among bays and fjords, the success of a given larval cohort is typically estimated from the recruitment of age 3 fish as adults. My past research of fjords around the periphery of PWS during the SEA program has shown that although certain groups of fjords have some common physical properties due to shared geographical location and watershed characteristics, the conditions within individual basins is highly site specific. In addition, a complicating factor exists in that many fjords are influenced by allochthonous glacial water from either large tidewater glacial fjords or interior rivers such as the Rude River. This makes attempting a survey of all types of habitat very impractical. While keeping the broad-scale monitoring surveys of the adult and juvenile spatial distribution ongoing, it may be beneficial to also start focusing on a more intensive effort on tracing the distribution of post-hatched larval herring from one large spawning aggregation such as Port Gravina into nearby habitats following emergence from the egg stage.

Tracing this drift will be no easy task by any means due to vagaries of the nearshore circulation, and it will require coordination with the ROMS/RAMS modeling effort to guide it. Of course a mass marking of larvae (if possible) would help this effort immensely. But it is very likely such as method will prove impractical. However, the use of methods outlined by Rick Crawford's proposal in 2006 could provide a method for establishing ground-truthing for the results of a circulation based larval-drift simulation for eastern PWS (i.e. Orca Bay). His proposal would also provide greater details of how the herring use the habitat, a component that is missing from our research. If this approach is taken in 2009, I could at least re-deploy the CT moorings to provide a time series within a specific site, such as Sheep Bay, to determine coherence and phasing of T/S properties within the inner and outer basins as was done at Simpson.

In addition to tracking the herring population via research and monitoring, the restoration plan gives two options that include either allowing natural changes to ultimately bring the population back to a high biomass or to perform some type of management intervention to speed up the recovery process. It is certainly hoped that the current research programs and the eventual synthesis this new knowledge will guide these efforts. In my opinion, the ultimate success in relating the status of herring in PWS to the general physical oceanographic patterns will require a more collaborative effort, utilizing all of the sources of data at our disposal and enlisting the aid of the ocean modeling. The modeling domain could also be extended to include a given nursery based on observational data the author and others have, or will, collect. In addition, periodic future meetings should be planned for the primary physical and biological principal investigators along with fishery managers to discuss new scientific knowledge gained from our research and incorporate the latter's concerns to improve direction of future efforts.

In 2008, I intend on finalizing the work from the previous two summers and to synthesize the information into the PhD dissertation. As such, any proposal submitted for the summer of 2009 will be for funds to cover analysis and writing, and will have limited field work, if any. After graduation (hopefully) in the spring of 2010 I will be available to continue with research of PWS herring.

ACKNOWLEDGEMENTS

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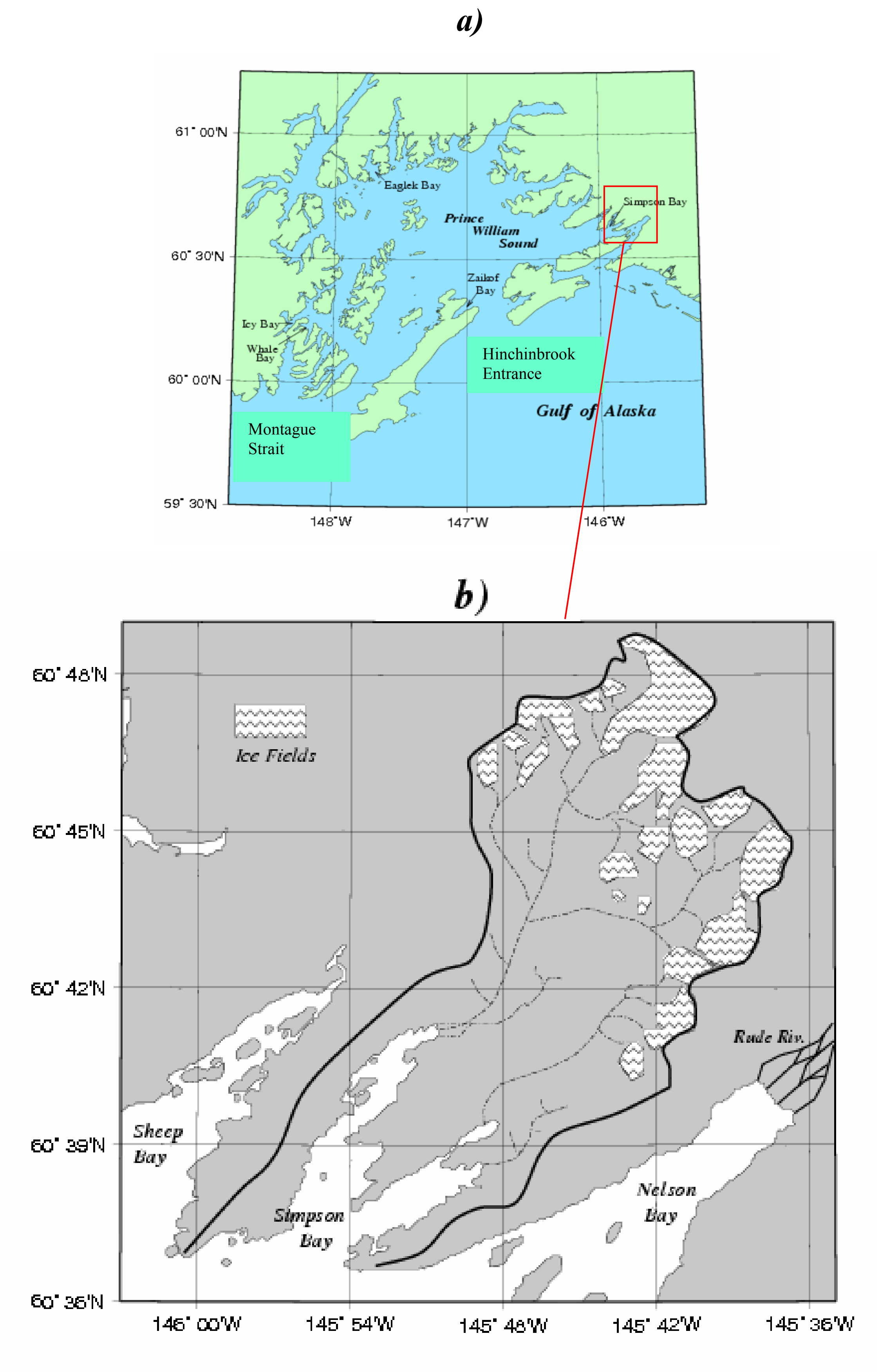


Fig. 1. a) Prince William Sound, Alaska and the two major inlets (Hinchinbrook Entrance and Montague Strait) and the four fjords surveyed during the SEA program. **b)** Watershed area and characteristics affecting runoff into Simpson Bay. Note that the alpine glaciers feeding mostly into the head of the northern arm have melted significantly over the past few decades.

c)

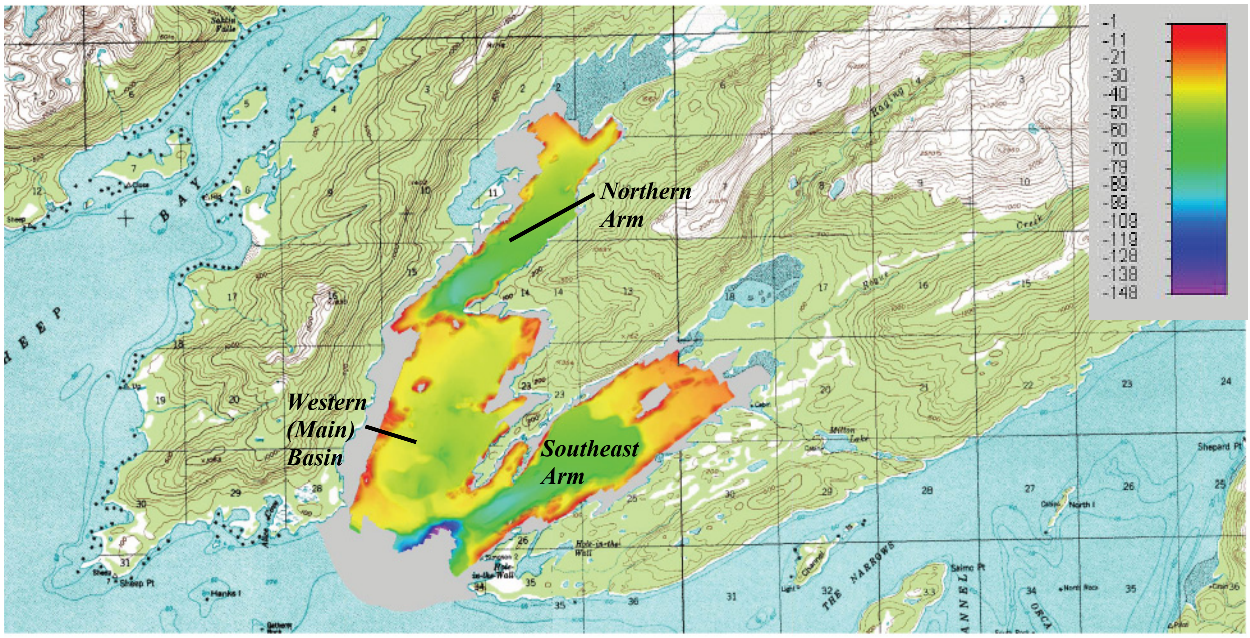


Fig. 1. c) Bathymetry of Simpson Bay showing a relatively shallow (50-60m) main basin joined by two deeper (80-90m) inner basins: the Southeast Arm and Northern Arm. Also shown is the leading edge of a deep (>130m) trench entering along the SE side. ***(Swath Bathymetry courtesy of Chris Noll, Texas A&M University at Galveston)***

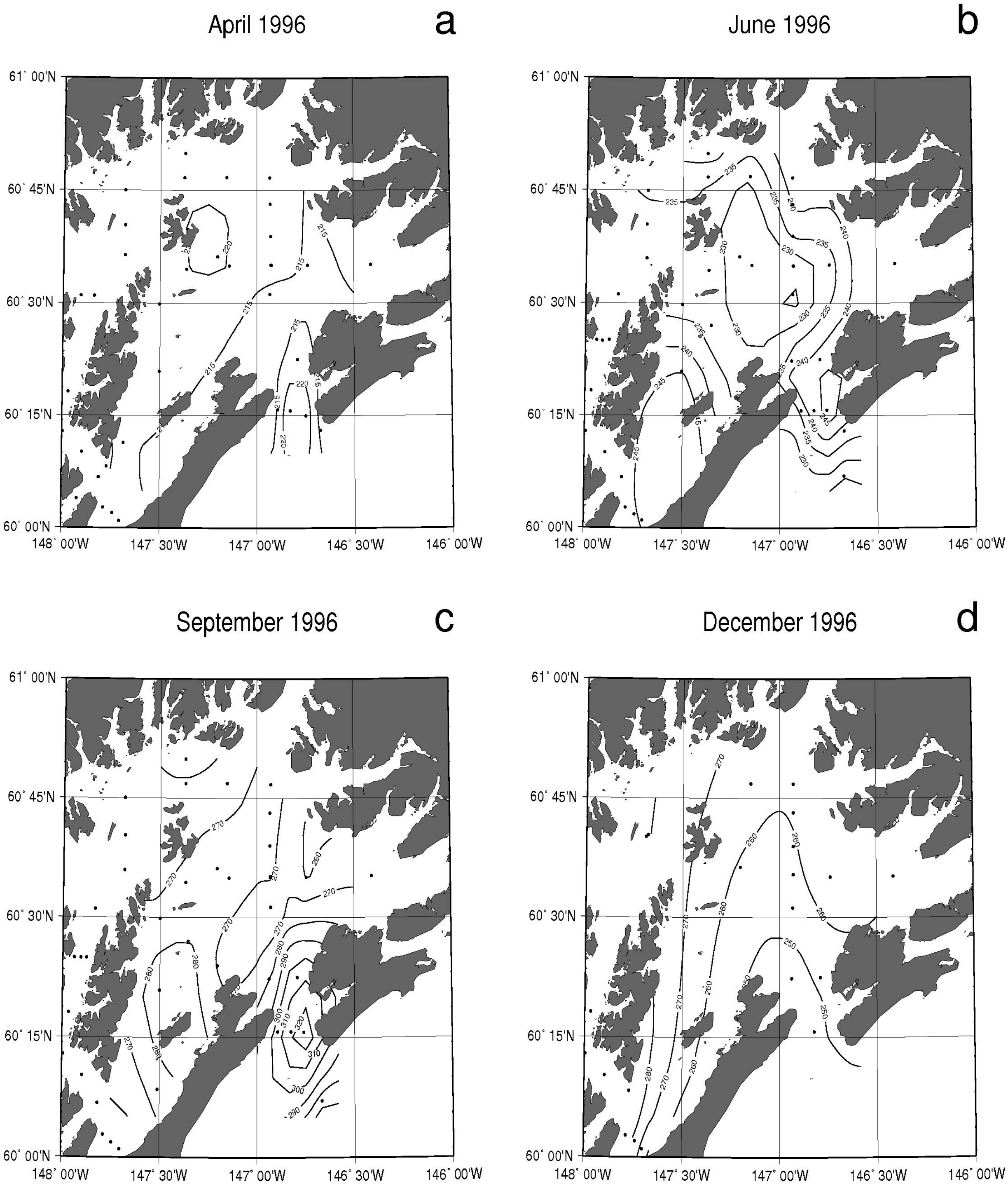


Fig. 2. Dynamic heights (20/100 db) within PWS during various months in 1996 (from Vaughan et al., 2001).

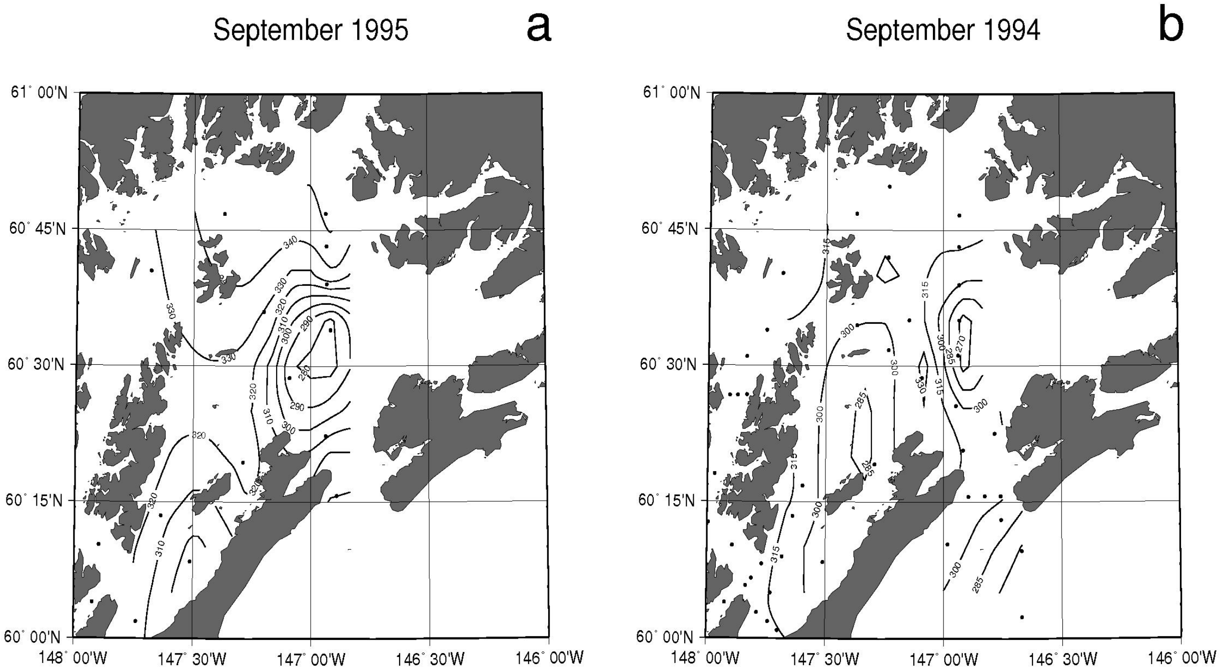


Fig. 2 (cont). Dynamic heights (20/100 db) within PWS in September 1995 and 1994 (from Vaughan et al., 2001).

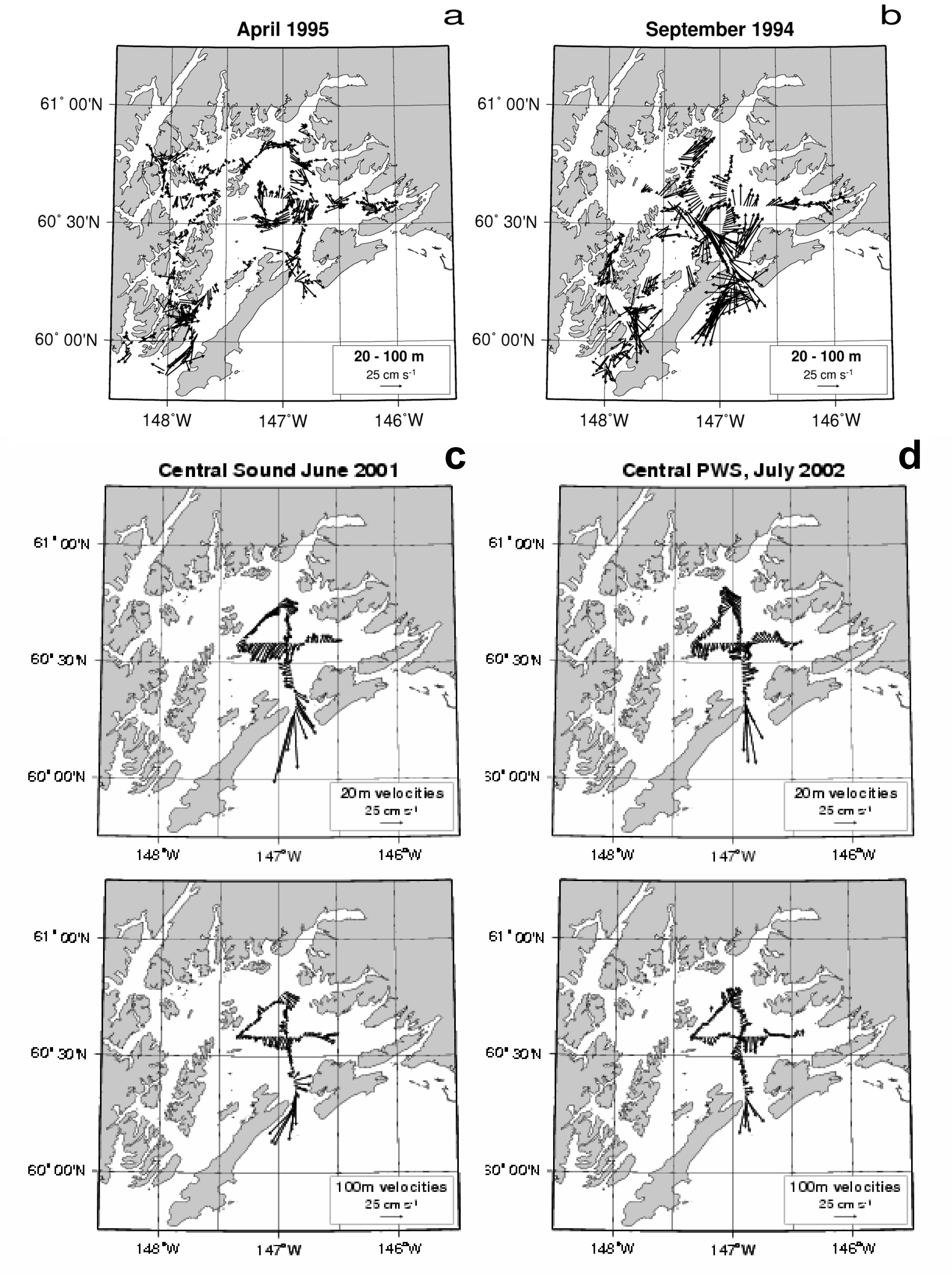


Fig. 3. ADCP velocity vectors and shears (20-100m) calculated from towed ADCP measurements (from Vaughan et al., 2001).

e)

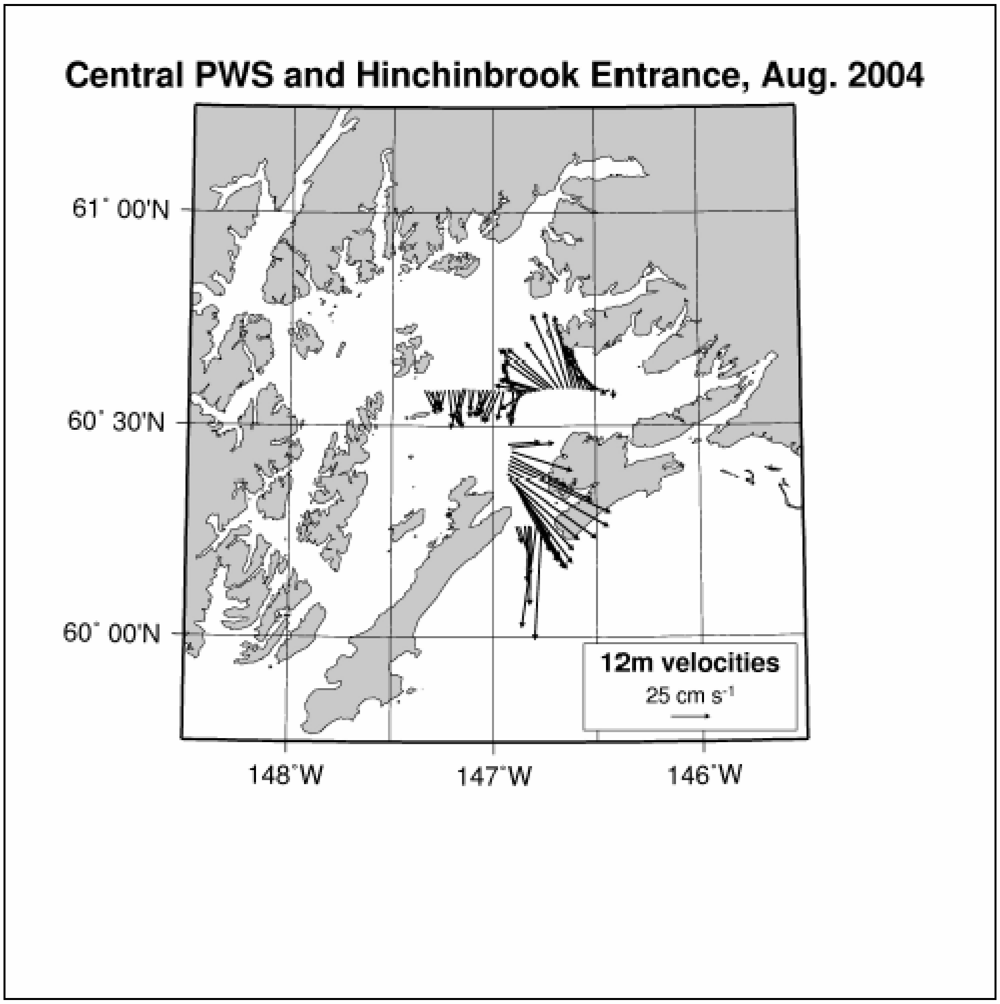


Fig. 3 (continued). ADCP velocity vectors at 12m depth from towed ADCP measurements obtained during the first stages of the Lagarngian Drifter Experiment in July 2004

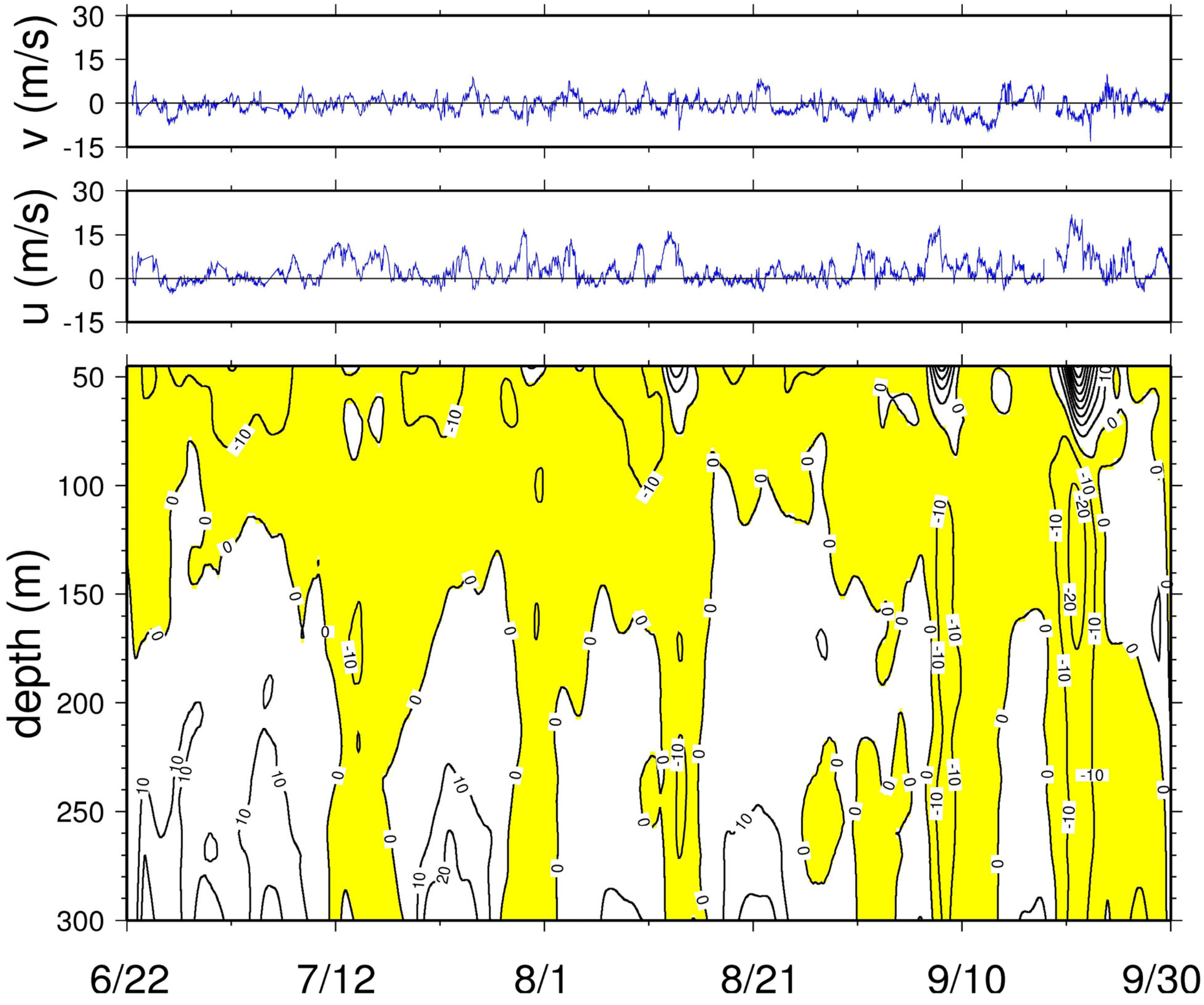
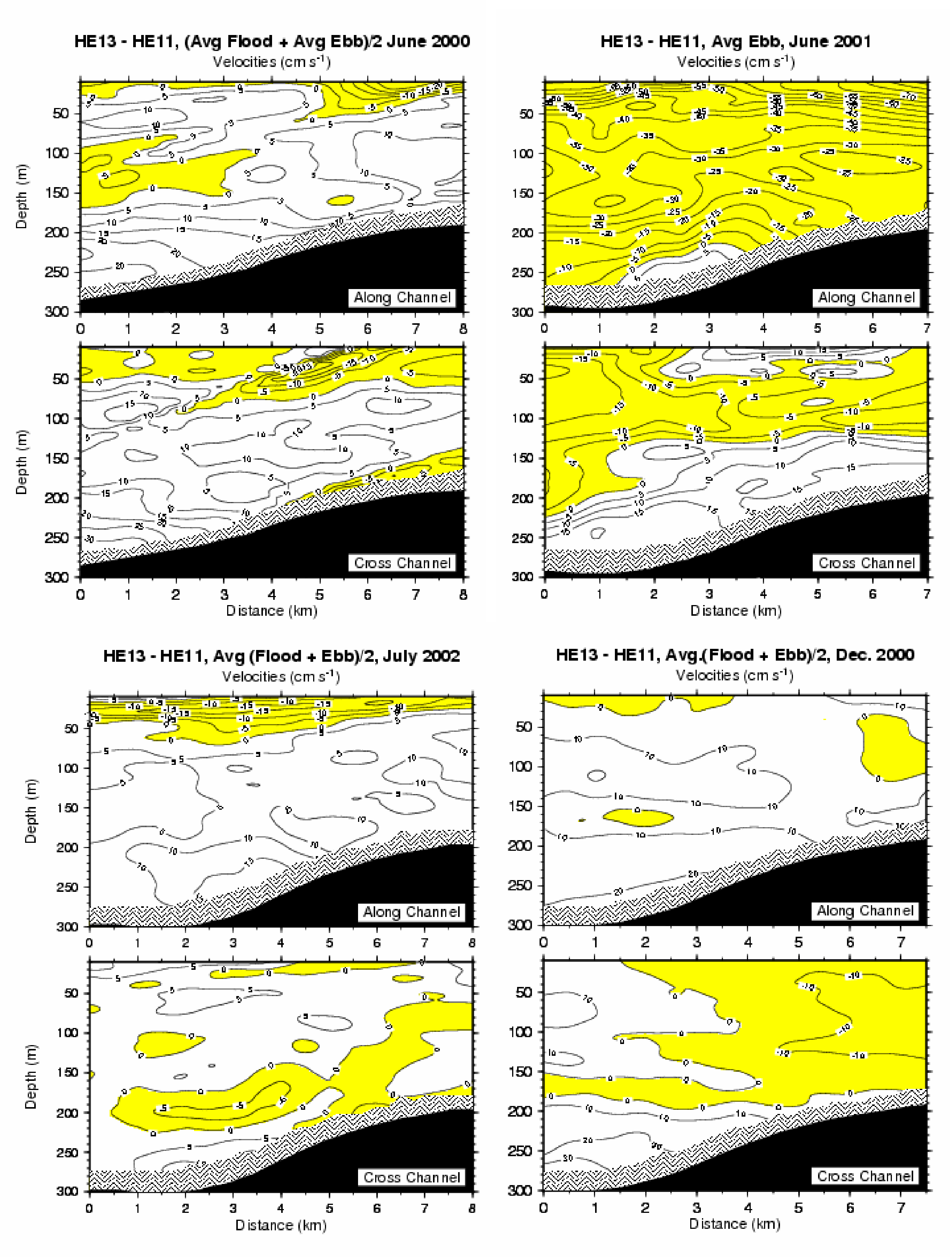


Fig. 4. Time series of along-channel velocities (cm/s) from June 22 to Sep. 30, 1995 (lower panel) and winds at Seal Rocks (upper panel), located just south of the mooring in Fig. 1. (from Vaughan et al., 2001). Current data were 40hr low-pass filtered to remove the tides.



HE13 - HE11, (Avg Flood + Avg Ebb)/2 June 2000

HE13 - HE11, Avg Ebb, June 2001

HE13 - HE11, Avg (Flood + Ebb)/2, July 2002

HE13 - HE11, Avg.(Flood + Ebb)/2, Dec. 2000

Fig. 5. ADCP velocity contours at Hinchinbrook Entrance averaged over repeat ebb and flood tide transects from towed ADCP measurements (unpublished data from OSRI sponsored cruises).

a)

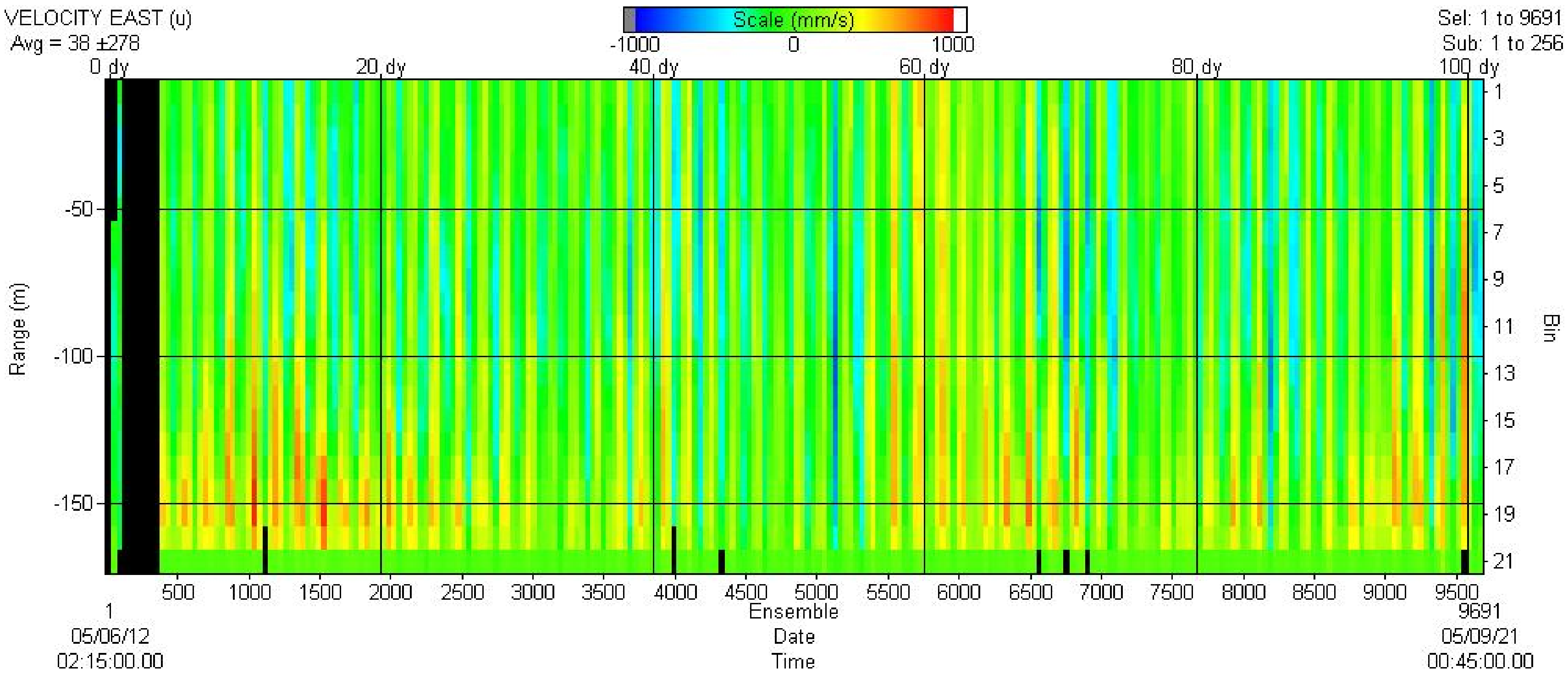


Fig. 6. *u* velocity contours on the deep western side of Hinchinbrook Entrance from a down-looking ADCP deployed at 100m depth From June to October 2005. Periods of strong flow of ~ 0.75 to 1.0 mps occur in the deep water column indicating that deep water exchange into PWS possibly occurs as early as June. Note these vectors have not been rotated to account for a 45 deg. offset which brings the directions of the inflow closer to NE in direction.

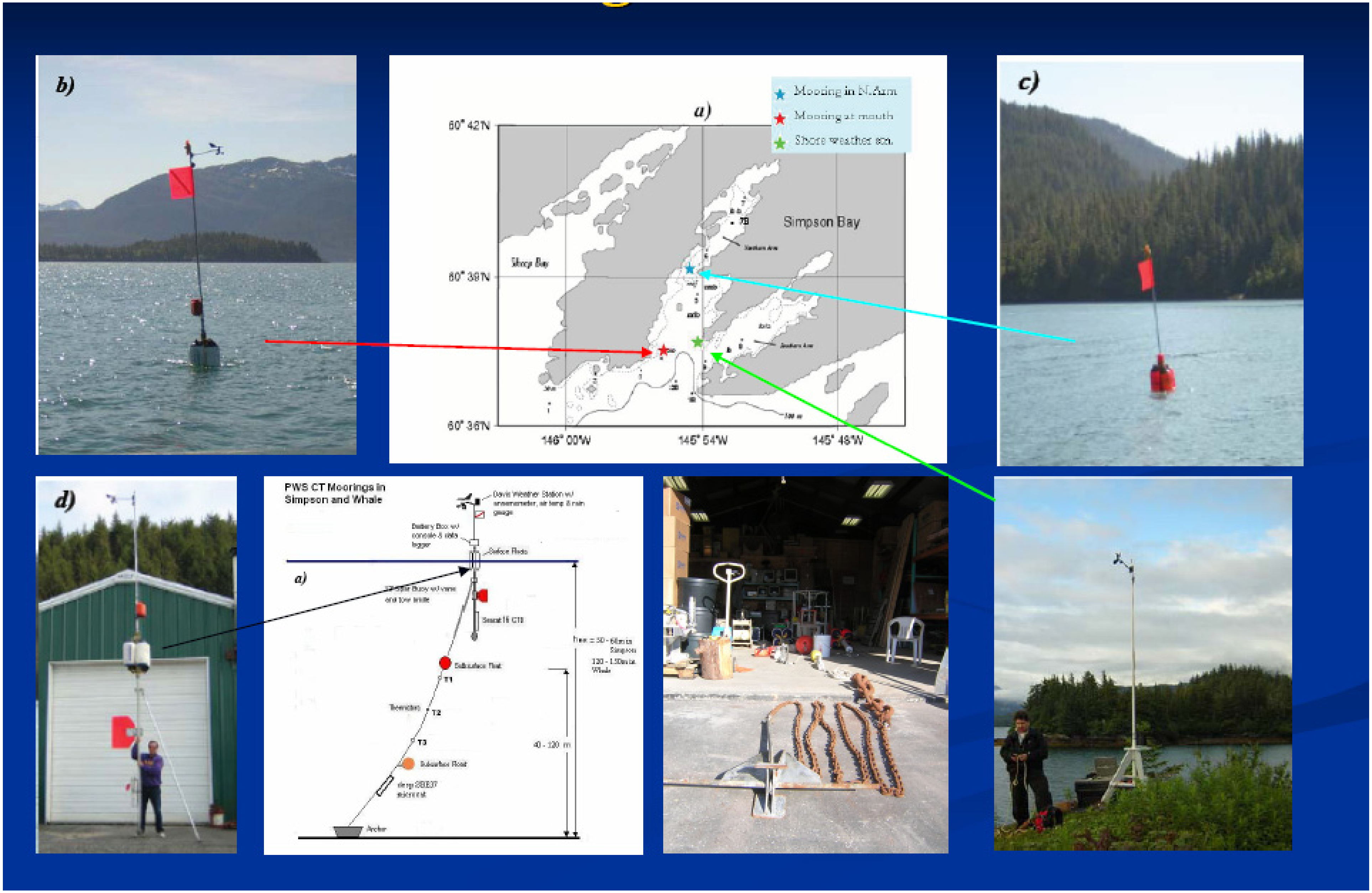


Fig. 7. Locations and design of CT moorings and weather stations deployed in Simpson Bay in the summer of 2007.

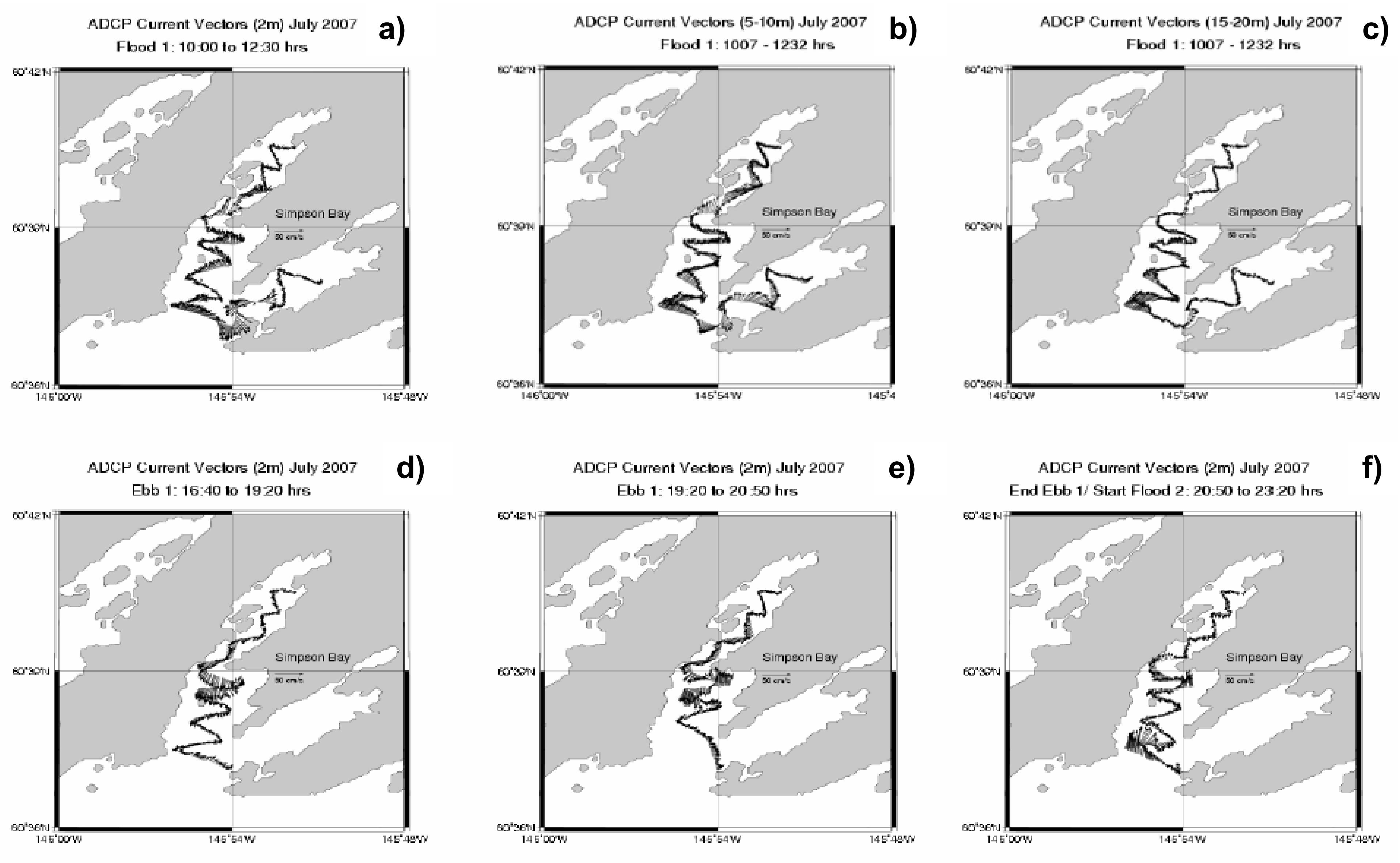


Fig. 8. ***a-c)*** Currents at 2m, 5-10m and 15-20m depth measured at Simpson Bay during a spring flood tide on July 16, 2007 showing a tidal jet flowing from the southwest side of the mouth towards the northeast side of the upper main basin; ***d-f)*** a cyclonic eddy developing around the sill during ebb tides at the entrance to the northern inner basin. Note that all patterns shown, with exception of the near-surface flows in a) that were affected by SW winds, were repeatedly observed during all cruises with some degree of variability due to differences in hydrography and size of tidal prisms.

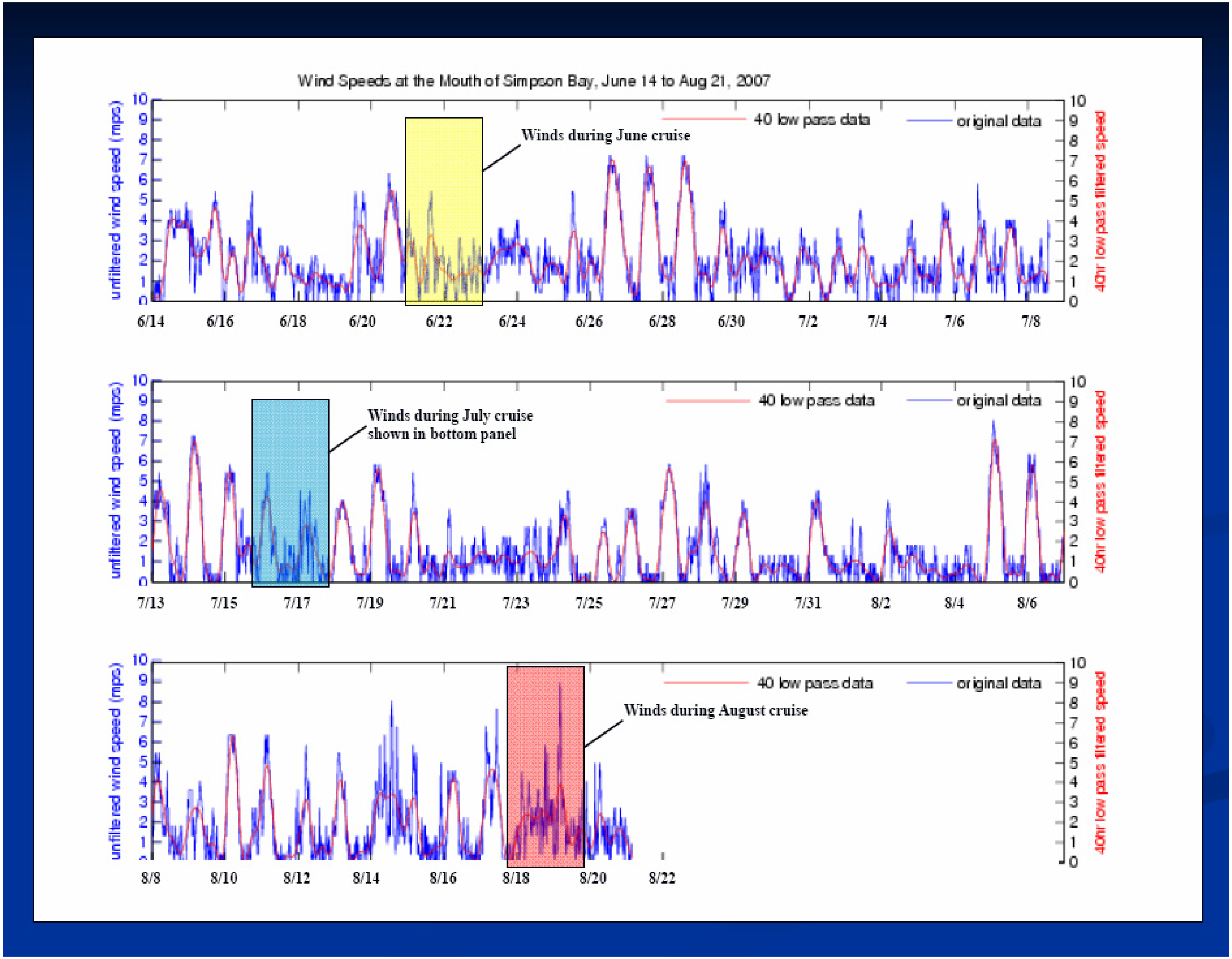


Fig. 9. Wind speeds measured at the CT mooring and shore station near the mouth of Simpson Bay in the summer of 2007.

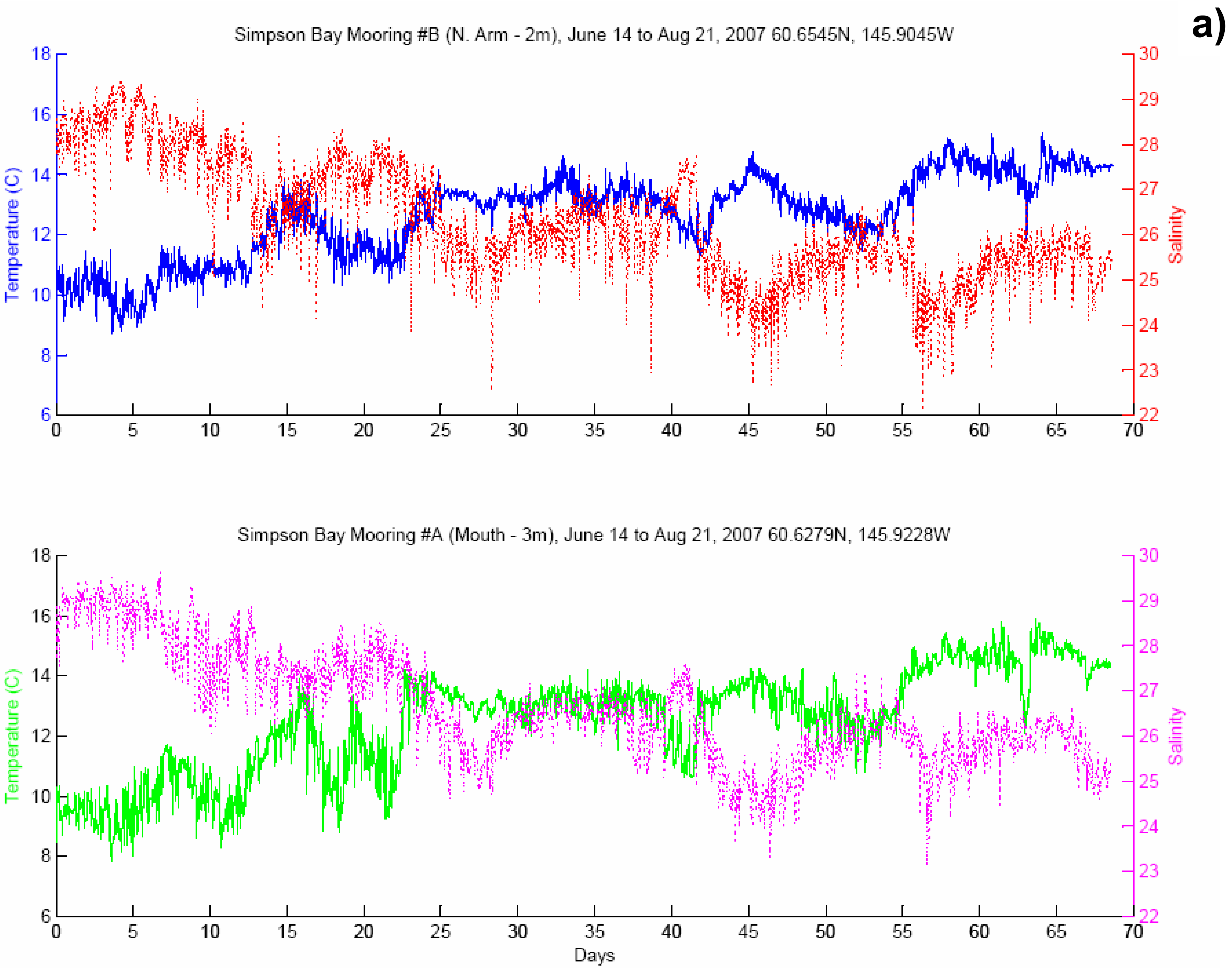


Fig. 10. Temperature and salinity time series at 2-3m for the moorings deployed at Simpson Bay in the summer pf 2007

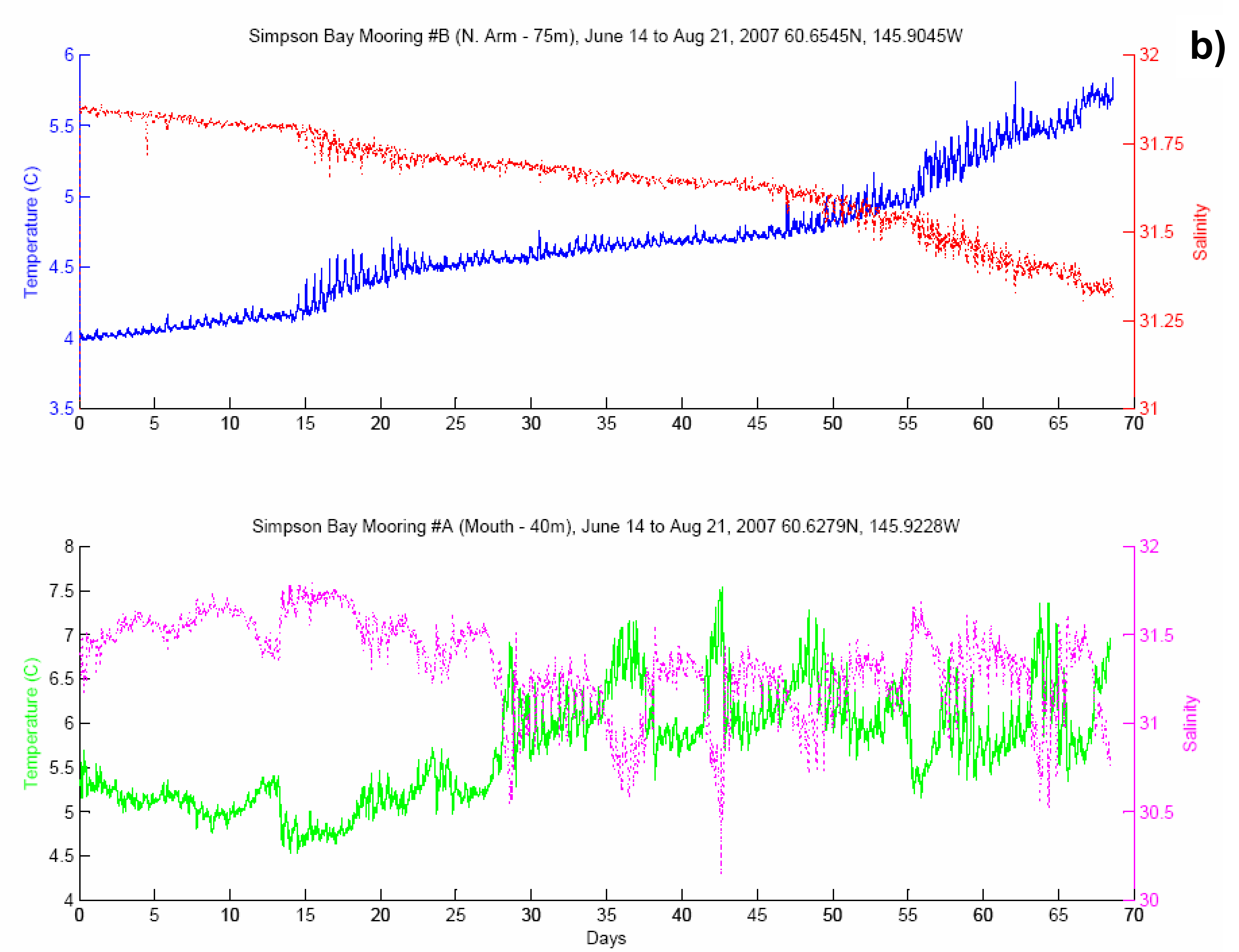


Fig. 10 (cont). Temperature and salinity time series at 70 and 40m for the moorings deployed at Simpson Bay in the summer of 2007

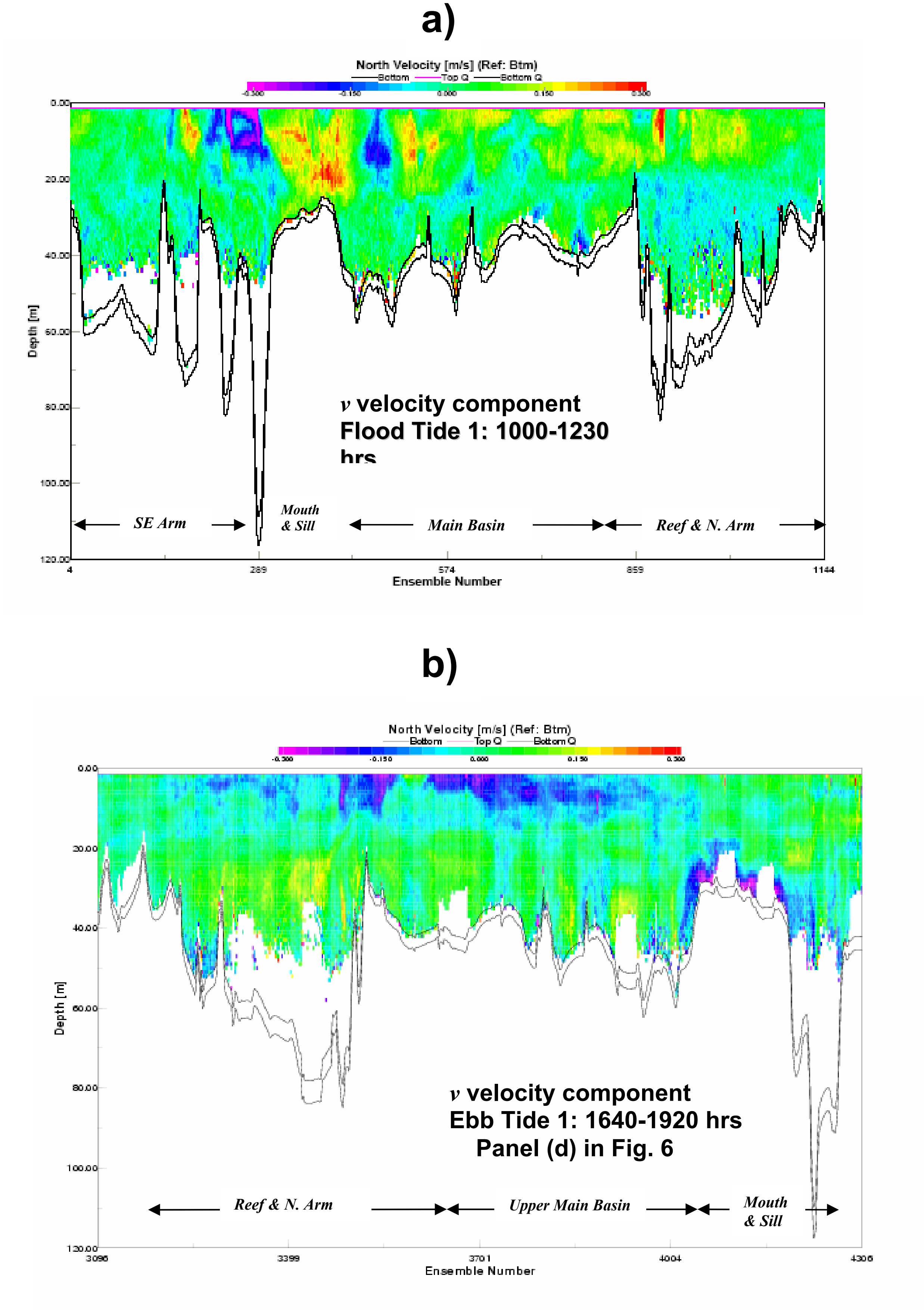


Fig. 11. **a)** *v* velocity component for flood tide 1 (Fig. 8 panel a-c) and **b)** *v* velocity component for ebb tide 1 (Fig. 8 panel d). Note the flows in the northern arm exhibit possibly three layers with reversals in each layer.

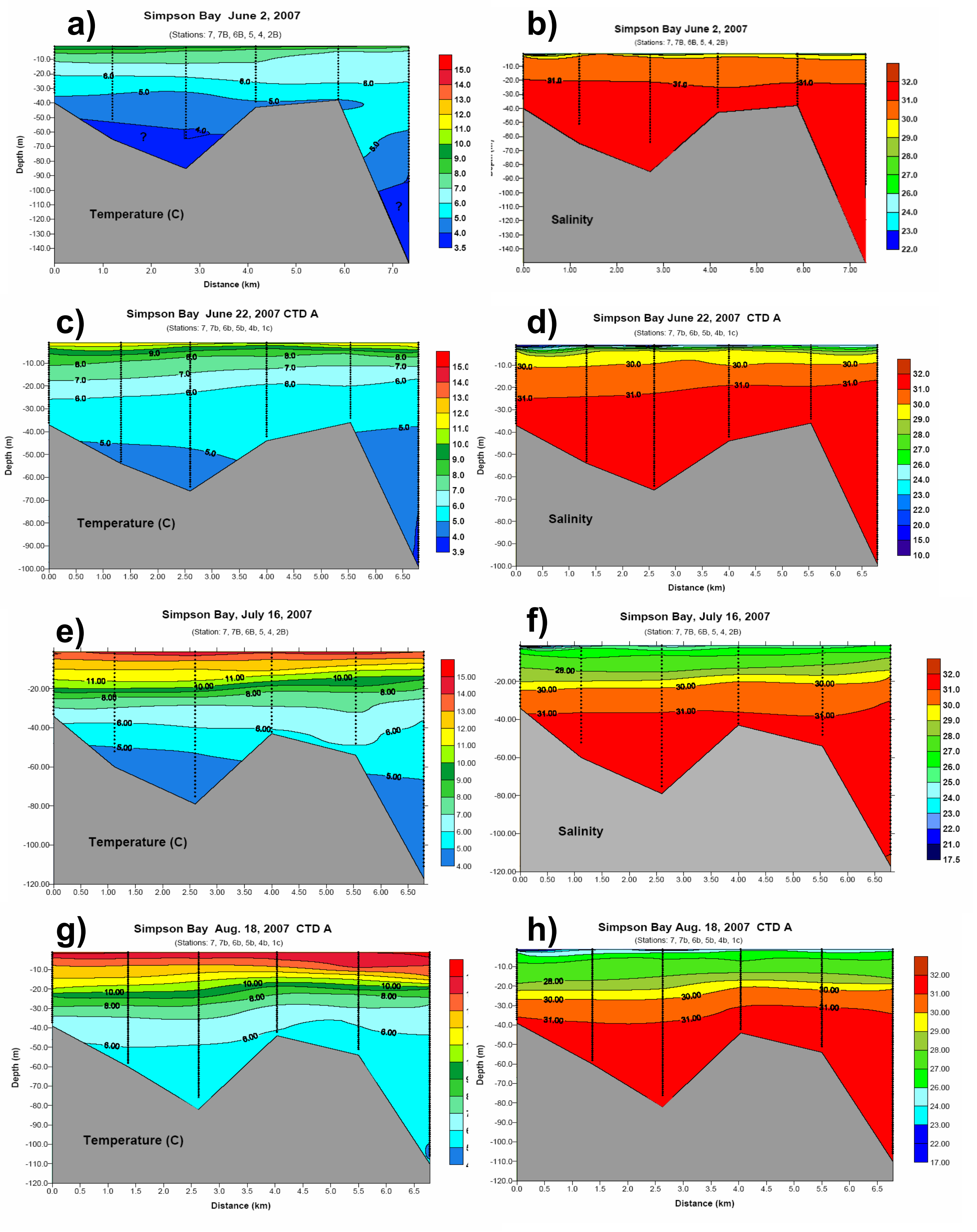
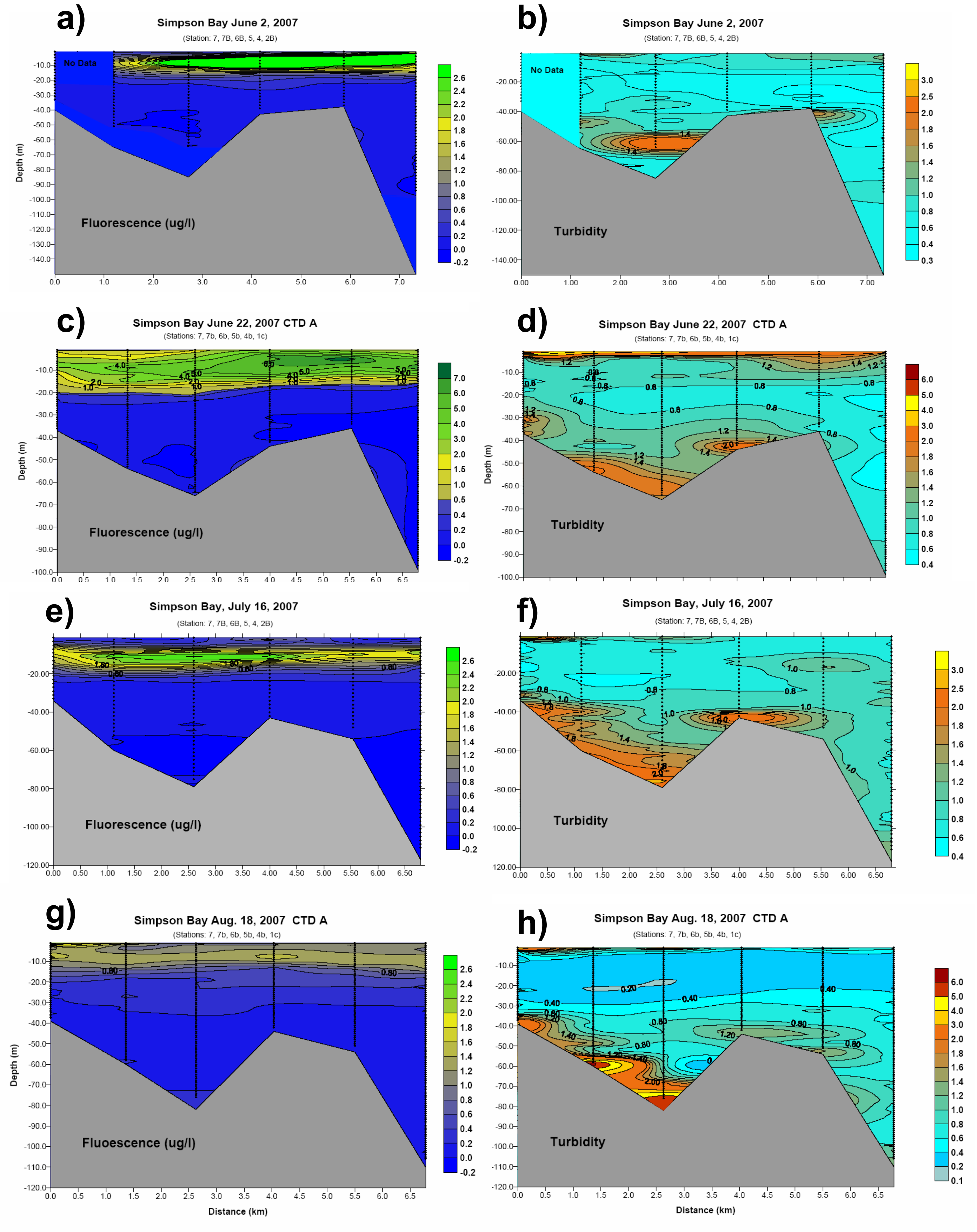


Fig. 12. Vertical sections of temperature and salinity over the summer at Simpson Bay. a,b) June 2, flood tide; c,d) June 21, ebb tide; e,f) July 16, flood tide; and g,h)Aug. 18, ebb tide.


a) Simpson Bay June 2, 2007 (Station: 7, 7B, 6B, 5, 4, 2B)

b) Simpson Bay June 2, 2007 (Station: 7, 7B, 6B, 5, 4, 2B)

c) Simpson Bay June 22, 2007 CTD A (Stations: 7, 7b, 6b, 5b, 4b, 1c)

d) Simpson Bay June 22, 2007 CTD A (Stations: 7, 7b, 6b, 5b, 4b, 1c)

e) Simpson Bay, July 16, 2007 (Station: 7, 7B, 6B, 5, 4, 2B)

f) Simpson Bay, July 16, 2007 (Station: 7, 7B, 6B, 5, 4, 2B)

g) Simpson Bay Aug. 18, 2007 CTD A (Stations: 7, 7b, 6b, 5b, 4b, 1c)

h) Simpson Bay Aug. 18, 2007 CTD A (Stations: 7, 7b, 6b, 5b, 4b, 1c)

Fig. 13. Vertical sections of chlorophyll (fluorescence) and turbidity over the summer at Simpson Bay. a,b) June 2, flood tide; c,d) June 21, ebb tide; e,f) July 16, flood tide; and g,h)Aug. 18, ebb tide.

2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2006 - September 30, 2007

Budget Category:	Authorized FY 2006	Proposed FY 2007	Proposed FY 2008	Proposed FY 2009				
Personnel		$ 20.8	$ 21.2	$ 27.5				
Travel		$ 1.5	$ 1.7	$ 1.7				
Contractual		$ 20.1	$ 26.6	$ 10.6				
Commodities		$ 1.3	$ 1.8	$ 0.5				
Equipment		$ 8.5	$ -	$ -				
Subtotal	$0.0	$ 52.1	$ 51.3	$ 40.3				
Indirect at 25.57%		$ 13.3	$ 13.1	$ 10.3				
Project Total w/o G&A	$0.0	$ 65.5	$ 64.4	$ 50.5	Estimated FY 2007	Estimated FY 2008	Estimated FY 2009	Project Total
Trustee Agency GA (9% of Project Total)		$ 5.9	$ 5.8	$ 4.5				
Project Total w/G&A		$71.4	$70.1	$55.1	$71.4	$70.1	$55.1	$196.6
Full-time Equivalents (FTE)		0.3	0.3	0.4				
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

Unauthorized travel in the amount of $3,200 was removed during the proposal review processes. This resulted in an additional reduction of $1,200 in Indirect and Agency G&A, The travel not funded was for your advisor, Tim Dellapenna from Texas A&M , Galveston campus, to attend the Annual Marine Science Symposium in FY 07 and FY 08. This project was funded for FY 07 only; FY 08 & FY 09 are pending.

CTD Surveys in late fall and late winter within the four nursery bays would be conducted on vessel charters provided by the following collaborative projects:
1) "Trends in adult and juvenile herring distribution and abundance in Prince William Sound" (Principal Investigator Richard Thorne, Prince William Sound Science Center) proposed for EVOS 07 funds
2) Stellar Sea Lion Winter Food Limitation study (Nov 07 only juvenile herring survey; Principal Investigator Richard Thorne, Prince William Sound Science Center), funded by NOAA.

FY07 - FY 09

Project Number: 070817
Project Title: Physical Oceanographic Factors Affecting Productivity in Junvenile Pacific Herring Nursery habitats - Submitted under the BAA
Name: Prince William Sound Science Center. Shelton M Gay III

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Non

Prepared:

2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

Personnel Costs:			Months	Monthly		Proposed
Name	Position Description		Budgeted	Costs	Overtime	FY 2007
Shelton M. Gay III	Principal Investigator		4.0	5.2		20.8
	Subtotal		4.0	5.2	0.0	
					Personnel Total	$20.8

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2007
College Station to Anchorage for Alaska Marine Symposium	0.7	1	5	0.2	$1.5
				Travel Total	$1.5

FY07

Project Number: 070817
Project Title: Physical Oceanographic Factors Affecting Productivity in Junvenile Pacific Herring Nursery habitats - Submitted under the BAA
Name: Prince William Sound Science Center. Shelton M Gay III

Prepared:

2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2006 - September 30, 2007

Contractual Costs: Description	Proposed FY 2007
Vessel Charter - provided by collaborative proposal, P.I. Thorne	
Vessel Charter - primarily provided by PWSOS TSG cruises - these funds include additional fuel and time cost	5.0
Vessel Charter - seine vessel for intensive surveys at Simpson bay	10.0
network costs (based on $100/mo x staff mo)	0.4
phone/fax/copying charges/mail/freight	0.2
Repair of Chelsea Instruments Aquapack (note this needs to be sent back to the manufacturer in the UK)	3.0
calibration for 2 SBE16 Seacats	1.0
fabrication costs of spare buoy for CT mooring	0.5
Contractual Total	20.1

Commodities Costs: Description	Proposed FY 2007
field & office supplies	0.5
batteries & maintenance supplies for Seacats	0.3
lines, shackles etc. for moorings	0.5
Commodities Total	1.3

FY07

Project Number: 070817
Project Title: Project Physical Oceanographic Factors Affecting Productivity in Junvenile Pacific Herring Nursery habitats - Submitted under the BAA
Name: Prince William Sound Science Center, Shelton Gay III

Prepared:

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 2007
SBE37 microcat CTDs (includes shipping)	2	4.3	8.5
Davis Weather Station (covered by surplus in contractual or commodities)	2	0.3	
Those purchases associated with replacement equipment should be indicated by placement of an R.			
		New Equipment Total	8.5

Existing Equipment Usage: Description	Number of Units	
600 kHz ADCP - Prince william sound Science Center (loaned from ADF&G)	1	
Chelsea Instr. Aquashuttle w/ Aquapack CTDF (includes winch w/ slip rings)	1	
SBE16 Seacat CT	2	
SBE19plus CTD w flourometer & turbidity	1	
SBE 19 CTD	1	
surface mooring buoys and anchors	2	
portable weather station (RCAC)	1	
Safety equipment - Prince William Sound Science Center	1	
Desktop Computers and software (PWSSC)	1	
SUN Unix workstation	1	
laptop	1	

FY07

Project Number: 070817
Project Title: Project Physical Oceanographic Factors Affecting Productivity in Junvenile Pacific Herring Nursery habitats - Submitted under the BAA
Name: Prince William Sound Science Center, Shelton Gay III

Prepared

2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2006 - September 30, 2007

Personnel Costs:				Months Budgeted	Monthly Costs	Overtime	Proposed FY 2008
	Name	Position Description					
	Shelton M. Gay III	Principal Investigator		4.0	5.3		21.2
		Subtotal		4.0	5.3	0.0	
						Personnel Total	$21.2

Travel Costs:		Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FY 2008
	Description					
	Galveston, Texas to Anchorage for Alaska Marine Symposium	0.7	1	5	0.2	$1.7
					Travel Total	$1.7

FY08

Project Number: 070817
Project Title: Physical Oceanographic Factors Affecting Productivity in Junvenile Pacific Herring Nursery habitats - Submitted under the BAA
Name: Prince William Sound Science Center. Shelton M Gay III

Prepared:

2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

Contractual Costs: Description	Proposed FY 2008
Vessel Charter - provided by collaborative proposal, P.I. Thorne	0
Vessel Charter - primarily provided by PWSOS TSG cruises - these funds include additional fuel and time cost	6.0
Vessel Charter - seine vessel for intensive surveys at Whale Bay	18.0
network costs (based on $100/mo x staff mo)	0.4
phone/fax/copying charges/mail/freight	0.2
calibration for 2 SBE16 Seacats	2.0
Contractual Total	26.6

Commodities Costs: Description	Proposed FY 2008
field & office supplies	0.5
batteries & maintenance supplies for Seacats & weather stations	0.5
lines, shackles etc. for moorings	0.5
GPS w/ electronic compass and serial output	0.3
Commodities Total	1.8

FY08

Project Number: 070817
Project Title: Project Physical Oceanographic Factors Affecting Productivity in Junvenile Pacific Herring Nursery habitats - Submitted under the BAA
Name: Prince William Sound Science Center, Shelton Gay III

Prepared:

2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2006 - September 30, 2007

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 2008
Those purchases associated with replacement equipment should be indicated by placement of an R.			
New Equipment Total			0.0

Existing Equipment Usage: Description	Number of Units	
600 kHz ADCP - Prince william sound Science Center (loaned from ADF&G)	1	
300 or 150kHz ADCP - PWSSC	1	
Chelsea Instr. Aquashuttle w/ Aquapack CTDF (includes winch w/ slip rings)	1	
SBE16 Seacat CT	2	
SBE19plus CTD w flourimeter & turbidity	1	
SBE 19 CTD	1	
surface mooring buoys and anchors	2	
Davis weather stations	2	
Safety equipment - Prince William Sound Science Center	1	
Desktop Computers and software (PWSSC)	1	
SUN Unix workstation	1	
laptop	1	

FY08

Prepared

Project Number: 070817
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2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

Personnel Costs:				Months Budgeted	Monthly Costs	Overtime	Proposed FY 2009
	Name	Position Description					
	Shelton M. Gay III	Principal Investigator		5.0	5.5		27.5
			Subtotal	5.0	5.5	0.0	
						Personnel Total	$27.5

Travel Costs:		Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FY 2009
	Description					
	Galvestion, Texas to Anchorage for Alaska Marine Sympoisum	0.7	1	5	0.2	$1.7
					Travel Total	$1.7

FY09

Project Number: 070817
Project Title: Physical Oceanographic Factors Affecting Productivity in Junvenile Pacific Herring Nursery habitats - Submitted under the BAA
Name: Prince William Sound Science Center. Shelton M Gay III

Prepared:

2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2006 - September 30, 2007

Contractual Costs: Description	Proposed FY 2009
Vessel Charter - provided by collaborative proposal, P.I. Thorne	0
Vessel Charter - primarily provided by PWSOS TSG cruises - these funds include additional fuel and time cost	6.0
Vessel Charter - money to cover the TSG survey in 2008	4.0
network costs (based on $100/mo x staff mo)	0.4
phone/fax/copying charges/mail/freight	0.2
Contractual Total	10.6

Commodities Costs: Description	Proposed FY 2009
field & office supplies	0.5
Commodities Total	0.5

FY09

Project Number: 070817
Project Title: Project Physical Oceanographic Factors Affecting Productivity in Junvenile Pacific Herring Nursery habitats - Submitted under the BAA
Name: Prince William Sound Science Center, Shelton Gay III

Prepared:

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 2009

Those purchases associated with replacement equipment should be indicated by placement of an R.			
		New Equipment Total	0.0

Existing Equipment Usage: Description	Number of Units	

FY09

Project Number: 070817
Project Title: Project Physical Oceanographic Factors Affecting Productivity in Junvenile Pacific Herring Nursery habitats - Submitted under the BAA
Name: Prince William Sound Science Center, Shelton Gay III

Prepared