CRUISE REPORT

ALPHA HELIX CRUISE 213

15 August to 6 September 1998

I. Project Title: Collaborative Research: Prolonged production and trophic transfer to predators: Processes at the Inner Front of the Southeastern Bering Sea

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Support: NSF OPP-9617287

II. Scientific Purpose: It is hypothesized that elevated primary production at the inner front of the southeastern Bering Sea continues longer than in the upper mixed layer of non-frontal waters, and that this production provides an energy source throughout the summer for a food web that supports shearwaters, salmon, and their zooplankton prey. To test this hypothesis, we collected and interpreted observations on physical and biological features in the vicinity of the inner front to determine: 1) the availability of nutrients in the euphotic zone, 2) the physical processes responsible for enhanced vertical flux of nutrients, 3) primary production, 4) the distribution, abundance and trophic ecology of near-surface swarms of euphausiids and other zooplankton, and 5) the distribution, abundance, and foraging ecology of shearwaters, and 6) by stable isotope enrichment, trophic pathways from phytoplankton to shearwaters at and away from the front. This cruise was the last of four planned for this project.

III. Personnel

Terry E. Whitledge	Chief Sci.	UAF	USA	Chem Oceanography
Steve Zeeman	Co-PI	U. New England	USA	Primary Production
Ken O. Coyle	Co-PI	UAF	USA	Zooplankton
Nancy Kachel	Res. Assoc.	PMEL	USA	Physical Oceanog.
Cheryl Baduini	Student	UCI	USA	Ornithology
Heather Revilee	Student	UCI	USA	Ornithology
David Hyrenbach	Student	Scripps	USA	Ornithology
John Carlson	Student	Montana State U	USA	Ornithology
Taekeun Rho	Student	UAF	Korea	Nutrients/Pigments

Keven Neely	Technician	U. Texas	USA	Nutrients
Alexey Pinchuk	Technician	UAF	Russia	Zooplankton
Viktor G. Egorov	Sr. Scientist	I. Energy Problems	Russia	UV Radiation Effects

Cruise Activity Log

DATE/TIME		ACTIVITY
15 August	0900	Depart Seward
18 August	1730	Arrive Dutch Harbor
18 August	2100	Depart Dutch Harbor
19 August	0900	Arrive Line-C of Slime Bank Grid. Hove to due to high winds. Blowing 30-50 knots.
	1230	Still blowing 35-55 knots. Continue to hove to near SBC-1
	1500	Still blowing 30-45 knots.
	1600	Wind down to 15 knots. Start CTD transect at SBC-1
20 August	0015	End SBC-line and transit to SBA-line
	0630	End SBA-line and transit to SBE-line
	1330	In Situ prod & N-15 prods at SBE-6
	1700	End SBE-line CTD survey
	1715	Deploy HTI acoustics for SBE-10 to SBE-1 transect; bird obs
	2130	End HTI acoutics at SBE-1
21 August	0030	Mocness tows at SBE-3
	0220	Deploy HTI and Mocness at SBC-3
	0830	Collect birds at SBE-3
	1000	Collect more birds at SBE-3
	1130	In situ prod & N-15 prods at SBC-1
	1315	Deploy HTI acoustics & XBT's for SBC-1 to SBC-12 transect; bird obs
	1930	Start Mocness tows at SBC-11
	2130	Start Mocness tows at SBC-9
22 August	0100	Start Mocness tows at SBC-12
	0300	Start Mocness tows at SBC-7
	0430	Start Mocness tows at SBC-6
	0910	Collect birds at SBE-4
	1300	In situ prod & N-15 prods at SBC-12
	1530	Move to SBA-12 for possible acoustic run
	1630	Depart Slime Bank for Cape Newenham grid
	2245	Start Cape Newenham transect at CNC-20
23 August	0840	Re-start transect at CNC-18 after weather delay
	1900	Stop CTD transect after CNC-2 due to poor weather conditions
	1915	Continue bird observations along CNCX transrct
	2130	Stop bird observations at CNC-X8
	2200	Depart CNC line for Nunivak Island grid

24 August		Underway to Nunivak Island with poor weather conditions
25 August	0420	Start Nunivak Island CTD transect at NIC-12
	1100	Stop Nunivak Island CTD transect at NIC-1 due to poor weather
	1130	transit to station NIA-1 to wait for good weather
26 August	0830	Start CTD transect stations at NIA-1
	1530	Finish A line transect at NIA-11 and depart for NIE-11
	1645	Start E line transect at NIE-11
	2130	Finish E line transect at NIE-1
	2320	Deploy HTI and Mocness at NIC-6
27 August	0050	Deploy HTI and Mocness at NIC-7A
	0230	Deploy HTI and Mocness at NIC-8A
	0400	Deploy HTI and Mocness at NIC-9A
	0550	Deploy HTI and Mocness at NIC-11A
	0800	Deploy HTI acoustics for NIC-12 to NIC-1 transect; bird obs
	1400	In situ prod & N-15 prods at NIC-1; TSRB and UV sensors deployed
	1600	Deploy HTI acoustics for NIE-1 to NIE-12 transect; bird obs
	2315	Deploy HTI and Mocness at NIC-5
28 August	0230	Deploy HTI and Mocness at NIC-X6
	0445	Deploy HTI and Mocness at NIE-X8
	0800	Deploy HTI acoustics for NIC-1 to NIC-X8 transect; bird obs
	1240	Collect bird specimens at NIC-X8
	1250	In situ prod & N-15 prods at NIC-X8; TSRB and UV sensors deployed
	1420	Deploy HTI acoustics for NIC-X8 to NIC-X15 transect, bird obs
	2200	Deploy HTI and Mocness at NIC-X12
29 August	0030	Deploy HTI and Mocness at NIE-X14
	0215	Deploy HTI and Mocness at NIC-X15
	0320	Start Nunivak to St Paul CTD transect at NIC-X15; Calvet samples
	1400	In situ prod & N-15 prods at NIC-8; TSRB and UV sensors deployed
30 August		0300 Finish Nunivak to St. Paul CTD transect at NP-5
	0820	Start bird obs transect to East while underway to Cape Newenham line
	2020	Collect birds
31 August	0800	Start CTD transect at CNC-12; bird obs; Calvet samples
	1230	In situ prod & N-15 prods at CNC-4; TSRB and UV sensors deployed
	1630	Stopped CTD operation at CNC-2 because of high wind and seas
	1745	Resumed CTD transect at CNC-X1
1 September	0220	Finished CTD transect at CNC-X16
	0840	Collect birds near CNE-X16
	1030	Deploy HTI at CNC-X16
	1100	Terminate HTI due to rough seas and bad data
	1400	In situ prod & N-15 prods at CNE-X17; TSRB and UV sensors deployed

1650 Start CTD transect at CNE-X15
1710 Stop CTD transect due to rough seas; anchor at Cape Pierce

2 September 0815 Depart anchorage
0930 Collect birds near CNE-X17
1130 Start CTD transect at CNE-X15
1550 Deploy UV sensor at CNEX-9
Deploy HTI at CNE-X8; Bird Observations started
End bird obs but continue HTI to CNE-X14
Deploy Mocness and HTI at CNC-X14

3 September 0045 Deploy Mocness and HTI at CNC-X12
Deploy Mocness and HTI at CNC-X8
Deploy Mocness and HTI at CNC-X1
Start bird transect and HTI from CNC-X8 to offshore with XBT
Depoy In Situ Productivity at CNC-1
Continue bird transect and HTI from CNC-1 to offshore
Recover HTI and start bird collecting at CNC-11
Deploy Mocness and HTI at CNC-10
Deploy Mocness and HTI at CNC-2

4 September 0140 Deploy Mocness and HTI at CNC-6
Deploy Mocness and HTI at CNC-10
Start bird transect and HTI from CNC-10 to CNC-20 with XBT
Deploy In Situ Productivity at CNC-17
Continue bird transect and HTI from CNC-17 to CNC-20
Start XBT transect from CNC-20 to CNC-14
Deploy Mocness and HTI at CNC-14

5 September 0220 Deploy Mocness and HTI at CNC-17
Deploy Mocness and HTI at CNC-20
0545 Depart CN line for Dutch Harbor

Summary of Results

The late summer of 1998 in the Bering Sea was quite variable with short periods of good weather interspersed with wind events. However, the winds only prevented work for about 3 days during the total cruise so all sampling goals were exceeded. This description only presents highlights. Check the work group reports for specific details.

At Slime Bank there was no evidence of the coccolithophorid bloom. On the contrary, initial particulate filters gave the appearance of diatoms. The general conditions were typical for this sampling area.

The coccolithophorid bloom was first observed about mid-way of the transit from the Slime Bank grid to the Cape Newenham C-line. It was a very sharp transition and was quite noticeable since the sun was shining. The remainder of the cruise was in the coccolithophorid waters except for the short time while near St. Paul Island. During transit from St. Paul Island back to the Cape Newenham line, the ship passed through coccolithophorid "rich" water, to clear water and back to coccolithophorid water. This was interpreted to be relatively new water possibly advected onto the shelf from the shelfbreak submarine canyon. Nutrient results supported the hypothesis that the coccolithophorid bloom was still present in 1998 because the mixed layer nutrients were in very low concentrations.

Although very few dead birds was observed during the cruise, there was an apparent lack of feeding on euphausids. Many of the collected birds had been eating fish. This was in apparent contrast to several large patches of euphausids that were collected in nearby areas by the Mocness tows and HTI scattering data. There were no particularly unusual whale or mammal sightings during the trip.

Physical Oceanography
Nancy B. Kachel

At Slime Bank we occupied three lines of Ctd stations on August 20-2: twelve stations on the C-line and 7 stations on each the A and E lines. Also, a line of 20 XBTs was stations were taken on the SBC line on August 21. The upper water layer was well mixed to ~ 35m and had temperatures between 9° and 10.5° C and salinities between 31.6-31.8 psu. The inner front was found between stations SBC08 where the bottom is approximately 80m deep. The temperature below the pycnocline decreased to 5.8°C, while the observed salinity increases to >32.3psu. Shoreward of station #6 on each line, the water column was well-mixed or poorly stratified, with increasingly fresher, warmer waters found closer to shore.

At the Nunivak Island grid a total of 42 Ctd stations were occupied: all 12 stations on the main grid on the C-line and generally every second station on the A and E-lines. We repeated the length of the C-line from inshore at NICX15 to offshore and NIC15, occupying every other station. The inshore edge of the inner front was found near the 04 positions on each line, at about 50m depth. The warmest temperatures in the upper layer were 6-7°C. Below the thermocline the temperature in the cold pool was about 3.5°C. We found that salinities varied by less than 0.5psu and sigma-t by ~0.6. The coccolithiphorid bloom was evident throughout the Nunivak grid area when we were there, and was visible all the way to the Pribilovs.

A line of five CTD stations was occupied going east from the Pribilovs on the way to the Cape Newenham grid. Warmer, saltier water was present next to the islands, but temperatures less than 2.5°C were sampled in the heart of the cold pool. We transited out of the coccolith bloom at a longitude of ~166° 25' W.

One line of Ctd stations was occupied on Aug. 23-24 at the Cape Newenham grid before bad weather sent us to the Nunivak Island area. The coccolith bloom was present in the area at that time, but had disappeared by the time we reoccupied Newenham grid on August 31. By September 3, a somewhat weakened bloom was again seen. A total of 37 Ctd stations were taken along the gridlines, excluding isolated productivity stations. All but six of the Ctds were located on the C-Line.

The first occupation of the CNC line began at CNC20 located in the cold pool region.
CNC18 and 17 are close to the site of NOAA/PMEL Buoy 2. The inner front was assumed to be positioned near CNC04, although we never saw completely unstratified water column on this date. On The August 31- September 1 transect completely unstratified water column was observed between CNCX6 and CNCX14. Over the cold pool the surface mixed layer depth increase from 28m on August 23 to 32m on September 5 at CNC18. The surface layer temperature decreased from near 10° to 7°C. The bottom temperature remained 3.5°C. The difference on more the 6°C above and below the thermocline observed here on August 23 was the largest amount seen in the three grid areas.

In addition to the Ctd lines, we took a line of 34 XBTs on the CNC line on September 4 and 5 from CNC5 to CNC20.

HX213 August 15 to September 7, 1998
CTD Lines Occupied

Line ID	Sta. ID	Cast No.	Date(s)
Slime Bank			
SBA	SBA10,8,6,5,4,2,1	15-22	Aug. 20
SBC	SBC1-12	3-14	Aug. 20
SBE	SBE1,2,4-6,8,10	23-32	Aug. 20-21
Nunivak Island			
NIA	NIA1,3,5,6,7,9,11	60-67	Aug. 26
NIC	NIC12-1 (incl.)	48-59	Aug. 25
NIE	NIE11,9,8,7,5,4,6,1	68-75	Aug. 27
NICX (long)	NICX15,x13,x11,x8,x4, NIC1,3-6,8,10,12,13,15	80-97	Aug. 29-30
Cape Newenham			
CNC	CNC20,18,16,14,12, 9,8,6,4,2	38-47	Aug. 23-24
CNC2	CNC12,10,7,6,4,2, CNCX2,4,6,10,14,16,17	103-117	Aug. 31-Sept. 1
CNEX (inner only)	CNEX15,X13,X11,X9	120-126	Sept. 2
CNC (outer only)	CNC 20-14(incl.)	131-137	Sept. 4
Pribilov Is. To Cape Newenham Line			
NP	NP1-5	98-102	Aug. 30
Other Stations			
Resurrection Bay	ResBay	1	Aug. 15
Gulf of Alaska	GA1	2	Aug. 15

Cruise	Cast No	Sta.ID	Date/Time	Lat	Long	Bottom Depth	Cast Depth	Comment
HX213	1	RES2.5	8/15/98 18:41	60.0234	-149.359	264	252	no PAR
HX213	2	GAK1	8/15/98 20:25	59.8445	-149.466	270	268	no PAR
HX213	3	SBC1	8/20/98 00:12	55.0975	-163.854	27	26	no PAR
HX213	4	SBC2	8/20/98 00:57	55.1386	-163.887	32	32	no PAR
HX213	5	SBC3	8/20/98 01:32	55.1786	-163.92	44	42	no PAR
HX213	6	SBC4	8/20/98 02:08	55.2185	-163.955	53	50	no PAR
HX213	7	SBC5	8/20/98 02:57	55.2603	-163.987	59	55	PAR SN 4497 added
HX213	8	SBC6	8/20/98 03:34	55.3005	-164.023	77	74	
HX213	9	SBC7	8/20/98 04:13	55.3413	-164.057	86	81	
HX213	10	SBC8	8/20/98 04:51	55.3811	-164.091	96	92	
HX213	11	SBC9	8/20/98 05:34	55.4224	-164.125	96	92	
HX213	12	SCB10	8/20/98 06:18	55.4626	-164.158	98	95	
HX213	13	SBC11	8/20/98 07:01	55.5036	-164.19	98	95	
HX213	14	SBC12	8/20/98 07:46	55.5439	-164.225	96	92	
HX213	15	SBA12	8/20/98 09:06	55.5896	-164.05	96	94	
HX213	16	SBA10	8/20/98 10:05	55.5081	-163.982	92	90	
HX213	17	SBA8	8/20/98 11:02	55.4267	-163.917	89	86	
HX213	18	SBA6	8/20/98 12:00	55.3456	-163.85	71	67	
HX213	19	SEA5	8/20/98 12:38	55.3053	-163.816	65	63	
HX213	20	SEA4	8/20/98 13:14	55.2646	-163.783	57	56	
HX213	21	SBA2	8/20/98 14:08	55.1836	-163.717	58	46	
HX213	22	SBA1	8/20/98 14:42	55.1424	-163.683	44	40	
HX213	23	SBE1	8/20/98 16:30	55.0511	-164.028	29	26	
HX213	24	SBE2	8/20/98 17:08	55.0909	-164.064	39	38	
HX213	25	SBE4	8/20/98 18:02	55.1728	-164.131	54	51	
HX213	26	SBE5	8/20/98 18:38	55.2121	-164.164	63	59	
HX213	27	SBE6	8/20/98 19:20	55.2531	-164.199	74	73	
HX213	28	SBE06	8/20/98 20:29	55.2527	-164.197	72	23	Prod-Z
HX213	29	SBE06	8/20/98 21:07	55.2539	-164.192	72	41	Prod-R
HX213	30	SBE08	8/20/98 23:23	55.3373	-164.262	96	94	
HX213	31	SBE10	8/21/98 00:23	55.4178	-164.327	100	95	
HX213	32	SBE10	8/21/98 00:50	55.4213	-164.308	100	95	
HX213	33	SBC01	8/21/98 19:06	55.096	-163.859	26	27	Prod-Z
HX213	34		8/21/98 19:37	55.0961	-163.859	0	23	Prod-Ro
HX213	35	SCB12	8/22/98 20:57	55.5442	-164.227	100	94	Prod
HX213	36	SBC12	8/22/98 21:20	55.545	-164.226	100	41	Prod
HX213	37	SCB12	8/22/98 21:52	55.5444	-164.226	100	36	Prod
HX213	38	CNC20	8/23/98 06:48	56.6452	-164.247	77	71	Coccoliths
HX213	39	CNC18	8/23/98 16:44	56.8003	-164.082	74	73	first seen
HX213	40	CNC16	8/23/98 17:58	56.9552	-163.915	72	69	
HX213	41	CNC14	8/23/98 19:12	57.1093	-163.748	68	68	
HX213	42	CNC12	8/23/98 20:28	57.2651	-163.578	61	64	Prod
HX213	43	CNC10	8/23/98 21:58	57.3427	-163.497	60	54	
HX213	44	CNC08	8/23/98 23:41	57.42	-163.412	52	47	
HX213	45	CNC06	8/24/98 00:38	57.4978	-163.332	47	42	
HX213	46	CNC04	8/24/98 01:35	57.576	-163.248	47	41	
HX213	47	CNC02	8/24/98 02:29	57.6525	-163.165	0	44	
HX213	48	NIC12	8/25/98 12:08	58.432	-168.571	62	59	
HX213	49	NIC11	8/25/98 12:57	58.473	-168.529	62	58	
HX213	50	NIC10	8/25/98 13:33	58.512	-168.487	60	57	

Cruise	Cast No	Sta.ID	Date/Time	Lat	Long	Bottom Depth	Cast Depth	Comment
HX213	51	NIC09	8/25/98 14:13	58.551	-168.441	58	56	
HX213	52	NIC08	8/25/98 14:42	58.5901	-168.399	54	55	
HX213	53	NIC07	8/25/98 15:20	58.6286	-168.355	53	50	
HX213	54	NIC06	8/25/98 15:53	58.6684	-168.312	50	48	
HX213	55	NIC05	8/25/98 16:30	58.7099	-168.271	49	51	
HX213	56	NIC04	8/25/98 16:57	58.7452	-168.225	48	46	
HX213	57	NIC03	8/25/98 17:35	58.784	-168.181	47	47	
HX213	58	NIC02	8/25/98 18:11	58.8227	-168.138	44	42	
HX213	59	NIC01	8/25/98 18:51	58.8621	-168.096	43	43	
HX213	60	NIA01	8/26/98 16:43	58.9161	-168.276	45	42	
HX213	61	NIA03	8/26/98 17:41	58.8397	-168.362	47	44	
HX213	62	NIA05	8/26/98 18:42	58.7617	-168.447	50	47	
HX213	63	NIA06	8/26/98 19:17	58.7228	-168.49	51	49	
HX213	64	NIA07	8/26/98 19:59	58.6821	-168.535	53	51	
HX213	65	NIA09	8/26/98 21:18	58.6037	-168.62	58	57	
HX213	66	NIA11	8/26/98 22:09	58.5257	-168.707	63	62	Prod-Z
HX213	67	NIA11	8/26/98 22:46	58.5265	-168.707	63	24	Prod-R
HX213	68	NIE11	8/27/98 01:10	58.4194	-168.349	61	58	
HX213	69	NIE09	8/27/98 01:59	58.4979	-168.265	57	53	
HX213	70	NIE08	8/27/98 02:28	58.5366	-168.222	55	52	
HX213	71	NIE07	8/27/98 02:56	58.5756	-168.179	0	49	
HX213	72	NIE05	8/27/98 03:41	58.6536	-168.092	49	44	
HX213	73	NIE04	8/27/98 04:10	58.6924	-168.049	47	45	
HX213	74	NIE03	8/27/98 04:38	58.7313	-168.006	46	44	
HX213	75	NIE01	8/27/98 05:22	58.8091	-167.919	43	39	
HX213	76	NIC01	8/27/98 21:24	58.8618	-168.091	44	42	Prod-Z
HX213	77	NICO1	8/27/98 21:49	58.8608	-168.096	44	22	Prod-R
HX213	78	NICX8	8/28/98 19:57	59.1739	-167.752	40	38	Prod-Z
HX213	79	NICX8	8/28/98 20:23	59.1739	-167.749	40	24	Prod-R
HX213	80	NICX15	8/29/98 11:20	59.6397	-167.233	30	30	
HX213	81	NICX13	8/29/98 12:45	59.4837	-167.405	31	29	
HX213	82	NICX11	8/29/98 14:05	59.3276	-167.579	36	33	
HX213	83	NICX8	8/29/98 15:24	59.1711	-167.753	40	38	
HX213	84	NICX4	8/29/98 16:39	59.0179	-167.927	41	36	
HX213	85	NIC01	8/29/98 17:56	58.8619	-168.1	43	40	
HX213	86	NIC03	8/29/98 18:47	58.7846	-168.185	46	44	
HX213	87	NIC04	8/29/98 19:13	58.7458	-168.227	47	46	
HX213	88	NIC05	8/29/98 19:39	58.7067	-168.271	48	50	
HX213	89	NIC06	8/29/98 20:16	58.6673	-168.314	51	50	
HX213	90	NIC08	8/29/98 21:02	58.59	-168.399	55	54	
HX213	91	NIC08	8/29/98 21:04	58.5901	-168.398	55	52	Prod.Z /Upcast
HX213	92	NIC08	8/29/98 21:29	58.589	-168.399	55	54	Prod.Z
HX213	93	NIC08	8/29/98 22:02	58.5889	-168.401	0	26	Prod-R
HX213	94	NIC10	8/30/98 00:05	58.5113	-168.485	61	56	
HX213	95	NIC12	8/30/98 00:50	58.4333	-168.572	61	59	
HX213	96	NIC13	8/30/98 01:35	58.3512	-168.653	66	62	
HX213	97	NIC15	8/30/98 02:47	58.2009	-168.832	69	65	
HX213	98	NP1	8/30/98 04:15	58.0138	-169.04	70	68	
HX213	99	NP2	8/30/98 05:42	57.8272	-169.246	64	61	
HX213	100	NP3	8/30/98 07:14	57.6415	-169.453	71	67	

Cruise	Cast No	Sta.ID	Date/Time	Lat	Long	Bottom Depth	Cast Depth	Comment
HX213	101	NP4	8/30/98 08:51	57.4519	-169.66	70	69	
HX213	102	NP5	8/30/98 10:46	57.2653	-169.867	49	48	New termination/pump stopped due to loss of connection
HX213	103	CNC12	8/31/98 16:07	57.2647	-163.585	61	58	
HX213	104	CNC10	8/31/98 17:01	57.342	-163.502	54	51	
HX213	105	CNC08	8/31/98 17:56	57.4198	-163.417	50	47	
HX213	106	CNC06	8/31/98 18:51	57.4979	-163.334	49	46	
HX213	107	CNC04	8/31/98 19:47	57.5749	-163.248	47	44	CTD/Prod-Z
HX213	108	CNC04	8/31/98 20:24	57.5756	-163.252	47	21	Prod-R
HX213	109	CNC02	8/31/98 22:45	57.6521	-163.163	46	45	
HX213	110	CNCX2	9/1/98 00:34	57.7674	-163.039	45	27	CTD aborted due to heavy seas
HX213	111	CNCX2	9/1/98 01:59	57.7688	-163.04	45	42	
HX213	112	CNCX4	9/1/98 02:58	57.8475	-162.956	42	38	
HX213	113	CNCX6	9/1/98 03:53	57.9247	-162.873	43	38	
HX213	114	CNCX10	9/1/98 05:30	58.0791	-162.708	37	35	
HX213	115	CNCX12	9/1/98 07:02	58.2357	-162.541	35	33	
HX213	116	CNCX14	9/1/98 08:32	58.3915	-162.375	36	34	
HX213	117	CNCX16	9/1/98 10:06	58.5472	-162.212	43	41	
HX213	118	CNEX17	9/1/98 21:23	58.5721	-161.946	27	27	CTD/Prod-Z
HX213	119	CNEX17	9/1/98 21:44	58.5717	-161.954	28	28	Prod-R
HX213	120	CNEX15	9/2/98 00:49	58.4145	-162.114	44	38	
HX213	121	CNEX15	9/2/98 19:51	58.415	-162.12	44	43	
HX213	122	CNEX	9/2/98 21:04	58.2588	-162.284	33	31	
HX213	123	CNEX11	9/2/98 22:16	58.1043	-162.451	36	34	
HX213	124	CNEX9	9/2/98 23:23	57.9868	-162.576	41	40	CTD/Prod.Z
HX213	125	CNEX9	9/2/98 23:40	57.9893	-162.574	41	4	Prod-Z
HX213	126	CNEX9	9/2/98 23:52	57.9884	-162.574	41	29	Prod-R
HX213	127	CNC01	9/3/98 21:00	57.6919	-163.125	45	43	Prod-Z
HX213	128	CNC01	9/3/98 21:28	57.6911	-163.127	45	22	Prod-R
HX213	129	CNC17	9/4/98 21:31	56.8774	-164.003	71	69	Prod-Z
HX213	130	CNC17	9/4/98 21:59	56.8749	-164.003	71	3	Prod-R
HX213	131	CNC20	9/5/98 03:02	56.6446	-164.25	76	71	
HX213	132	CNC19	9/5/98 03:47	56.7219	-164.167	74	70	
HX213	133	CNC18	9/5/98 04:33	56.7993	-164.083	74	70	
HX213	134	CNC17	9/5/98 05:18	56.8762	-164.001	72	68	
HX213	135	CNC16	9/5/98 06:05	56.954	-163.918	70	65	
HX213	136	CNC15	9/5/98 06:51	57.0314	-163.834	69	63	
HX213	137	CNC14	9/5/98 07:38	57.1086	-163.752	66	62	

Nutrient and Pigment Studies

Terry Whitledge, Keven Neely and Taekeun Rho

The nutrients and plant pigments at the Slime Bank were nearly typical with relatively low nutrients at the surface with increasing concentrations offshore and deeper representing the proximity of deeper basin waters. Inshore depletion of nitrate below 1 uM corresponded to low salinity waters that contained low amounts of chlorophyll. The maximum chlorophyll concentrations were located about 40-50 km offshore in transects SBA, SBC and SBE as shown by the figures. Stratification was sufficient to allow the rather typical looking diatom bloom to at about the 60m isobath. Ammonium concentrations were somewhat higher than expected but may be due to larger amounts of regeneration in the warmer than usual waters.

The coccolithophorid bloom was first observed on the transit from the Slime Bank grid to the Cape Newenham line. The entire CN line was positioned within the Coccolithophorid bloom waters. The stratification on outer end of the Cape Newenham line was strong but the inner end was well mixed. The transition from the stratified to unstratified had the classic structure of the inner front. Nutrients in the upper layer were depleted in the middle shelf but normal concentrations in the bottom layer (NO3=10uM; SiO4=25uM; PO4=2.5uM and NH4=6 uM). The unstratified inner shelf end of the transect was nearly uniform with nitrates < 1uM and silicates between 5 and 10uM. The relatively high chlorophyll in the upper stratified layer declined to small values throughout the water column on the inner half of the transect. The transect was terminated at the 40m isobath due to high wind conditions.

Water stratification was relatively strong on the Nunivak Island transects centered between 30-35m. Inshore waters were relatively well mixed. Nitrate was about 2-3 uM in the upper layer and the chlorophyll maximum tended to be located at about 20m on the offshore end. Nitrate was depleted from the entire water column on the inner shelf and the chlorophyll fluorescence showed no significant accumulation. Coccolithophorids were present at all locations of the transect but the relative numbers were possibly lower in the low salinity waters nearest the coast.

The long transect from Nunivak Island to St. Paul Island clearly showed the well mixed waters at either end of the transect while stratification was quite strong in the center probably as a result of the "cold pool". The dramatic change in nitrate, silicate, ammonium and phosphate concentrations about 100 km from Nunivak Island clearly delineated the middle front. There was no apparent change in plant pigment fluorescence across the nutrient gradients.

Five nutrient ammendment experiments were carried out in diatom (Slime Bank) and coccolithophorid (Nunivak Island) dominated waters. Shipboard fluorescence measurements indicated that nitrate plus phosphate, ammonium plus phosphate, and iron additions gave the largest responses. Filters and HPLC samples will be examined to quantify the changes during the 5-7 day incubations.

^{14}C Primary Production

Stephan I. Zeeman

On HX213 we collected our usual primary productivity samples for ^{14}C incubations. These were *in situ* incubations, and on-deck incubator experiments to determine P-I curves. We did P-I curves at 14 stations and *in situ* experiments at 12 of those. Chlorophyll for the productivity samples was analyzed on board by freezing the filters and then cold extracting them for 24 hours prior to measuring fluorescence.

Samples were collected for phytoplankton counts by two methods. Samples were preserved in neutral Lugol's solution or filtered on 0.45 µm membrane filters and air dried. Samples for counts were collected from all productivity samples and also at several depths at stations along one of the transect lines at each grid. Samples will be counted later with an inverted microscope.

Similar to the phytoplankton counts, DOM samples were collected at several depths along one of the transect lines on each grid. These were prepared by filtering 50 ml samples through GF/F filters, freezing the water and keeping them in darkness. These will be analyzed by spectrofluorometry later.

DMS samples were collected for Maureen Keller at Bigelow Laboratory for Ocean Sciences. As with the phytoplankton and DOM samples, these were collected at several depths along one transect on each grid. Samples were put in vials, injected with KOH and capped with serum caps.

At each site for an *in situ* productivity measurement, we deployed a Tethered Spectroradiometer Buoy (TSRB). This instrument measures incident irradiation at one wavelength and upwelled radiance at 7 wavelengths corresponding to those measured by the SeaWiFS satellite. The TSRB was in the water for about 30-40 minutes, at least twice during an overpass of the satellite under relatively clear skies.

DOM, Phytoplankton in Lugol's, Phytoplankton dried on filter, DMS

C line at Slime Bank - 49 samples each
SBC1 24, 20, 10, 0 m
SBC2 30, 20, 10, 0 m
SBC3 40, 30, 20, 10, 0 m
SBC4 48, 30, 20, 10, 0 m
SBC5 44, 30, 20, 10, 0 m
SBC6 72, 0 m
SBC7 80, 50, 20, 0 m
SBC8 92, 50, 20, 0 m
SBC9 92, 50, 20, 0 m
SBC10 94, 60, 30, 0 m

SBC11 93, 40, 20, 0 m
SBC12 90, 50, 20, 0 m

C line at Cape Newenham - 16 samples each
CNC16 30, 0 m
CNC14 30, 0 m
CNC12 30, 0 m
CNC10 30, 0 m
CNC8 30, 0 m
CNC6 30, 0 m
CNC4 30, 0 m
CNC2 30, 0 m

C line at Nunivak Island - 24 samples each
NIC12 30, 0 m
NIC11 30, 0 m
NIC10 30, 0 m
NIC9 30, 0 m
NIC8 30, 0 m
NIC7 30, 0 m
NIC6 30, 0 m
NIC5 30, 0 m
NIC4 30, 0 m
NIC3 30, 0 m
NIC2 30, 0 m
NIC1 30, 0 m

Productivity - 14 on-deck prods, 10 *in situ* prods (200 *in situ*, 405 P-I samples)
SBE6 - *in situ* 0, 5, 10, 20 m, on-deck 0, 20 m
SBC1 - *in situ* 0, 5, 10, 15 m, on-deck 0 m
SBC12 - *in situ* 0, 10, 15, 20 m
CNC12 - on-deck 0 m
NIC12 - on-deck 0 m
NIA11 - on-deck 12 m
NIC1 - *in situ* 0, 5, 10, 15 m, on-deck 0 m
NICX8 - *in situ* 0, 5, 10, 15 m, on-deck 0 m
NIC8 - *in situ* 0, 5, 10, 15 m, on-deck 15 m
CNC4 - *in situ* 0, 5, 10, 15 m, on-deck 15 m
CNEX17 - *in situ* 0, 5, 10, 15 m, on-deck 0 m
CNEX9 - on-deck 0 m
CNC1 - *in situ* 0, 5, 10, 15 m, on-deck 0, 15 m
CNC17 - *in situ* 0, 5, 10, 15 m, on-deck 15 m

The optical measurements.

Viktor G.Egorov

The optical properties of ocean waters were investigated at stations SBE6, SBC1, SBC12, CNC12, NIC12, NIA7, NIA11, NIC1, NICX8, NIC8, CNC4, CNEX17, CNEX9, CNC01, CNC17.

PUV-500 submersible spectrophotometer (Biospherical Instruments, Inc.) was used for determination of the intensity of solar fluxes in 305 nm, 320 nm, 340 nm, 380 nm and PAR spectral regions and natural fluorescence (NF). The spectrophotometer consists of two main parts - one submersible and the other on deck. The two provide simultaneous measurements and allow for correction of incident irradiance fluctuations when measuring the underwater light field.

The measurements were used to calculate the coefficients of absorption of a sea waters at 305 nm, 320 nm, 340 nm, 380 nm and PAR spectral regions and distribution of Chlorophyll A in the water with a depth at each station. The data on irradiation at different depths allows one to determine the "DNA weighted" doses of UV irradiation of marine microorganisms.

All measurements were conducted simultaneously with sampling for primary productivity.

In the framework of a program of the development of DNA dosimeters four groups of samples containing unshielded DNA were exposed under the Sun for the period of 1,2,3 and 5 days . The intensities of solar fluxes were recorded continuously during this time. The amount of damaged DNA will be determined at the lab. The DNA results and solar fluxes will be used to determine biologically effective doses.

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New Productivity Studies

T. Rho and J. Goering

Productivity studies were conducted on the R/V Alpha Helix cruise HX213 in the Bering Sea from 15 August to 6 August. At productivity studies the rates of photosynthesis and nitrogen uptake(NO_3^-, NH_4^+ and Urea) were measured in the euphotic zone 100%, 50%, 30%, 12%, 5% and 1% surface light penetration depths.
The photosynthetic and nitrogen uptake rate measurements were estimated by addition of $H^{13}CO_3^-$, $^{15}NO_3^-$, $^{15}NH_4^+$ and ^{15}N-Urea to euphotic zone water collected at the choosen light depths. Euphotic zone light levels were determined with an underwater PAR sensor. After additon of ^{13}C and ^{15}N enriched compound the uptake sample were incubated on deck for about 4 hours in a surface sea water cooled tank exposed to 100%,50%, 30%, 12%, 5%, and 1% surface light intensities(light levels were simulated using neutral density metal screen that attenuated the surface light to the above value. We filtered seawater for the analysis of natural abundance of ^{13}C and ^{15}N of phytoplankton at each productivity station . We also measured pH of seawater at each depth productivity is measured for calculation of total CO2. At CNC17 station, we did some addition study of 13C and 15NO3 uptake; Control ($^{13}C + {^{15}NO_3}$), Treatment #1($^{13}C + {^{15}NO_3}$+ Fe), Treatment #2($^{13}C + {^{15}NO_3}$+Fe+PO4), Treatment #3(^{13}C + $^{15}NO_3$+Fe+PO_4)

The following table is summary of the productivity studies conducted on Alpha Helix 213.
These studies will provide us with information needed to estimate photosynthetic carbon uptake and the proportions of new productivity(NO_3^- uptake) and regenerated productivity(NH_4^+ and Urea uptake) at Inner Shelf region of Bering Sea.

	Station	^{13}C	$^{15}NO_3$	$^{15}NH_4$	^{15}N-Urea	Nat'l 13C &15N	pH
1	SBE06	O	O	O	O	O	O
2	SBC01	O	O	O	O	O	O
3	SBC12	O	O	O	O	O	O
4	CNC12	O	O	O	O	O	O
5	NIA01	O	O	O	O	O	O
6	NIC01	O	O	O	O	O	O
7	NICX08	O	O	O	O	O	O
8	NIC08	O	O	O	O	O	O
9	CNC04	O	O	O	O	O	O
10	CNCX17	O	O	O	O	O	O
11	CNCX9	O	O	O	O	O	O
12	CNC01	O	O	O	O	O	O
*13	CNC17	O	O			O	O

At each station we measure primary production at six light depths ,100, 50, 30, 12, 5, and 1%, for each substrate
* addition study of ^{13}C and $^{15}NO_3$ uptake

Zooplankton

Ken Coyle and Alexey Pinchuk

One of the major goals of the Inner Front project is the determination of the effects of frontal circulation on energy transfer to apex predators. Shorttail shearwaters, which feed primarily on euphausiids, serve as the apex predator in this project. Zooplankton are therefore the critical link between processes influencing production at the inner front and its ultimate transfer to shearwaters. The primary task of the zooplankton component is determination of the species composition, concentration and distribution of the major zooplankton taxa at the four study grids.

Zooplankton species composition, abundance and horizontal distribution were assessed at stations in the mixed, frontal and stratified regimes using a 1-m square MOCNESS system equipped with 0.5 mm mesh. In addition, the distribution of large zooplankton, micronekton and fish was assessed with an HTI model 244 multifrequency split beam acoustic system. Operating frequencies included 43, 120, 200 and 420 kHz. Transects were run from the near-shore mixed region across the front and into the stratified area to assess target distribution relative to the three hydrographic regimes. Acoustic data were also collected concurrently with each MOCNESS tow to aid in target strength determinations for scaling the acoustic data. Microzooplankton were collected with a CalVET net to assess the density of small copepods and euphausiid larvae. The CalVET net, equipped with 0.150 mm mesh, was towed vertically from the bottom to the surface at CTD stations along transect C in each sampling grid All samples were preserved in formalin for later analysis. Selected taxa from various trophic levels were sorted from tows taken in the various hydrographic regimes in each grid; the specimens were acidified, dried at 60° C and returned to the lab for stable isotope analysis. A summary table of all of the samples collected is provided below.

Generally, zooplankton and nekton at Slime Bank and Cape Newenham were dominated by fish and jelly fish. The fish included zero class pollock, however, target strength measurements from the split beam transducers indicate the presence of larger fish, particularly at Slime Bank. Although juvenile pollock were present at Nunivak Island, the samples were dominated by euphausiids, primarily *Thysanoessa rachii* adult males, females with spermatophores and juveniles. A scattering layer containing euphausiids was present near the bottom along the entire transect from deep to shallow water at the Nunivak site. Juvenile *Thysanoessa inermis* were present at Slime Bank and adult *Thysanoessa spinifera* occurred in the stratified regime at Cape Newenham. The zooplankton during the 1998 sampling season seemed to be dominated by euphausiids, in contrast to 1997 when the dominant zooplankter was *Calanus marshallae*. Detailed comparisons will be done following sample analysis.

Zooplankton samples collected during Alpha Helix research cruise HX213 (August 15 - September 7, 1998).

Type of samples	Slime Bank	Nunivak Island	Cape Newenham
CalVET	12	11	18
MOCNESS	62 (9 tows)	73 (11 tows)	71(10 tows)
Isotope	24	56	20

Marine Ornithology (Cheryl Baduini, David Hyrenbach, Heather Revillee and John Carlson).

Marine Ornithology

Cheryl Baduini, John Carlson, K. David Hyrenbach and Heather Revilee

Samples collected: Surveys of bird distribution and abundance: 1065 km trackline,
125 hours survey effort, 49, 730 birds encountered
Birds collected for prey analysis: 41
Samples collected for stable isotope analyses: 164
Samples collected for lipid analysis: 129

Preliminary results and interpretation:

The objectives of the ornithological portion of this study were to determine the distribution, abundance and foraging patterns of short-tailed shearwaters relative to the structural inner front located within each of the study areas. These observations were recorded to determine if short-tailed shearwaters, the apex predators in this study, focus their foraging efforts in frontal waters. A second objective was to determine the diet composition of foraging shearwaters relative to prey abundance and availability within each of the study areas. Additionally, we collected information on stable isotope ratios and fatty acid composition relative to trophic structure and long-term diet trends of short-tailed shearwaters in the eastern Bering Sea.

Bird observations were made when the ship was underway at speeds of 5 knots or greater. All birds within an arc of 90° from the bow to the side with the best visibility were counted from the bridge, and were recorded on a laptop computer for later analysis. Behaviors of all birds were recorded, with particular attention paid to whether shearwaters were feeding by hydroplaning at the surface or were diving deeply.

Forty-one shearwaters were collected in the study areas to assess stomach contents and foraging patterns. Shearwaters were collected when feeding, if possible, or when resting at the surface, if necessary. Morning collections were made at Slime Bank, Cape Newenham, and Nunivak Island grids. Two evening collections were made in the Cape Newenham grid and just offshore of the CN grid in the middle shelf area (57° 15.34 N 166° 39.74 W). Stomach contents were removed from short-tailed shearwaters immediately after collection and stored in 80% ethyl alcohol/distilled water for processing in the laboratory.

Slime Bank:

We observed few shearwaters (average density=76 birds/km^2) overall, in the Slime Bank grid and found little evidence of shearwaters foraging in the area (Fig). The only indication of foraging that we observed were small groups (50-100 birds) sitting on the surface with their heads underwater. A total of 10 birds were collected on two consecutive mornings well inshore of the front around Station E3. The biomass of stomach contents was low (1-18 g, and one 42 g sample) and a wide variety of prey items was observed such as juvenile euphausiids, *T. raschii* and *T. spinifera,* as well as crab megalopie, and fish tissue. Preliminary examination of MOCNESS tows collected at this site showed an abundance of juvenile *T. inermis*, *T. spinifera*, and a few juvenile *T. raschii*, as well as juvenile walleye pollock (*Theragrama chalcograma*). There was a lack of mature adult *T.raschii*, usually the most common prey item of short-tailed shearwaters in the southeastern Bering Sea, collected in the MOCNESS tows at this site.

Cape Newenham:

Our best observation of foraging by short-tailed shearwaters occurred in the Cape Newenham grid, and just offshore of the outer grid over the middle shelf (Fig). Upon transit to the Newenham grid, we observed approximately 2,000 shearwaters engaged in shallow, short (15-30 sec) plunge dives and feeding with black-legged kittiwakes and at least two humpback whales. The nine birds collected in this area contained recognizable juvenile pollock or partially digested fish assumed to be pollock. Whole specimens of the fish were removed to take back to the laboratory for further analysis. We suspect some of the bird specimens collected may belong to the species, sooty shearwater, *P. griseus*. Because it is difficult to differentiate between sooty and short-tailed shearwaters in the field, a detailed analysis of morphometrics will be conducted in the laboratory to verify their identity.

Within the Cape Newenham grid, loose foraging flocks (up to 100 individuals per flock) were observed foraging well inshore of the structural front around Station EX17 and 9 individuals were collected during two morning attempts. Collection was difficult due to significant winds and stormy weather, along with the unusually rapid formation and subsequent dispersal of foraging groups. The shearwaters were feeding with black-legged kittiwakes and tufted puffins. Eight of nine birds collected contained sandlance and partially digested fish. Whole specimens of sandlance were removed to take back to the lab for analysis of fatty acid composition. The identity of these shearwaters, also needs to be confirmed. Preliminary examination revealed that the foraging flocks might contain both *P. tenuirostris* and *P. griseus.*

A third evening collection was made of shearwaters foraging on juvenile pollock between stations C10 and C11, well offshore of the front in stratified water. Approximately 700 shearwaters were observed hydroplaning with their heads underwater and foraging just behind and after a large group of kittiwakes diving underwater.

No shearwaters were observed foraging in the Cape Newenham grid where there was any extent of coccolithophore bloorn.

Nunivak Island

No short-tailed shearwaters were observed foraging within the entire area comprising the inner and outer grids. Also, few shearwaters were sighted flying or sitting on the water in the area. Our expectation was that we would encounter more birds in this area during fall than in the spring, since this is an area where shearwaters migrate to in late summer/early fall. These observations were similar to last year's observations when we observed a major coccolithophore bloom and subsequent die-off of short-tailed shearwaters. However, this year, we saw no obvious die-off of shearwaters in the area (only 1 dead shearwater observed) though a strong coccolithophore bloom covered the entire Nunivak grid. Although there were no birds in the area, mature adult *T. raschii* were available in layers both on the bottom and in the water column (30-m) in both the outer and inner grids, as shown by the MOCNESS and acoustic records. The unusual finding of high biornass of adult euphausiids and few foraging shearwaters suggests that shearwaters do not forage in coccolithophore bloom areas possibly because they cannot detect or "see" prey items. Five birds were collected while flying past the vessel and four contained no prey items. One of five birds contained one adult euphausiid.

Summary:

In fall of 1998, we observed few flocks of foraging shearwaters and few total birds overall in all areas. The densities of birds feeding, sitting on the water, and overall, within each of the study areas were lower than last year during the same time period (Table 1). Because our effort covered a significant portion of the southeastern Bering Sea including not only our study sites but also off St. Paul Island, and during transit along the middle domain in between sites, our conclusion was that there were low numbers of shearwaters in the area during the fall 98 cruise. Moreover, birds collected in Jun and Aug/Sep 1998 had lower body mass than those collected in Jun 97 (Table 2). Shearwaters may have experienced poorer foraging conditions in. In particular, birds collected on this cruise had significantly lower body mass than during any season surveyed thus far (Table 2) and had low body fat. It is possible that under such poor feeding conditions, shearwaters may have migrated out of the southeastern Bering Sea earlier than usual (late Sept./early Oct.) or that a significant portion of the population occupied an area we did not survey.

An additional unusual observation was that shearwaters were foraging almost exclusively on fish, mostly juvenile pollock and sandlance. Because short-tailed shearwaters usually forage on euphausiids in the eastern Bering Sea, it is unusual to observe them foraging on a different prey resource in this area. It is possible that some of the shearwaters collected may belong to the species, *P. griseus*, which are piscivorous and usually, geographically limited to the Gulf of Alaska. A detailed morphometrics study on the collected specimens will reveal if *P. griseus* migrated further north into the Bering Sea than their usual range this year.

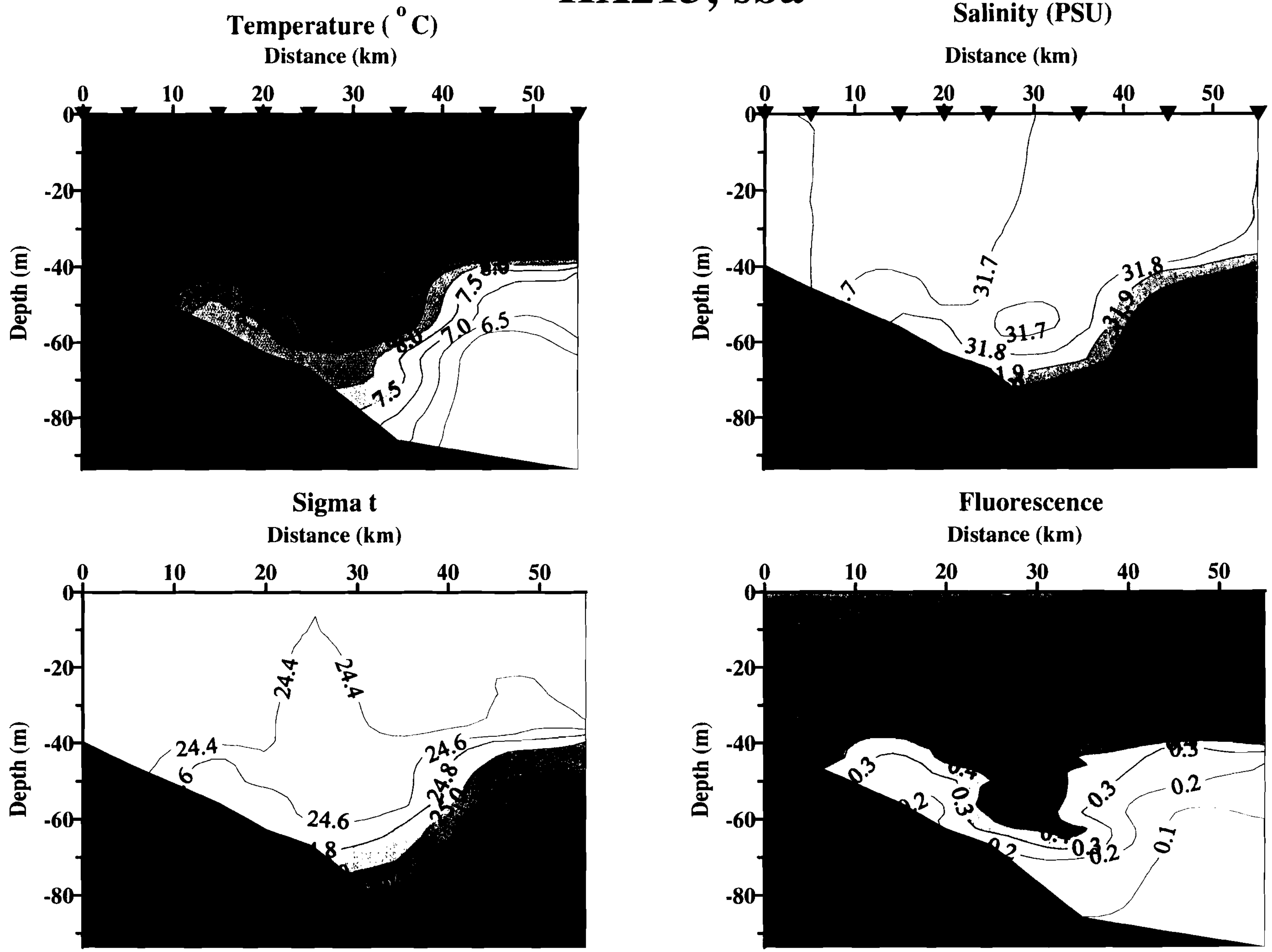
Table 1. **Densities of shearwaters during fall 1997 and 1998. (Birds / km ^{2})**

Site	Survey Effort (km trackline)	Mean ± s.e. (all behaviors)	Mean ± s.e. (feeding and on water)
Nunivak Island 1997	591	32.61 ± 8.43	3.53 ± 1.19
Nunivak Island 1998	543	19.23 ± 1.37	0.12 ± 0.07
Slime Bank 1997	210	188.86 ± 50.08	36.77 ± 11.59
Slime Bank 1998	210	76.18 ± 12.66	22.98 ± 9.81
Cape Newenham 1998	705	21.71 ± 4.11	5.57 ± 2.11

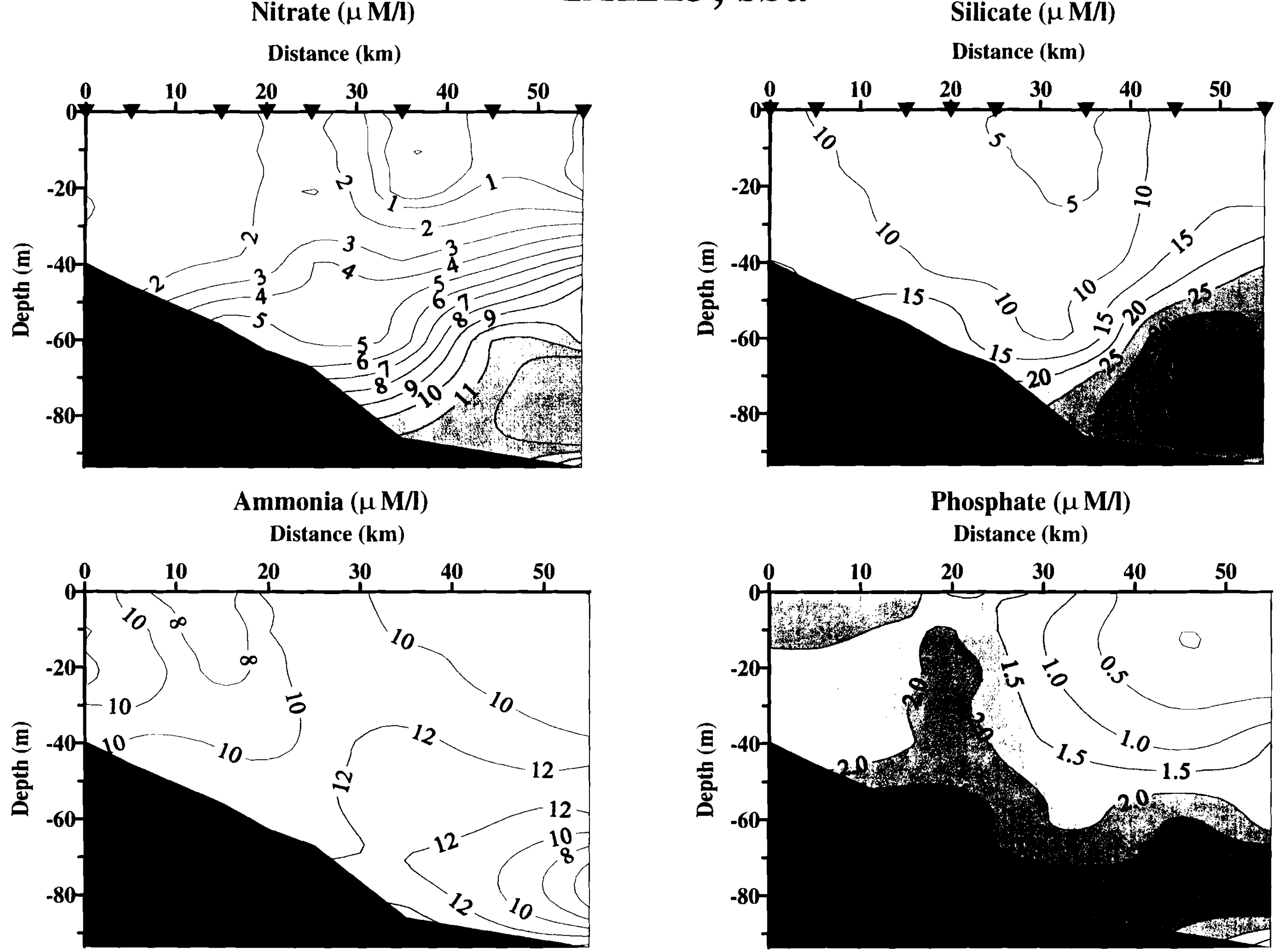
Table 2. Gross mass, mass of stomach contents, net mass, and sex ratios of shearwaters collected in the southeastern Bering Sea

Date	Sample Size	Mean gross Mass (g)	Mean mass stomachs (g)	Mean net mass (g)	% birds <500 g net mass	M/F
Jun 97	**39**	**656**	**57**	**598**	**0**	**10/25**
Sep 97	**55**	**535**	**19**	**517**	**42**	**36/17**
Jun 98	**51**	**579**	**48**	**532**	**14**	**27/22**
Sep 98	**41**	**531**	**33**	**498**	**61**	**29/12**
Aug 89	**26**	**572**	**14**	**559**	**?**	**7/17**

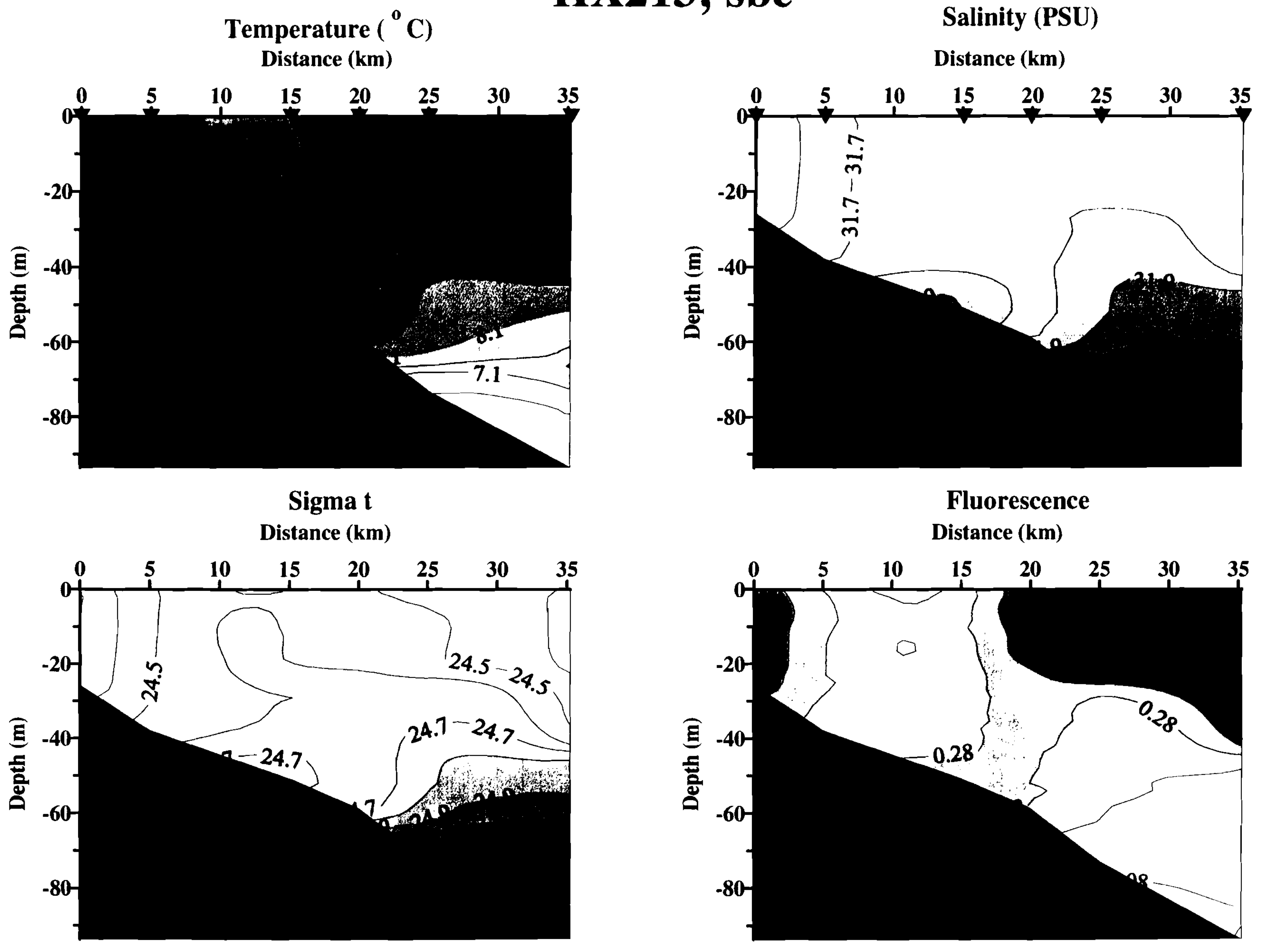
HX213; sba


Temperature (°C)
Distance (km)
Depth (m)
7.5
7.0
6.5
Salinity (PSU)
Distance (km)
Depth (m)
31.7
31.8
31.9
Sigma t
Distance (km)
Depth (m)
24.4
24.6
24.8
Fluorescence
Distance (km)
Depth (m)
0.3
0.2
0.1

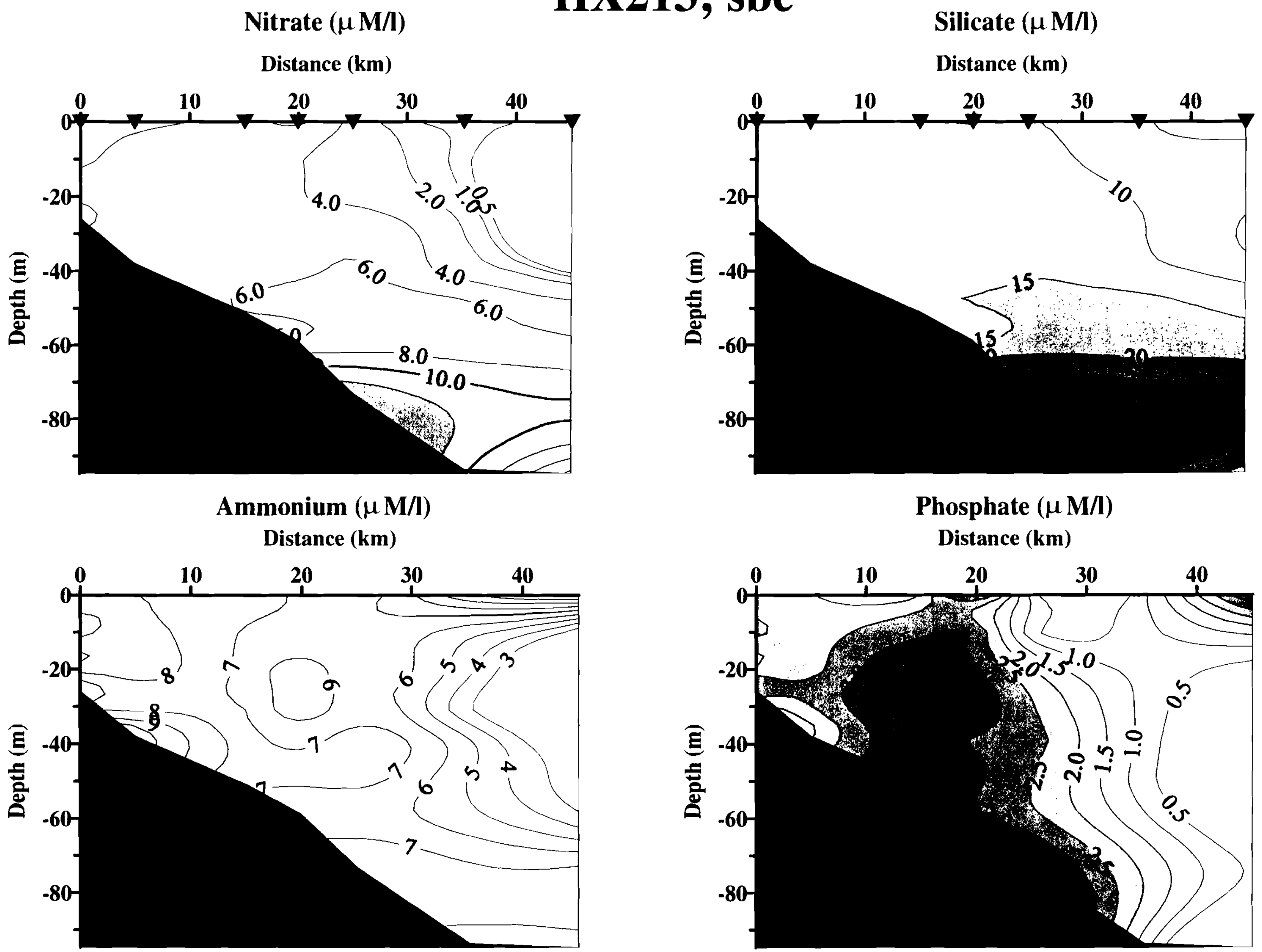
HX213; sba


Nitrate (µ M/l)
Distance (km)
Depth (m)
Silicate (µ M/l)
Distance (km)
Depth (m)
Ammonia (µ M/l)
Distance (km)
Depth (m)
Phosphate (µ M/l)
Distance (km)
Depth (m)

HX213; sbe

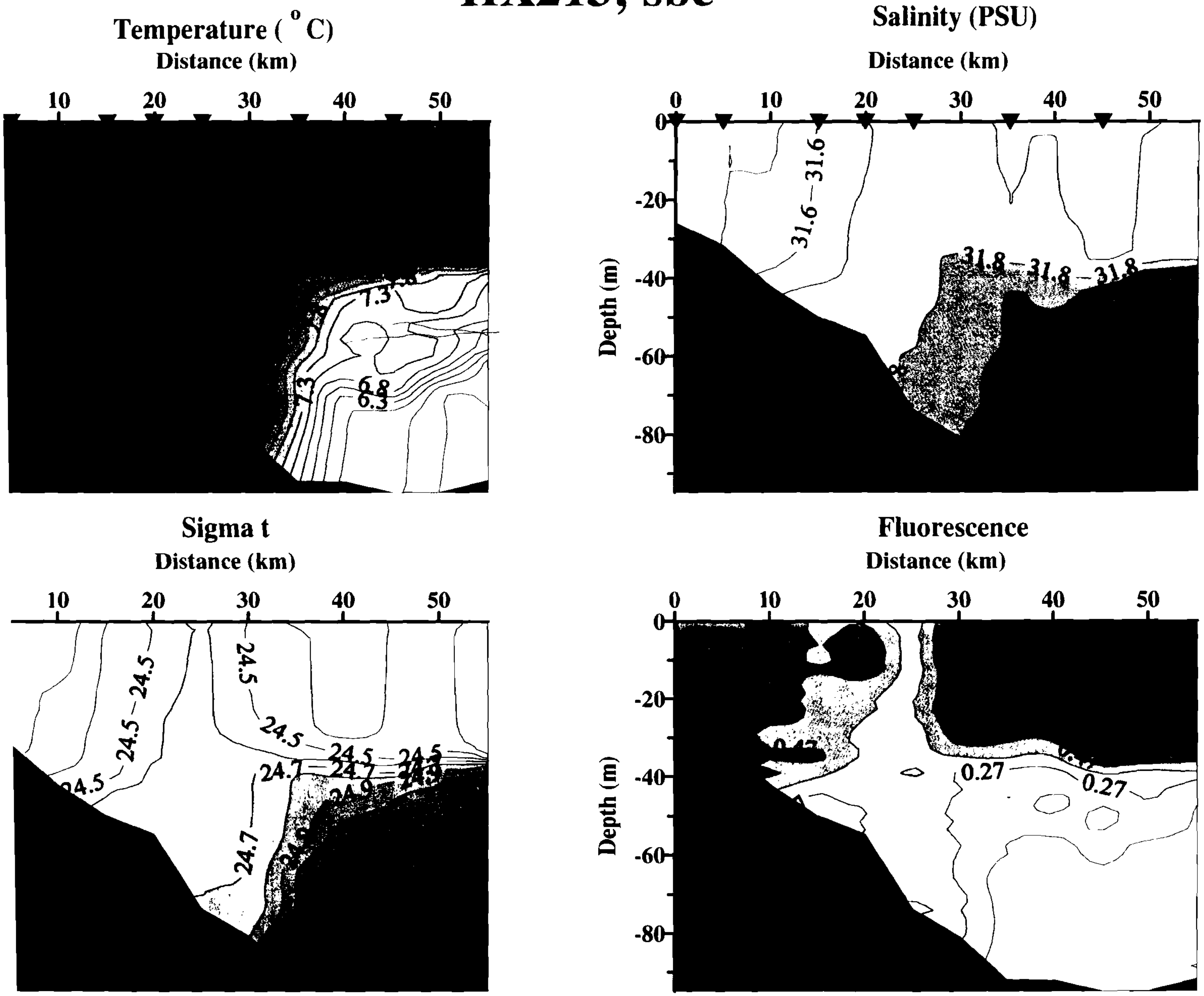

Temperature (°C)
Distance (km)
Depth (m)
7.1
Salinity (PSU)
Distance (km)
Depth (m)
31.7
Sigma t
Distance (km)
Depth (m)
24.5
24.7
Fluorescence
Distance (km)
Depth (m)
0.28

HX213; sbe



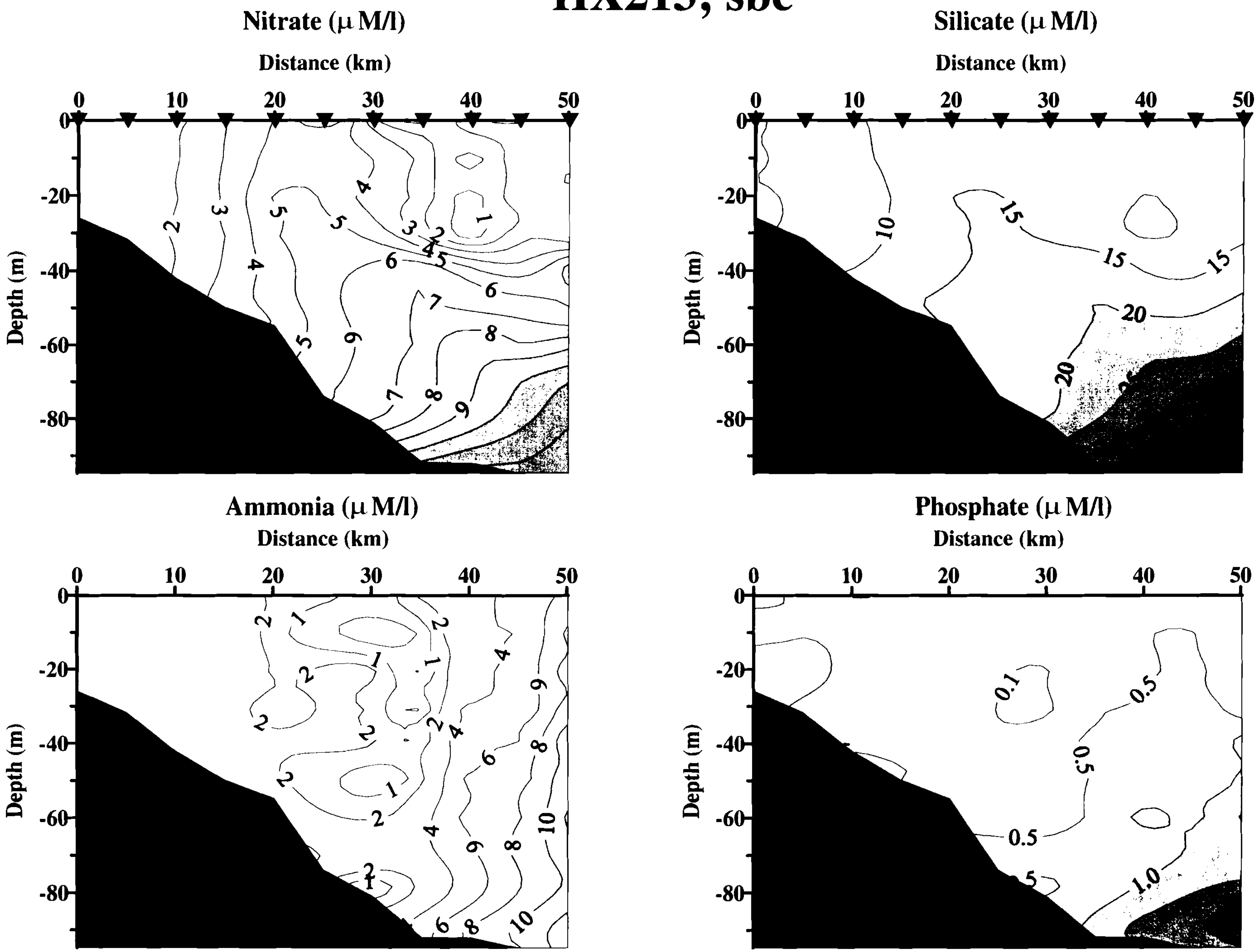
Nitrate (µ M/l)
Distance (km)
Depth (m)
Silicate (µ M/l)
Distance (km)
Depth (m)
Ammonium (µ M/l)
Distance (km)
Depth (m)
Phosphate (µ M/l)
Distance (km)
Depth (m)

HX213; sbc

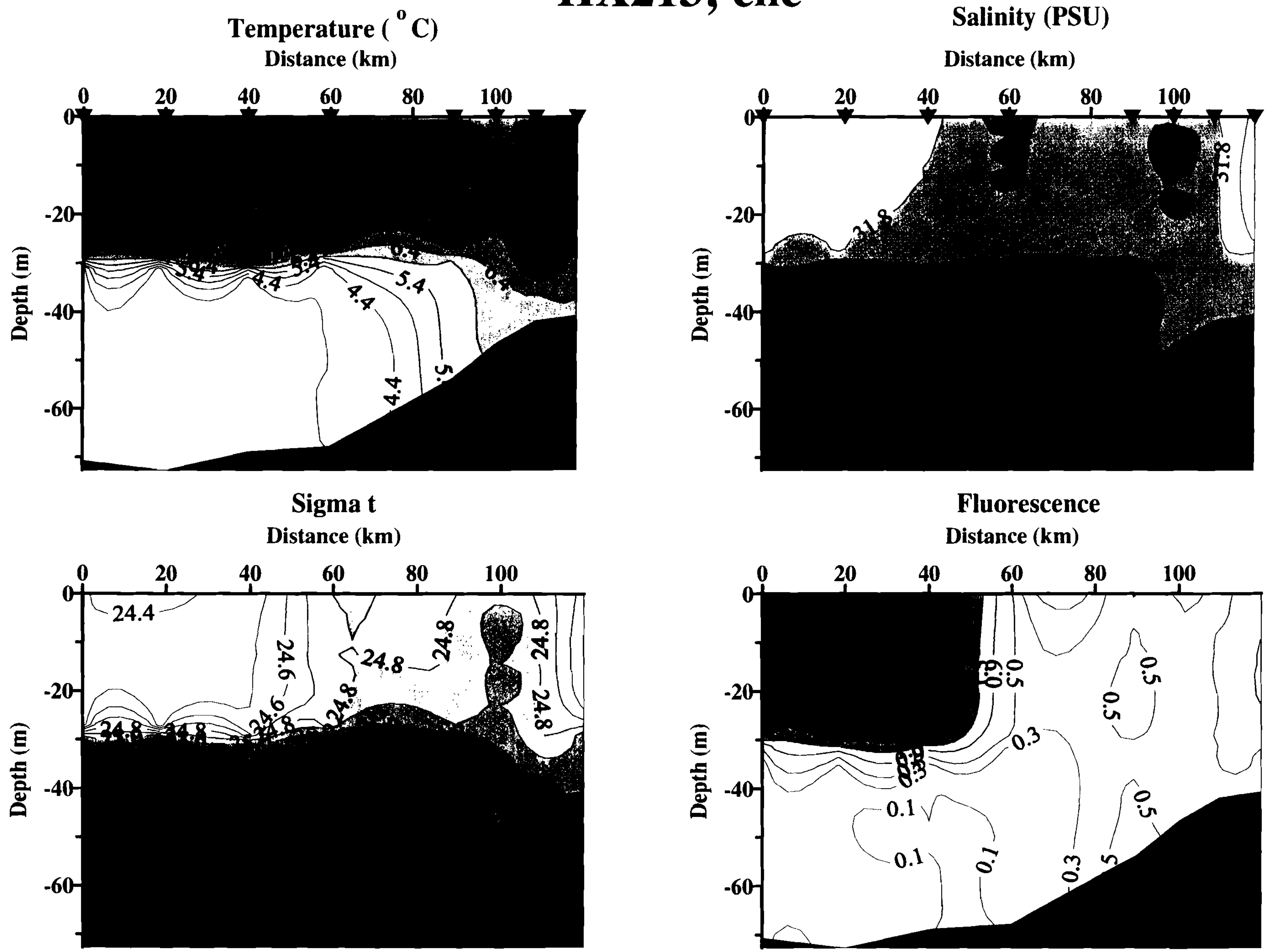


Temperature (°C)
Distance (km)
7.3
6.8
6.3
Salinity (PSU)
Distance (km)
Depth (m)
31.6
31.8
Sigma t
Distance (km)
24.5
24.7
Fluorescence
Distance (km)
Depth (m)
0.27

HX213; sbc


Nitrate (μ M/l)
Distance (km)
Depth (m)
Silicate (μ M/l)
Distance (km)
Depth (m)
Ammonia (μ M/l)
Distance (km)
Depth (m)
Phosphate (μ M/l)
Distance (km)
Depth (m)

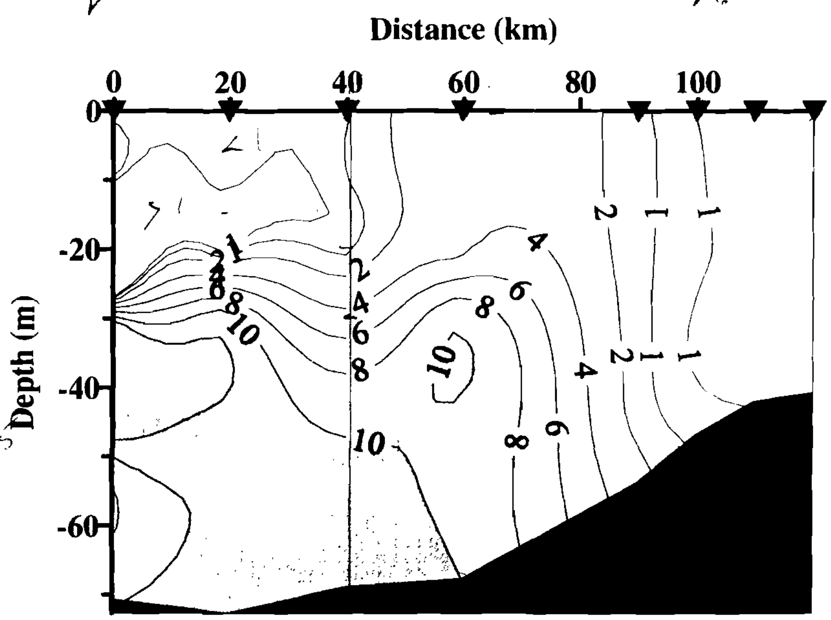
HX213; cnc



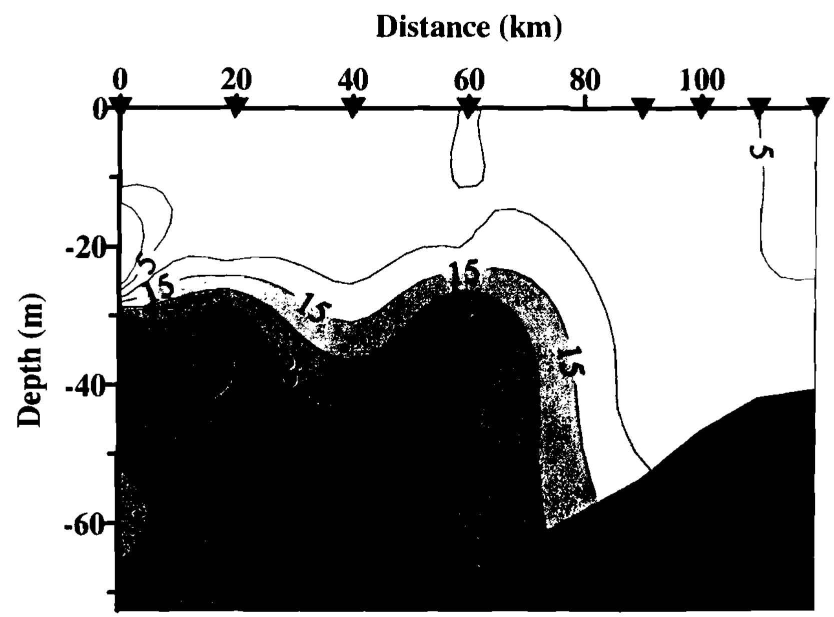
Temperature (°C)
Distance (km)
Depth (m)
Salinity (PSU)
Distance (km)
Depth (m)
31.8
Sigma t
Distance (km)
Depth (m)
24.4
24.6
24.8
Fluorescence
Distance (km)
Depth (m)
0.5
0.3
0.1

HX213; cnc

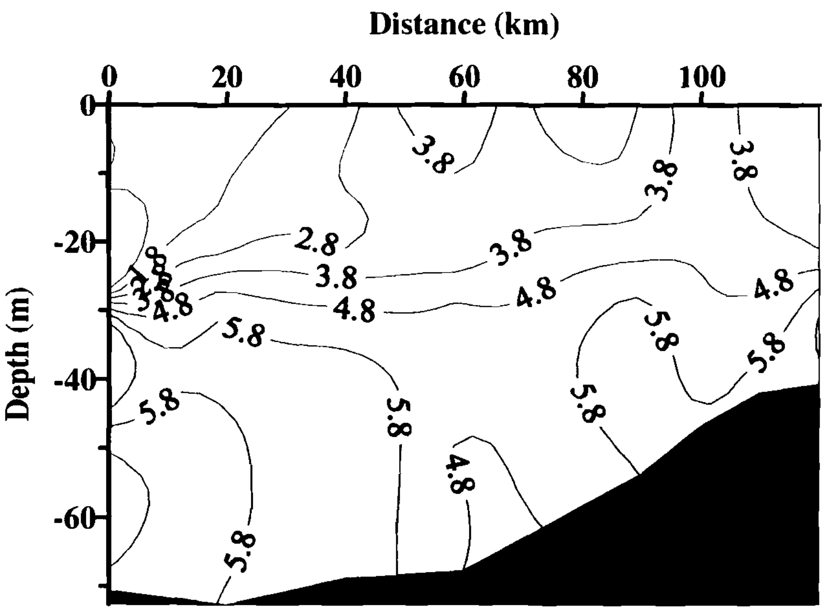
Nitrate (μ M/l)



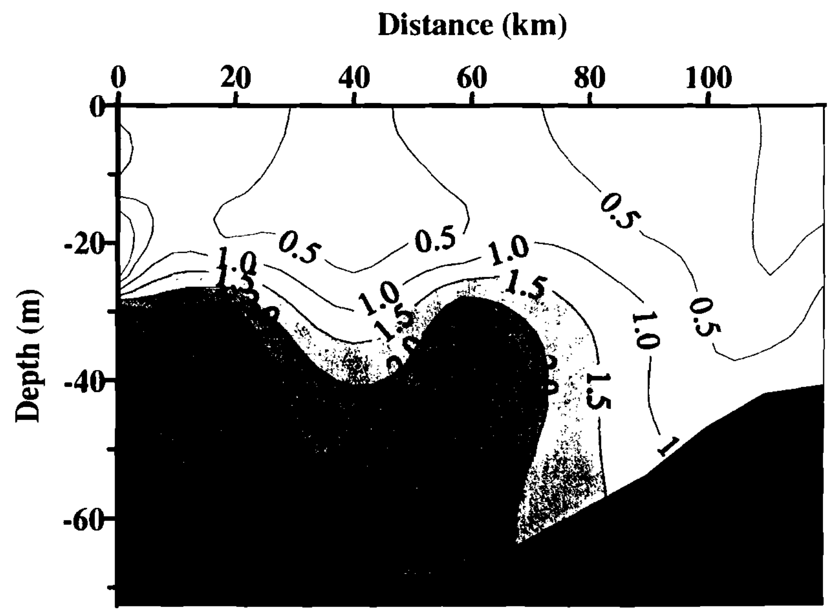
Silicate (μ M/l)



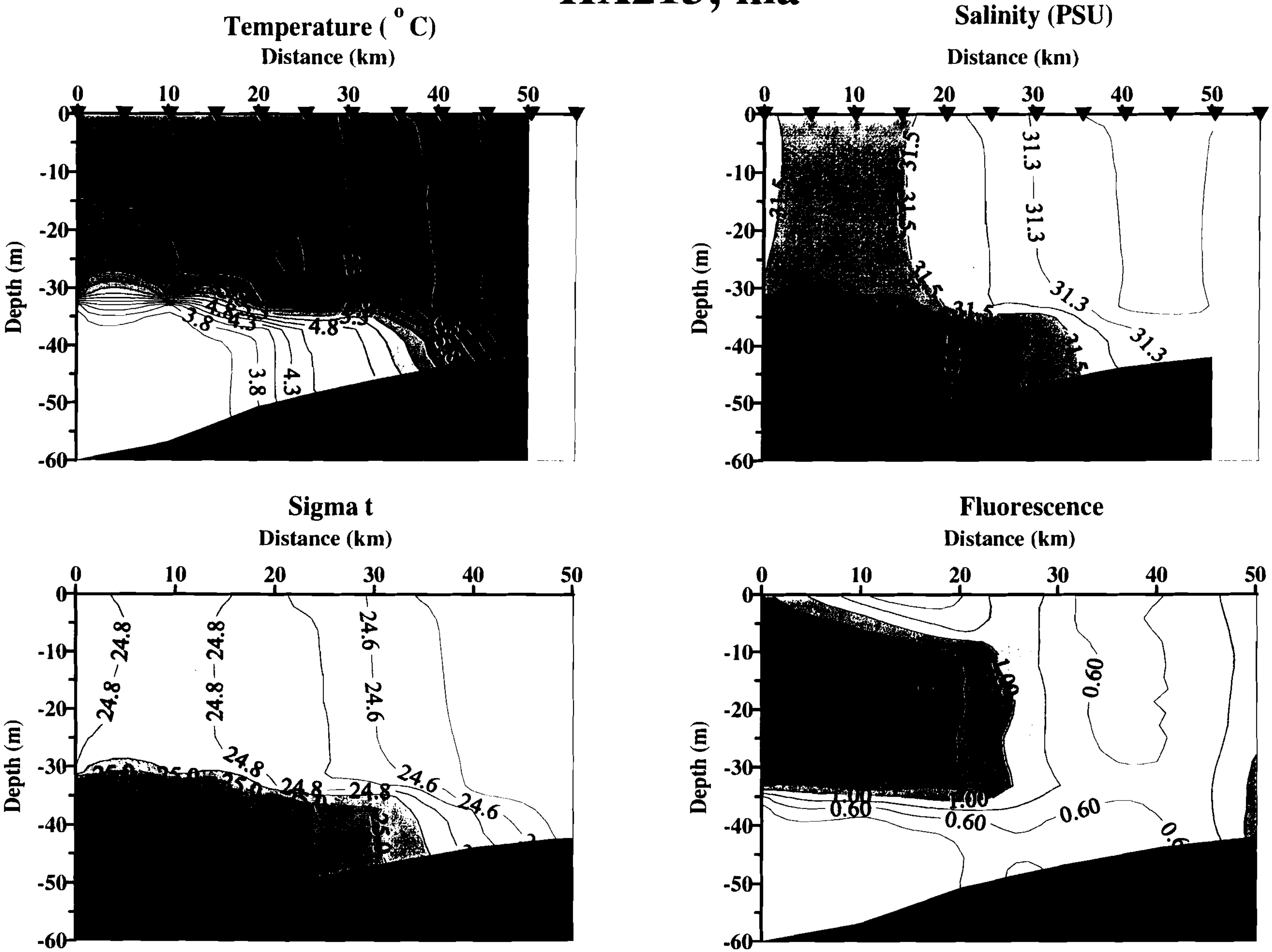
Ammonium (μ M/l)



Phosphate (μ M/l)

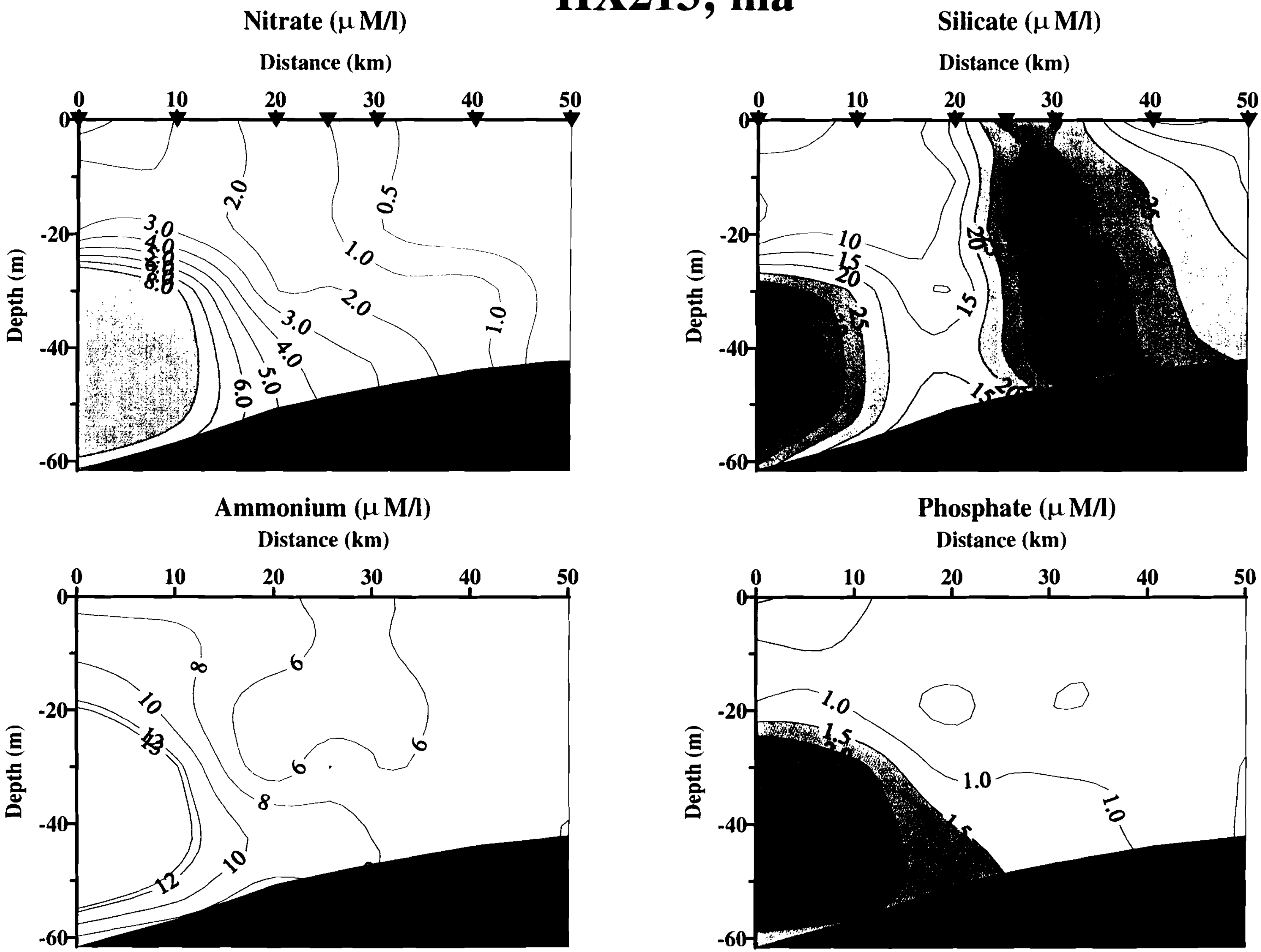


HX213; nia



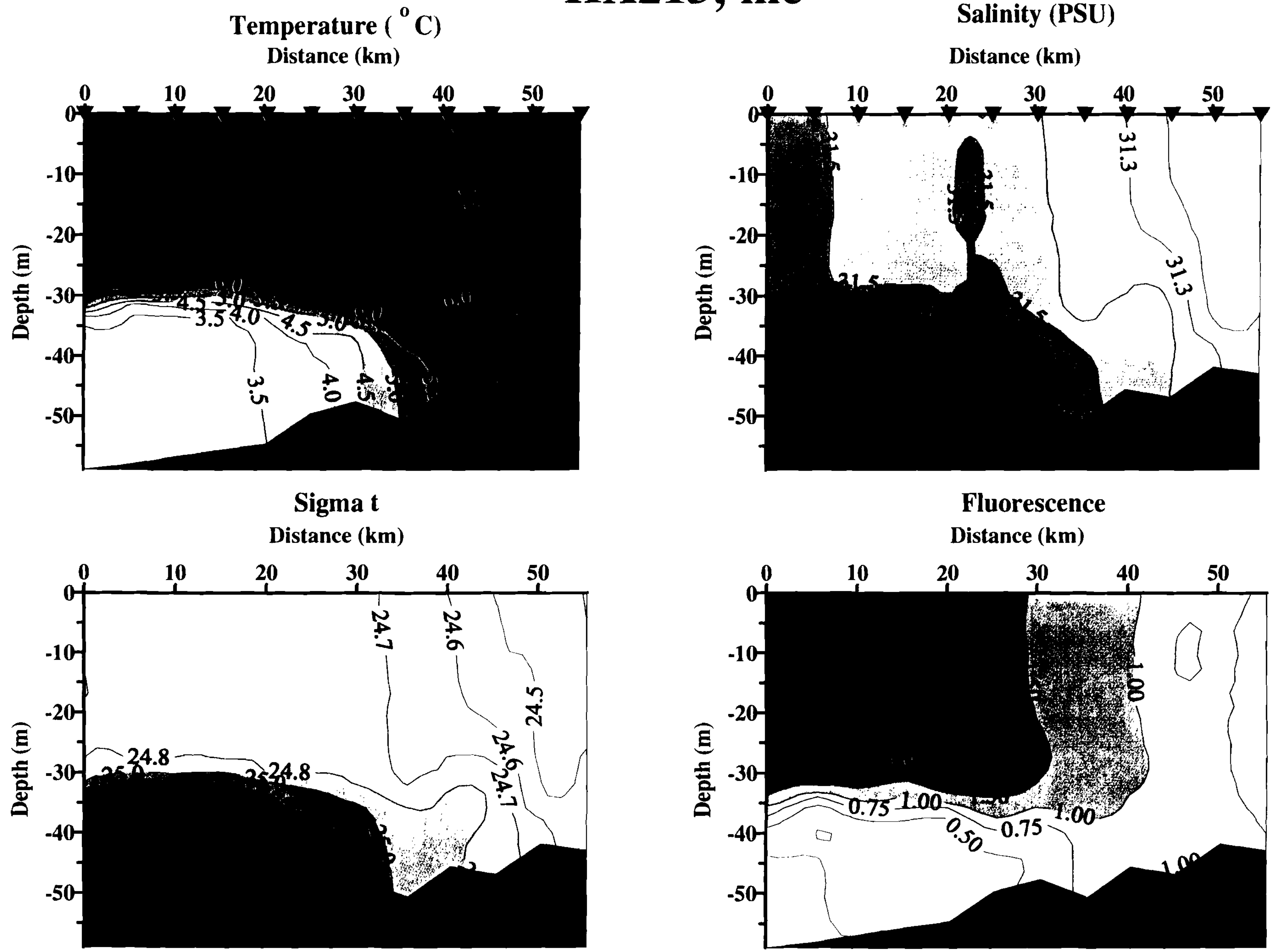
Temperature (°C)
Distance (km)
Depth (m)
4.8
4.3
3.8
Salinity (PSU)
Distance (km)
Depth (m)
31.3
31.5
Sigma t
Distance (km)
Depth (m)
24.8
24.6
Fluorescence
Distance (km)
Depth (m)
0.60
1.00

HX213; nia

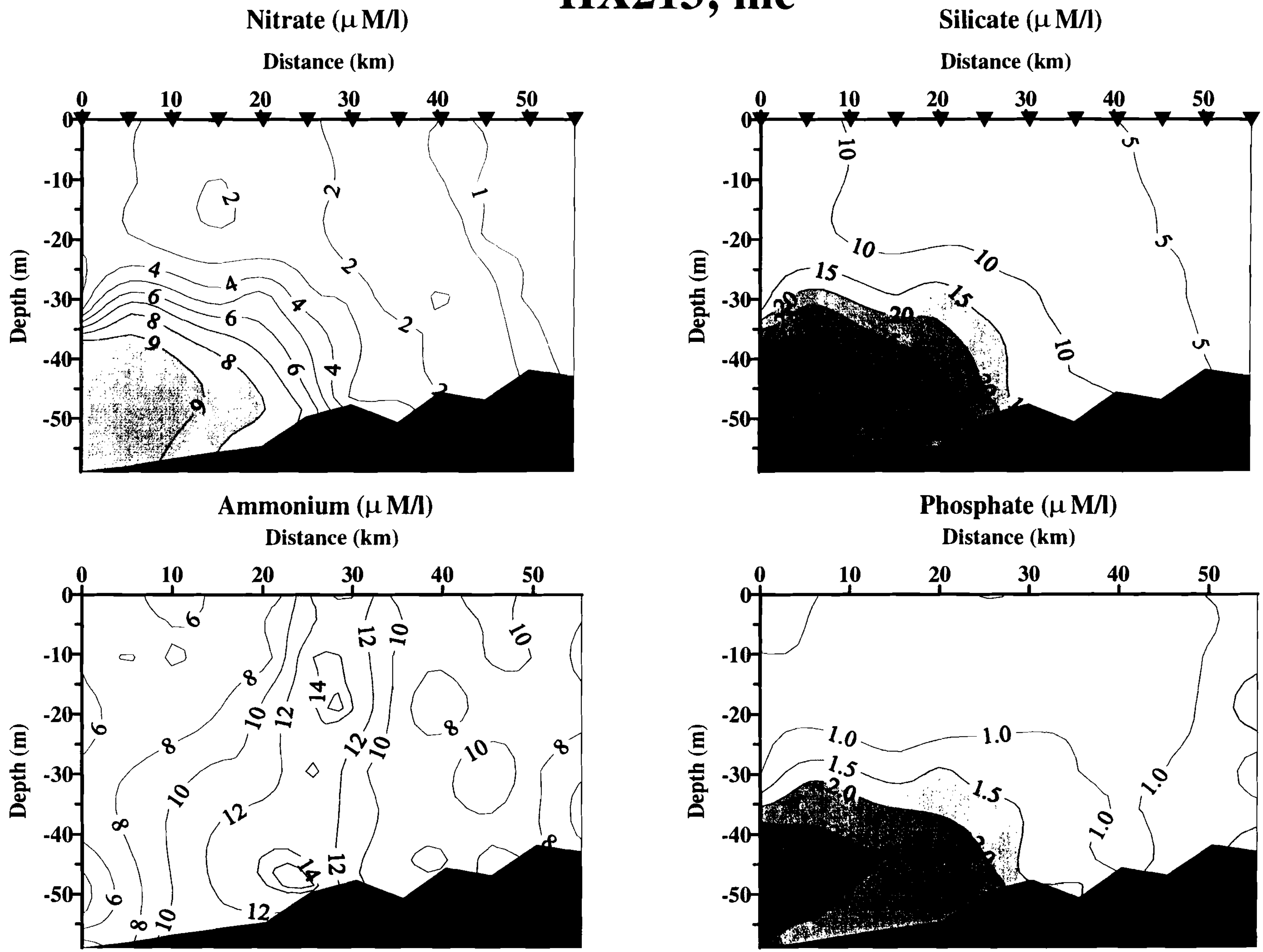


Nitrate (μ M/l)
Distance (km)
Depth (m)
Silicate (μ M/l)
Distance (km)
Depth (m)
Ammonium (μ M/l)
Distance (km)
Depth (m)
Phosphate (μ M/l)
Distance (km)
Depth (m)

HX213; nic

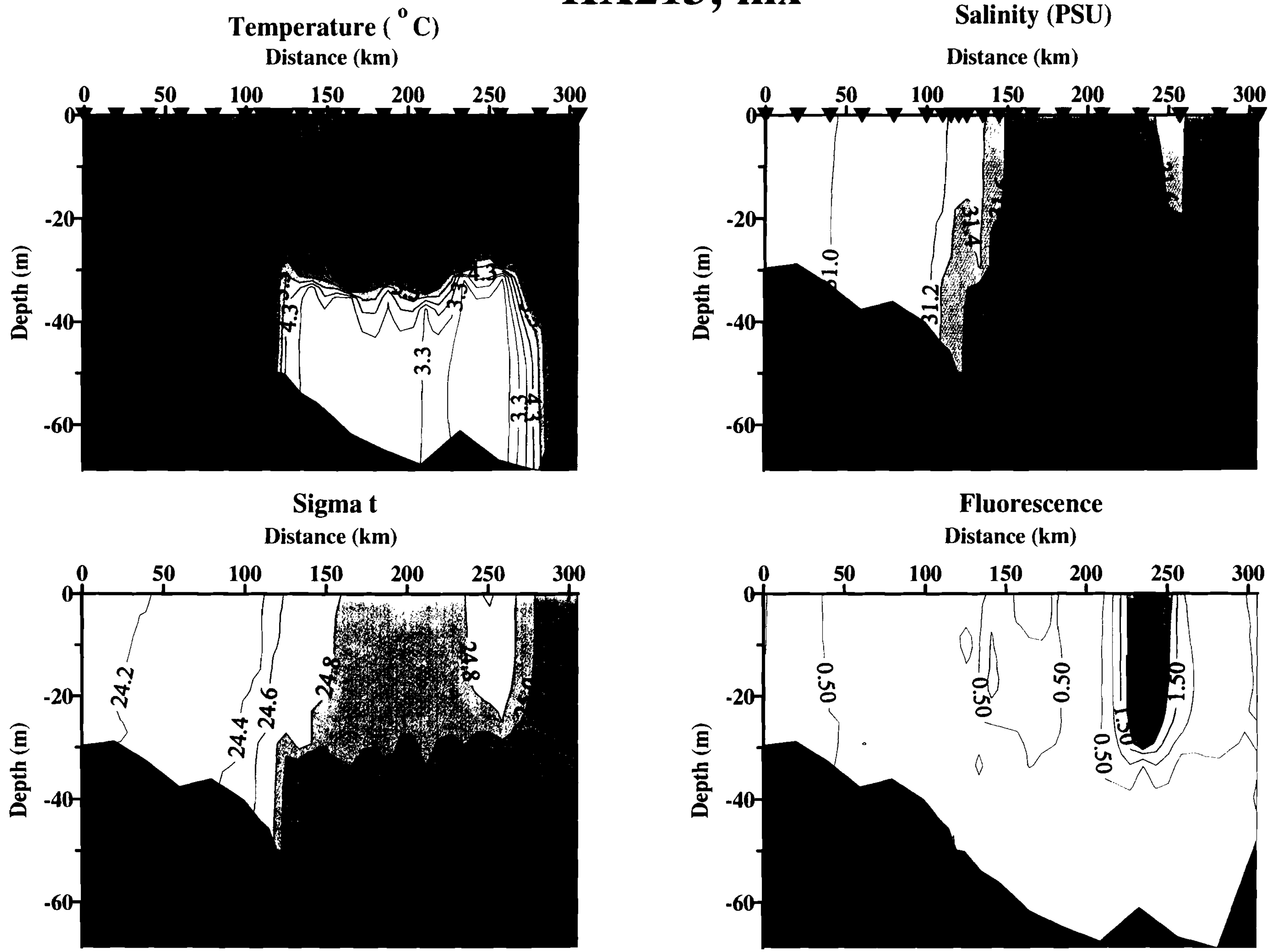

Temperature (°C)
Distance (km)
Depth (m)
3.5
4.0
4.5
5.0
Salinity (PSU)
Distance (km)
Depth (m)
31.3
31.5
Sigma t
Distance (km)
Depth (m)
24.5
24.6
24.7
24.8
Fluorescence
Distance (km)
Depth (m)
0.50
0.75
1.00

HX213; nic



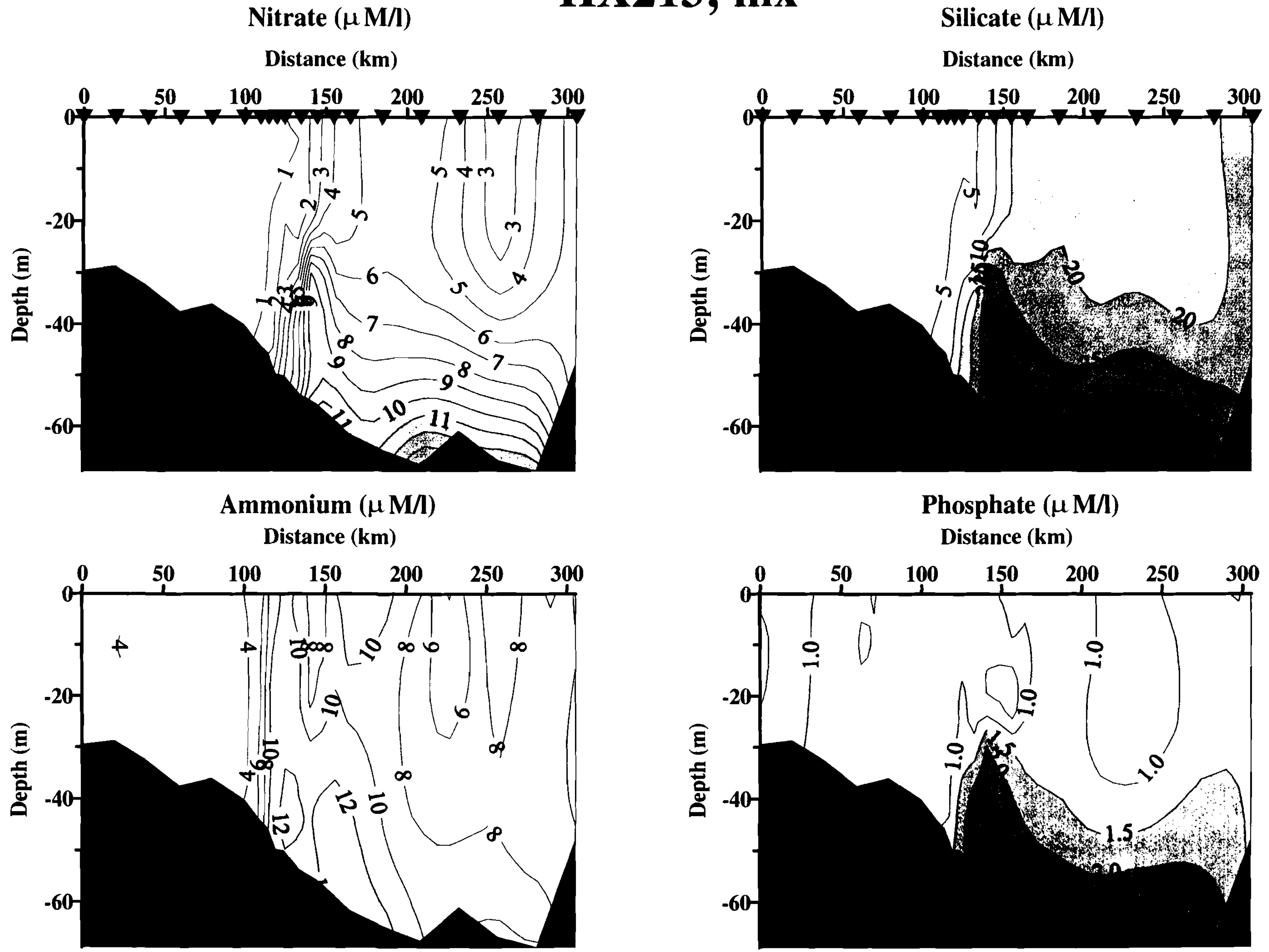
Nitrate (μ M/l)
Silicate (μ M/l)
Ammonium (μ M/l)
Phosphate (μ M/l)
Distance (km)
Depth (m)
0
10
20
30
40
50
-10
-20
-30
-40
-50

HX213; nix

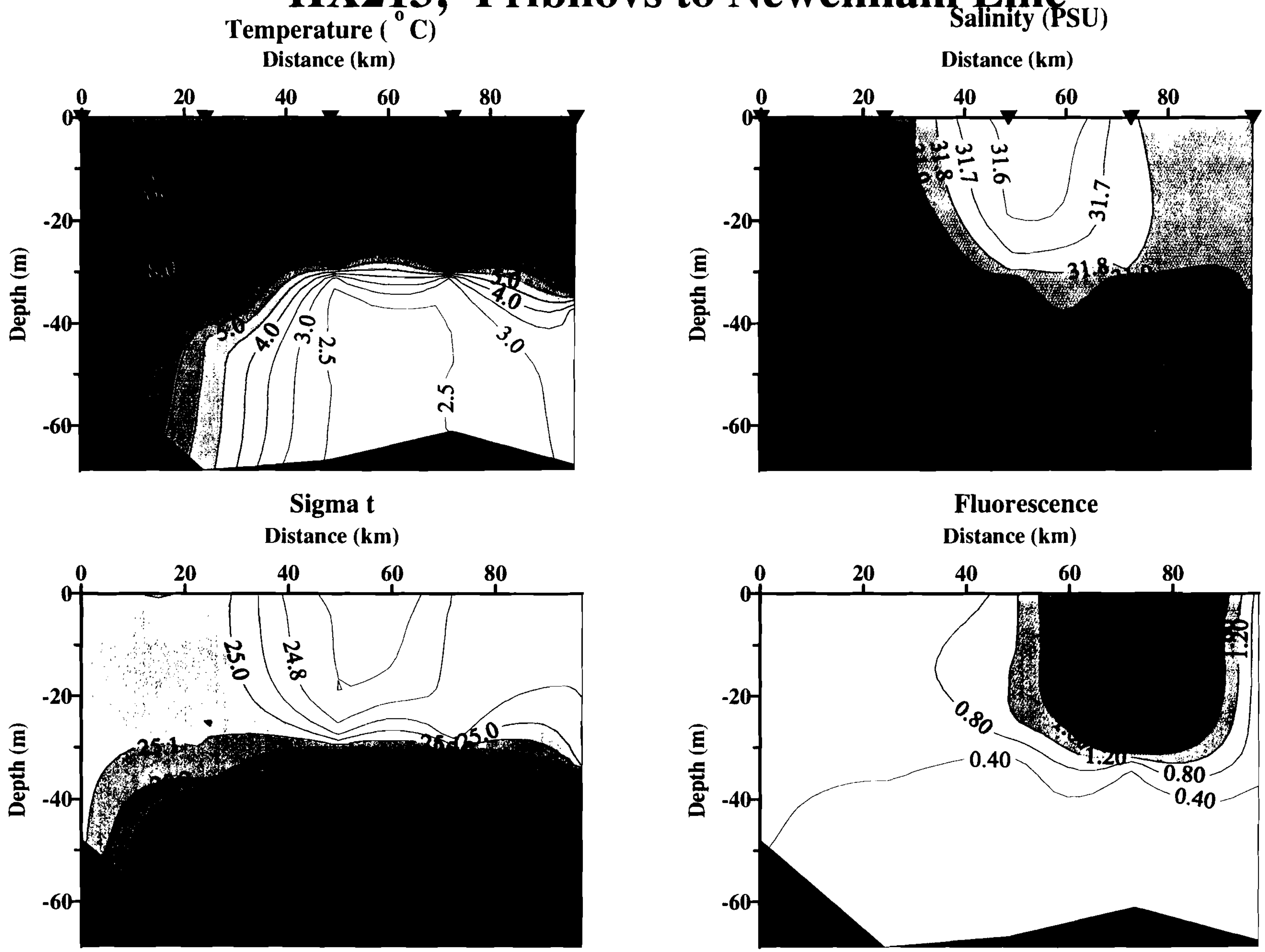


Temperature (°C)
Distance (km)
Depth (m)
4.3
3.3
Salinity (PSU)
Distance (km)
Depth (m)
31.0
31.2
31.4
Sigma t
Distance (km)
Depth (m)
24.2
24.4
24.6
24.8
Fluorescence
Distance (km)
Depth (m)
0.50
1.50

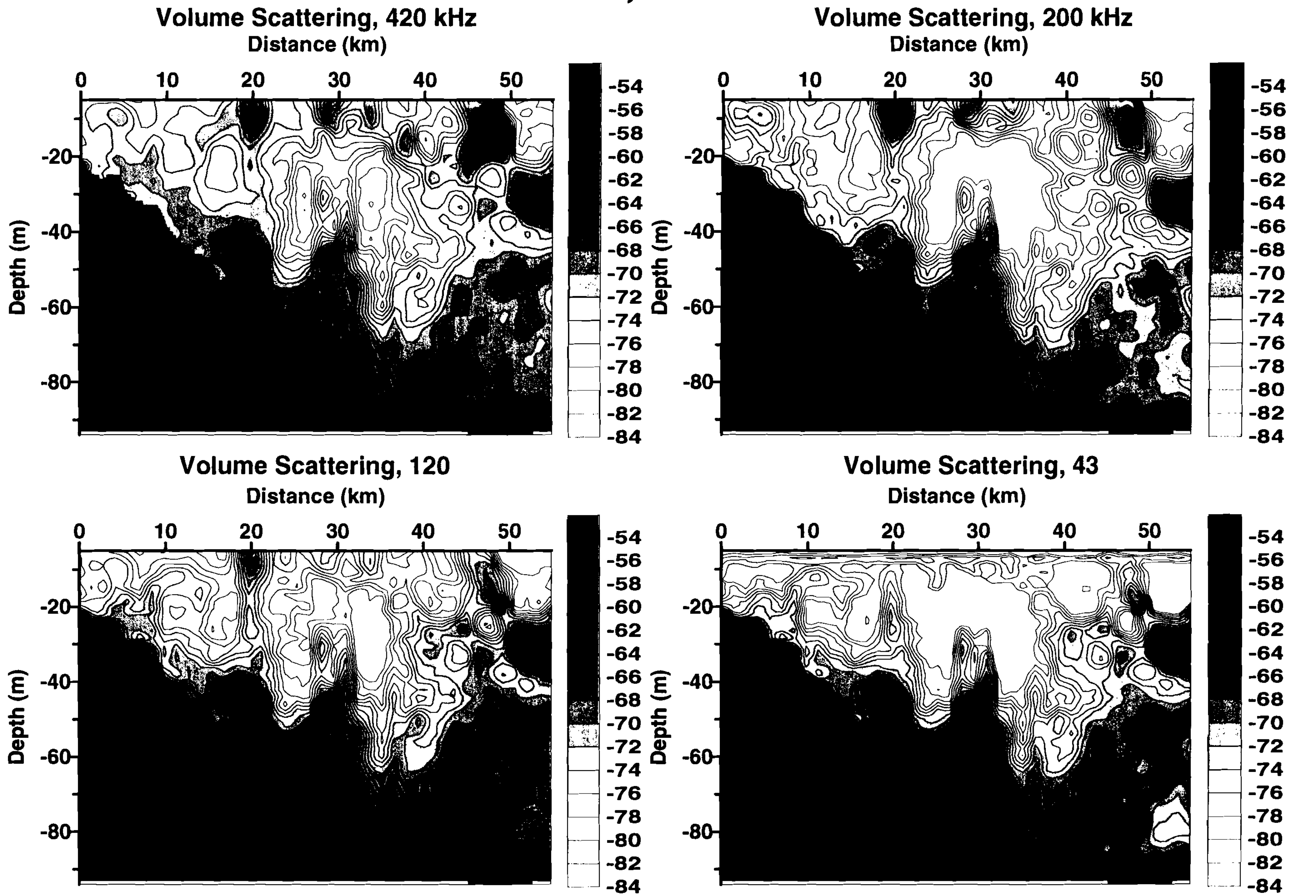
HX213; nix


Nitrate (µ M/l)
Distance (km)
0 50 100 150 200 250 300
Depth (m)
0 -20 -40 -60
1 2 3 4 5 6 7 8 9 10 11
Silicate (µ M/l)
Distance (km)
0 50 100 150 200 250 300
Depth (m)
0 -20 -40 -60
5 10 15 20
Ammonium (µ M/l)
Distance (km)
0 50 100 150 200 250 300
Depth (m)
0 -20 -40 -60
4 6 8 10 12
Phosphate (µ M/l)
Distance (km)
0 50 100 150 200 250 300
Depth (m)
0 -20 -40 -60
1.0 1.5

HX213; Pribilovs to Newenham Line

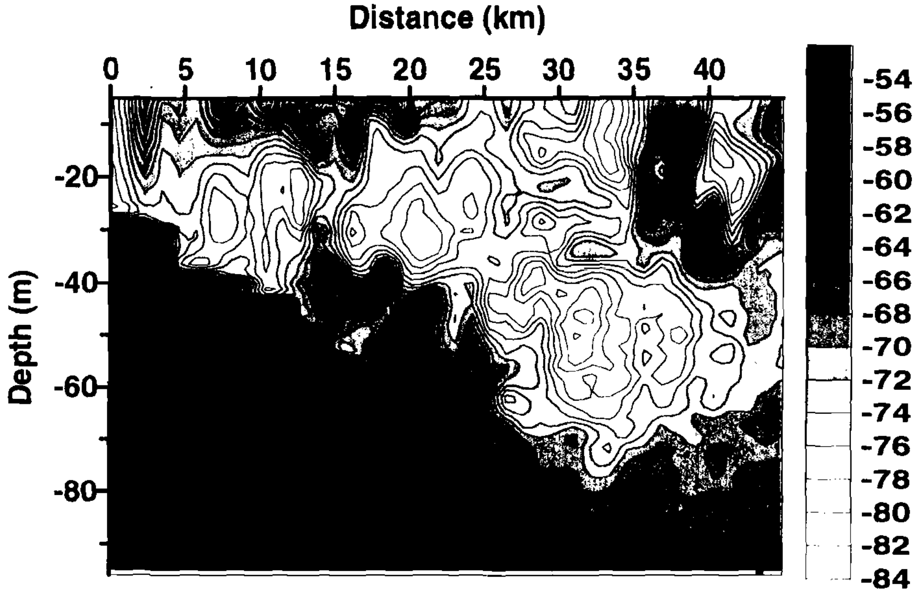


HX213; slmb-c

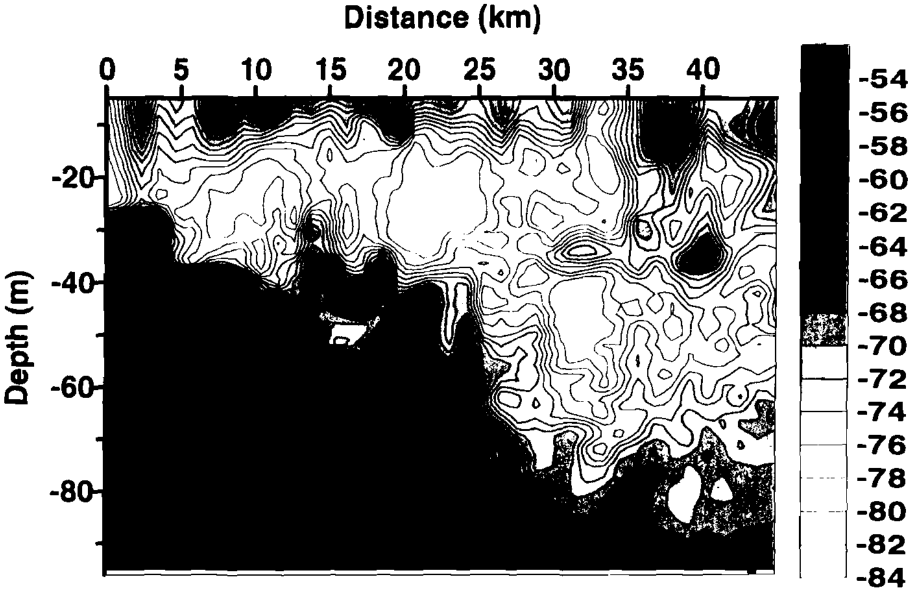

Volume Scattering, 420 kHz
Distance (km)
0 10 20 30 40 50
Depth (m)
-20 -40 -60 -80
-54 -56 -58 -60 -62 -64 -66 -68 -70 -72 -74 -76 -78 -80 -82 -84
Volume Scattering, 200 kHz
Distance (km)
0 10 20 30 40 50
Depth (m)
-20 -40 -60 -80
-54 -56 -58 -60 -62 -64 -66 -68 -70 -72 -74 -76 -78 -80 -82 -84
Volume Scattering, 120
Distance (km)
0 10 20 30 40 50
Depth (m)
-20 -40 -60 -80
-54 -56 -58 -60 -62 -64 -66 -68 -70 -72 -74 -76 -78 -80 -82 -84
Volume Scattering, 43
Distance (km)
0 10 20 30 40 50
Depth (m)
-20 -40 -60 -80
-54 -56 -58 -60 -62 -64 -66 -68 -70 -72 -74 -76 -78 -80 -82 -84

HX209; slmb-e

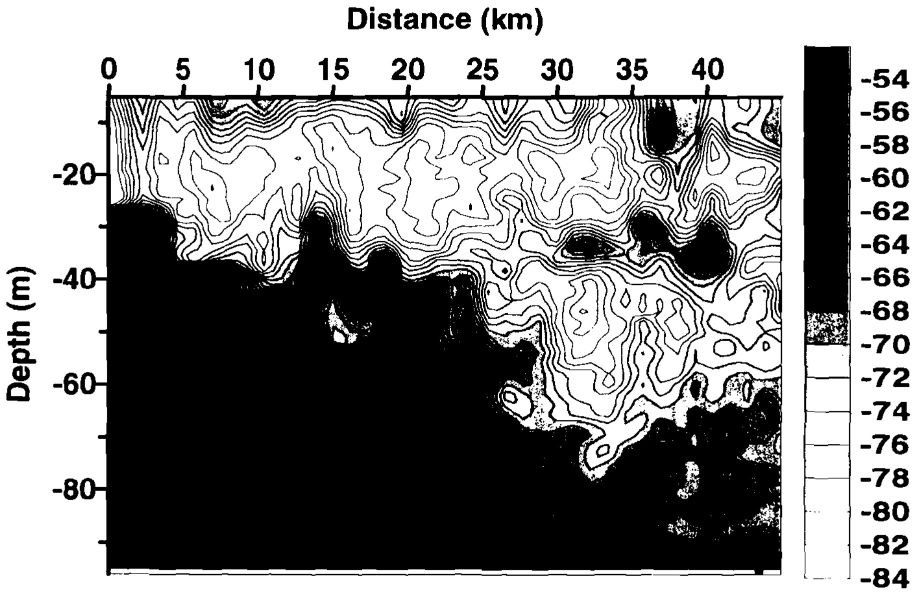
Volume Scattering, 420 kHz



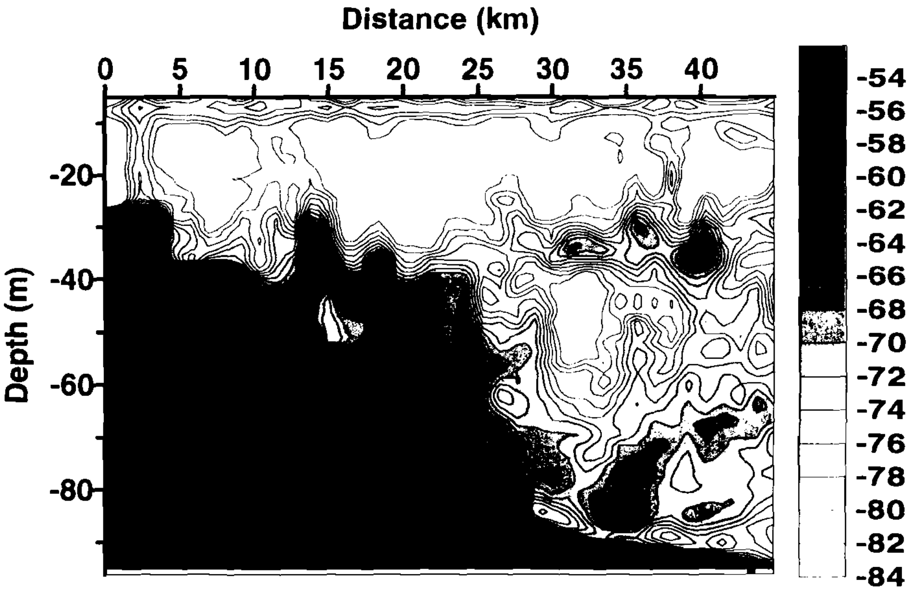
Volume Scattering, 200 kHz



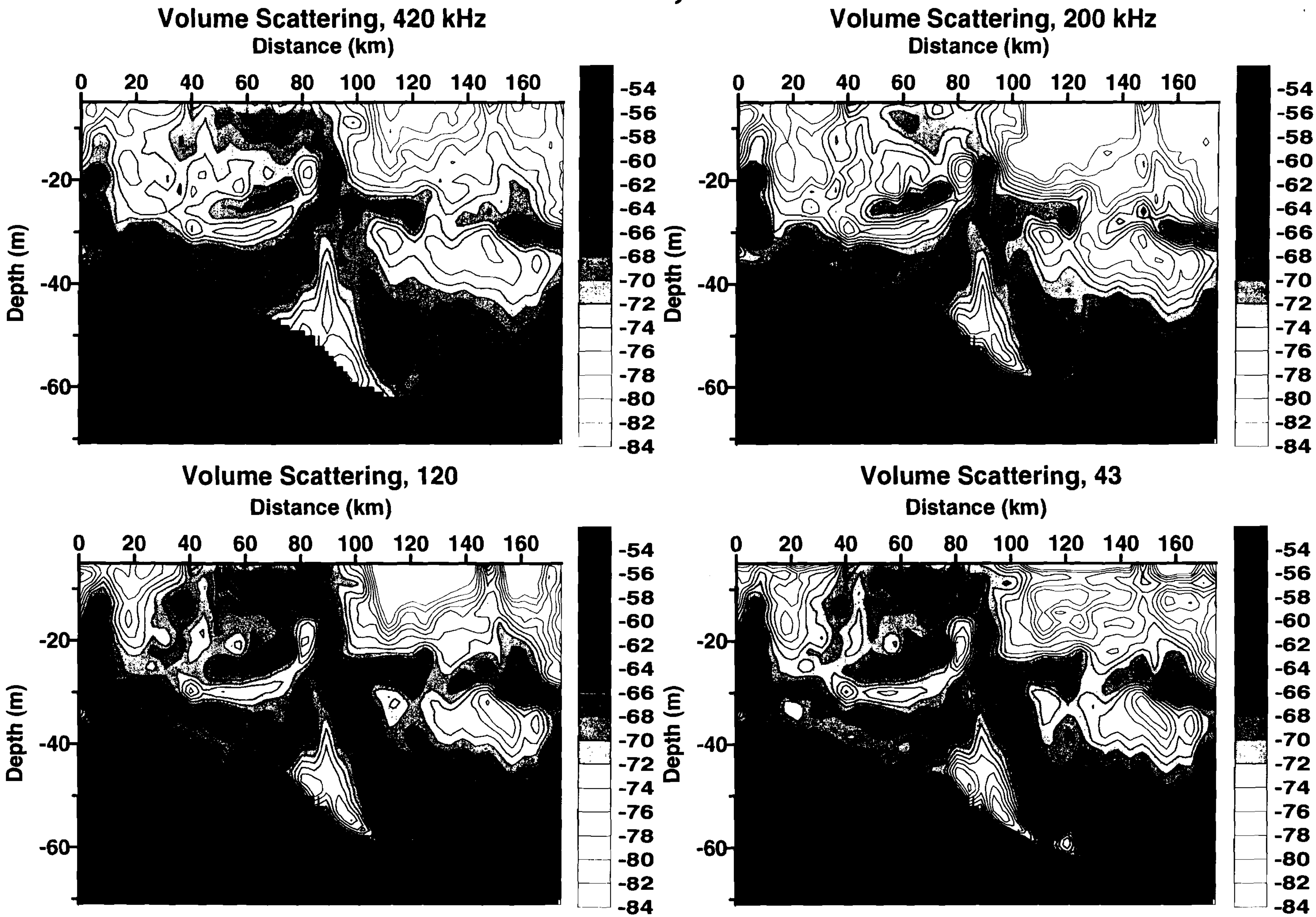
Volume Scattering, 120



Volume Scattering, 43

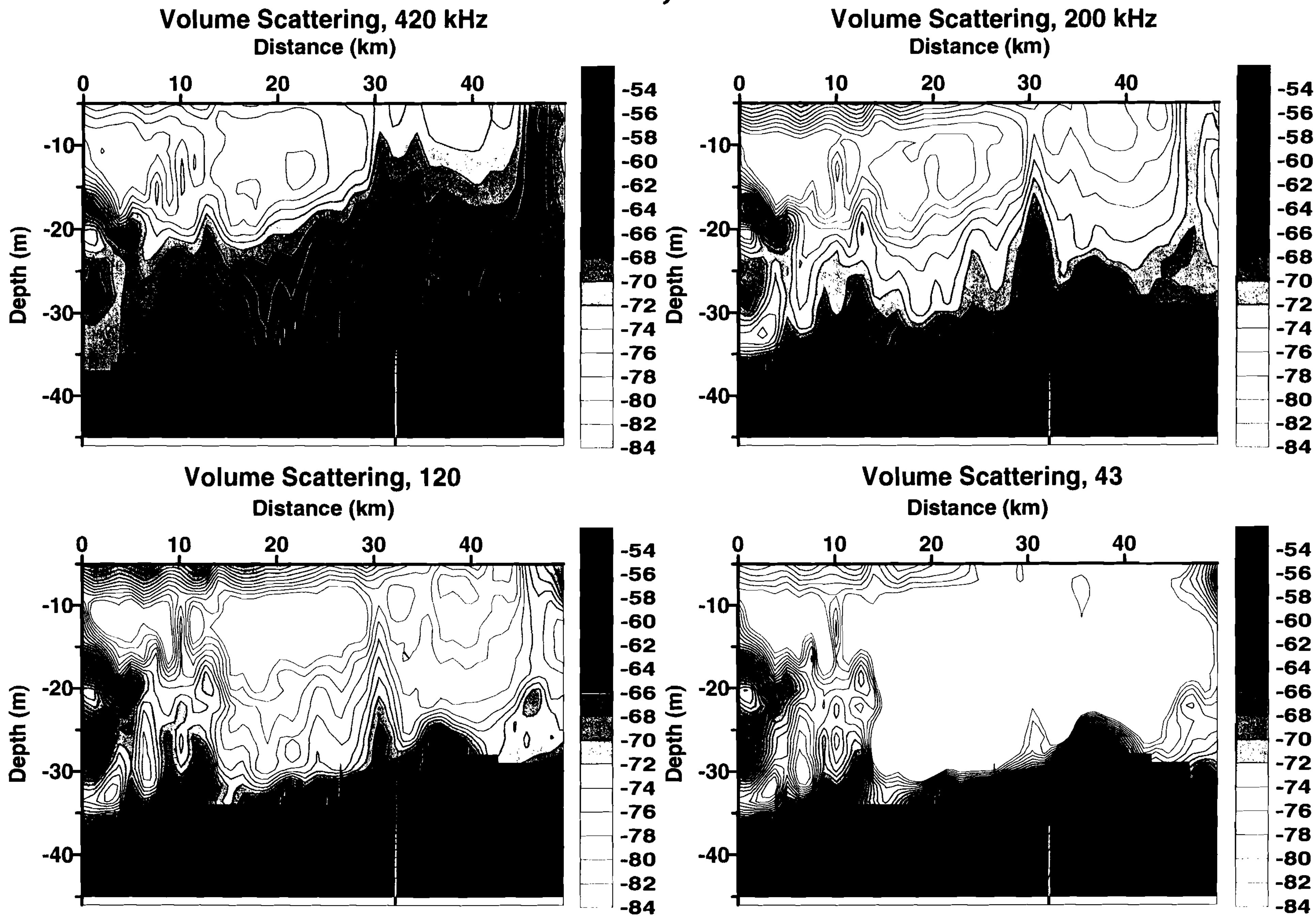


HX213; cnc



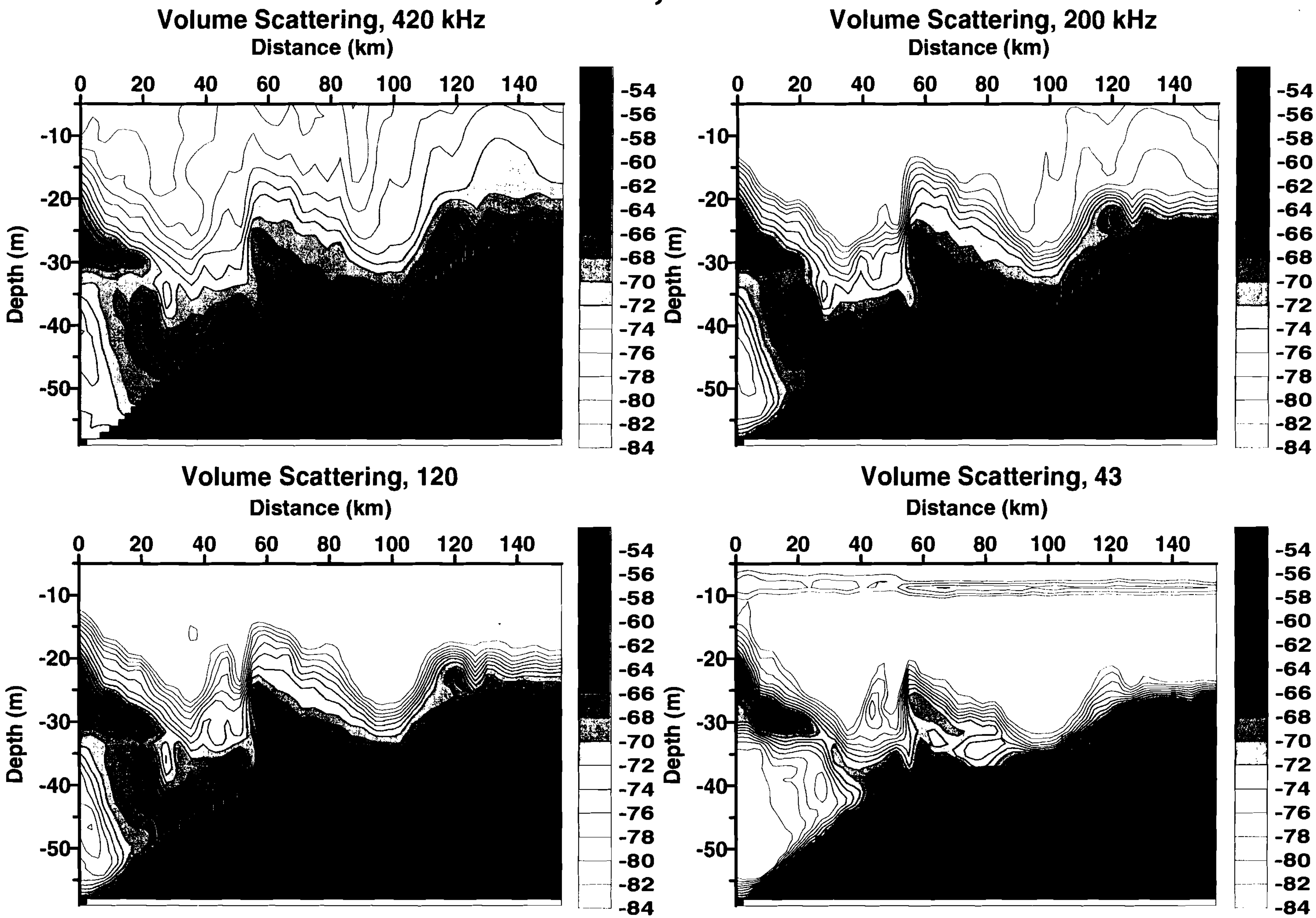
Volume Scattering, 420 kHz
Distance (km)
Depth (m)
Volume Scattering, 200 kHz
Distance (km)
Depth (m)
Volume Scattering, 120
Distance (km)
Depth (m)
Volume Scattering, 43
Distance (km)
Depth (m)
0
20
40
60
80
100
120
140
160
-20
-40
-60
-54
-56
-58
-60
-62
-64
-66
-68
-70
-72
-74
-76
-78
-80
-82
-84

HX213; cncx

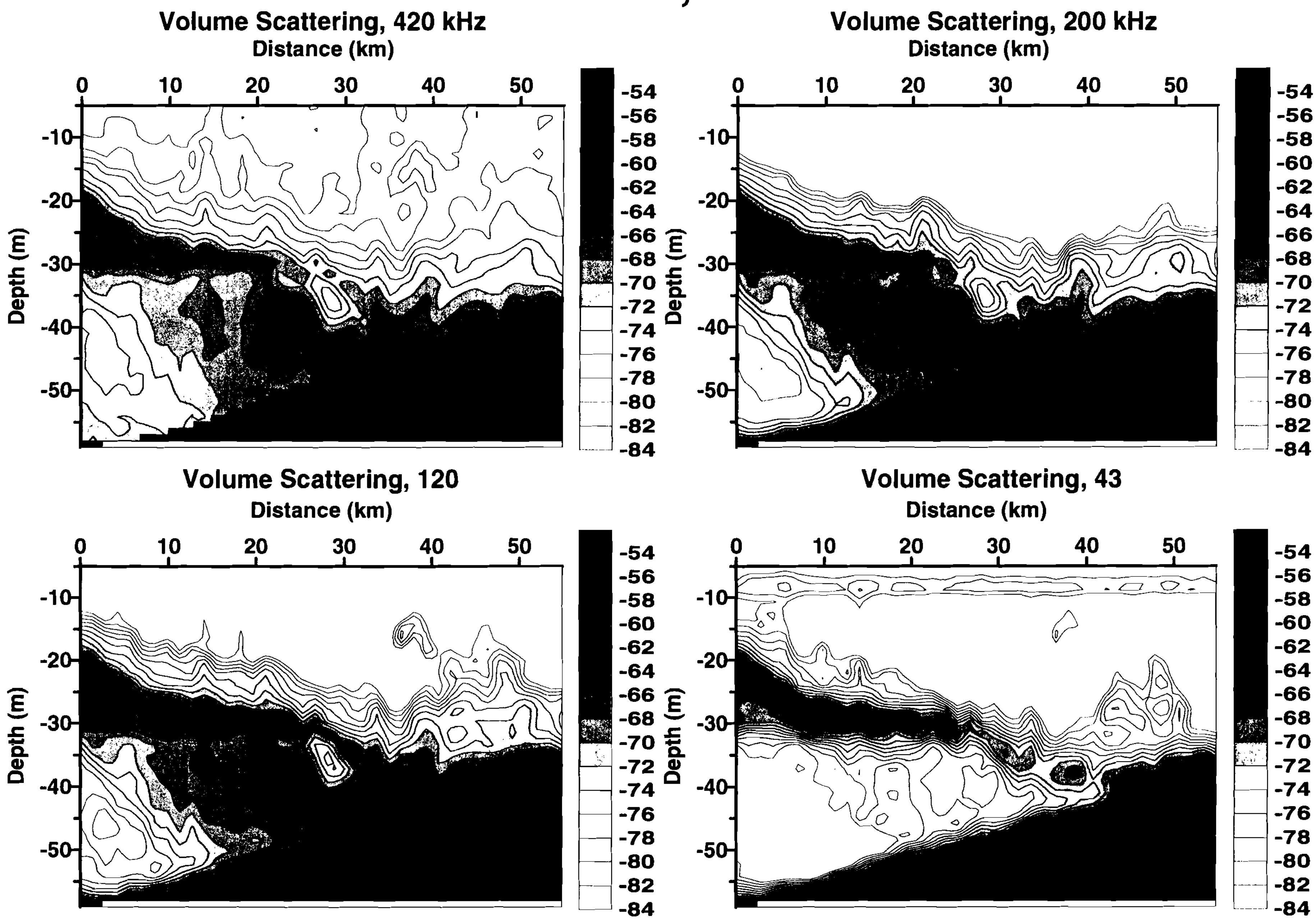


Volume Scattering, 420 kHz
Distance (km)
Depth (m)
Volume Scattering, 200 kHz
Distance (km)
Depth (m)
Volume Scattering, 120
Distance (km)
Depth (m)
Volume Scattering, 43
Distance (km)
Depth (m)
0
10
20
30
40
-10
-20
-30
-40
-54
-56
-58
-60
-62
-64
-66
-68
-70
-72
-74
-76
-78
-80
-82
-84

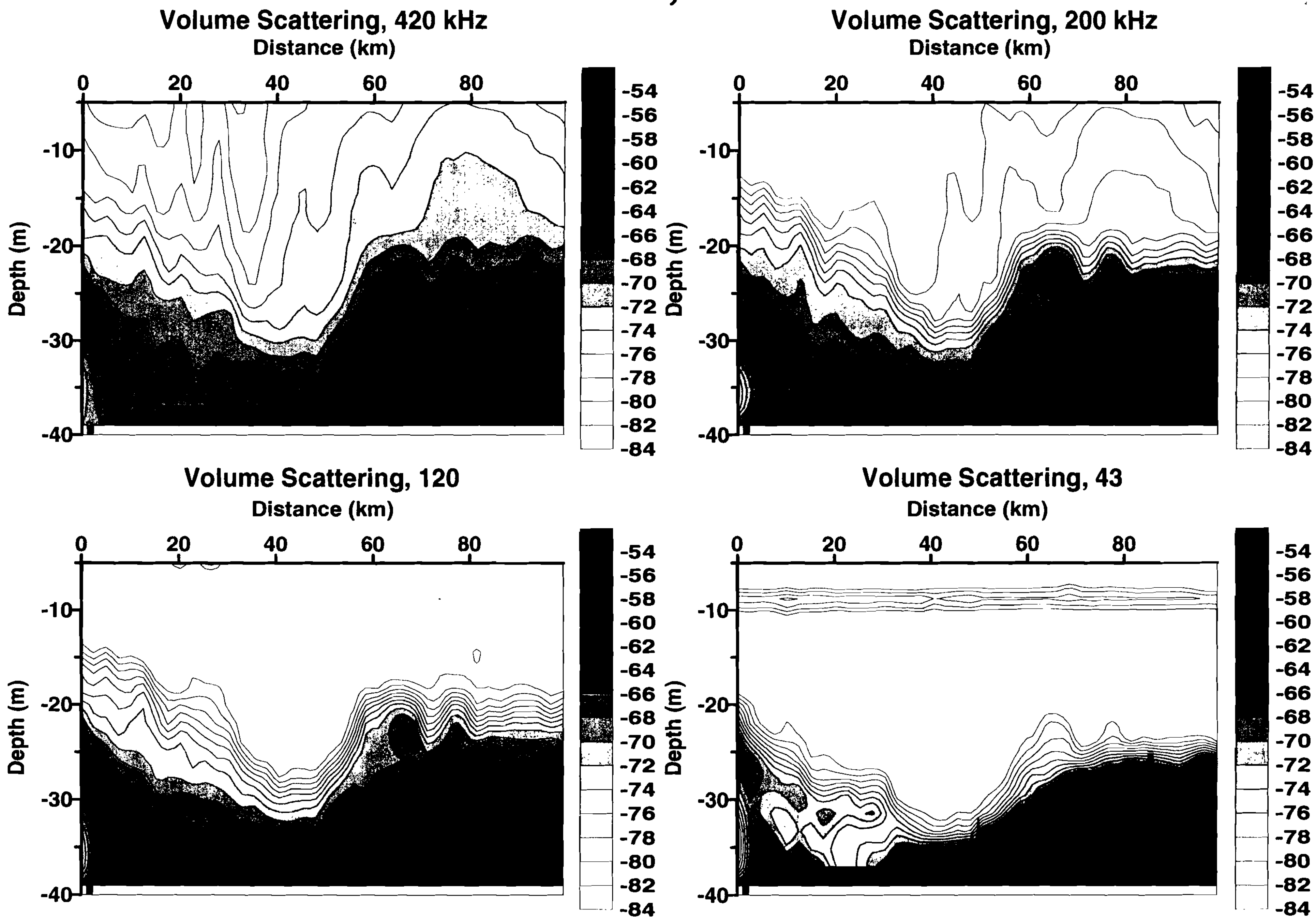
HX213; nicx2


Volume Scattering, 420 kHz
Distance (km)
Depth (m)
Volume Scattering, 200 kHz
Distance (km)
Depth (m)
Volume Scattering, 120
Distance (km)
Depth (m)
Volume Scattering, 43
Distance (km)
Depth (m)

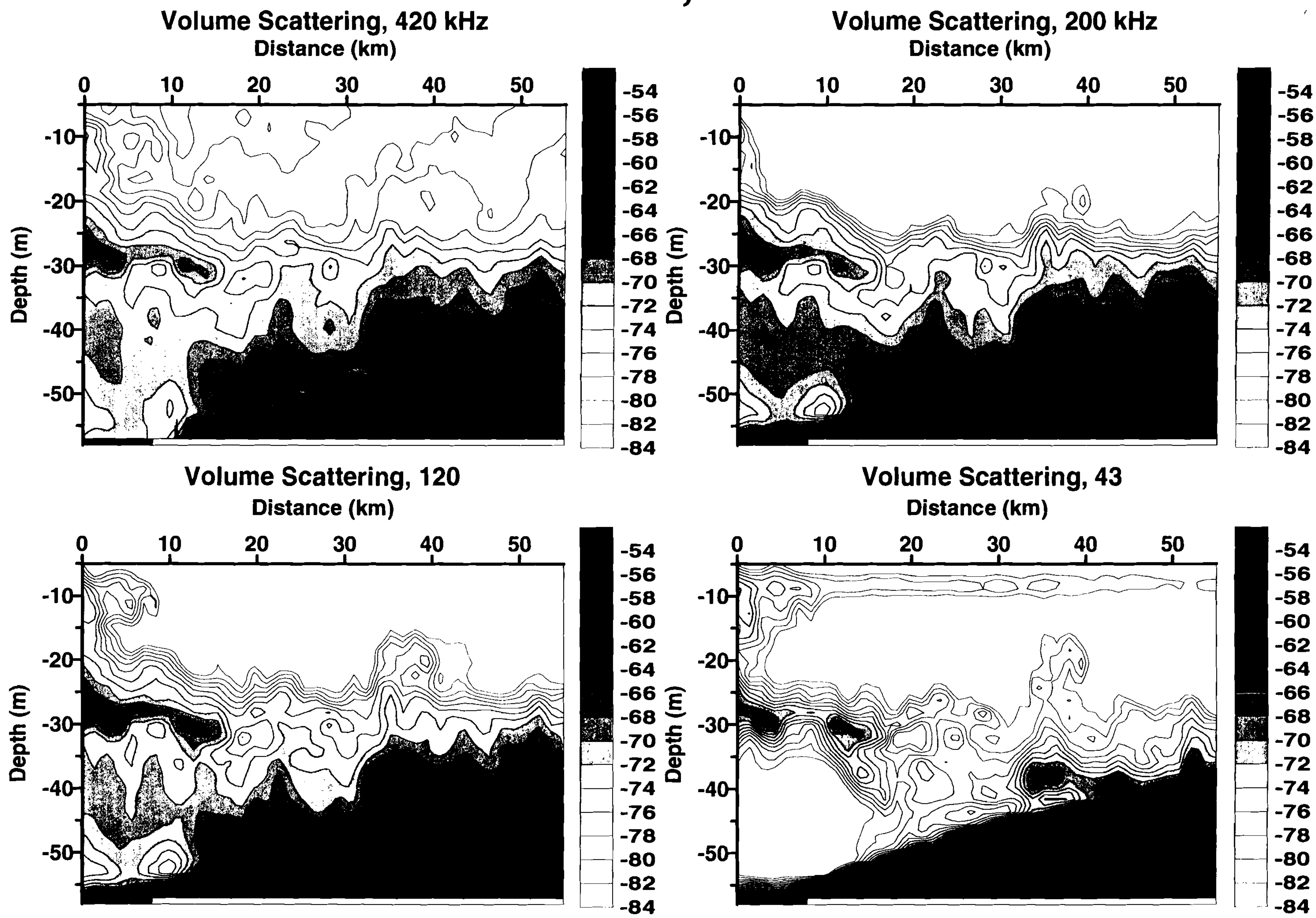
HX213; nic


Volume Scattering, 420 kHz
Volume Scattering, 200 kHz
Volume Scattering, 120
Volume Scattering, 43
Distance (km)
Depth (m)
0 10 20 30 40 50
-10 -20 -30 -40 -50
-54 -56 -58 -60 -62 -64 -66 -68 -70 -72 -74 -76 -78 -80 -82 -84

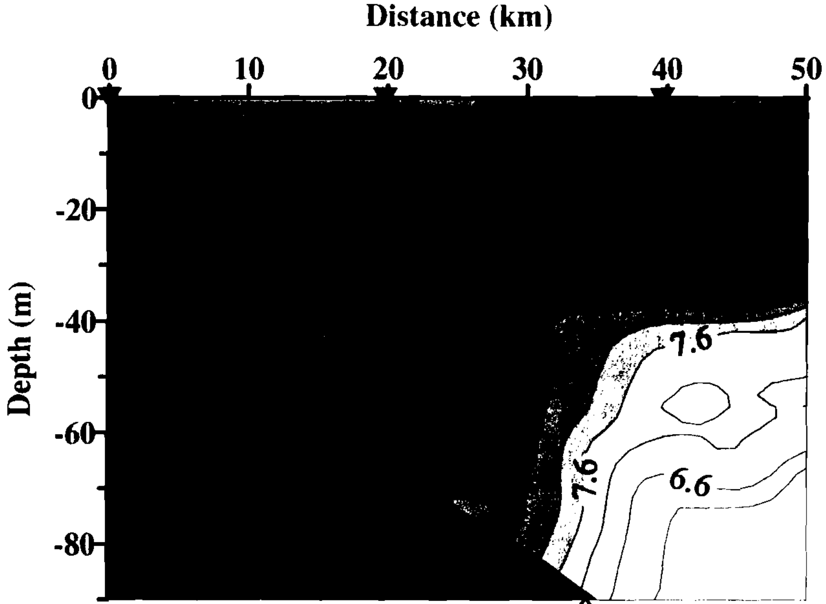
HX213; nicx


Volume Scattering, 420 kHz
Distance (km)
Depth (m)
0
20
40
60
80
-10
-20
-30
-40
-54
-56
-58
-60
-62
-64
-66
-68
-70
-72
-74
-76
-78
-80
-82
-84
Volume Scattering, 200 kHz
Distance (km)
Depth (m)
Volume Scattering, 120
Distance (km)
Depth (m)
Volume Scattering, 43
Distance (km)
Depth (m)

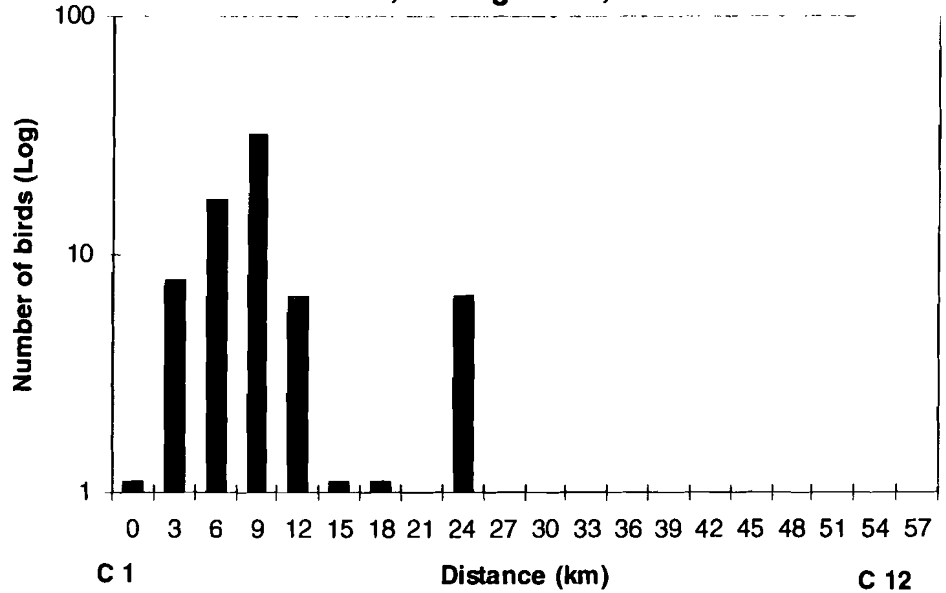
HX213; nie


Volume Scattering, 420 kHz
Distance (km)
Depth (m)
Volume Scattering, 200 kHz
Distance (km)
Depth (m)
Volume Scattering, 120
Distance (km)
Depth (m)
Volume Scattering, 43
Distance (km)
Depth (m)
0 10 20 30 40 50
-10 -20 -30 -40 -50
-54 -56 -58 -60 -62 -64 -66 -68 -70 -72 -74 -76 -78 -80 -82 -84

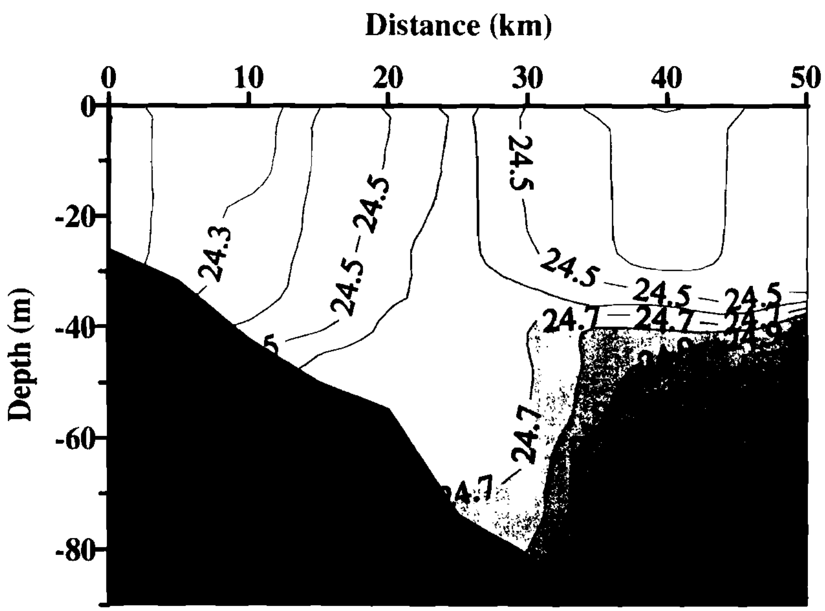
Slime Bank - C Line



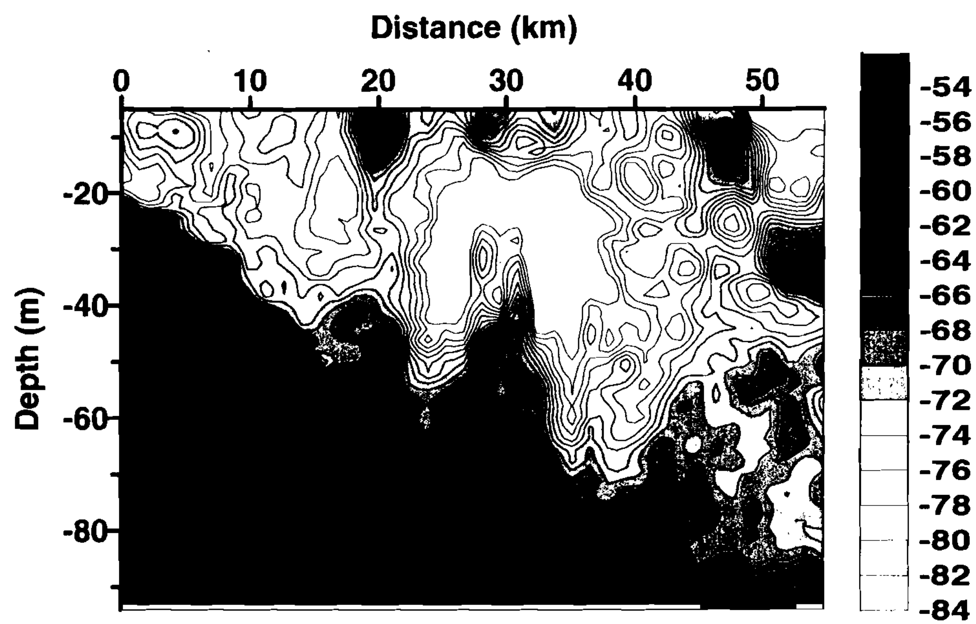
Temperature (°C)



Short-tailed shearwaters feeding and on the water, Slime Bank, 21 August 98, Stations C1-C12

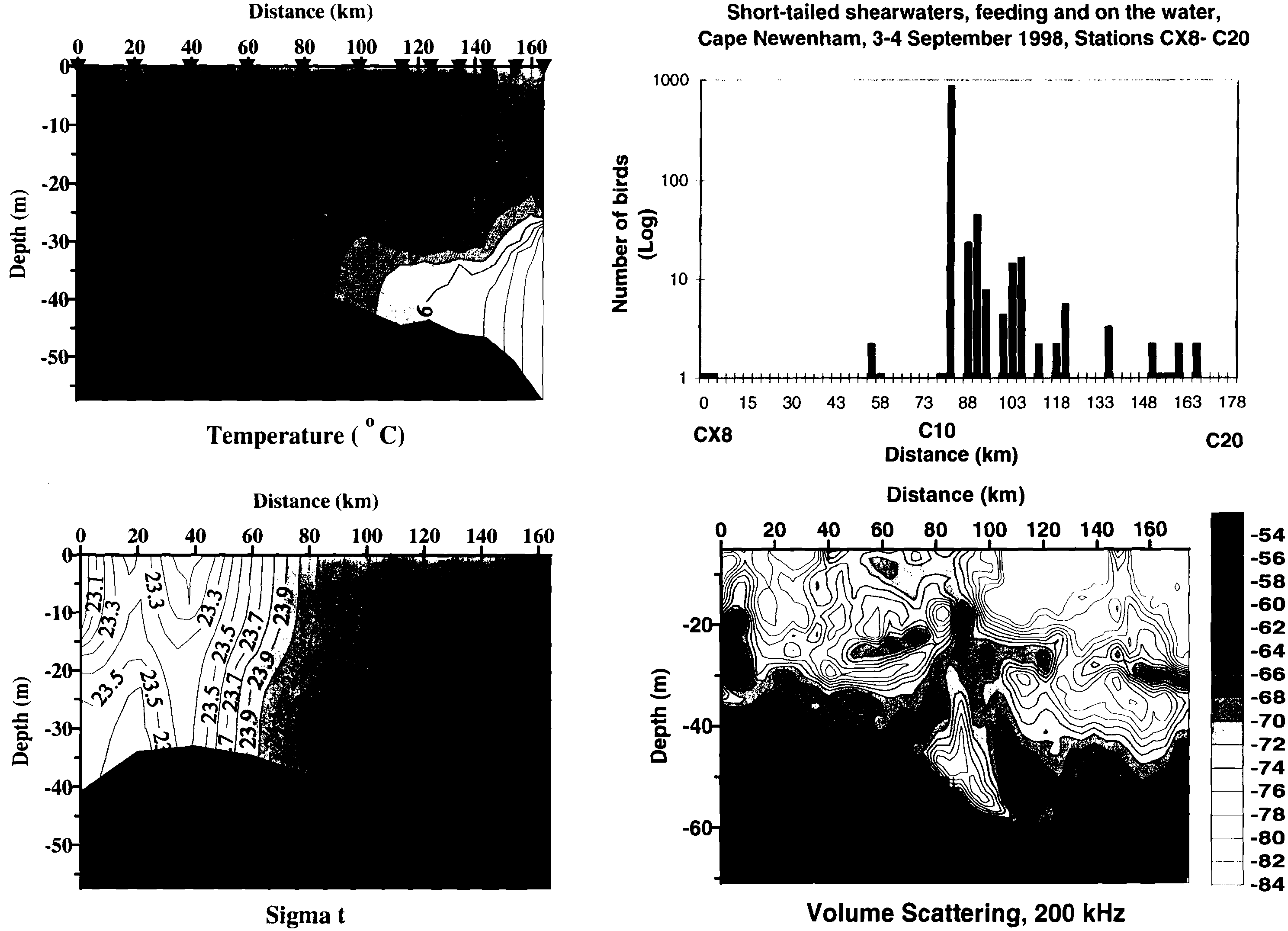


Sigma t



Volume Scattering, 200 kHz

Cape Newenham - C Line



APPENDIX A

Nunivak Island Grid Positions

station name	Lat.	Long.	Lat.	Long.
A-Line				
NIA-24	57.5546	169.7850	57 33.28	169 47.10
NIA-23	57.6324	169.6988	57 37.95	169 41.93
NIA-22	57.7102	169.6126	57 42.61	169 36.76
NIA-21	57.7880	169.5264	57 47.28	169 31.59
NIA-20	57.8658	169.4402	57 51.95	169 26.41
NIA-19	57.9436	169.3541	57 56.62	169 21.24
NIA-18	58.0214	169.2679	58 01.29	169 16.07
NIA-17	58.0992	169.1817	58 05.95	169 10.90
NIA-16	58.1770	169.0955	58 10.62	169 05.73
NIA-15	58.2548	169.0093	58 15.29	169 00.56
NIA-14	58.3326	168.9232	58 19.96	168 55.39
NIA-13	58.4104	168.8370	58 24.62	168 50.22
NIA-12	58.4882	168.7508	58 29.292	168 45.049
NIA-11	58.5271	168.7077	58 31.626	168 42.460
NIA-10	58.5660	168.6645	58 33.960	168 39.871
NIA-09	58.6049	168.6214	58 36.294	168 37.283
NIA-08	58.6438	168.5782	58 38.628	168 34.695
NIA-07	58.6827	168.5351	58 40.962	168 32.106
NIA-06	58.7216	168.4919	58 43.296	168 29.514
NIA-05	58.7605	168.4488	58 45.630	168 26.928
NIA-04	58.7994	168.4057	58 47.964	168 24.340
NIA-03	58.8383	168.3625	58 50.298	168 21.751
NIA-02	58.8772	168.3194	58 52.632	168 19.162
NIA-01	58.9161	168.2762	58 54.966	168 16.574
NIA-X2	58.9939	168.1900	58 59.63	168 11.40
NIA-X4	59.0717	168.1038	59 04.30	168 06.23
NIA-X6	59.1495	168.0177	59 08.97	168 01.06
NIA-X8	59.2273	167.9315	59 13.64	167 55.89
NIA-X10	59.3051	167.8453	59 18.31	167 50.72
NIA-X11	59.3829	167.7591	59 22.97	167 45.55
NIA-X12	59.4607	167.6729	59 27.64	167 40.38
NIA-X13	59.5385	167.5867	59 32.31	167 35.20
NIA-X14	59.6163	167.5006	59 36.98	167 30.03
NIA-X15	59.6941	167.4144	59 41.64	167 24.86
NIA-X16	59.7719	167.3282	59 46.31	167 19.69
NIA-X17	59.8497	167.2420	59 50.98	167 14.52

B-Line

NIB-12	58.4613	168.6612	58	27.678	168	39.670
NIB-11	58.5002	168.6180	58	30.012	168	37.081
NIB-10	58.5391	168.5749	58	32.346	168	34.492
NIB-09	58.5780	168.5317	58	34.680	168	31.902
NIB-08	58.6169	168.4886	58	37.014	168	29.313
NIB-07	58.6558	168.4454	58	39.348	168	26.724
NIB-06	58.6947	168.4022	58	41.682	168	24.132
NIB-05	58.7336	168.3591	58	44.016	168	21.546
NIB-04	58.7725	168.3159	58	46.350	168	18.957
NIB-03	58.8114	168.2728	58	48.684	168	16.368
NIB-02	58.8503	168.2296	58	51.018	168	13.779
NIB-01	58.8892	168.1865	58	53.352	168	11.190

C-Line

NIC-24	57.5010	169.6082	57	30.06	169	36.49
NIC-23	57.5788	169.5219	57	34.73	169	31.31
NIC-22	57.6566	169.4355	57	39.40	169	26.13
NIC-21	57.7344	169.3491	57	44.07	169	20.94
NIC-20	57.8122	169.2627	57	48.73	169	15.76
NIC-19	57.8900	169.1763	57	53.40	169	10.58
NIC-18	57.9678	169.0899	57	58.07	169	05.39
NIC-17	58.0456	169.0035	58	02.74	169	00.21
NIC-16	58.1234	168.9171	58	07.40	168	55.03
NIC-15	58.2012	168.8307	58	12.07	168	49.84
NIC-14	58.2790	168.7443	58	16.74	168	44.66
NIC-13	58.3568	168.6579	58	21.41	168	39.47
NIC-12	58.4346	168.5715	58	26.079	168	34.287
NIC-11	58.4735	168.5283	58	28.410	168	31.698
NIC-10	58.5123	168.4852	58	30.741	168	29.109
NIC-09	58.5512	168.4420	58	33.072	168	26.520
NIC-08	58.5900	168.3988	58	35.403	168	23.931
NIC-07	58.6289	168.3557	58	37.734	168	21.342
NIC-06	58.6678	168.3125	58	40.068	168	18.750
NIC-05	58.7066	168.2694	58	42.396	168	16.164
NIC-04	58.7455	168.2262	58	44.727	168	13.575
NIC-03	58.7843	168.1831	58	47.058	168	10.985
NIC-02	58.8232	168.1399	58	49.389	168	08.396
NIC-01	58.8620	168.0968	58	51.720	168	05.807
NIC-X2	58.9398	168.0104	58	56.39	168	00.62
NIC-X4	59.0176	167.9240	59	01.06	167	55.44
NIC-X6	59.0954	167.8376	59	05.72	167	50.26
NIC-X8	59.1732	167.7512	59	10.39	167	45.07
NIC-X10	59.2510	167.6648	59	15.06	167	39.89
NIC-X11	59.3288	167.5784	59	19.73	167	34.71

NIC-X12	59.4066	167.4920	59	24.39	167	29.52
NIC-X13	59.4844	167.4056	59	29.06	167	24.34
NIC-X14	59.5622	167.3192	59	33.73	167	19.15
NIC-X15	59.6400	167.2328	59	38.40	167	13.97
NIC-X16	59.7178	167.1465	59	43.07	167	08.79
NIC-X17	59.7956	167.0601	59	47.73	167	03.60

D-Line

NID-12	58.4078	168.4818	58	24.465	168	28.906
NID-11	58.4466	168.4386	58	26.796	168	26.317
NID-10	58.4855	168.3955	58	29.127	168	23.728
NID-09	58.5243	168.3523	58	31.458	168	21.139
NID-08	58.5632	168.3092	58	33.789	168	18.549
NID-07	58.6020	168.2660	58	36.120	168	15.960
NID-06	58.6408	168.2228	58	38.448	168	13.368
NID-05	58.6797	168.1797	58	40.782	168	10.782
NID-04	58.7185	168.1366	58	43.113	168	08.193
NID-03	58.7574	168.0934	58	45.444	168	05.604
NID-02	58.7962	168.0502	58	47.775	168	03.015
NID-01	58.8351	168.0071	58	50.106	168	00.426

E-line

NIE-24	57.4469	169.4288	57	26.82	169	25.73
NIE-23	57.5247	169.3425	57	31.48	169	20.55
NIE-22	57.6025	169.2561	57	36.15	169	15.36
NIE-21	57.6803	169.1697	57	40.82	169	10.18
NIE-20	57.7581	169.0833	57	45.49	169	05.00
NIE-19	57.8359	168.9969	57	50.16	168	59.81
NIE-18	57.9137	168.9105	57	54.82	168	54.63
NIE-17	57.9915	168.8241	57	59.49	168	49.44
NIE-16	58.0693	168.7377	58	04.16	168	44.26
NIE-15	58.1471	168.6513	58	08.83	168	39.08
NIE-14	58.2249	168.5649	58	13.49	168	33.89
NIE-13	58.3027	168.4785	58	18.16	168	28.71
NIE-12	58.3805	168.3921	58	22.830	168	23.524
NIE-11	58.4194	168.3489	58	25.164	168	20.934
NIE-10	58.4583	168.3058	58	27.498	168	18.345
NIE-09	58.4972	168.2626	58	29.832	168	15.756
NIE-08	58.5361	168.2195	58	32.166	168	13.167
NIE-07	58.5750	168.1763	58	34.500	168	10.578
NIE-06	58.6139	168.1331	58	36.834	168	07.986
NIE-05	58.6528	168.0900	58	39.168	168	05.400
NIE-04	58.6917	168.0468	58	41.502	168	02.811
NIE-03	58.7306	168.0037	58	43.836	168	00.222

NIE-02	58.7695	167.9605	58	46.170	167	57.632
NIE-01	58.8084	167.9174	58	48.504	167	55.043
NIE-X2	58.8862	167.8310	58	53.17	167	49.86
NIE-X4	58.9640	167.7446	58	57.84	167	44.68
NIE-X6	59.0418	167.6582	59	02.51	167	39.49
NIE-X8	59.1196	167.5718	59	07.18	167	34.31
NIE-X10	59.1974	167.4854	59	11.84	167	29.13
NIE-X11	59.2752	167.3990	59	16.51	167	23.94
NIE-X12	59.3530	167.3126	59	21.18	167	18.76
NIE-X13	59.4308	167.2262	59	25.85	167	13.57
NIE-X14	59.5086	167.1398	59	30.51	167	08.39
NIE-X15	59.5864	167.0535	59	35.18	167	03.21
NIE-X16	59.6642	166.9671	59	39.85	166	58.02
NIE-X17	59.7420	166.8807	59	44.52	166	52.84

APPENDIX B

Slime Bank Station Positions

Station Name	Lat	Long	Lat	Long	Comment
SBC-0					
SBC-1	55.0965	163.8570	55 5.79	163 51.42	
SBC-2	55.1371	163.8903	55 8.23	163 53.42	
SBC-3	55.1777	163.9236	55 10.66	163 55.42	
SBC-4	55.2184	163.9568	55 13.10	163 57.41	
SBC-5	55.2591	163.9901	55 15.55	163 59.41	
SBC-6	55.2998	164.0234	55 17.99	164 01.40	
SBC-7	55.3405	164.0567	55 20.43	164 03.40	
SBC-8	55.3811	164.0900	55 22.87	164 05.40	
SBC-9	55.4218	164.1233	55 25.31	164 07.40	
SBC-10	55.4625	164.1566	55 27.75	164 09.40	
SBC-11	55.5032	164.1899	55 30.19	164 11.39	
SBC-12	55.5844	164.2565	55 35.06	164 15.39	
SBC-13	55.6656	164.3231	55 39.94	164 19.38	
SBC-14	55.7468	164.3897	55 44.81	164 23.38	
SBC-15	55.8280	164.4563	55 49.68	164 27.38	
SBC-16	55.9092	164.5228	55 54.55	164 31.37	
SBC-17	55.9904	164.5894	55 59.42	164 35.37	
SBC-18	56.0716	164.6560	56 04.30	164 39.36	
SBC-19	56.1528	164.7226	56 09.17	164 43.36	
SBE-10	55.4170	164.3279	55 25.02	164 19.67	
SBE-8	55.3356	164.2613	55 20.14	164 15.68	
SBE-6	55.2543	164.1947	55 15.26	164 11.68	
SBE-5	55.2136	164.1615	55 12.81	164 09.69	
SBE-4	55.1729	164.1282	55 10.37	164 07.69	
SBE-2	55.0915	164.0616	55 05.49	164 03.70	
SBE-1	55.0508	164.0283	55 03.05	164 01.70	
SBD-1	55.0736	163.9426	55 04.42	163 56.56	
SBD-2	55.1143	163.9759	55 06.86	163 58.56	
SBD-4	55.1957	164.0425	55 11.74	164 02.55	
SBD-5	55.2363	164.0758	55 14.18	164 04.55	
SBD-6	55.2770	164.1091	55 16.62	164 06.55	
SBD-7			55 19.06	164 08.54	
SBD-8	55.3584	164.1757	55 21.50	164 10.54	
SBD-10	55.4397	164.2422	55 26.38	164 14.53	

SBB-10	55.4853	164.0709	55 29.12	164 04.26
SBB-8	55.4039	164.0043	55 24.23	164 00.26
SBB-7			55..21.92	163 58.38
SBB-6	55.3225	163.9378	55 19.35	163 56.27
SBB-5	55.2819	163.9045	55 16.91	163 54.27
SBB-4	55.2412	163.8712	55 14.47	163 52.27
SBB-3			55 12.03	163 50.28
SBB-2	55.1598	163.8046	55 09.59	163 48.28
SBB-1	55.1191	163.7713	55 07.15	163 46.28
SBA-0			55 06.13	163 39.10
SBA-1	55.1419	163.6856	55 08.51	163 41.14
SBA-2	55.1826	163.7189	55 10.96	163 43.14
SBA-4	55.2640	163.7855	55 15.84	163 47.13
SBA-5	55.3046	163.8188	55 18.28	163 49.13
SBA-6	55.3453	163.8521	55 20.72	163 51.13
SBA-8	55.4267	163.9187	55 25.60	163 55.12
SBA-10	55.5080	163.9853	55 30.48	163 59.12