EVOS Annual Progress Report

Project Number: # **10100132-E**

Project Title: PWS Herring Survey: Physical Oceanographic Characteristics of Nursery Habitats of Juvenile Pacific Herring

PI Name: Shelton Gay - PWSSC

Time Period Covered by Report: April- August 2011

Date of Report: Sept. 22, 2011

Work Performed: The CT moorings within Simpson Bay, Eaglek Bay, Whale Bay and Zaikof Bay (Fig. 1) were retrieved and serviced during two oceanographic cruises conducted in April and August 2011 respectively (Tables 1 to 4). Profiles of temperature (T), salinity (S), Fluorescence (F), Turbidity (Tb), Nitrates and Transmissivity (August) were also collected during these cruises using an SB19 plus CTD. A problem encountered in the mooring deployments over the winter of 2010/2011 and its resolution is also discussed. Each of these research segments is described in greater detail below. Additional work included revising and adding new material to the final report covering the first herring research program: *Physical Oceanographic Factors Affecting Productivity in Juvenile Pacific Herring Nursery Habitats*. This report was re-submitted to Peter Hagen of NOAA in August.

The initial results of the April cruise were put into a cruise report submitted to Scott Pegau (Herring Survey Coordinator at PWSSC) and presented at a PI meeting held in Cordova, Alaska in May. The present report mainly addresses the results of the mooring deployments in 2010 and 2011, and compares the hydrographic profiles of CTD casts performed in March and August of 2010 to the casts made in April and August 2011. However, an opportunity occurred during the August 2011 cruise to obtain additional CTD data within a new fjord being formed by the retreat of the Columbia Glacier. The T/S profiles from these casts are also included in this report.

Mooring Deployments

The dates of the cruises to retrieve and re-deploy the CT moorings and deployment parameters including mooring coordinates, times, depths, sensor types and sample intervals are listed in Tables 1 to 4. During the cruises the sensors were uploaded and mooring components were cleaned and replaced as necessary, and then redeployed (Figs. 2 and 3). However, to mitigate the potential problem of mooring loss due to the motion of sheet ice over the winter, break-away links were installed beneath the surface floats in the fall of 2010. By late November, the surface buoys in all sites (except Zaikof) were indeed lost to sheet ice, but the above links functioned effectively to keep the moorings in place. Therefore, such links were installed again on the moorings in August 2011 (Fig. 3).

The breakage of the surface floats in late 2010 resulted in the use of a drag technique to recover the moorings in 3 out of 4 locations in April 2011. To assist in locating the moorings prior to dragging, transits over the sites with the bottom sounder were performed. In all cases the presence of the moorings was identified by slight echo anomalies, stacked above one-another from the reflection of sound from the subsurface buoys and microcats (Fig. 2). The drag itself consisted of one long 360 m line attached to 10 m of 3/8 in chain. Above the chain, a series of 3 grapples were installed ~ every 5 m. This array was deployed in a spiral fashion with 2 to 5 lb (1-2 kg) dive weights attached every 1/3 the length of the of the circle in order to ensure that the spiraled drag line sank beneath the depth of the first subsurface buoys (i.e. 10 m). Figure 2 shows two examples of successful snagging of the first subsurface buoy and the upper (broken) line with the microcat attached. The method was successful in 4 out of 5 first attempts, but unfortunately during the recovery at Simpson two of the thermistors were lost from the line.

The other problem of excessive growth of macrophytic algae over the summer appears to have been resolved by the use of SB37 microcats in place of the SB16.03 Seacats as near-surface (2m) CTs. The recessed antifoulant cells of the microcats prevented the algae from pulling cells off of the instrument housing, and the experimental application of copper tape at Simpson (where the most growth was consistently observed) also significantly reduced growth over the instrument (Fig. 3). In general, the amount of growth in 2011 was much less than in 2010, except at Zaikof, in which the growth rates between years appeared opposite to the other fjords. This is very likely a function of differences in circulation and water exchange with Hinchinbrook Entrance (HE), and this is discussed in more detail below along with the mooring T/S time series.

Mooring T/S Time Series

The results of the near-surface and deep CTs over the first three deployments extending from late winter of 2010 to late summer of 2011 are shown for Simpson and Zaikof in Figure 4 and for Eaglek and Whale in Figure 5. These time series reveal typical T/S variation in all basins at frequencies ranging from seasonal warming and freshening (i.e. fundamental) to tidal excursions and meteorological effects, both at frequencies above the Nyquist interval (i.e. $2\Delta t = 1$ hr). As in 2010, periods of cooling and salinification followed by warming and freshening occur in 2011 at intermediate frequencies in the near-surface sensors, possibly related to increased advection occurring due to spring-neap tidal cycles or by winds and ephemeral bursts of runoff during large scale meteorological events. The latter can be seen in 2011 starting in late July, in which freshwater input increases substantially at all locations, except Zaikof. At the latter, the surface water remains both cooler and much saltier in comparison to Simpson in both years. In contrast, the coolest and warmest surface conditions among the four fjords occur at Whale and Eaglek respectively. In both years the latter two sites also tend to be significantly fresher in comparison to the two shallow sites. All of these differences are consistent with the inter-fjord T/S variation observed during the SEA project years (Gay and Vaughan, 2001).

Although the amplitudes of the seasonal and intermediate signals in the deep sensors tends to be more suppressed relative to the surface water, all sites exhibit substantial warming of the deep water in the late fall followed by cooling over winter as expected. However, the two shallow fjords begin the subsurface warming phase immediately in the spring, and the cycle of deep warming at Zaikof significantly leads that of Simpson even though the magnitudes of heat input appear similar. Zaikof's inner basin also tends to remain saltier in comparison to Simpson, the exception being in late August to mid September 2010 when deep freshening reaches a maximum. The generally salty conditions at Zaikof are expected on the basis of the watershed characteristics of this fjord (Gay and Vaughan, 2001). However, the deep freshening event is mirrored in the near-surface salinities, and these conditions suggest that advection and mixing occur more frequently at Zaikof than at the other fjords. This is presumably due to both Zaikof's shallow inner basin and the strong influence of winds, which may promote a more consistent mixing of the inner basin water column via wind generated advection. In contrast, Eaglek and Whale both exhibit limited cycles of variation in deep physical properties over the summer and early fall until the beginning of October 2010, at which time a marked warming and freshening event occurs at both fjords. However, the response in Eaglek's inner basin is more extreme with changes in T/S values of +4 ^{o}C and -3 g/kg respectively in comparison to changes in T/S values at Whale of +1 ^{o}C and -1.5 g/kg. A similar event, albeit of significantly lower magnitude, occurs in August 2011.

Both of the above signals appear to be linked to increased storm activity and hence advection and water exchange. For example, the large perturbations in the fall of 2010 took place during a period of 3 to 4 days when wind speeds at the Midsound Buoy reach gusts of over 40 kts (~20 mps) (http://www.ndbc.noaa.gov/station_page.php?station=46060). In comparison to Eaglek and Whale, the effects of these storm generated winds on the deep T/S conditions within Simpson and Zaikof initially appear suppressed. However, Simpson's inner basin does show a lagged response in deep warming accompanied by minor freshening. Interestingly, the rise in deep temperatures through the fall of 2010 at Simpson has a pattern similar to Eaglek minus the large storm generated perturbation at the beginning of October. Zaikof, by contrast, exhibits little change in deep temperature during this period, with initial salinification followed by very minor freshening over the same period as Simpson. The perturbations in August 2011 occur at all four fjords, but whereas the deep T/S properties at Eaglek, Whale and Simpson exhibit relative consistency up until the increase in storm activity in August, marked warming and minor freshening occur over the entire spring and summer at Zaikof. The same above patterns in temperature changes are also evident in the subsurface thermistor series within the four fjords at depths of 20 to 30 m (Fig. 6). These plots also show bursts of warming followed by cooling at intermediate frequencies that may be associated with spring neap tides as well as periods of increased winds. Similar storm generated changes in deep T/S conditions occurred in August 2008 at Whale Bay, resulting in an apparent flushing of the inner basin (Gay, 2011).

Hydrography in Late Summer of 2010 and 2011

The results of the CTD casts performed in August 2011 and 2010 are shown as groups for the shallow and deep fjords respectively in Figures 7 and 8, and 9 and 10. Just as in 2010, these data indicate that the T/S properties in 2011 again differ significantly among the four fjords, but the intra-fjord variation in physical properties between years is remarkable. For example, at Simpson Bay the marked thermal and haline stratification across the mouth in 2010 is replaced by deep vertical gradients of warm, brackish water in 2011 extending to 100+ m in depth at SB1c. Inside the main basin the upper portion of the water column appears to be affected these subsurface conditions, producing a thick layer with similar T/S properties as at the mouth, overlying deeper seasonal vertical T/S gradients. The source of these anomalies at 10 to 30 m depth appears to be glacial water from the Rude River propagating from Nelson Bay. Fronts of this water, shown in Figure 3, were observed extending across the mouth of Simpson and as far west as Sheep Bay. The possible effects of allochthonous glacial water observed in moored CTs in Simpson's outer main basin are described in detail in Gay (2011). However, at the same time the glacial water occurs at the mouth, discharge from Simpson Bay's watershed also affects the surface T/S conditions within the fjord, particularly within the northern arm. This is evident from the temperature inversions and low surface salinity in this region of the fjord at SB7a, 7m and 6b.

At Zaikof Bay thermal and haline stratification remain relatively low in 2011, as observed in previous years, and the marked cross-channel variation in temperature profiles at the mouth still indicate convergence of water within HE with water inside the fjord. However, the thick thermostads and halostads observed in 2010 are not present in 2011, and the upper water column is instead comprised of a larger number of small mixed layers, the one exception being deep temperatures at SB2c. In both years these anomalies within the along-fjord profiles are probably moderated by subsurface mixing due to high current shear at the mouth and outer basin (Gay and Vaughan, 2001), but the deep water below 25 m in the inner basin at Zaikof is significantly cooler and saltier in comparison to the main basin and thus shows evidence of semi-isolation over the summer. The moored CT at 30 m indicates that this water mass begins to form in the early fall, possibly due to periodic intrusions of dense water in the outer basin formed due to mixing. All these characteristics are similar to hydrographic observations made in previous years. However, in addition to interannual variation in climate, some of the differences in cross-channel and along-channel gradients in the T/S profiles observed at Zaikof between 2010 and 2011 are possibly due to timing of the observations relative to the tide cycle. The latter can cause a marked redistribution of physical properties between ebb and flood phases due to circulation within the fjord basin (Gay and Vaughan, 2001).

In 2011 Whale and Eaglek again exhibit subsurface temperature minima and maxima reflecting the presence of subsurface glacial water in their outer basins and mouths. Similar features of temperature due to intrusions of ACC water are not evident at Zaikof, probably due to diffusion and mixing, but across the mouth of Simpson there are significant minima and maxima throughout the upper 30 m indicating the presence of the allochthonous glacial water that was observed visually (Gay and Vaughan, 2001; Gay, 2011). In 2011 Whale Bay again exhibits relatively high haline stratification throughout the inner and outer basins, but the upper 30 to 40 m of the water column are significantly warmer in comparison to 2010. The relatively small subsurface temperature minima within the main basin and mouth in 2011 also indicate that this fjord has less influence from glacial water in Icy Bay in comparison to the predominance of this water in 2010, and the near-surface water in the southern arm from WB5 to WB13m is thermally well stratified. In general the subsurface physical properties throughout Whale are relatively homogenous except for temperatures at 30 to 60 m depth. This layer exhibits a gradient of cooler conditions in the inner basin to warmer water near the mouth, similar to conditions in 2010.

At the mouth of Eaglek the T/S properties in 2011 show the influence of subsurface glacial water, most likely from Uakwik Inlet (Gay and Vaughan, 2001), but the signature is much more suppressed in comparison to 2010. This is possibly due to wind induced mixing across the mouth from storm conditions that occurred the day prior to occupying the stations. These effects are evident in a mixed layer gradient from EGB1b to 1d. Within the fjord basin, however, advection in the wind-affected layer may be responsible for what appears to be glacial water that produces an along-fjord subsurface temperature gradient increasing from the mouth to the inner basin. This is not unexpected on the basis of the responses of the near-surface and deep water column physical properties in Eaglek's inner basin to such wind events (Figs. 5 and 6).

Hydrography at Columbia Fjord in August 2011

During the August 2011 cruise a paucity of ice grounded on the outer moraine at Columbia Bay allowed collection of hydrographic data within the inner basin, hereafter referred to as Columbia Fjord. This new basin is being formed by the retreat of the Columbia Glacier (Fig. 3). Oceanographic stations, shown in Figure 11, were located close to the glacier and were spaced between the inner basin and the lower basin and across the outer sill (moraine) into Columbia Bay. The profiles from these casts and a TS diagram made from the data are shown in Figure 11. From these plots it can be seen that highly varied along-fjord physical properties occur within Columbia Fjord. These conditions result from interleaving of cold, brackish water in the far inner basin to warmer, saltier marine source water in the lower basin.

The source of the deep brackish conditions in the inner fjord is undoubtedly intense mixing of sub-glacial freshwater discharge at various points across the bottom of the glacier, similar to the process observed in the early 1980's by Walters et al. (1988) when the glacier had recently parted from the outer moraine. In fact, in 2011 upwelling of this water as a surface plume was clearly evident where the glacier had begun to shoal. Although the effects of the subglacial water are most dramatic on the temperature structure, a horizontal gradient in salinity also occurs throughout the water column, and this should induce baroclinic outflows as well as estuarine surface flow. The effects of the glacial water on water column conditions can also be seen in the TS diagram in the form of a gradually increasing down-fjord subsurface temperature maximum.

Another interesting aspect of the subsurface glacial water is its effects within PWS, shown by the substantial minimum and maximum of temperature in Columbia Bay. Note the similarity of this profile to the T/S conditions in Whale Bay in August 2010 (Fig. 10). The data in Columbia Fjord were collected during an ebb tide and the nearsurface water from 1 to 8 m over the outer sill is much colder and more brackish than the upper 5-7 m within Columbia Bay. This is likely due to mixing by turbulent flow over the sill, and interleaving of this water due to its higher density apparently results in the first temperature minimum in the outer basin. The second, more prominent minimum occurs from interleaving of water from 9 to 12 m. However, beneath this layer the water at the sill exhibits a marked increase in salinity and temperature at depth that exceeds values at the same depths over the entire fjord. The CTD cast at the sill in 2011 was performed directly over a gap in the sill (Fig. 11c), and it is very likely that this water represents an inflow over the moraine similar to observations made by Walters et al. (1988). The high salinity at depth is apparently from slightly deeper water in Columbia Bay that is drawn across the sill by hydraulics, and just as in the early 1980's this water probably provides a balance to the salt flux within the fjord following Knudsen's relations (Dyer, 1997).

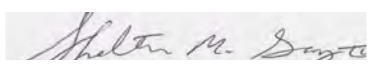
Future Work: Future research objectives include continued deployment of CT moorings in the four SEA fjords. Hydrographic data will also continue to be collected with a SB19 plus CTD profiler during all mooring cruises and during collaborative work described below. Data analyses performed thus far include integral scale analysis and spectral plots of T/S variation. These will be continued in order to make statistical comparisons between fjords. Ancillary data, such as buoy and shore-based weather data will be used to determine when sub-tidal variation is being forced by large scale meteorological events, and how the individual sites respond to these conditions.

Coordination/Collaboration: A coordination and collaboration with other projects included T/S profiles collected during both the EVOS sponsored cruises conducted by R. Campbell. Eventually, the physical data will be compared with the zooplankton collections among fjords and other parameters such as chlorophyll (fluorescence) and (nutrients) nitrates to determine how habitat conditions affect food availability for juvenile, and water column temperatures from the moored CTs will be used by Ron Heintz and J. J. Vollenweider at the NOAA Auk Bay lab to determine their effects on overwintering herring metabolism.

Community Involvement/TEK & Resource Management Applications:
During the 2010 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 2011 summer field season. However, presentation of results of the first three deployments were presented at the annual PI meeting held in Cordova, Alaska in May 2011. The new data collected in 2011 will also be analyzed for inclusion in my PhD dissertation, which is being written over the 2012 budget year. The dissertation will serve as additional material for this project in 2012.

Budget: No changes to the original budget are expected for fiscal year 2012.



Signature of PI: ______________________________________

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Table 1. April 2011 Herring Survey: CTD Mooring Deployment Parameters

Location	*Mooring*	*Latitude*	*Longitude*	*Depth (m)*	*Date*	*Time*	*Tide Stage*	*Max Mooring Length (m)*
Simpson	SB7m	60 39.930	145 52.840	59	18-Apr*	13:44	Ebb (+1.0hr)	~73
Zaikof	ZB13m	60 16.465	147 4.502	42	19-Apr	8:50	Ebb (bot. 0 hr)	54
Whale	WB13m	60 9.744	148 11.965	81	20-Apr	8:38	Ebb (+5.5hr)	92
Eaglek	EGB16m	60 55.425	147 44.317	63	21-Apr	8:34	Ebb (+4.3hr)	75

* Simpson mooring required a second retrieval and re-deployment on April 21 1800 hrs due to a mistake in the line arrangement.

Table 2. April 2011 Herring Survey: CTD Mooring Instrument List

Components:		*Instrument Type*	*Serial No.*	*Approx.* Depths (m)*	*Start Date*	*Start Time*	*Sample Interval (s)*	*N Avg*	*Press. Sensor (Y/N)*	*Ref. Press (db)*	*Salinity Ouput(Y/N)*
Simpson	SB7m	SB37	#4153	2.0	4/18/11	10:00:00	1800	3	N	2.0	Y
		HoBo TB		10-15	4/18/11	11:00:00	1800		n/a	n/a	n/a
		HoBo TB		20-25	4/18/11	11:00:00	1800		n/a	n/a	n/a
		HoBo TB		30-35	4/18/11	11:00:00	1800		n/a	n/a	n/a
		SB37	#5360	40-45	4/18/11	12:00:00	1800	3	Y	n/a	Y
Zaikof	ZB13m	SB37	#4149	5.0	4/19/11	22:30:00	1800	3	N	2.0	Y
		HoBo TB		10-15	4/18/11	21:00:00	1800		n/a		n/a
		HoBo TB		20-25	4/18/11	21:30:00	1800		n/a		n/a
		SB37	#3079	30-35	4/19/11	7:30:00	1800	3	N	30.0	Y
Whale	WB13m	SB37	#5001	5.0	4/19/11	22:00:00	1800	3	Y	n/a	Y
		HoBo TB		10-15	4/19/11	22:30:00	1800		n/a	n/a	n/a
		HoBo TB		20-25	4/19/11	22:30:00	1800		n/a	n/a	n/a
		HoBo TB		30-35	4/19/11	22:30:00	1800		n/a	n/a	n/a
		HoBo TB		50-55	4/19/11	22:30:00	1800		n/a	n/a	n/a
		SB37	#5359	70-75	4/19/11	22:00:00	1800	3	Y	n/a	Y
Eaglek	EGB16m	SB37	#4148^	2.0	4/20/11	22:00:00	1800	3	N	50.5^	Y
		HoBo TB		10-15	4/20/11	21:00:00	1800		n/a	n/a	n/a
		HoBo TB		20-25	4/20/11	21:00:00	1800		n/a	n/a	n/a
		HoBo TB		30-35	4/20/11	21:00:00	1800		n/a	n/a	n/a
		SB37	#5134	50-55	4/20/11	22:00:00	1800	3	Y	n/a	Y

^ microcats for EGB were swapped in April 2011; note that ref. press. for #4148 was still set to 50 m, so salinities will require recalculation.

Table 3. August 2011 Herring Survey: CTD Mooring Deployment Parameters

Location	Mooring	Latitude	Longitude	Depth (m)	Date	Time	Tide Stage	Max Mooring Length (m)
Zaikof	ZB13m	60 16.475	147 4.492	43	17-Aug	9:32	Ebb (+5.5hr)	54
Whale	WB13m	60 9.753	148 11.956	82	18-Aug	8:52	Ebb (+4.4hr)	92
Eaglek	EGB16m	60 55.428	147 44.341	61	19-Aug	11:30	Flood (+0.3hr)	75
Simpson	SB7m	60 39.929	145 52.822	60	20-Aug	17:40	Flood (+6.0hr)	~73

Table 4. August 2011 Herring Survey: CTD Mooring Instrument List

Components:		Instrument Type	Serial No.	Approx.* Depths (m)	Start Date	Start Time	Sample Interval (s)	N Avg	Press. Sensor (Y/N)	Ref. Press (db)	Salinity Ouput(Y/N)
Zaikof	ZB13m	SB37	#4149	5.0	8/17/11	7:30:00	1800	3	N	2.0	Y
		HoBo TB		10-15	8/17/11	7:00:00	1800		n/a		n/a
		HoBo TB		20-25	8/17/11	7:00:00	1800		n/a		n/a
		SB37	#4152	30-35	8/17/11	7:30:00	1800	3	N	30.0	Y
Whale	WB13m	SB37	#5001	5.0	8/18/11	7:30:00	1800	3	Y	n/a	Y
		HoBo TB		10-15	8/18/11	7:00:00	1800		n/a	n/a	n/a
		HoBo TB		20-25	8/18/11	7:00:00	1800		n/a	n/a	n/a
		HoBo TB		30-35	8/18/11	7:00:00	1800		n/a	n/a	n/a
		HoBo TB		50-55	8/18/11	7:00:00	1800		n/a	n/a	n/a
		SB37	#5359	70-75	8/18/11	7:30:00	1800	3	Y	n/a	Y
Eaglek	EGB16m	SB37	#4148^	2.0	8/19/11	10:30:00	1800	3	N	50.5^	Y
		HoBo TB		10-15	8/19/11	10:30:00	1800		n/a	n/a	n/a
		HoBo TB		20-25	8/19/11	10:30:00	1800		n/a	n/a	n/a
		HoBo TB		30-35	8/19/11	10:30:00	1800		n/a	n/a	n/a
		SB37	#5134	50-55	8/19/11	10:30:00	1800	3	Y	n/a	Y
Simpson	SB7m	SB37	#5360^	2.0	8/20/11	16:30:00	1800	3	Y	n/a	Y
		HoBo TB		10-15	8/20/11	16:30:00	1800		n/a	n/a	n/a
		HoBo TB		20-25	8/20/11	16:30:00	1800		n/a	n/a	n/a
		HoBo TB		30-35	8/20/11	16:30:00	1800		n/a	n/a	n/a
		SB37	#4153	40-45	8/20/11	16:30:00	1800	3	N	45	Y

^ microcats for EGB and SB were swapped to provide a pressure reading in the event the surface buoy is lost again to sheet ice

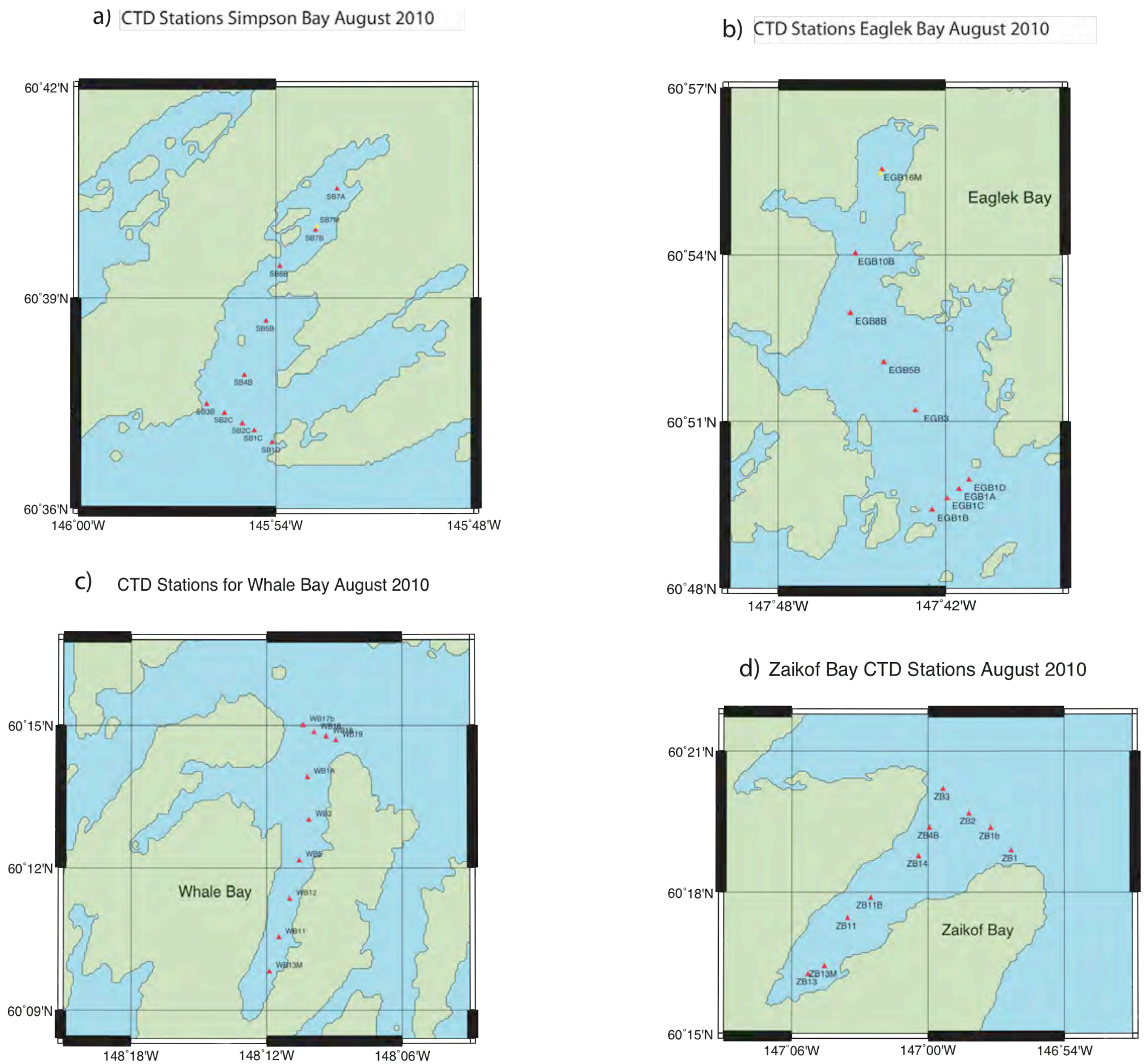
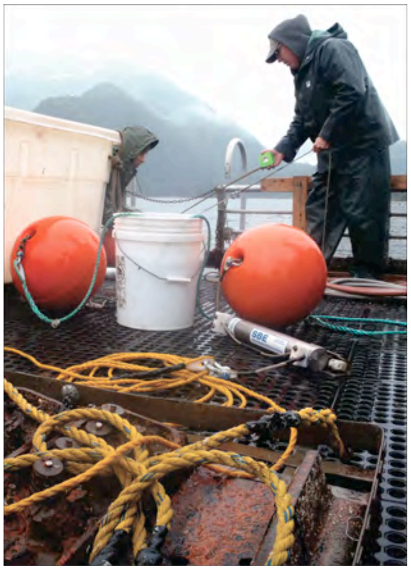


Fig. 1. Locations of CT moorings and oceanographic stations within the four SEA herring nurseries in April and August 2011.

Fig. 2. Highlights from mooring cruise in April 2011. Clockwise from upper left: i) echo anomalies (large inverted V's) signifying the presence of submerged buoys and microcats; ii and iii) recoveries of moorings using garpples following the loss of surface floats due to sheet ice; iv) mooring components in preparation for deployment at Whale Bay; and v) deployment of mooring at Eaglek Bay. (*All above photos are courtesy of Dave Janka.)*

A



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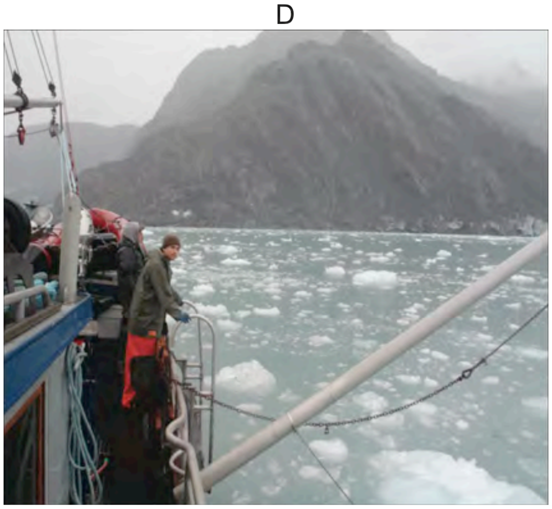

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Fig. 3. Highlights from mooring cruise in August 2011: a) preparation of mooring being deployed in Eaglek Bay; b) example of excessive macrophytic algal growth that occurred during both summers on the Simpson Bay near-surface SB37 microcat. Note that algae occurs everywhere except on the copper tape applied to the hull as an experiment in April 2011; c) high amounts of glacial discharge occurring due to rain during the cruise is shown above by Rude River water being advected towards Simpson Bay; d) small to medium brash ice within Columbia Fjord; and e) Columbia glacier in the background as the CTD is being readied for the first casts to be made wihin the expanded fjord basin since the early 1980's.

(*All above photos are courtesy of Dave Janka.)*

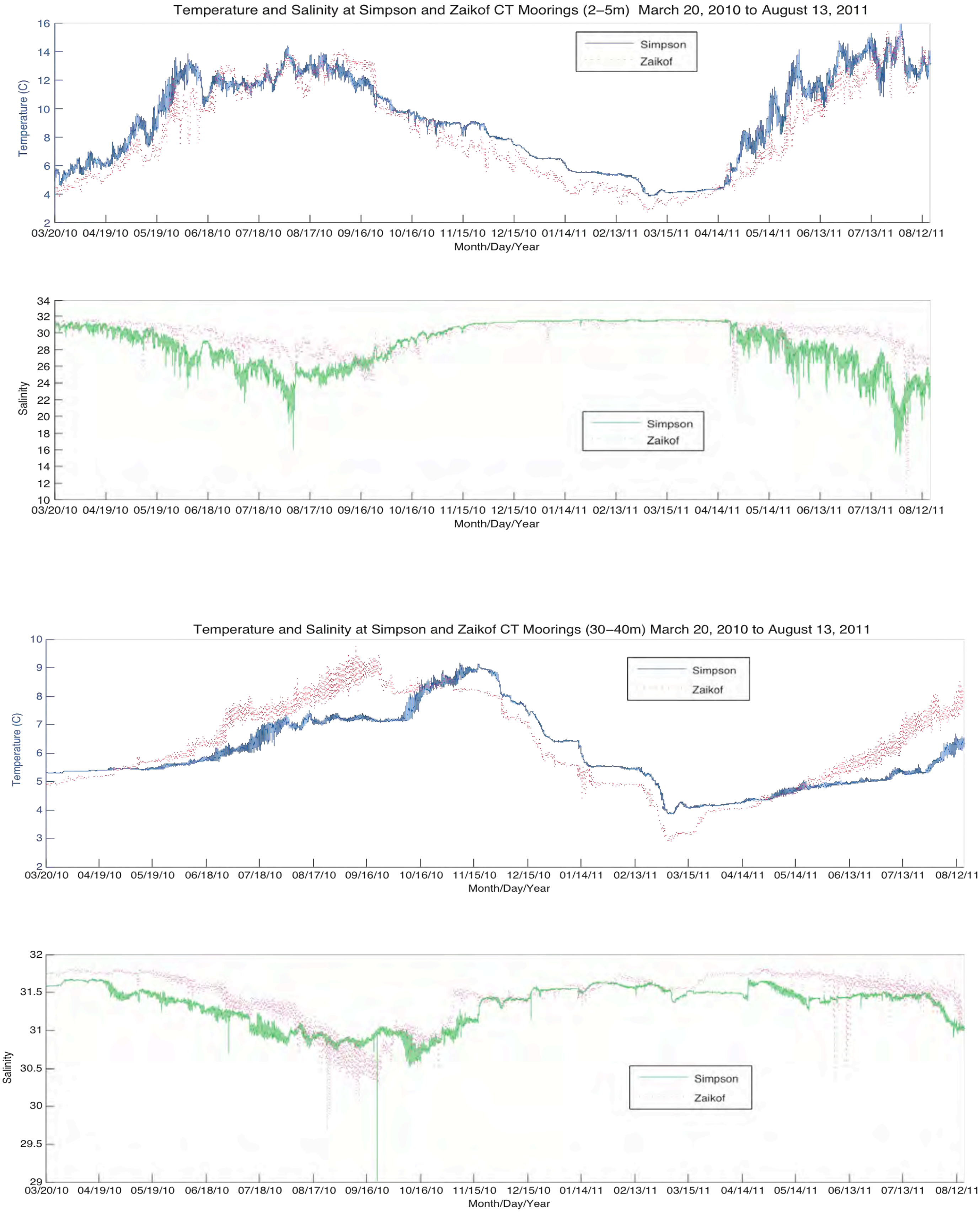


Fig. 4. Time series of temperature and salinity from March 2010 to August 2011 at Simpson Bay and Zaikof Bay for the near-surface (upper panels) and deep CTs (lower panels) respectively.

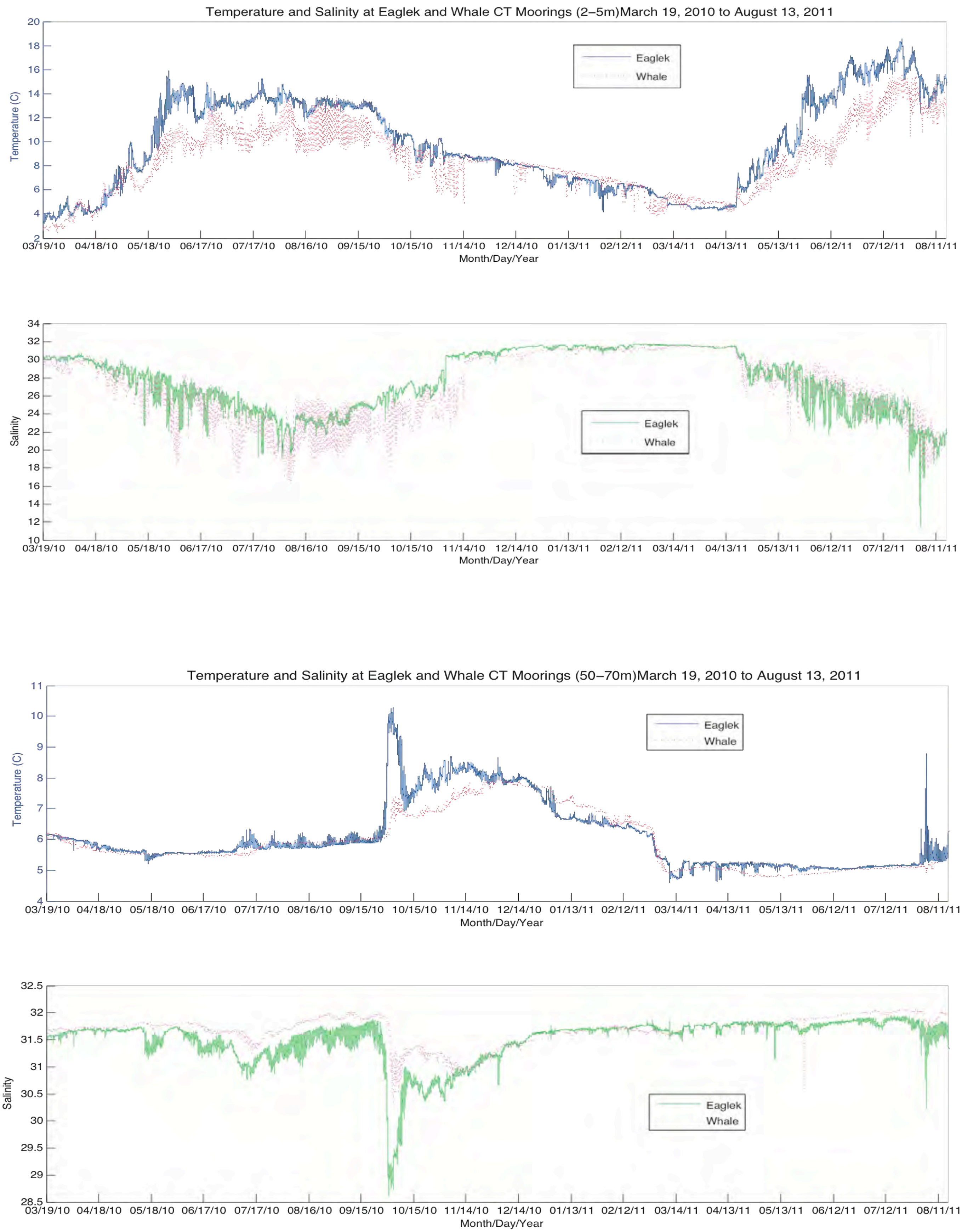


Fig. 5. Time series of temperature and salinity from March 2010 to August 2011 at Eaglek Bay and Whale Bay for the near-surface (upper panels) and deep CTs (lower panels) respectively.

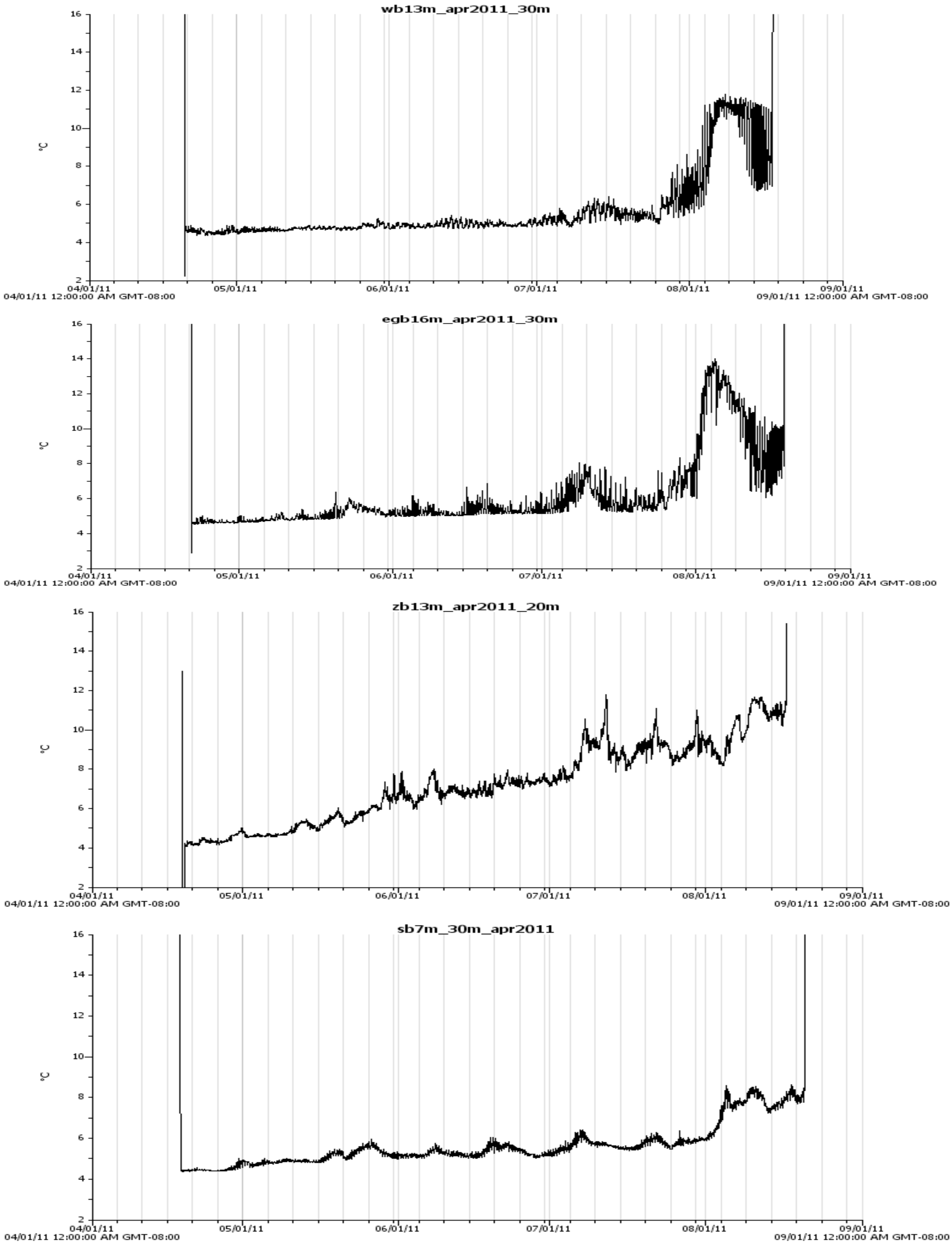


Fig. 6. Temperature time series from April to August 2011 for subsurface thermistors at Whale (top), Eaglek (upper middle), Zaikof (lower middle) and Simpson (bottom).

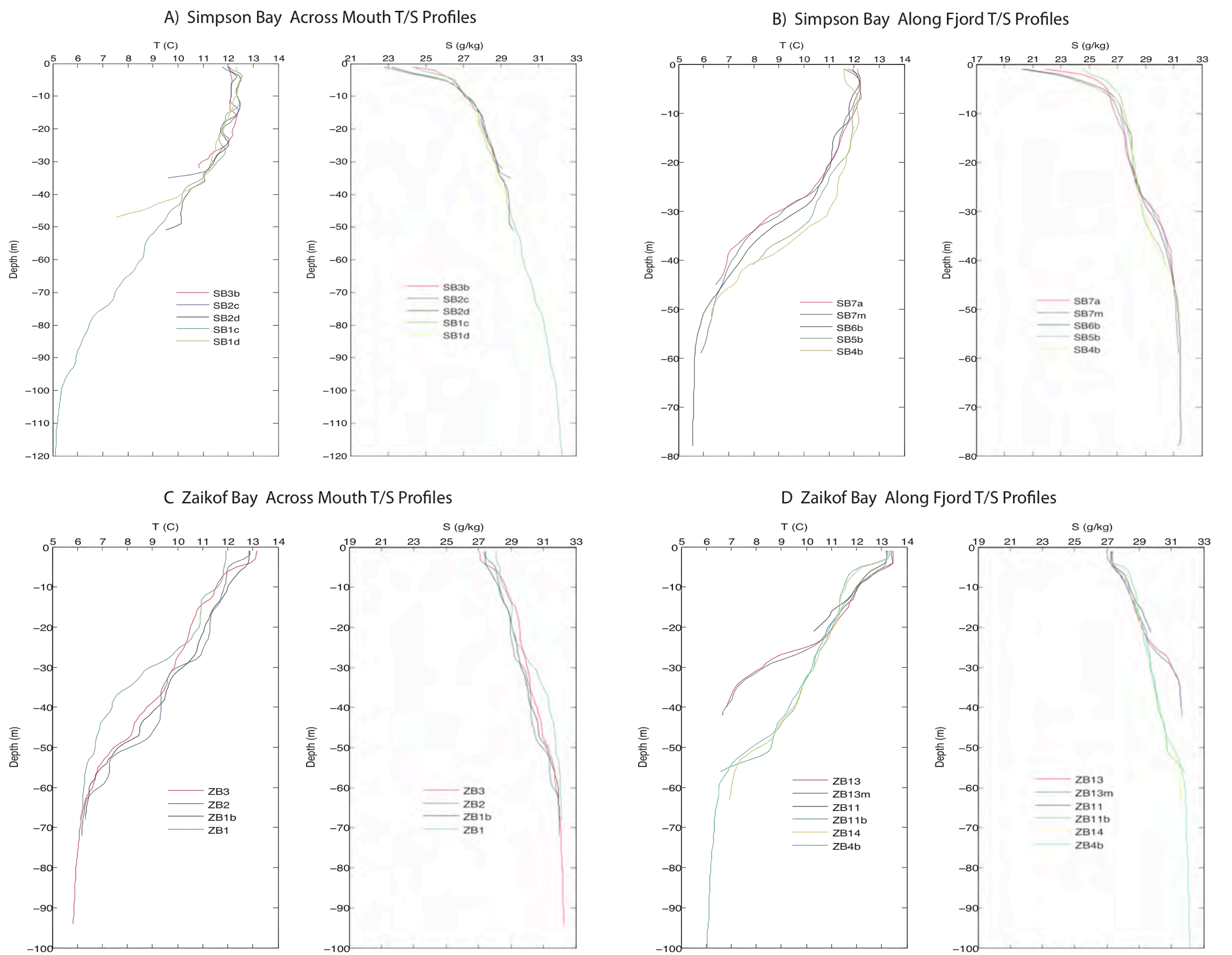


Fig. 7. Temperature and salinity profiles taken across the mouth and along the fjord at Simpson Bay and Zaikof Bay in August 2011.

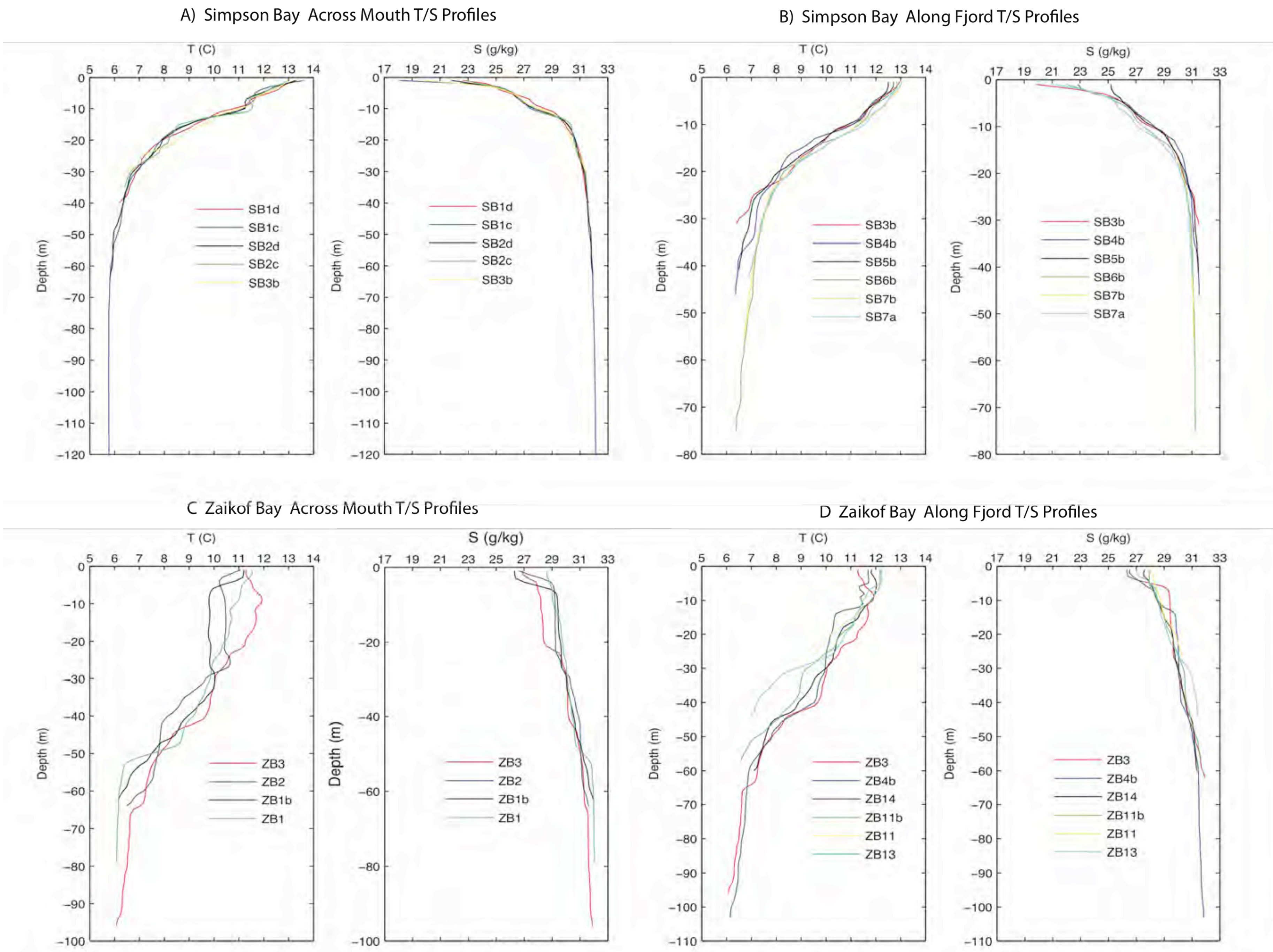


Fig. 8. Temperature and salinity profiles taken across the mouth and along the fjord at Simpson Bay and Zaikof Bay in August 2010.

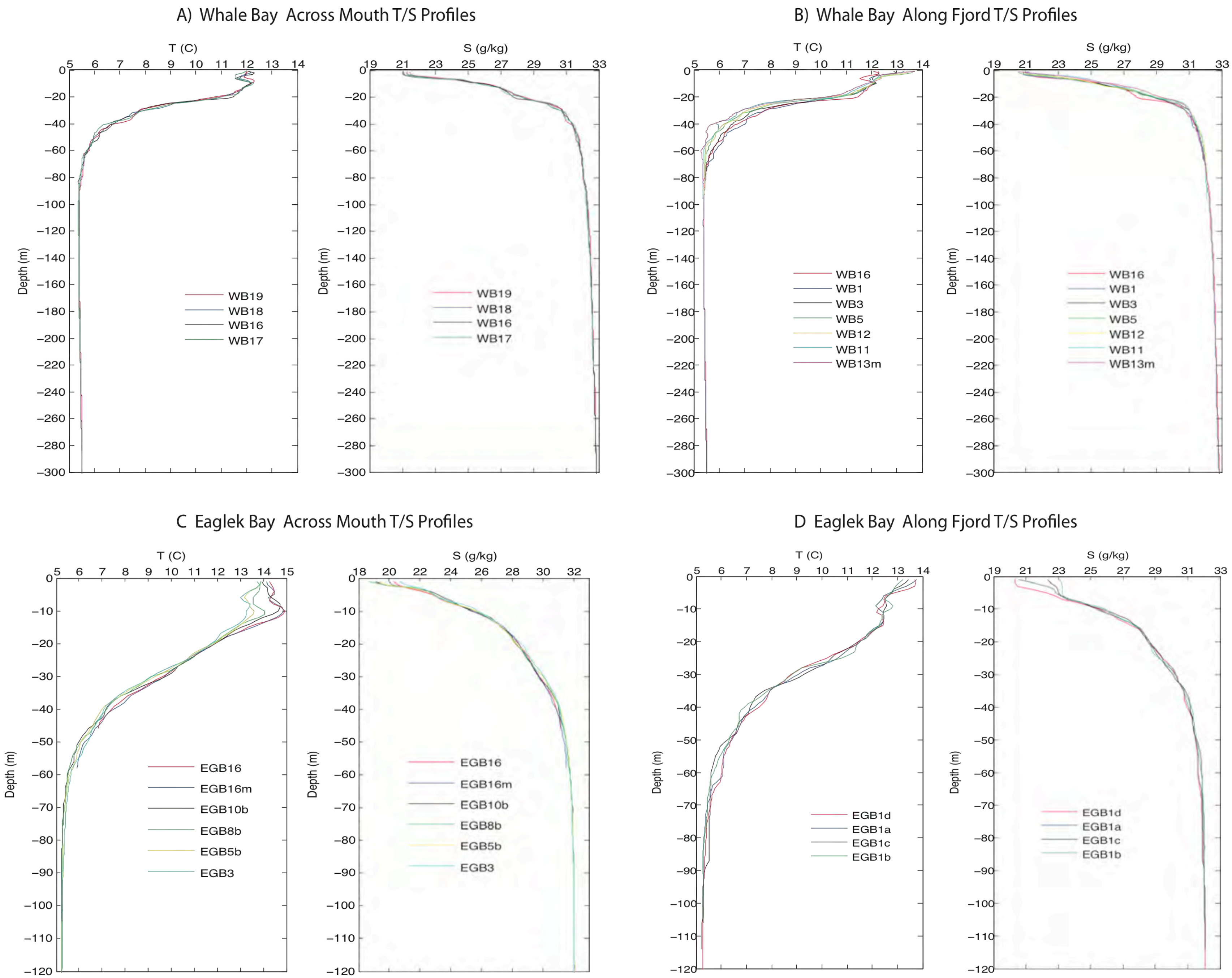


Fig. 9. Temperature and salinity profiles taken across the mouth and along the fjord at Whale Bay and Eaglek Bay in August 2011.

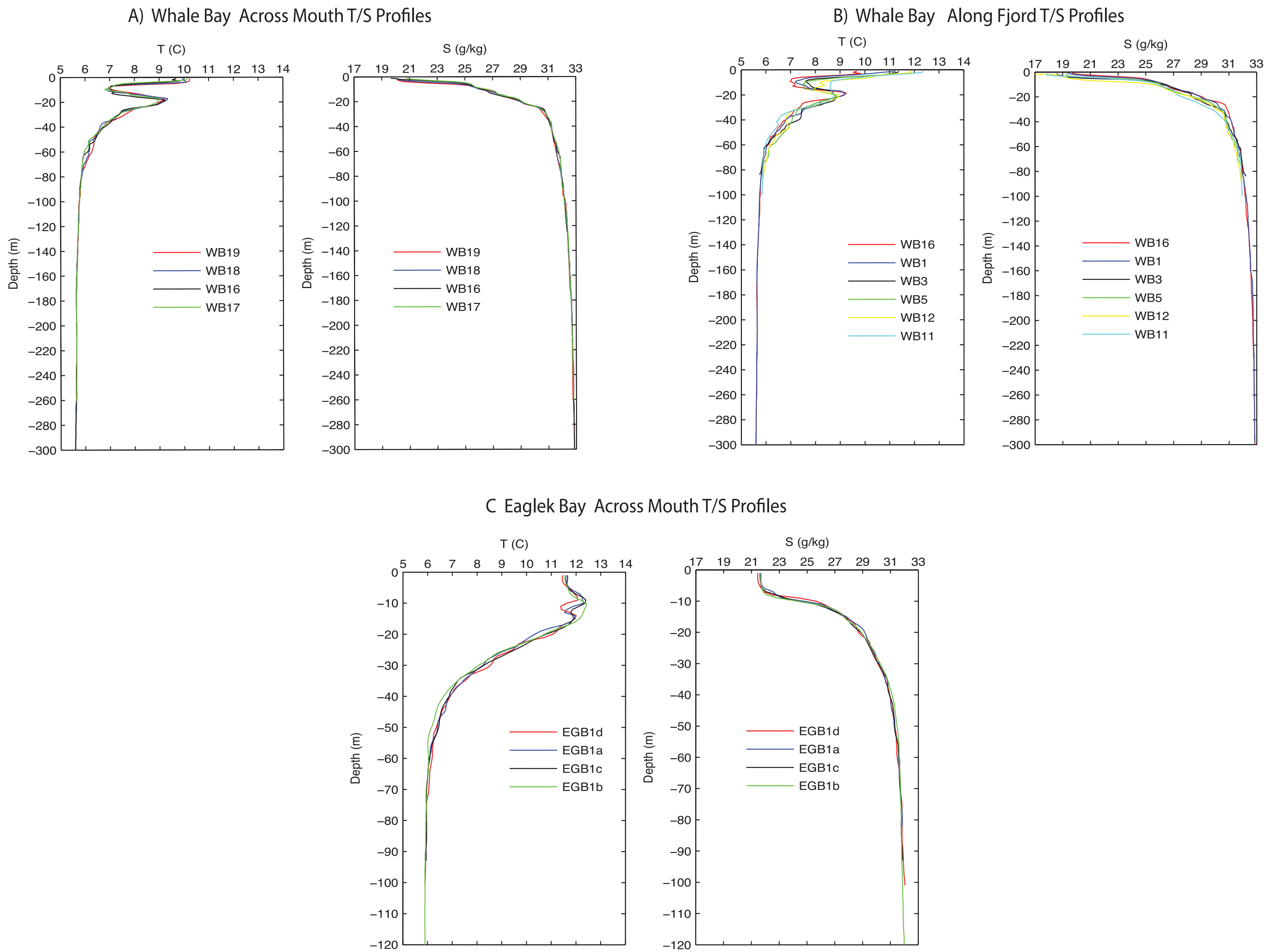
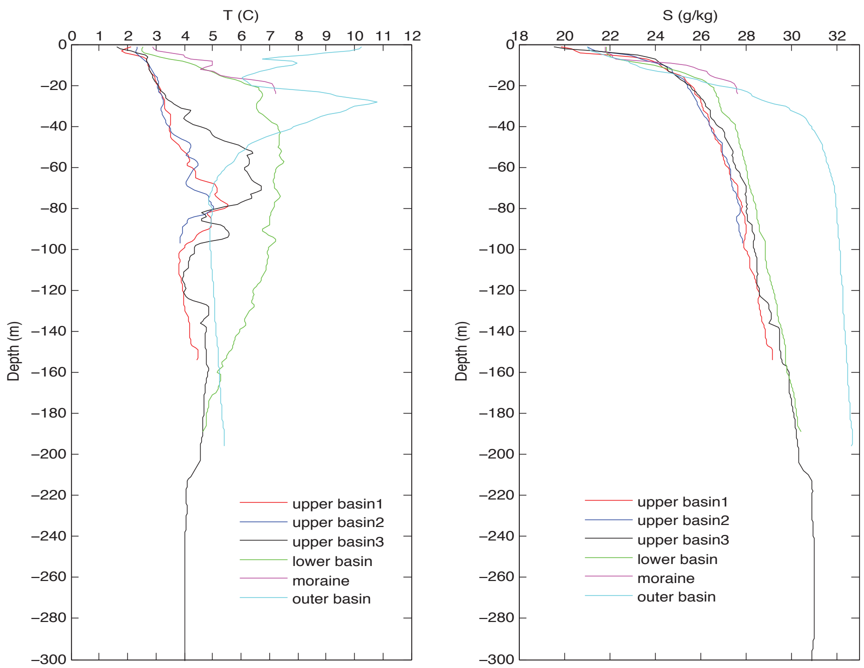
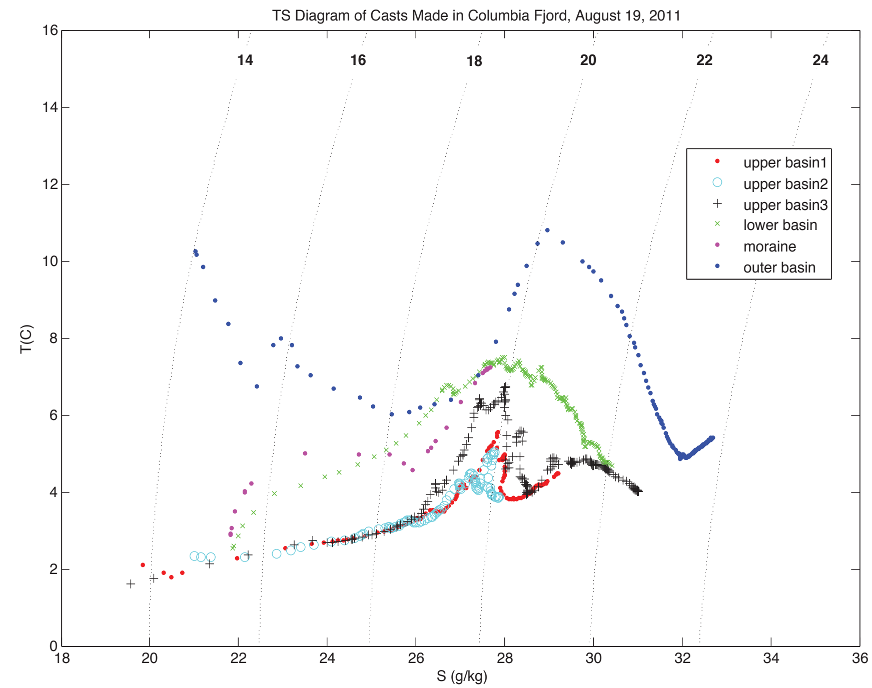


Fig. 10. Temperature and salinity profiles taken across the mouth and along the fjord at Whale Bay and Eaglek Bay in August 2010.

A



B



C

D

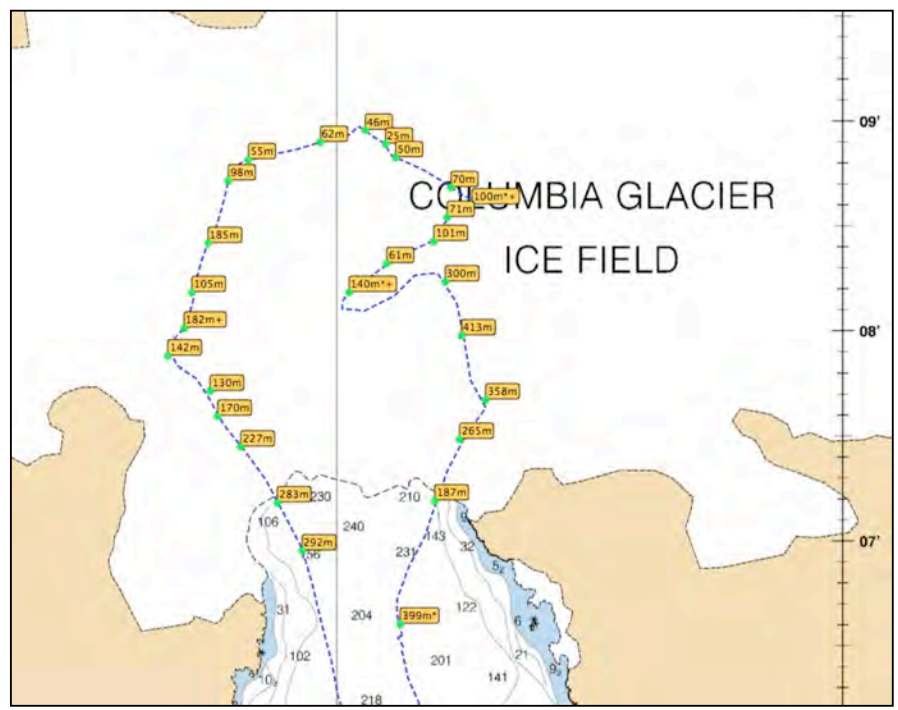


Fig. 11. Temperature and salinity data collected at Columbia Fjord in August 2011: A) T/S profiles; B) TS Diagram; C and D) locations of depth soundings in uncharted upper regions of the fjord and oceanographic stations where CTD casts were performed.

Note - cast locations are designated by stars next to the depth readings.

Cruise tracks in C and D courtesy of Dave Janka