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# Summary of Catch Data, Depth Plots, Track Maps, and Tag Recoveries from Adult Chinook Salmon Ultrasonic Telemetry 1990-1992, Johnstone Strait, British Columbia.

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SUMMARY OF CATCH DATA, DEPTH PLOTS, TRACK MAPS, AND TAG  
RECOVERIES FROM ADULT CHINOOK SALMON ULTRASONIC TELEMTRY 1990-  
1992, JOHNSTONE STRAIT, BRITISH COLUMBIA.

by

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**ABSTRACT**

Candy, J.R., E.W. Carter, and B. Riddell. 1995. Summary of catch data, depth plots, track maps, and tag recoveries for adult chinook salmon ultrasonic tracking 1990-1992, Johnstone Strait, British Columbia. *Can. MS. Fish. Aquat. Sci.* 2342: 66 p.

Forty-nine chinook salmon (*Oncorhynchus tshawytscha*), with pressure-sensing ultrasonic transmitters, were tracked in Johnstone Strait from mid-August to early September from 1990 to 1992. Fish were taken from the purse seine catches of commercial seine, DFO test fishing, and charter vessels. Tracking durations ranged from 0:15 h to 32:48 h for a total tracking time of 790:45 h. Fish were tracked for distances ranging from 0.1 km to 76.0 km for a total tracking distance of 1420.7 km. Average ground speed for tracks ranged from 0 km/h to 2.7 km/h (mean=1.9 km/h). A total of eight ultrasonic transmitters was returned from anglers, commercial fishermen, and hatcheries. Chinook salmon were recovered after carrying these transmitters from 6 to 62 days for estimated distances of 22 to 500 km.

**RÉSUMÉ**

Candy, J.R., E.W. Carter, and B. Riddell. 1995. Summary of catch data, depth plots, track maps, and tag recoveries for adult chinook salmon ultrasonic tracking 1990-1992, Johnstone Strait, British Columbia. C. Can. MS. Fish. Aquat. Sci. 2342: 66 p.

Les déplacements de 49 saumons quinnate (*Oncorhynchus tshawytscha*) munis d'émetteurs ultrasoniques manométriques ont été suivis dans le détroit Johnstone de la mi-août au début de septembre, de 1990 à 1992. Ces poissons ont été obtenus de prises de la pêche commerciale à la senne coulissante, de pêches d'essai du MPO et de pêches par bateaux affrétés. Les repérages ont duré de 790 heures et 45 minutes. Les distance de repérage variaient de 0,1 km à 76,0 km et la distance totale a été de 1420,7 km. La vitesse de déplacement par rapport au sol variait de 0 km/h à 2,7 km/h (moyenne de 1,9 km/h). Huit émetteurs ultrasoniques ont été retournés par des pêcheurs à la ligne, des pecheurs commerciaux ou de piscicultures. Les saumons ont été recapturés après avoir porté les émetteurs de 6 à 22 jours et après avoir parcouru des distance estimées variant entre 22 et 500 km.

## INTRODUCTION

Adult chinook salmon (*Oncorhynchus tshawytscha*) are caught in a commercial purse seine fishery directed at migrating sockeye salmon (*O. nerka*) along the east coast of Vancouver Island. In an effort to conserve declining chinook stocks, it may be possible to live-release fish from the purse seine vessels. However, chinook seine mortality rates are expected to be between 50 and 90% (CTC/PSC 1986). To determine the proportion of chinook which might survive seine catch and release, we used ultrasonic telemetry to track chinook salmon that were released from the fishing gear.

Catch and release studies have typically used net-pens or live-boxes to observe the fish once released from fishing gear. Ultrasonic tracking should more accurately reflect catch and release conditions encountered under commercial seining operations because it allows observation of individual fish without the confinement of a holding pen. The additive stress associated with artificial conditions imposed during holding experiments may bias mortality estimates (Wright 1970).

This manuscript summarizes the purse seine catch and release data, ultrasonic tracking, and tag recovery.

## METHODS

The purse seine fishery for sockeye salmon in Johnstone Strait operates between approximately mid to late summer. Chinook salmon were obtained for tracking by randomly selecting commercial seine vessels during the fishery. Since the commercial fishery lasted only a few days of each week, we also obtained salmon from the Department of Fisheries and Oceans (DFO) test fish vessels and charter vessels.

We recorded landing procedure, catch size and species composition for each set that provided a salmon for acoustic tracking. Landing procedure was defined as either "stern" - the catch was pulled over the stern of the vessel; or "side" - catch was held along side the vessel and fish were dipnetted from the seine net. We measured fork length, took scales for age determination and assessed degree of capture-induced injury. Injury was categorized as: 1) 0-5% scale loss and no injury; 2) 5-25% scale loss and/or minor injury (abrasions, fin damage, net marks); or 3) >25% scale loss and/or major injury (slashes through the flesh, bleeding from gills). The ultrasonic pressure sensing transmitter (Vemco V3P-3HI-R) was then inserted through the mouth into the stomach using a 13 mm x 30 cm dowel. A uniquely numbered Floy spaghetti tag was tied posterior to the dorsal fin to identify the fish and allow transmitter recovery if the fish were recaptured.

We tried to minimize the possibility that mortality could be attributed to handling. The first two fish (9001 and 9002) were anaesthetized (ms-222) before tagging and then allowed 10-20 minutes to recover before being released. We then discovered that chinook salmon could be successfully tagged underwater in a large darkened cooler without the use of anaesthetic, thus eliminating the recovery period and reducing handling time. For the first year (1990), salmon

taken from the capture vessel were transported by rigid-hull inflatable boat to a holding tank on the tracking vessel where each fish was measured and tagged. In subsequent years, we further reduced handling by tagging and releasing salmon directly from the inflatable boats.

In 1990, we used the F/V SEABOUND and DFO F/V WALKER ROCK consecutively as the tracking vessels. We increased the number of tracks in 1991 by dedicating an inflatable boat as a tracking boat along with the WALKER ROCK. The 18-foot, rigid-hull inflatable boat was ideal for boarding seiners to obtain salmon and when not tracking independently was periodically deployed to follow the fish through shallow pinnacle areas or into the middle of the seine and gillnet fleet. The inflatable boat was restricted to tracking only during daylight hours. These fish were either abandoned at dark or tracked by the WALKER ROCK overnight. The addition of the F/V CALIGUS to the program in 1992 as a second overnight tracking vessel gave us the capability of tracking two fish simultaneously. It was not always possible to attain our 24 h minimum track duration. We suspended tracks due to fish mortality, signal loss, or hazards such as inclement weather, shallow shoreline areas, and difficulty manoeuvring among the gillnet fleet at night.

In most cases, salmon were released in the vicinity of the capture site. We followed signals from the tagged salmon at a distance of 100-400 m using a directional hydrophone and Vemco VR-16 receiver/decoder. The ultrasonic tag transmitted a pulse rate that was proportional to depth and operated at frequencies from 50-76.8 kHz. After the first year, the transmitters with 50 kHz frequency were avoided because of signal interference with sounders on the tracking vessel and other vessels in the vicinity.

In 1990, we used pressure-sensing transmitters calibrated to an accuracy of less than 1 m for a 0-100 m depth range similar to those used for sockeye salmon telemetry studies in Johnstone Strait (Quinn et al., 1989). It was recommended that transmitters only be used up to 50% over calibrated range (F. Voegeli, Vemco Ltd. pers. comm.) However, for depths up to 100% over full scale, we were still able to recover depth values. To ensure the accuracy of the over-range data, we had a transmitter pressure tested showing a linear response between pressure and pulse frequency to 100% over full scale.

In 1990, three fish dove to depths over 100% full scale where the pulse frequency was too rapid for decoding depth data. Using the following methods (equation 1) we calculated depths values for 4:40 h, 8:30 h, and 4:30 h portions of tracks 9010, 9011, and 9013 respectively. The depth data cannot be decoded when missed pulses occur. The receiver/decoder calculates the depth using the following formula:

$$(1) \quad d = a + \frac{m}{\tau_p/(i+1)}$$

where:  $i=0$  no missed pulses  
 $i=1$  for 1 missed pulse.

Where  $m$  was the slope,  $a$  was the depth correction ( $y$  intercept) and  $\tau_i$  was the pulse rate. Slope and intercept were determined for each transmitter at the time of calibration by the manufacturer. We were able to select out observed depth values where a single pulse had been skipped and calculate a corrected depth. Given the continuity of the depth data, a computer program was designed to follow automatically the depth values from shallow to deep where it was updated as required to preserve the continuity of the depth values.

In subsequent years we used transmitters calibrated for a 0-200 m depth range and avoided depth problems. Time and depth readings were output at approximately 1-sec interval and recorded continuously by a microcomputer or logged internally by the receiver/decoder. Vessel position was determined by locally corrected Loran C readings, and (in 1992) a Magellan Nav5000 plus GPS unit. The Loran unit was periodically calibrated by radar or visually by landmarks. Vessel latitude and longitude coordinates, depth, and time (PST) were recorded at 5-min intervals.

We constructed track maps for each fish using the GIS program Chartgraph (Kronlund et al. in prep) and latitude and longitude coordinates of the fish plotted at 5-min intervals. The corresponding depth data were plotted separately also at 5-min intervals.

## RESULTS AND DISCUSSION

Ultrasonic tracking has been used to develop an understanding of salmonoid behaviour and interaction with environmental conditions. Ogura and Ishida (1992) studied the swimming behaviour of coho salmon (*O. kisutch*) on the high seas. Orientation and migration studies include sockeye migrating to the Fraser River (Quinn 1988; Quinn et al. 1989), the Skeena River (Groot et al. 1975) and steelhead trout (*O. mykiss*) migrating to the central coast (Ruggerone et al. 1990). Other studies relate fish movement to oceanographic conditions (Olson and Quinn 1993; Quinn and terHart 1987) and response to predators (Trites and Ellis submitted). Our study is apparently the first time telemetry has been used to study catch and release fishing mortality.

### FISH CAPTURE, TAGGING, AND RELEASE

It was often necessary to board between five and 30 commercial seiners before a chinook salmon was found in the catch. Most of the chinook were captured in beach sets (one end of the net secured to land) on the Vancouver Island side of Johnstone Strait from just south of Robson Bight to the northwestern fishing boundary near Blinkhorn Light.

In 1990, nine chinook salmon were captured by commercial seining, the test vessel, M/V MARC ALAN captured three, one was seined by the WALKER ROCK. Data from a coho salmon (9003) caught on a handline in Tribune Channel have been left out of the analysis. In 1991, 14 chinook salmon were taken by commercial seining during the fishery and the test vessel, M/V WESTERN MOON captured six chinook salmon. In 1992, eight chinook salmon were taken by commercial seine vessels, two by the test vessel M/V CHIEF TAPEET, and six

salmon by the charter vessel M/V OCEAN PREDATOR. Of the 14 fish that were side-landed, nine were taken from test fish sets. Since the test fish were not landed but were slowly spilled over the cork line to estimate number and species composition, we dipnetted the chinook from the net once most of the fish had been released. From the remaining five sets, we dipnetted fish from the net after most of the catch had been brailled aboard.

In 1990, total salmon catches in the sets from which we used chinook salmon were estimated by DFO observers (Nagtegaal and Riddell 1994). In 1991 and 1992 we estimated catch sizes ourselves. The target species, sockeye salmon and pink salmon, dominated the catches. Fisheries Branch staff provided catch sizes and species composition from test fishing sets. Chinook salmon were taken from seine catches which varied in size from 2 to 2006 salmon (Table 1). Approximately half of the sets contained a single chinook salmon. From the remaining sets, we selected a chinook salmon of acceptable size (>50 cm).

Landing time (interval when the seiner began drumming the net aboard to when the tagged salmon was dipped from the pursed net or landed on the deck of seiner) ranged from 0:07-0:40 h (mean=0:12 h) (Table 2). Tagging time (from the end of landing time to when the fish was released) ranged from 0:03-0:34 h (mean=12 h)(excluding 9005). Tagging time was greatest for fish 9005 because it was transported in a live tank aboard the tracking vessel from Parson's Bay where it was caught to Johnstone Strait before being released. Longer landing times were associated with larger catch sizes and side landed catches (Figure 2).

Frequently the inflatable boats had to travel a considerable distance from the tracking vessel in search of a chinook from the seine fleet. Once a salmon was captured, the dayboat would return to the tracking vessel to release the fish. Salmon were released from 0.30 km to 1.52 km from where they were captured.

## ULTRASONIC TRACKING

Ultrasonic tracking is the only means of directly observing movement and assessing mortality and behaviour of the fish after release back into the ocean. Typically, ultrasonic telemetry studies on salmonids are labour intensive; only one fish can be tracked by a vessel at one time. Each fish must be tracked continuously and for an adequate amount of time to determine movement patterns.

Tracking took place from 4 July to 31 August 1990, from 5 August to 2 September 1991, and from 2 to 27 August 1992 (Table 3). In 1990, we tracked 13 chinook in Johnstone Strait with a tracking time of 147:12 h. The minimum track time was 0:15 h and the maximum was 24:05 h (mean = 11:19 h).

In 1991, we tracked all twenty chinook salmon in Johnstone Strait for a total tracking time of 362:08 h. A marine mammal researcher (Dr. D. Bain, PDF, NMFS, Seattle, Washington) continued tracks 9106, 9109, 9114, 9116 and 9118 increasing our total tracking duration by 32:18 h. Track times ranged from 0:43 h to 32:48 h (mean=18:06 h).

The low sockeye catches and short fishing season made it difficult to acquire chinook for tracking during the fishery openings in 1992. The M/V OCEAN PREDATOR was chartered during the final week of the program to catch chinook for tracking. In 1992 all 16 chinook were caught and tracked in Johnstone Strait for a total tracking time of 281:50 h. Track times ranged from 2:29 h to 29:05 h (mean=17:37 h).

## HORIZONTAL MOVEMENTS

Chinook salmon generally tended to remain close to shorelines primarily on the Vancouver Island side of Johnstone Strait after release (Fig. 3). Few fish made excursions across the strait to the north shore. Some fish appeared to be very directional in their movements while others remained near the release site. A few fish swam into bays or confined shoreline areas and would remain there for up to 24 h. Of 30 fish tracked greater than 7 h, 60% moved northward up Johnstone Strait (50% beyond the northern fishing boundary), 26% moved southward down Johnstone Strait, and 14% remained within a nautical mile of the release site.

Gross distance is the sum of the distance travelled along the tracks where location was determined by loran/GPS readings every 5 min (Table 3). Gross distances travelled by salmon during tracking ranged from 0.6-72.4 km (mean = 29.5 km). The net distance was calculated from the point of release to the point where the track was terminated. Net distance ranged from 0.1-32.8 km (mean= 8.4 km) (Table 3).

The average rate of travel was a measure of the combined effect of current transport and active swimming. It was calculated as the gross tracking distance divided by the total track time for each salmon. The minimum rate of travel of 0 km/h occurred for 9120,9202 and the maximum rate of travel of 2.7 km/h occurred for track 9001 (Table 3). Both 9120 and 9202 suffered immediate mortality at time of release. Average rate of travel was 1.9 km/h.

The first year of the study we attempted to deploy current drogues to measure current and derive active swimming rates. The drogues were similar in construction to those used during the sockeye salmon study (Quinn et al. 1989). However, we were unable to deploy and retrieve the drogues successfully from the tracking vessel without the risk of losing the fish being tracked. As well, we were not confident that current measured at the surface with the drogue would reflect current acting upon a fish capable of rapidly changes in depth and which quickly became horizontally separated from the drogue. The chinook salmon show a wide variety of behaviour once released from the purse seine gear, for some chinook tracked, passive drifting may account for a large component of the movement seen. Olson and Quinn (1993) noted that chinook salmon homing to the Columbia river often tend to move in the direction of prevailing current and milled during periods of low current velocity. In Johnstone Strait there is a constant northward flow of surface water to about 100 m depth capable of moving a passive object at approximately 20 cm/s (Thomson 1981). The higher frequency of fish moving northwesterly up Johnstone Strait is probably due to this current transport.

Average rates of travel in this study (1.9 km/h) were similar to that seen for sockeye

salmon (2.0 km/h) in Johnstone Strait (Quinn et al. 1989) and slightly lower than for Columbia River chinook (2.4 km/h). Differences in chinook rate of travel between Johnstone Strait and Columbia River may merely reflect differences in tidal current regimes of the two sites.

## VERTICAL MOVEMENTS

Over the three years, we observed about 40% of the salmon to have made an initial deep dive (greater than 70 m) after release (Figure 3). They stayed at a considerable depth, then ascended toward the surface between 0:30 h to 12:00 h later. In some cases the vertical dives could be distinguished from subsequent vertical movement patterns but in other cases, the dive was less defined or absent. Many fish remained in a narrow depth range, then made periodic excursions to a much greater depth. Vertical track plots for the track 9001 and track 9010 show two extreme patterns of vertical movement, the first with no initial dive and the second with a protracted initial dive.

## MEASURE OF EXTERNAL INJURY

In 1990, injury was most severe for chinook 9002, 9006 and 9012 (Table 2). Fish 9002 had 25% scale loss. Fish 9006 suffered partial loss of snout and had one apparently dysfunctional eye as a result of seining. Fish 9012 had slight bleeding from gills in addition to scale loss.

Injuries to salmon in 1991 were most severe for 9104, 9106, 9107, 9108, and 9113. These injuries included a torn pectoral fin, deep wounds on head and bleeding (9104); bleeding from gills and 25% scale loss (9106); 50% and 65% scale loss (9107, 9108); slashes to belly and 20% scale loss (9113). Other, less severe injuries included varying degrees of scale loss and net marks on body.

Injuries to the tagged chinook in 1992 included abrasions on operculum and body, 25% scale loss (9204); bleeding, lower lip missing (9205); 40% scale loss (9206); severe bleeding from gills (9214), along with some degree of scale loss, body and fin damage due to net abrasion.

## MORTALITY

We inferred survival/mortality of the fish from its horizontal and vertical movements. We assumed that mortality had occurred if the fish slowly sank to a bottom depth determined from the ship's sounder. We continued to track the fish for a minimum of 2 h if its depth corresponded with the bottom. We attempted to relocate the fish 12-24 h later at the same Loran or GPS coordinates. An example of mortality is fish 9108 (Figure 3). For a more complete discussion of the mortalities see Candy et al. (submitted).

## TAG RECOVERIES

Eight of the 50 tags were returned to us over the three years. Recoveries were from anglers, commercial fishermen, and hatcheries (Table 4). Return rates were 1/14 (7.1%) - 1990, 1/20 (5%) - 1991, and 6/16 (37.5%) - 1992. Days at large ranged from 6 to 62 days and minimum distance travelled ranged from 22 to 500 km. Tagged fish returning to hatcheries may have arrived up to one month prior to the recovery date and were held for spawning. The short commercial fishing seining season in 1992 may be responsible for higher tag returns in that year.

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## LITERATURE CITED

- CTC/PSC (Chinook Technical Committee, Pacific Salmon Commission). 1986 Summary Report. Report TCCHINOOK (87) 4.
- Candy, J.R., E.W. Carter, T.P. Quinn, and B.E. Riddell. (submitted) A study of adult chinook salmon behaviour and an estimate of survival after catch and release from purse seine vessels in Johnstone Strait, B.C. North American Journal of Fisheries Management.
- Groot, C., K. Simpson, I. Todd, P.D. Murray, and G.A. Buxton. 1975. Movements of sockeye salmon (*Oncorhynchus nerka*) in the Skeena River estuary as revealed by ultrasonic tracking. J. Fish. Res. Board Can. 32: 233-242.
- Kronlund A.R., D.W.A. Whitfield and L. Lapi (in prep) Chartgraph: a software system for statistical mapping. Can. Tech. Rept. Fish. Aquat. Sci.
- Nagtegaal, D.A. and B. Riddell. 1994. Estimation of total chinook mortality associated with seine fishing in Johnstone Strait and Juan de Fuca 1990. Can. MS Rep. Fish. Aquat. Sci. 2229.
- Ogura, Miki and Y. Ishida. 1992. Swimming behaviour of coho salmon, *Oncorhynchus kisutch*, in the open sea as determined by ultrasonic telemetry. Can. J. Fish. Aquat. Sci. 49:453-457.
- Olson, A.F. and T.P. Quinn. 1993. Vertical and horizontal movements of adult chinook salmon, *Oncorhynchus tshawytscha*, in the Columbia River estuary. Fish. Bull. 91(1):171-178.
- Pincock, D.G. and F.A. Voegeli. 1992. Quick course in underwater telemetry systems. Vemco Limited, Halifax, Nova Scotia, Canada.
- Quinn, T.P. and B.A. terHart. 1987. Movements of adult sockeye salmon (*Oncorhynchus nerka*) in British Columbia coastal waters in relation to temperature and salinity stratification: ultrasonic telemetry results. Can. Spec. Publ. Fish. Aquat. Sci. 96:61-77.
- Quinn, T. P. 1988. Estimated swimming speeds of migrating sockeye J. Zool. 66:2160-2163.
- Quinn, T.P., B.A. terHart and C. Groot. 1989. Migratory orientation and vertical movements of homing adult sockeye salmon, *Oncorhynchus nerka*, in coastal waters. Anim. Behav. 37:587-599.
- Ruggerone, G.T., T.P. Quinn, I.A. MacGregor, and T.D. Wilkinson. 1990. Horizontal and vertical movements of adult steelhead trout *Oncorhynchus mykiss*, in the Dean and Fisher channels, British Columbia. Can. J. Fish. Aquat. Sci. 47:1963-1969.

- Thomson, R.E. 1981. Oceanography of British Columbia coast. Can. Spec. Publ. Fish. Aquat. Sci. 56:291 p.
- Trites, A.W. and G.M. Ellis (submitted) Sonic tracking chinook salmon movements in a river estuary: evidence of a flight response. Can. J. Fish. Aquat. Sci.
- Voegeli F. 1991. Personal communication. Vemco Ltd. 3895 Shad Bay, RR#4, Armdale, Halifax County, Nova Scotia. B3L 4J4.
- Wright, S. 1970. A Review of the subject of hooking mortalities in Pacific salmon (*Oncorhynchus*). Pacific Marine Fisheries Commission Annual Report 23:47-65.

Table 1. Catch size in numbers and species composition of catches where chinook salmon were taken for ultrasonic tracking 1990-1992.

Track	Sockeye	Pink	Chinook	Coho	Chum	Steelhead	Total
9001	20	0	1	0	0	0	21
9002	13	0	1	0	0	0	14
9004	850	550	2	0	15	0	1417
9005	0	0	5	0	0	0	5
9006	200	200	8	1	0	0	409
9007	2	10	1	0	0	0	13
9008	8	70	7	0	0	0	85
9009	10	40	1	0	2	0	53
9010	0	2	1	0	2	0	5
9011	850	15	2	0	2	0	869
9012	200	0	1	0	0	1	202
9013	0	0	2	0	0	0	2
9014	0	20	1	0	2	0	23
9101	60	10	4	0	0	0	74
9102	10	0	6	0	0	0	16
9103	70	0	2	0	5	0	77
9104	170	30	2	0	0	0	202
9105	150	20	2	0	3	0	175
9106	350	200	1	0	0	0	551
9107	200	50	2	25	0	0	277
9108	200	50	2	25	0	0	277
9109	20	10	1	0	0	0	31
9110	20	15	1	0	0	0	36
9111	575	150	2	1	0	0	728
9112	6	5	3	0	0	0	14
9113	200	25	1	0	0	0	226
9114	80	175	2	0	1	0	258
9115	40	50	1	0	0	0	91
9116	0	1	1	0	0	0	2
9117	50	40	1	0	0	0	91
9118	50	10	5	0	0	0	65
9119	160	200	1	0	0	0	361
9120	25	325	3	25	25	0	403
9201	150	0	1	0	0	0	151
9202	300	0	4	0	0	0	304
9203	850	0	6	0	0	0	856
9204	2000	0	2	0	4	0	2006
9205	175	100	2	6	0	0	283
9206	350	0	1	0	0	0	351
9207	1000	0	2	0	0	0	1002
9208	1000	0	2	0	0	0	1002
9209	40	0	2	0	0	0	42
9210	0	11	2	0	0	0	13
9211	2	1	1	0	0	0	4
9212	0	20	6	0	0	0	26
9213	5	2	4	0	0	0	11
9214	2	3	6	0	0	0	11
9215	8	2	4	0	0	0	14
9216	8	2	4	0	0	0	14

Table 2. Summary of landing procedure, landing time, tagging time, scale loss, and injury category for the chinook salmon tracked 1990-1992.

Track No.	Landing Type	Landing Time (h:min)	Tagging Time (h:min)	Scale Loss (%)	Injury Category	Injury
9001	Stern	0:25	0:34	10	2	none
9002	Stern	0:25	0:14	25	3	open sore lower left jaw
9004	Side	0:28	0:20	0	1	none
9005	Side	0:40	1:10 <sup>1</sup>	0	1	none
9006	Stern	0:20	0:20	5	3	missing 1/2 snout
9007	Stern	N/A	0:32	0	2	slight damage to caudal fin
9008	Side	0:30	0:23	0	1	none
9009	Stern	N/A	0:19	5	1	none
9010	Stern	N/A	0:20	0	2	old hook injury lower jaw
9011	Side	0:35	0:24	0	1	some net marks
9012	Stern	0:10	0:22	25	3	light bleeding from gills
9013	Stern	0:17	0:07	0	1	none
9014	Stern	0:15	0:15	0	2	some minor net marks
9101	Stern	0:15	0:25	5	2	torn dorsal fin
9102	Stern	0:31	0:10	3	1	none
9102	Stern	0:20	0:09	15	2	none
9104	Stern	0:23	0:16	5	3	torn pec, head wounds, blood
9105	Side	0:28	0:08	5	1	none
9106	Stern	0:25	0:06	25	3	bleeding from gills
9107	Stern	0:20	0:08	50	3	none
9108	Stern	0:20	0:14	65	3	none
9109	Stern	0:16	0:09	5	1	none
9110	Side	0:35	0:05	5	1	none
9111	Side	0:38	0:17	15	2	none
9112	Stern	0:11	0:09	5	2	damage to left eye
9113	Stern	0:15	0:20	20	3	slashes to belly 4 cm long
9114	Stern	0:22	0:08	10	2	none
9115	Stern	0:20	0:05	5	1	none
9116	Stern	0:20	0:17	15	2	none
9117	Side	0:31	0:06	0	1	none
9118	Stern	0:29	0:10	15	2	none
9119	Side	0:26	0:08	5	2	some net marks
9120	Side	0:24	0:08	0	2	net burns on belly
9201	Stern	0:15	0:03	5	1	none
9202	Stern	0:28	0:16	5	2	net abrasions, stressed
9203	Stern	0:38	0:06	5	1	none
9204	Side	0:35	0:05	25	2	abrasions operculum/body
9205	Stern	0:07	0:05	05	3	bleeding, lower lip missing
9206	Stern	0:20	0:04	40	3	none
9207	Side	0:23	0:07	05	2	net marks on belly and side
9208	Side	0:17	0:07	0	1	none
9209	Stern	0:21	0:10	10	2	torn dorsal fin
9210	Stern	0:20	0:08	0	2	slight bleeding in eye
9211	Stern	0:11	0:09	5	2	anal fin damaged
9212	Stern	0:12	0:08	5	2	right pectoral fin frayed
9213	Stern	0:15	0:06	0	1	none
9214	Stern	0:09	0:18	2	3	severe bleeding from gills
9215	Stern	0:11	0:07	0	1	none
9216	Stern	0:14	0:16	10	2	caudal fin damaged
Average		0:22	0:12			

<sup>1</sup> value not included in mean tagging time

Table 3. Summary of fork length, release date, time tracked, distance tracked, average speed, and maximum depth for chinook salmon tracked in 1990-1992.

Track Number	Fork Length (cm)	Release Date	Time Tracked (hr:min)	Gross Distance (km)	Net Distance (km)	Average Speed (km/hr)	Max Depth (m)
9001	74	04JUL90	20:09	54.4	23.7	2.7	97.5
9002	75	05JUL90	6:18	8.6	2.0	1.4	71.0
9004	85	08AUG90	22:08	28.9	0.9	1.3	214.0
9005	92	10AUG90	0:15	0.6	0.6	2.5	1.8
9006	62	12AUG90	5:15	12.2	7.7	2.3	53.1
9007	89	13AUG90	22:50	45.8	20.9	2.0	62.8
9008	103	18AUG90	9:27	16.7	6.5	1.8	290.0
9009	82	20AUG90	2:01	4.8	4.1	2.4	59.5
9010	89	21AUG90	10:10	25.4	6.3	2.5	265.1
9011	86	25AUG90	22:00	44.8	18.3	2.0	363.0
9012	76	26AUG90	2:38	1.6	0.8	0.6	5.0
9013	82	27AUG90	12:01	21.9	1.7	1.8	370.1
9014	86	28AUG90	12:00	19.8	9.7	1.7	93.5
9101	84	05AUG91	7:55	14.2	9.9	1.8	372.1
9102	81	05AUG91	2:34	5.3	3.5	2.0	314.8
9103	77	05AUG91	9:56	13.1	2.5	1.3	379.4
9104	84	08AUG91	29:06	76.0	9.8	2.6	248.6
9105	51	08AUG91	0:43	1.2	1.2	1.7	50.3
9106	96	11AUG91	22:35	47.9	6.7	2.1	118.8
9107	64	12AUG91	8:20	11.9	2.3	1.4	97.2
9108	59	12AUG91	21:06	34.5	10.0	2.6	128.2
9109	64	13AUG91	32:25	42.9	9.1	1.3	58.6
9110	64	14AUG91	9:45	13.5	5.9	1.4	177.5
9111	66	15AUG91	28:35	51.9	32.8	1.8	188.6
9112	64	19AUG91	11:30	18.3	12.9	1.6	172.7
9113	62	19AUG91	24:24	4.4	1.7	0.4	90.1
9114	72	20AUG91	29:21	70.4	13.2	2.4	167.4
9115	70	21AUG91	3:10	7.8	7.0	2.5	42.3
9116	92	21AUG91	24:45	51.7	7.1	2.1	148.9
9117	85	22AUG91	15:10	24.6	8.7	2.1	419.3
9118	65	27AUG91	32:48	69.7	12.8	2.1	91.6
9119	85	30AUG91	29:35	15.8	0.9	1.6	288.0
9120	103	02SEP91	18:25	8.0	0.1	0.0	156.0
9201	100	02AUG92	11:27	8.6	2.3	0.8	38.7
9202	109	03AUG92	5:21	16.7	1.0	0.0	331.6
9203	78	03AUG92	2:29	5.3	2.9	2.2	182.8
9204	89	08AUG92	18:05	22.9	3.0	2.5	363.7
9205	90	09AUG92	26:00	51.4	9.8	2.0	239.6
9206	89	10AUG92	11:30	26.0	11.9	2.3	96.4
9207	70	12AUG92	24:12	58.2	16.1	2.4	131.6
9208	80	12AUG92	24:00	42.1	1.3	1.8	398.0
9209	89	13AUG92	24:04	46.7	14.1	1.9	270.2
9210	81	17AUG92	29:05	60.2	32.3	2.1	152.9
9211	91	24AUG92	24:11	58.9	7.7	2.4	235.3
9212	90	24AUG92	21:20	36.6	10.5	1.7	76.4
9213	83	26AUG92	19:49	33.9	13.5	1.7	371.7
9214	89	26AUG92	7:57	13.9	5.5	1.7	72.8
9215	56	27AUG92	7:55	15.4	8.6	2.0	61.0
9216	75	27AUG92	24:00	55.3	8.5	2.3	166.2
Average Total	80		16:18 814:50	29.2 1455.8	8.3 413.1	1.9	

Table 4. Tag recoveries for chinook salmon tracked in Johnstone Strait 1990-1992.

Track No.	Date Recovered	Capture Type	Recovery Location	Days from Release	Min. Distance Travelled (km)
9006	26 Aug 90	Processor	Juan de Fuca St.	15	444
9110	19 Aug 91	Seiner	Naka Creek	6	22
9206	27 Aug 92	Sport	Bargain Harbour	17	228
9207	21 Sept 92	Spawning	Big Qualicum Hatch.	41	176
9212	26 Sept 92	Spawning	Quinsam Hatch.	34	130
9213	29 Sept 92	Sport	Nitinat Lake	35	500
9214	26 Oct 92	Spawning	Big Qualicum Hatch.	62	176
9216	13 Oct 92	Spawning	Nanaimo River Hatch.	48	278

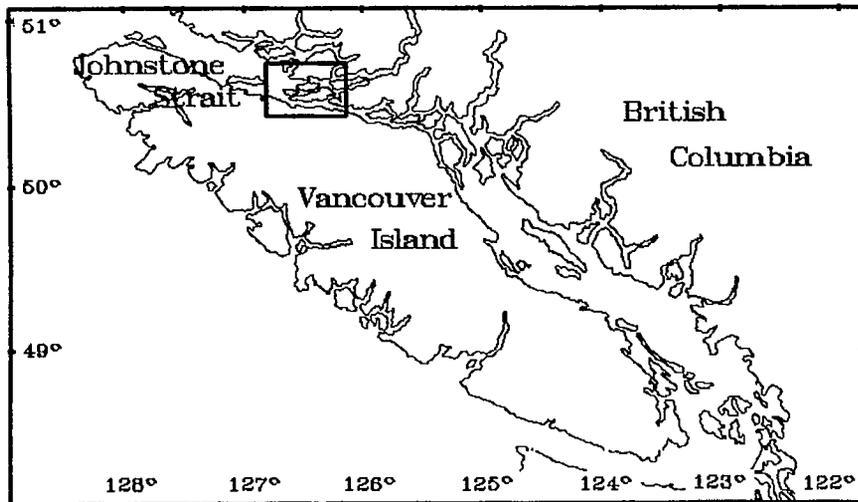


Figure 1 - Map of Vancouver Island showing Johnstone Strait where the chinook salmon were tracked 1990-1992.

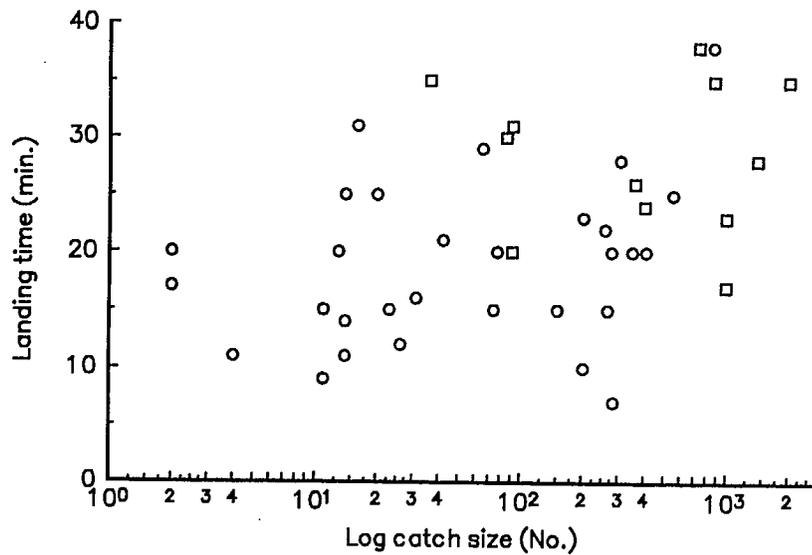
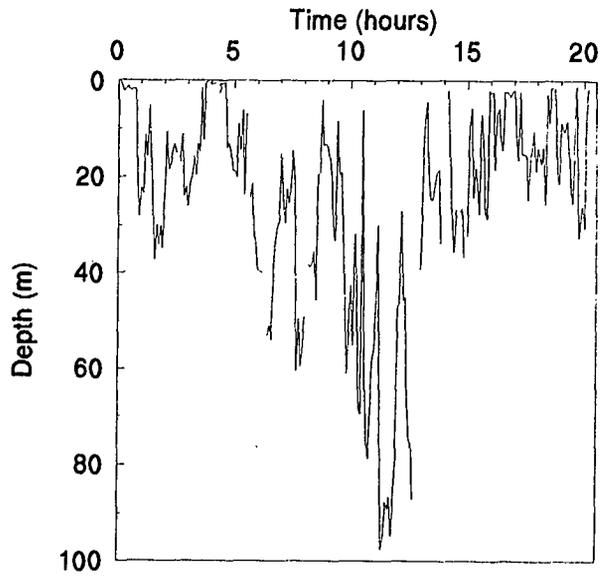
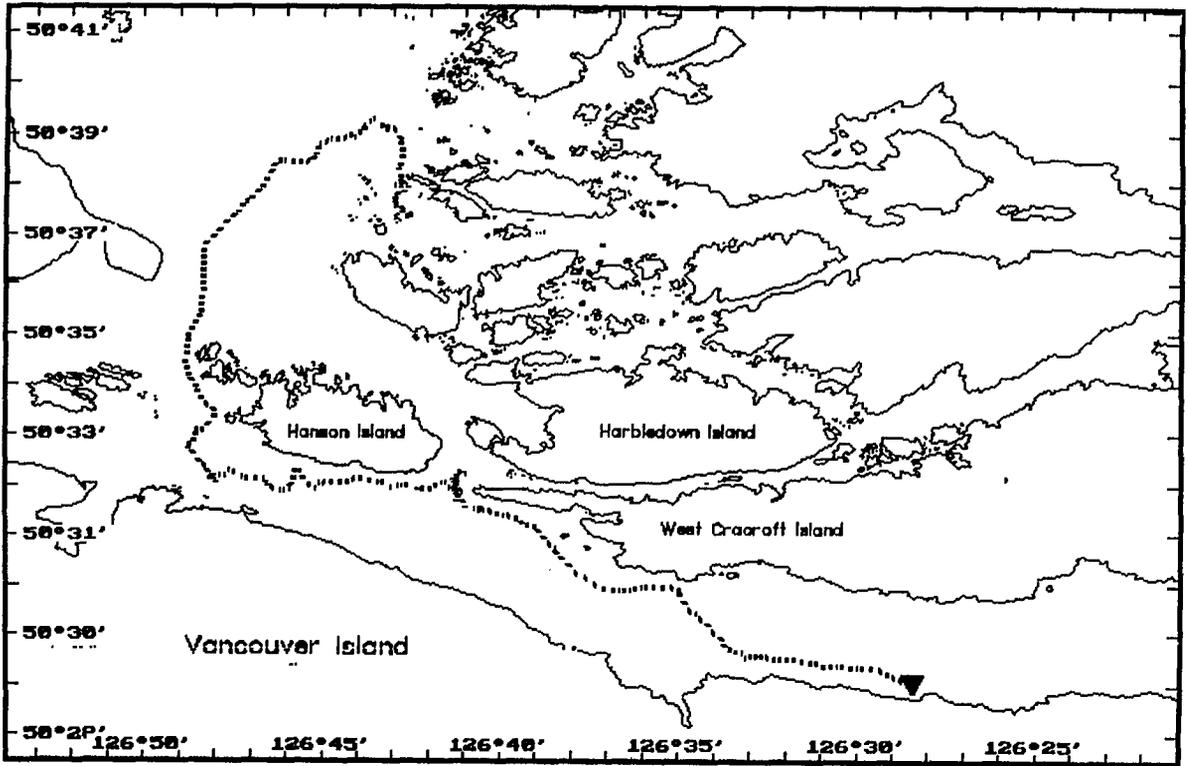
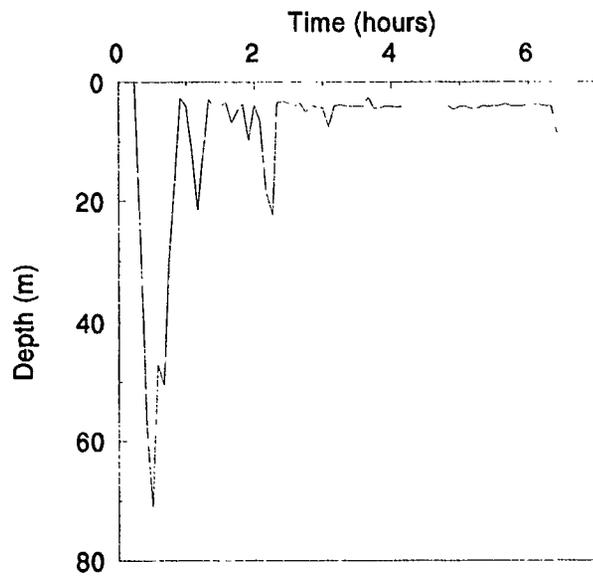
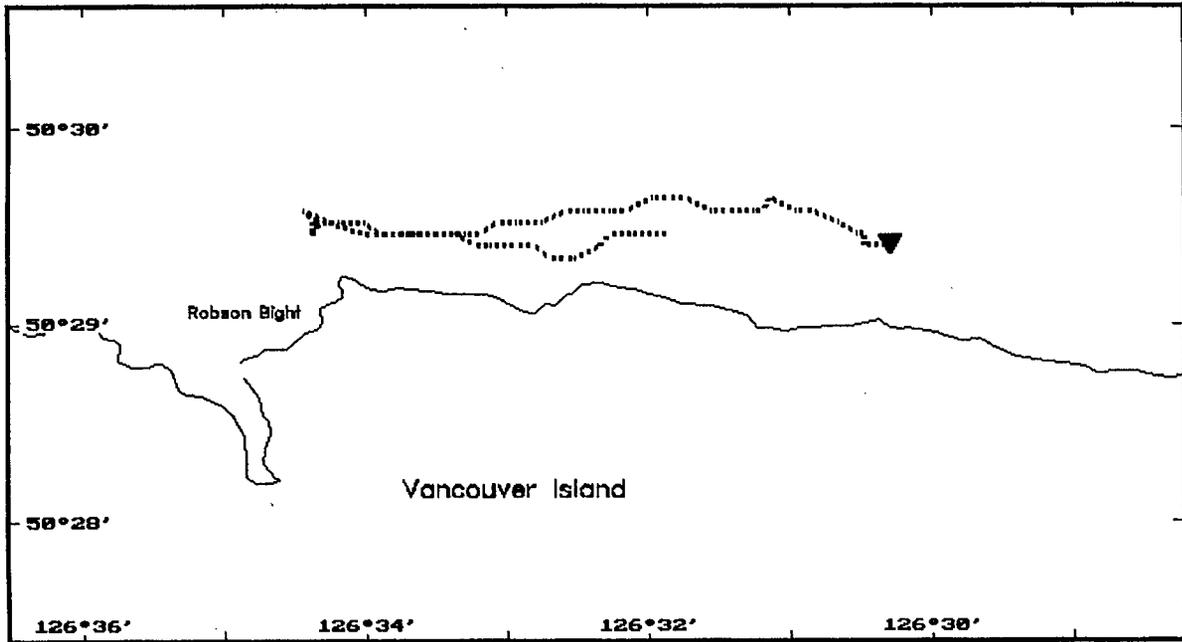


Figure 2. Relation between landing time and catch size for side (square) and stern (circle) landed fish in Johnstone Strait.

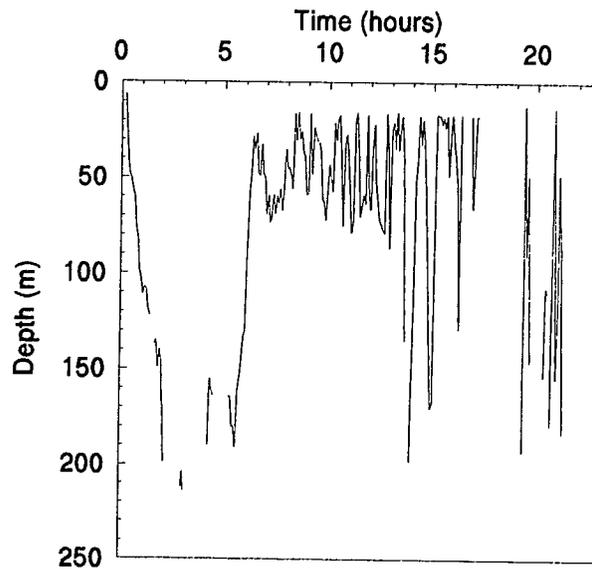
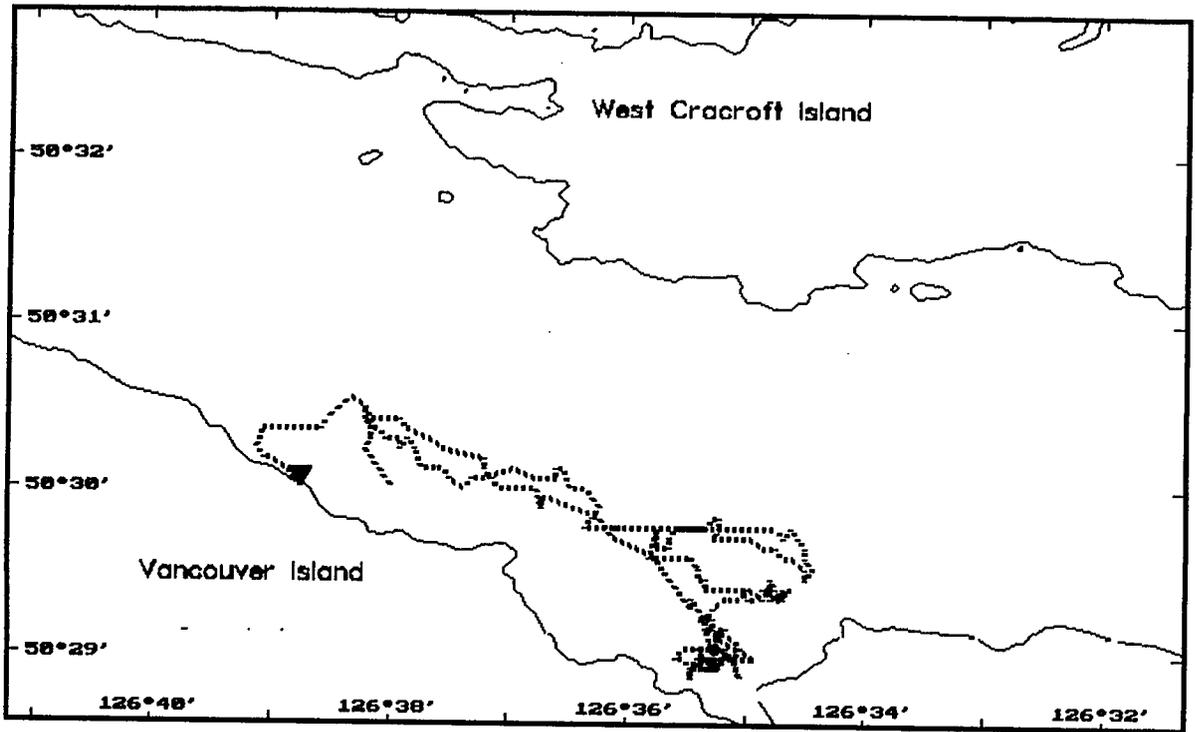
Figure 3. Horizontal and vertical movements of chinook salmon tracked 1990-1992.  
Upside-down triangle on horizontal track map indicates release site.



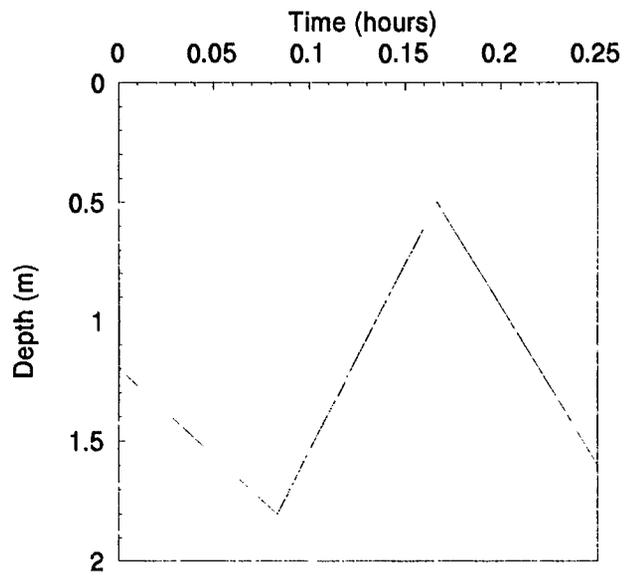
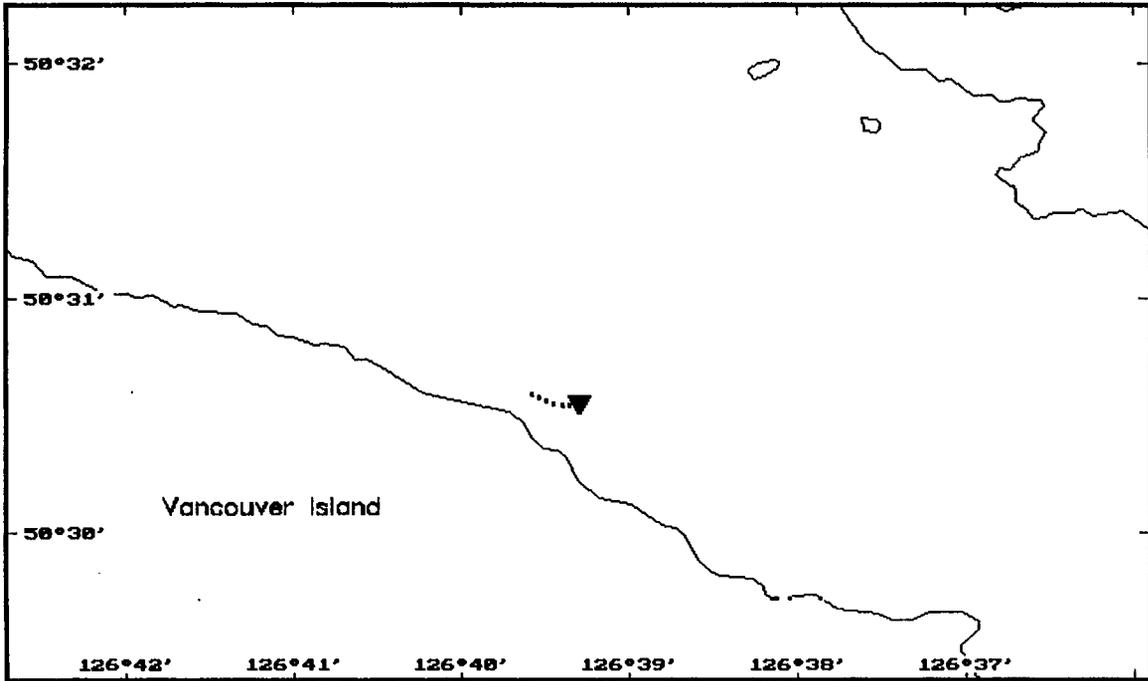
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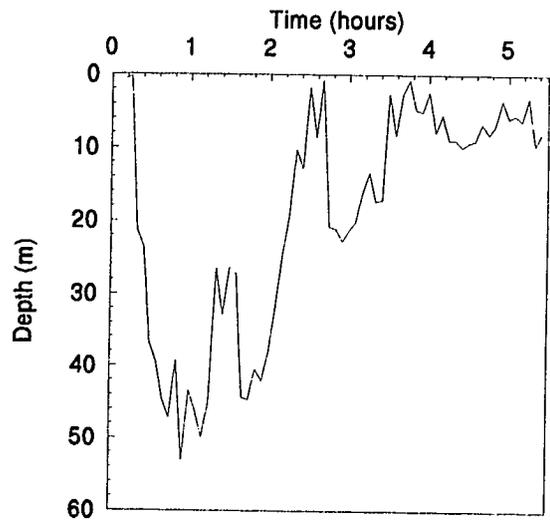
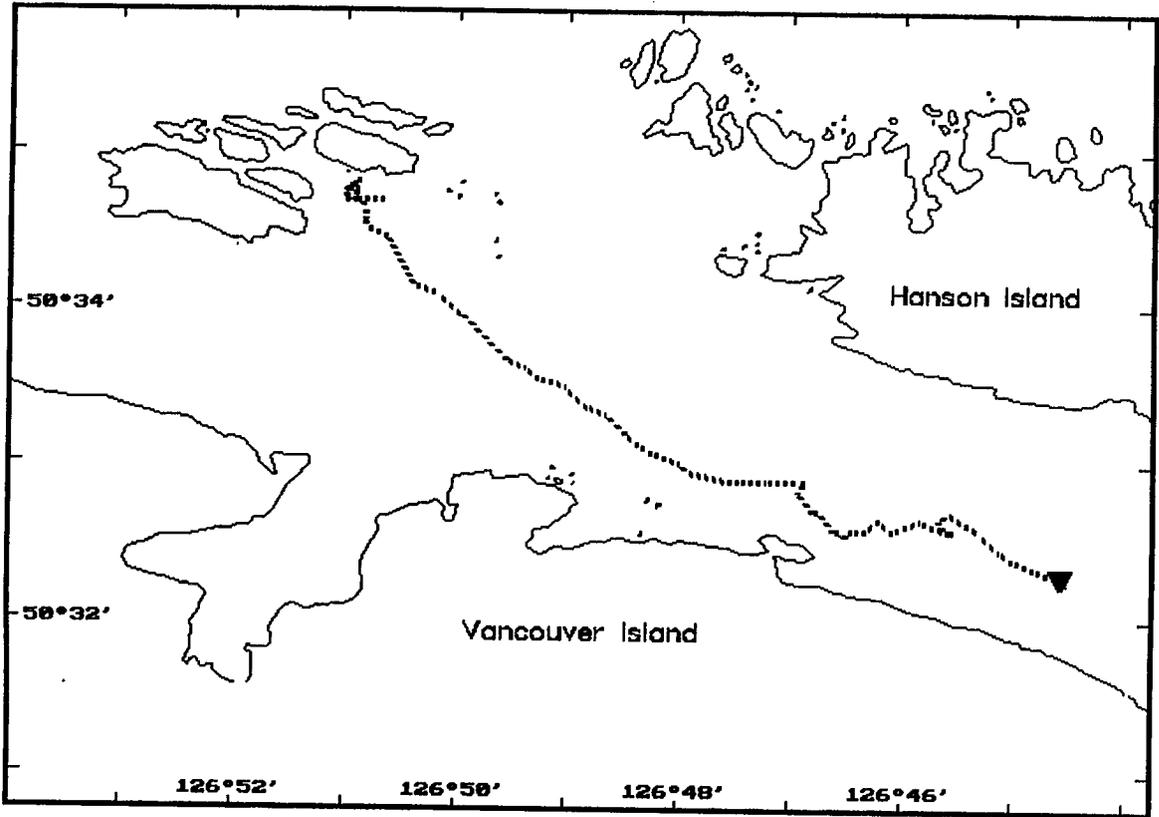
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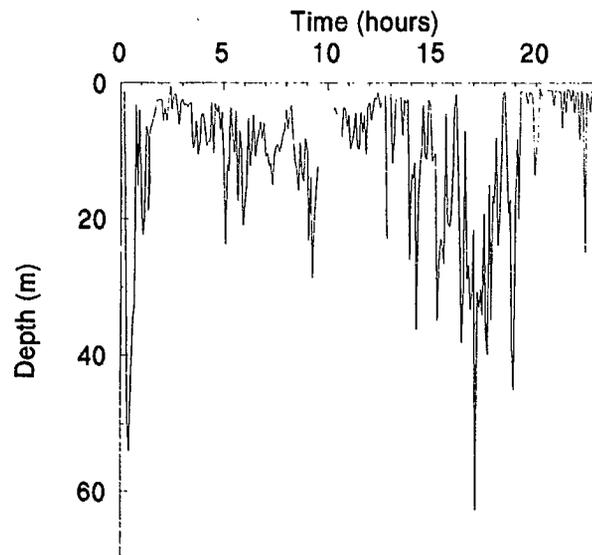
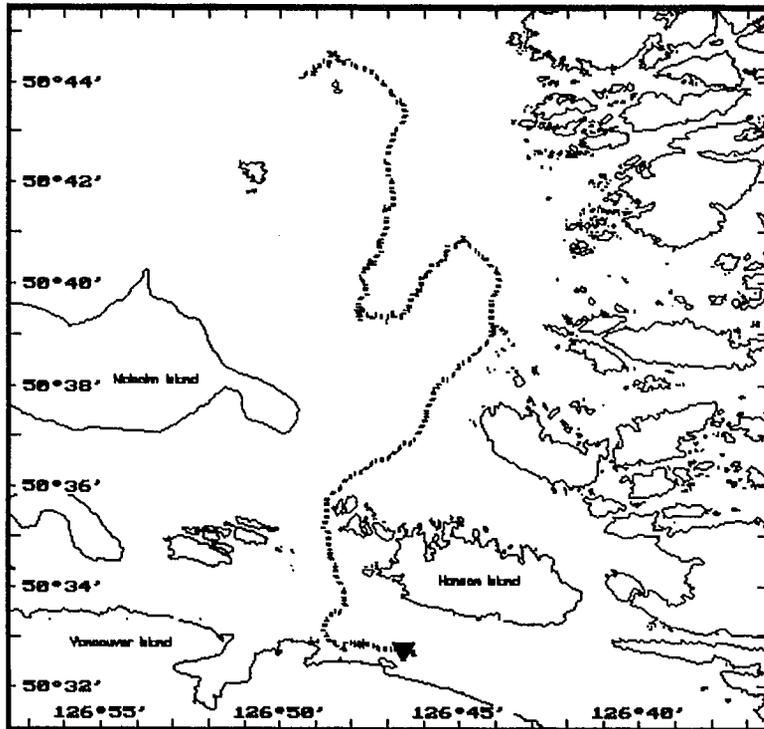
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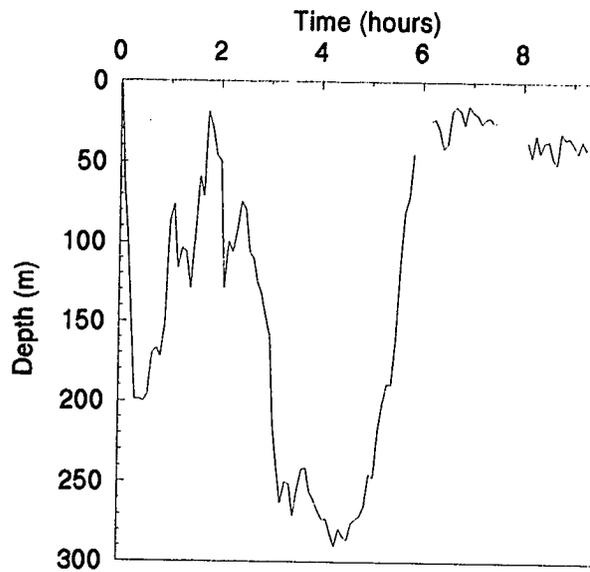
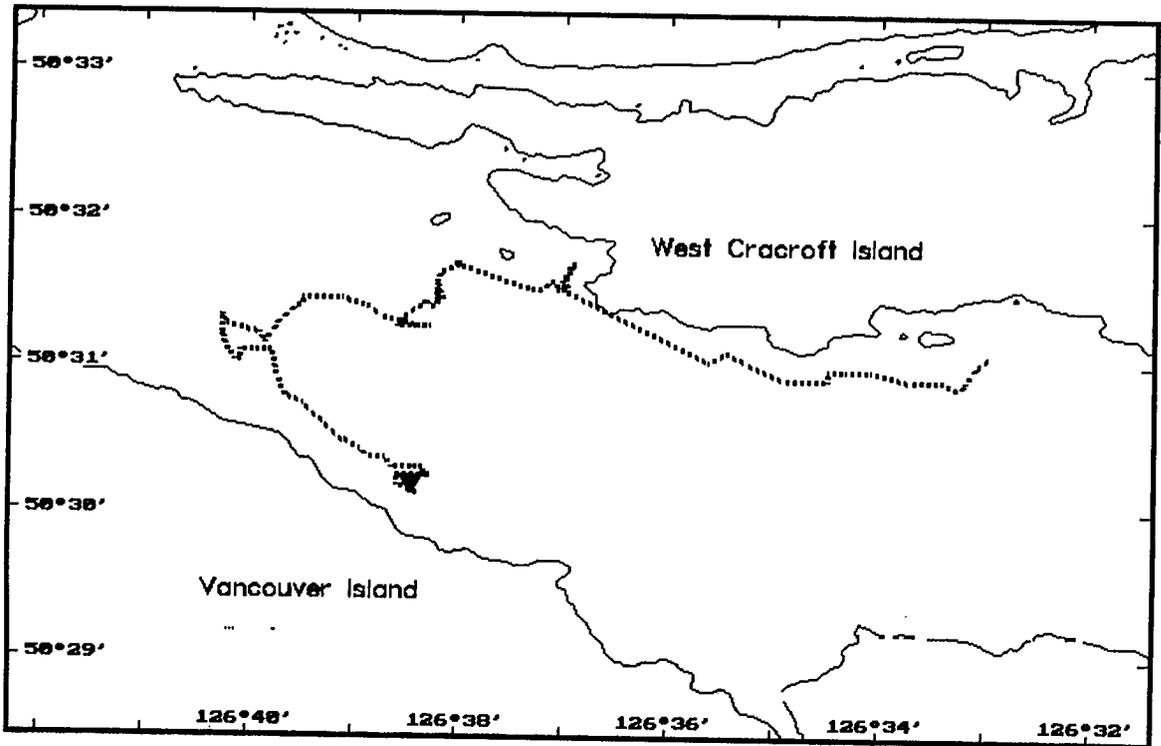
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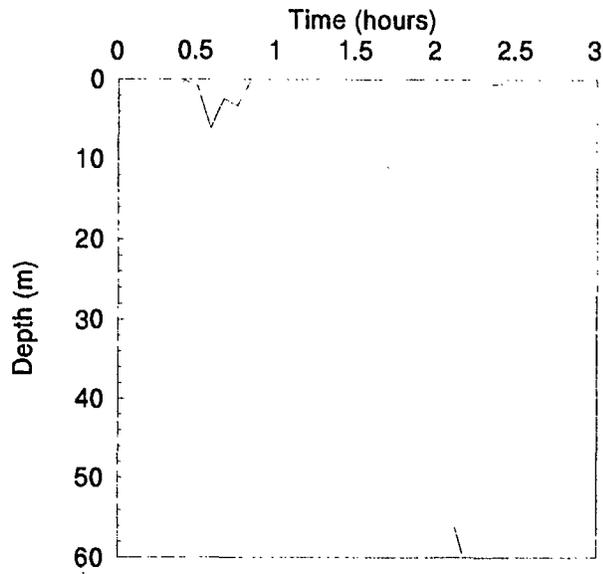
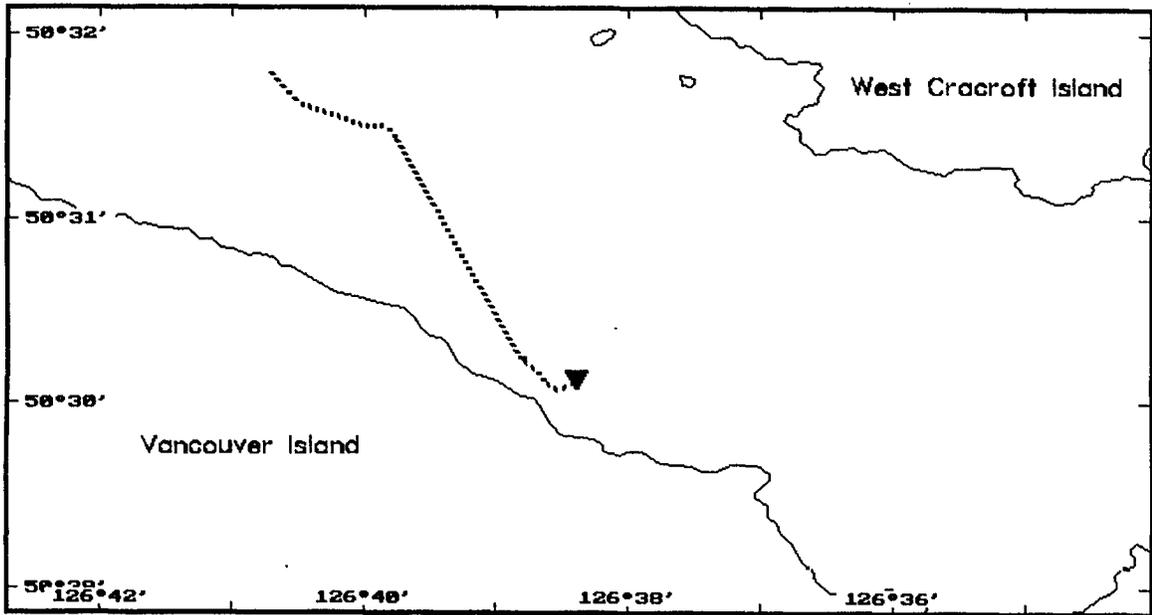
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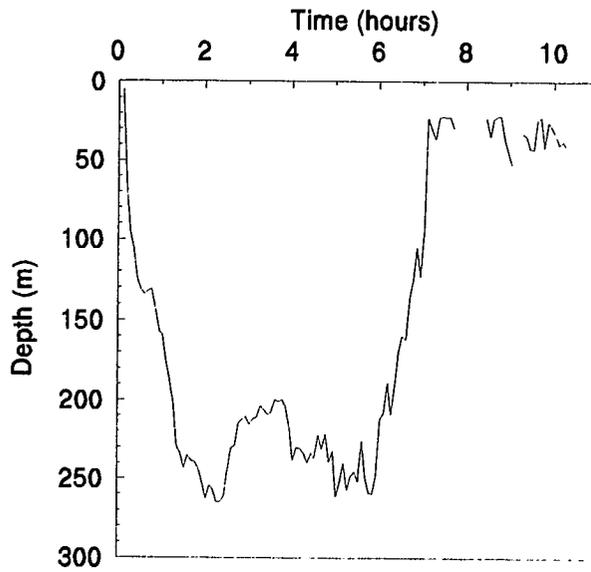
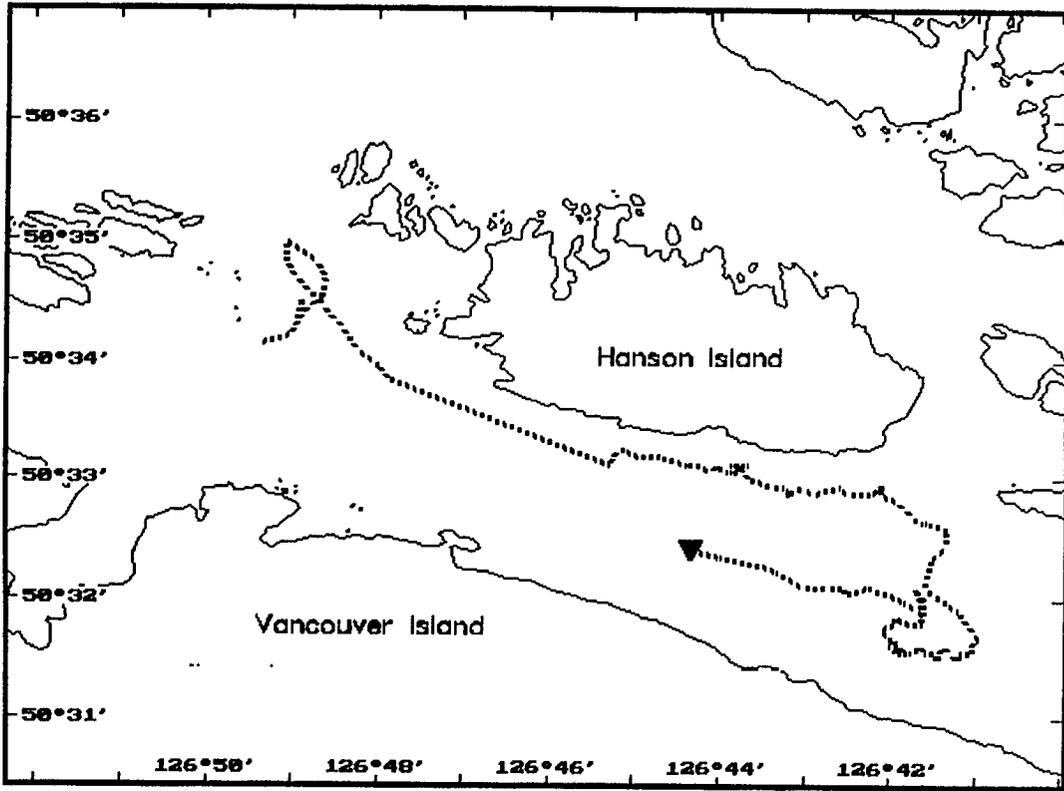
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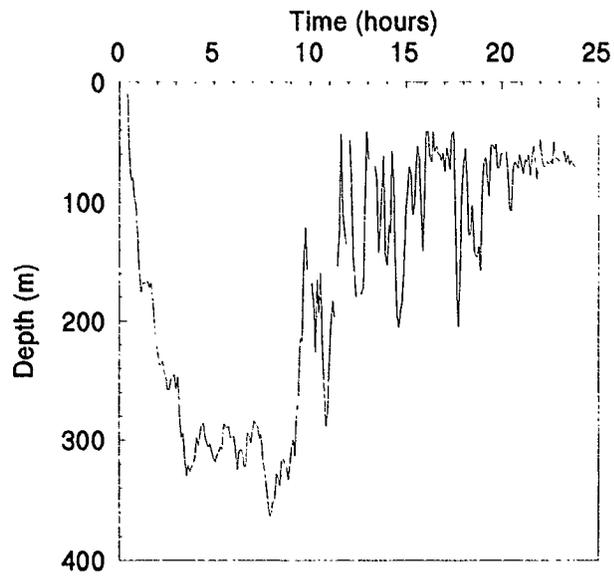
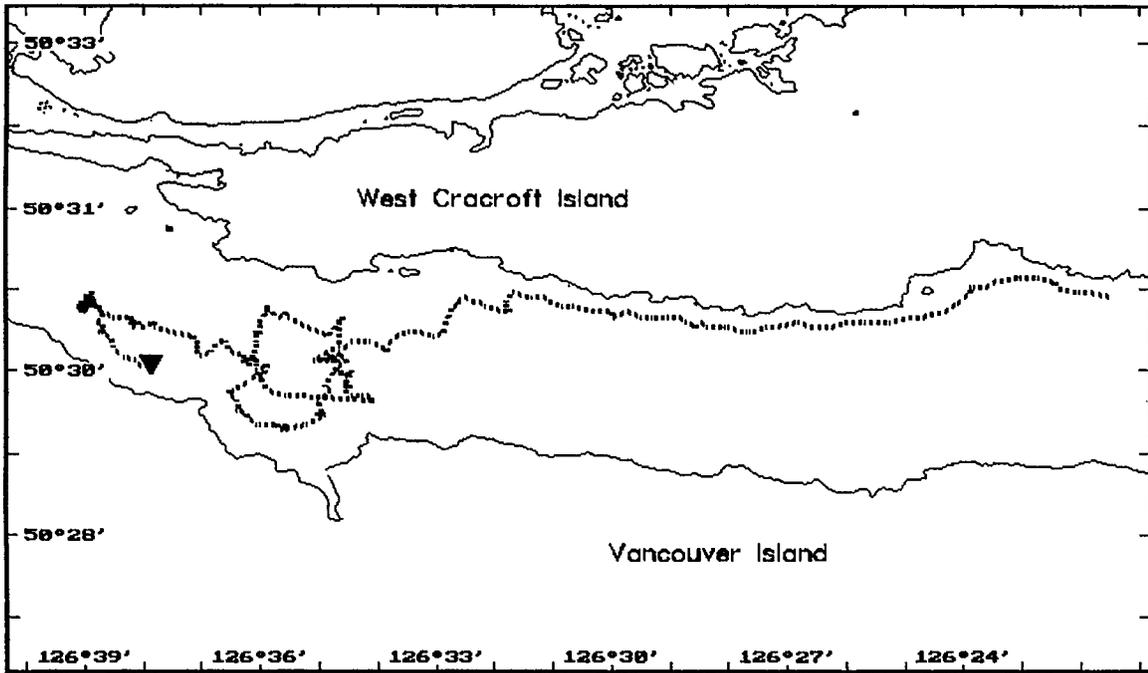
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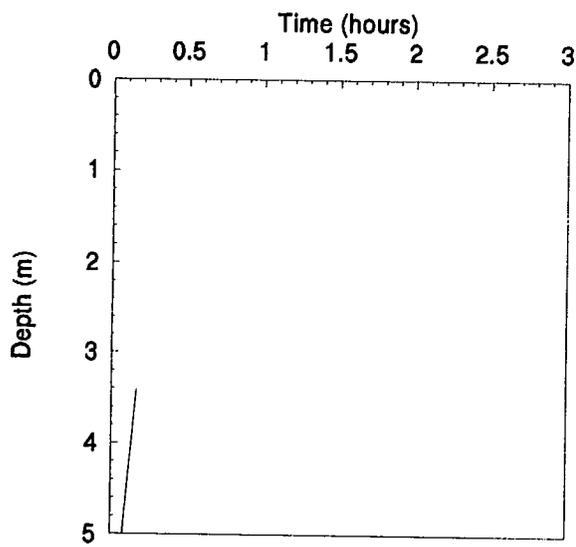
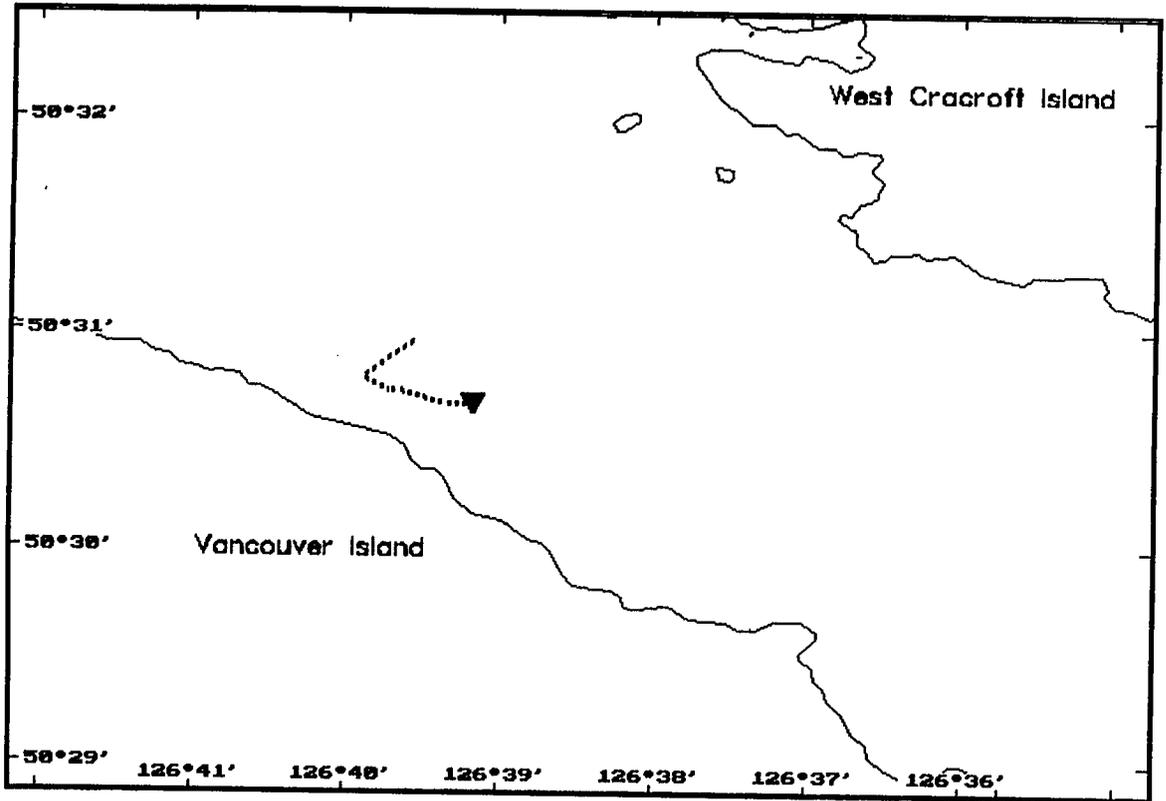
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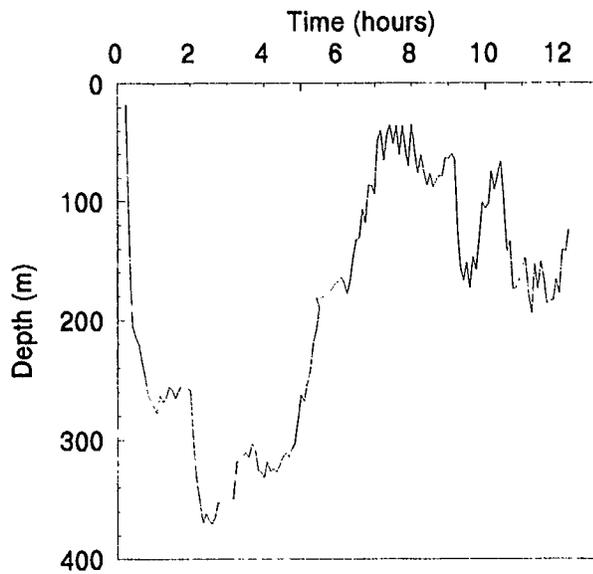
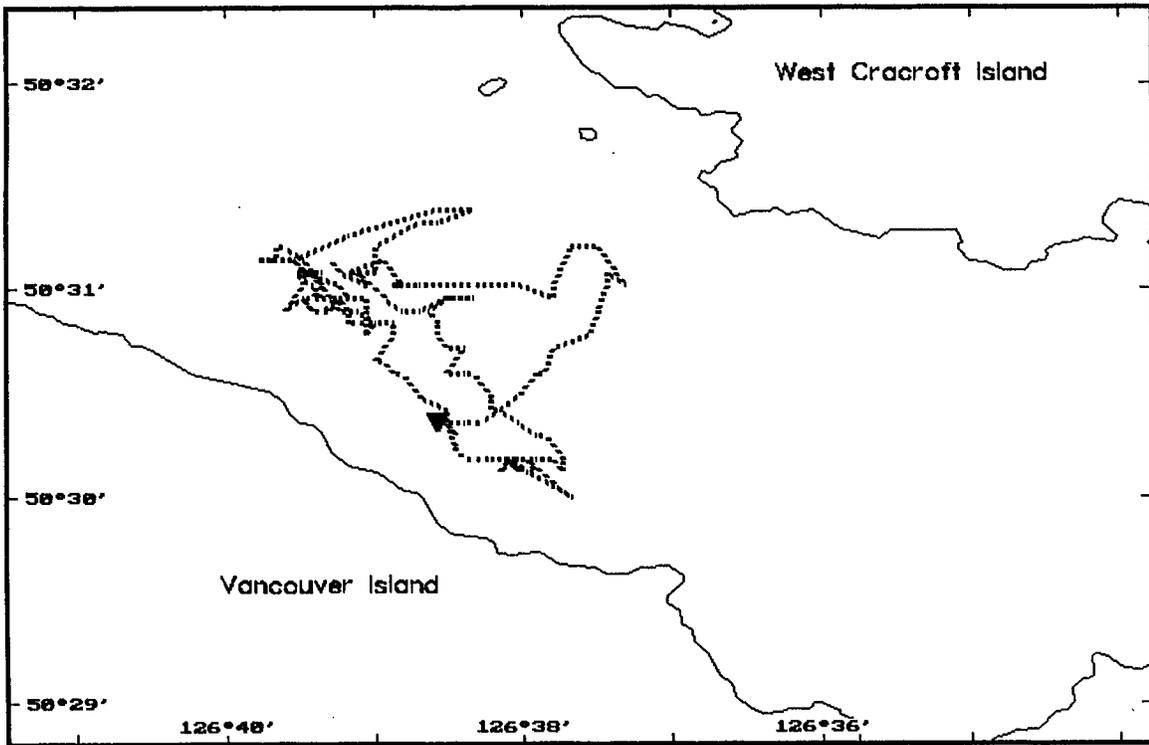
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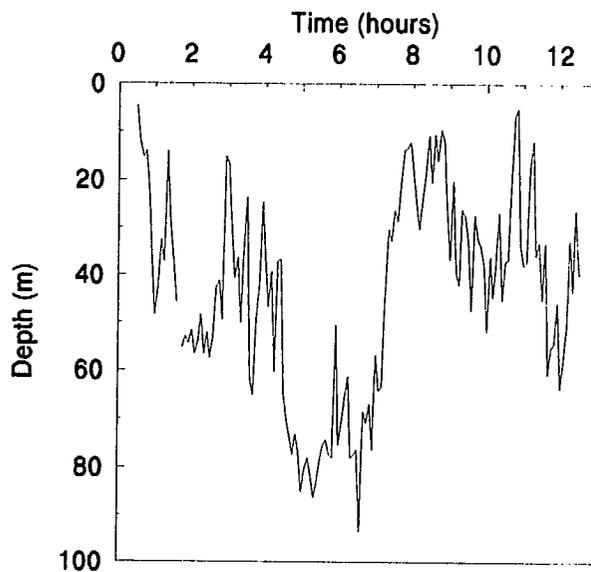
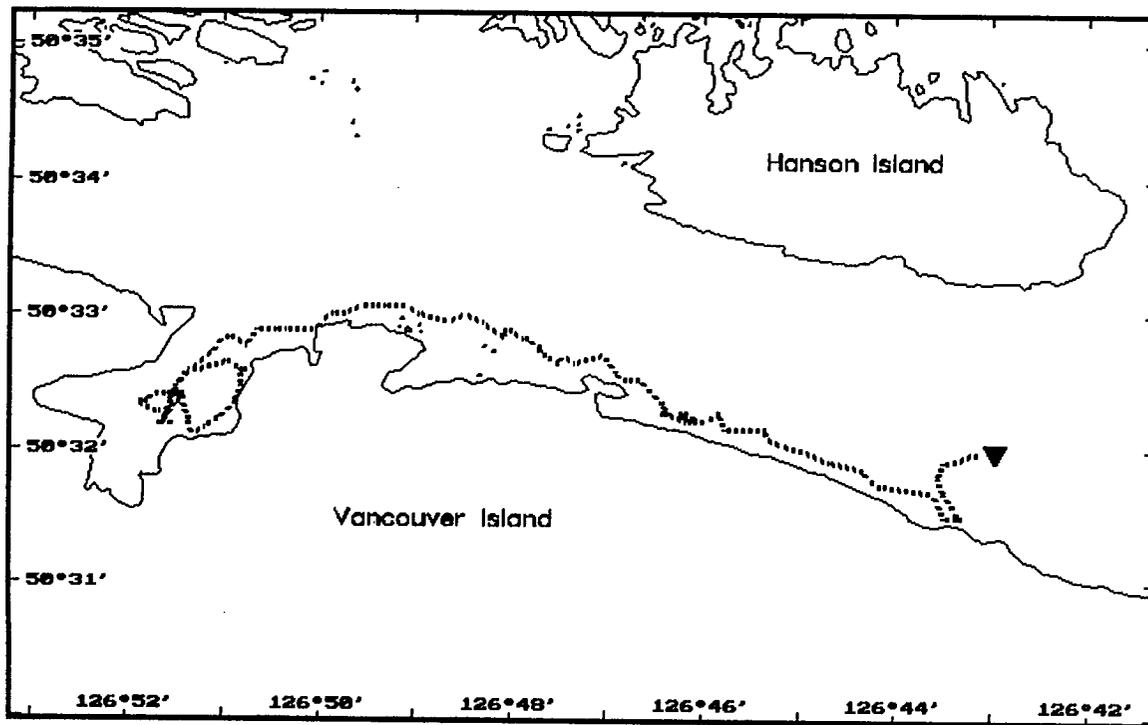
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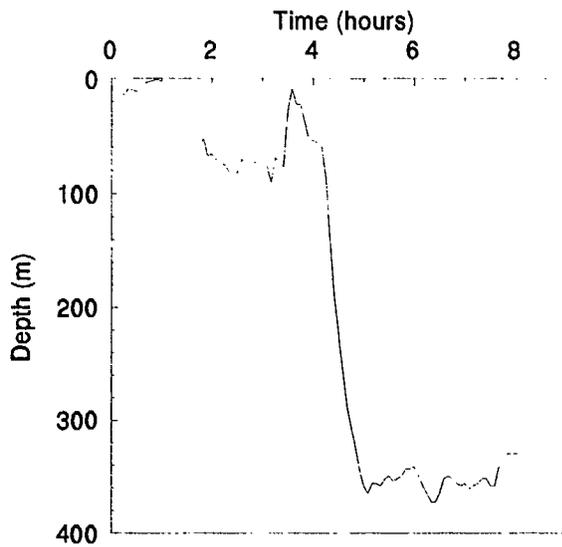
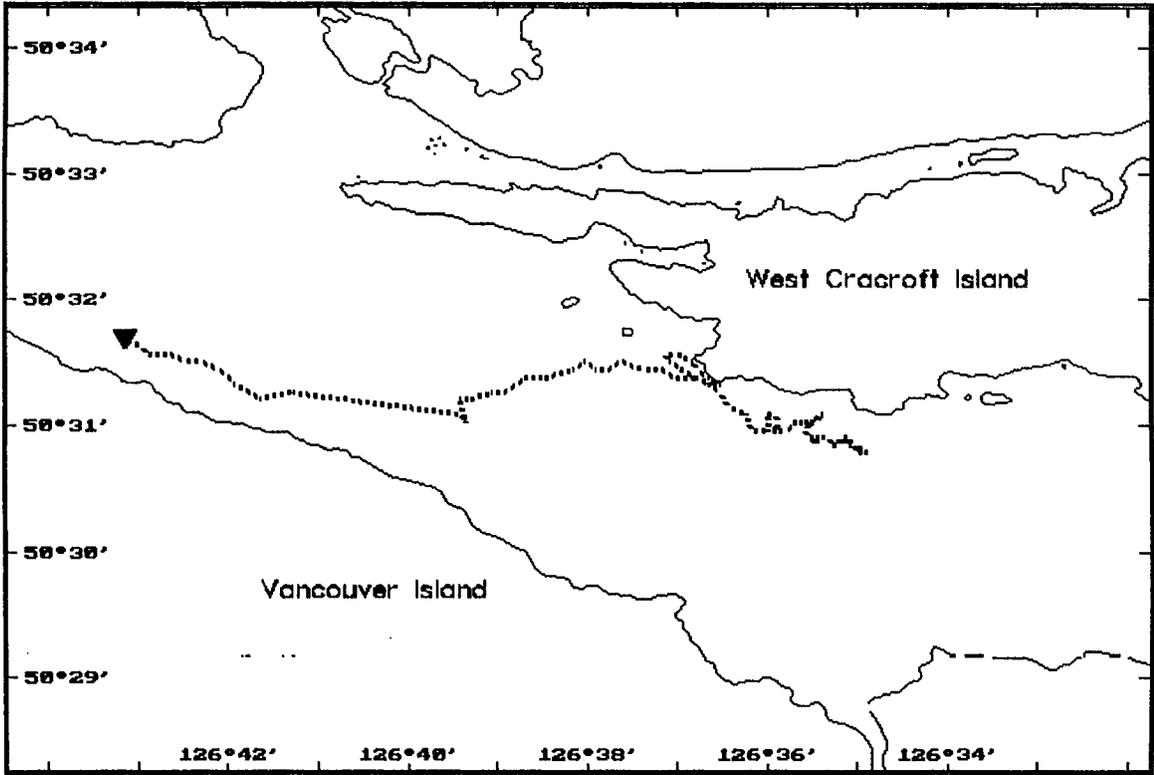
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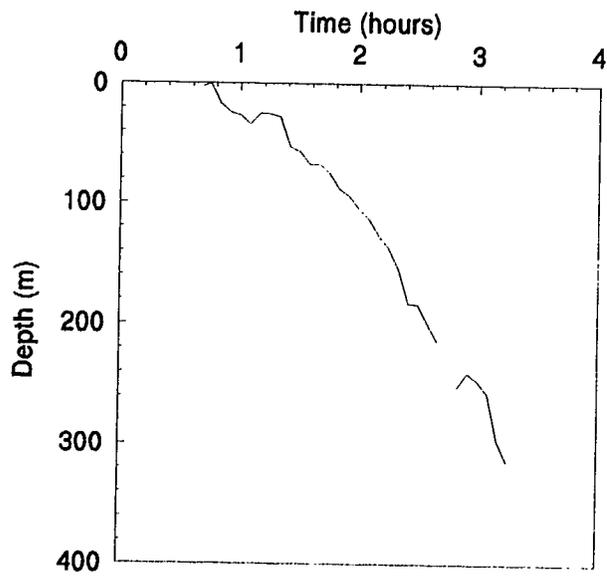
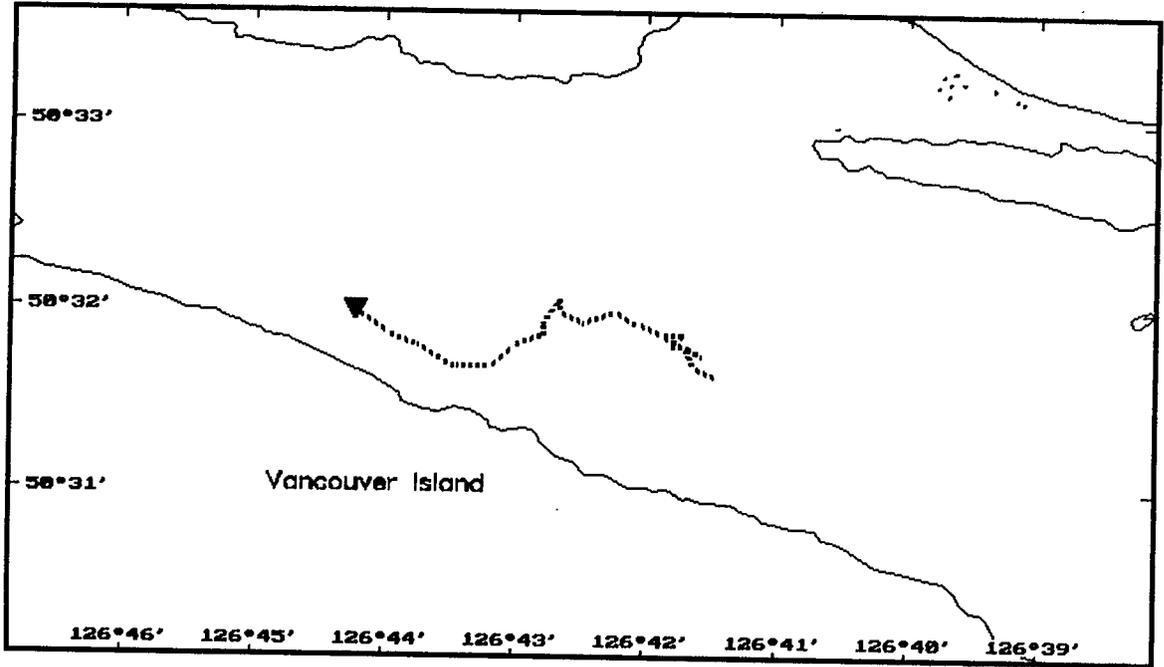
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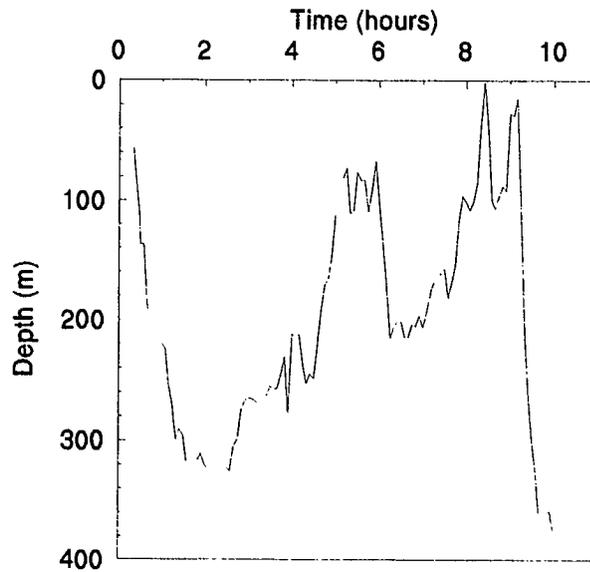
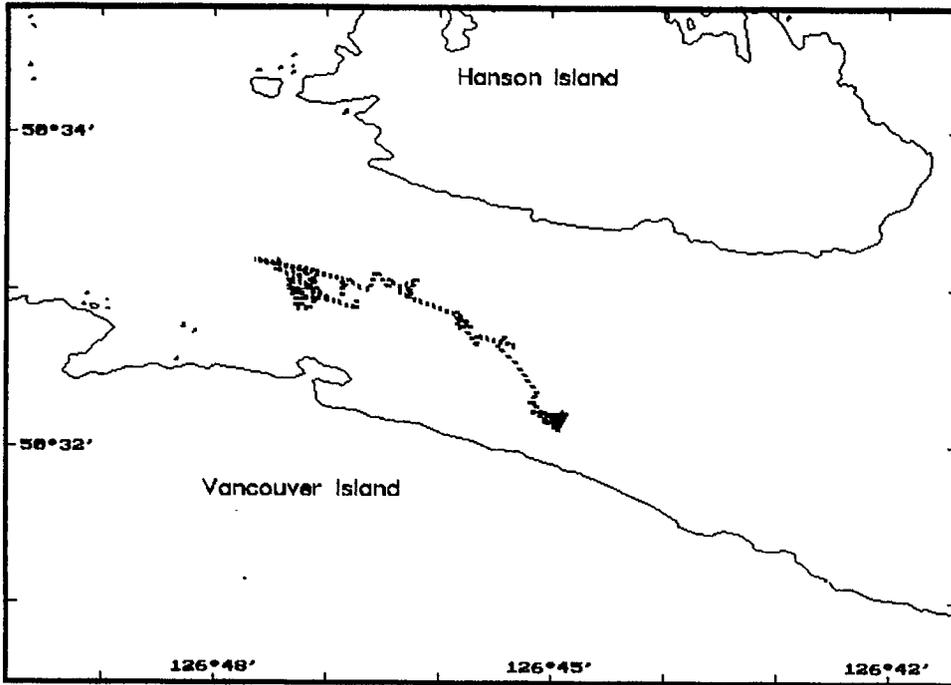
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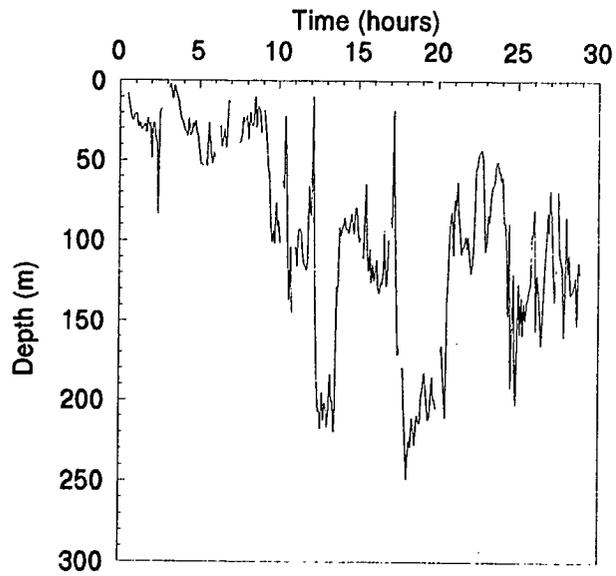
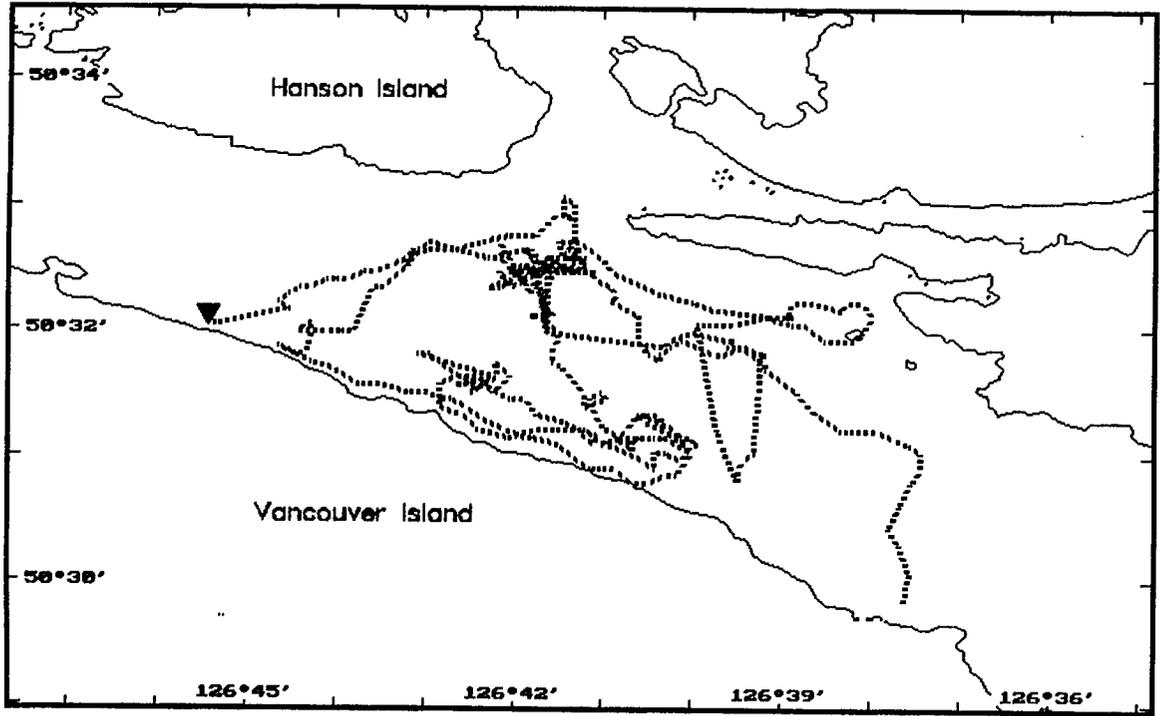
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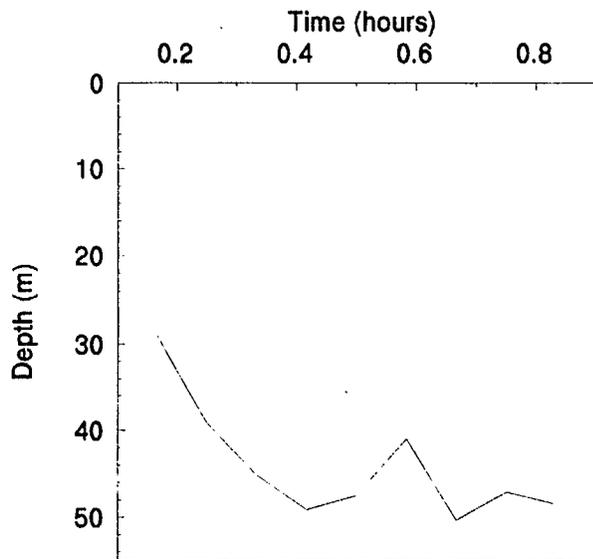
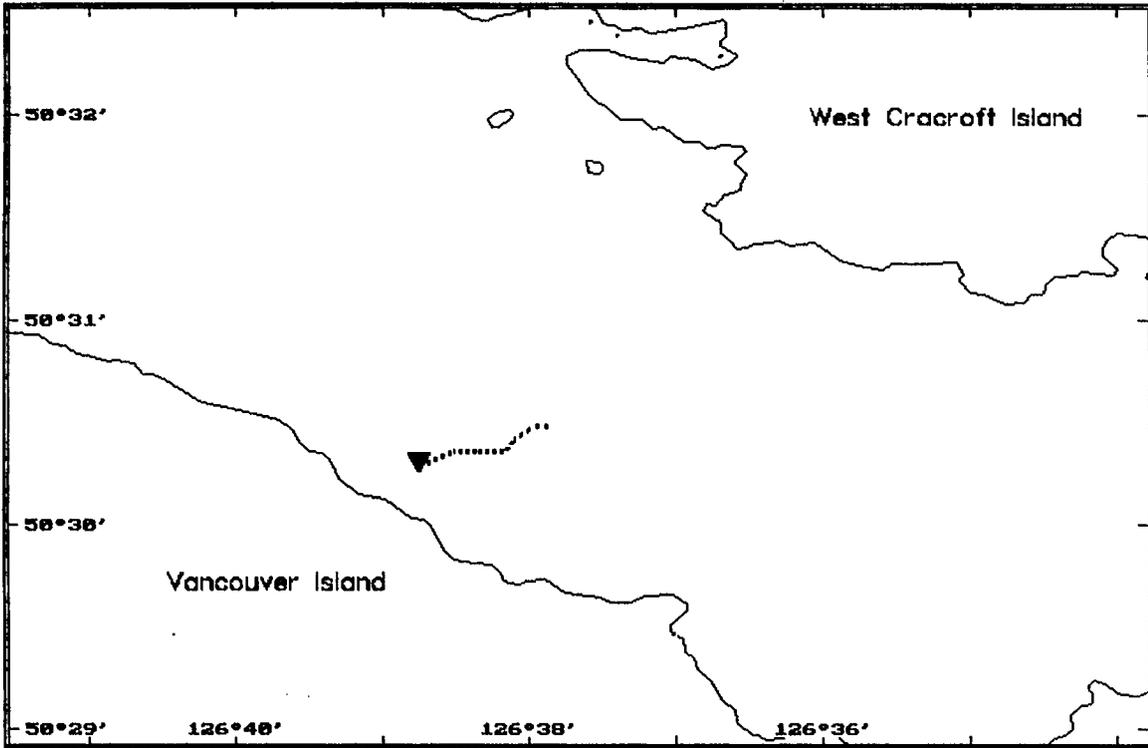
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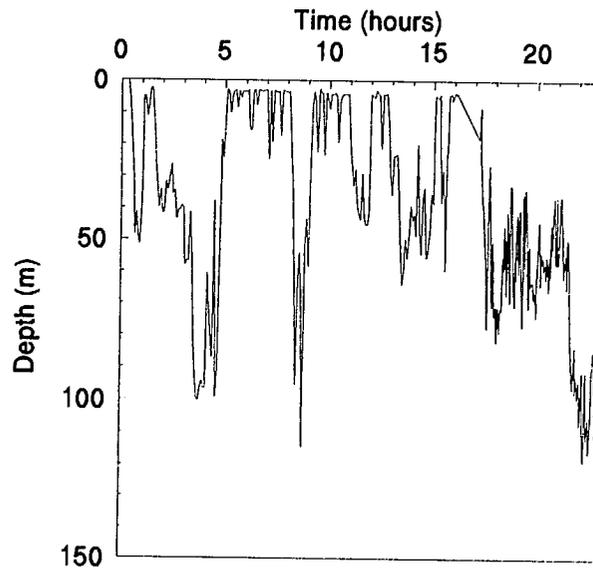
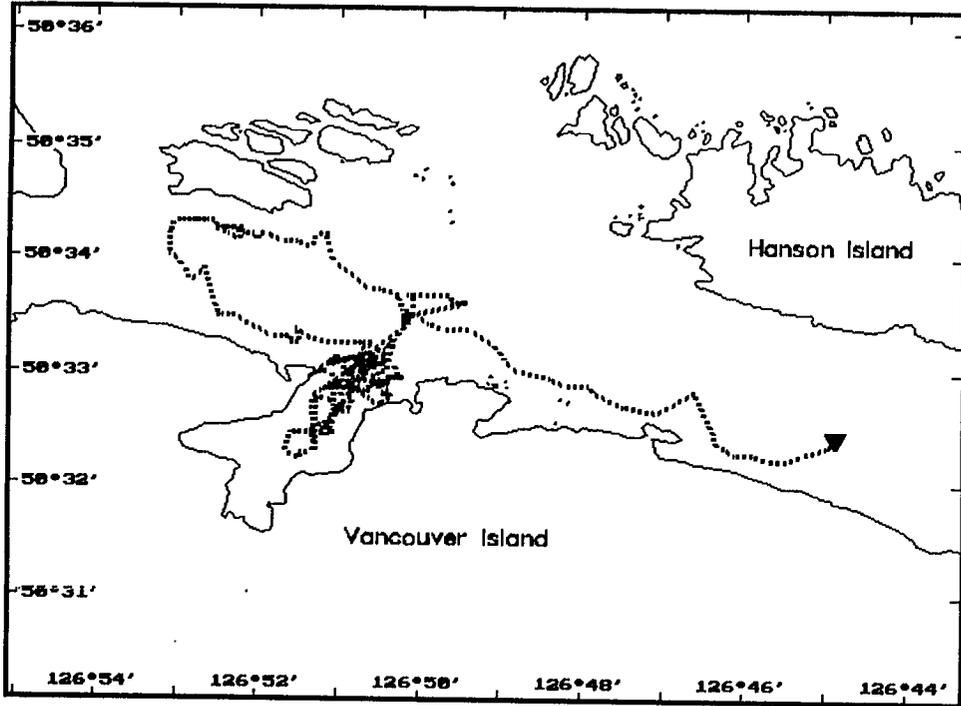
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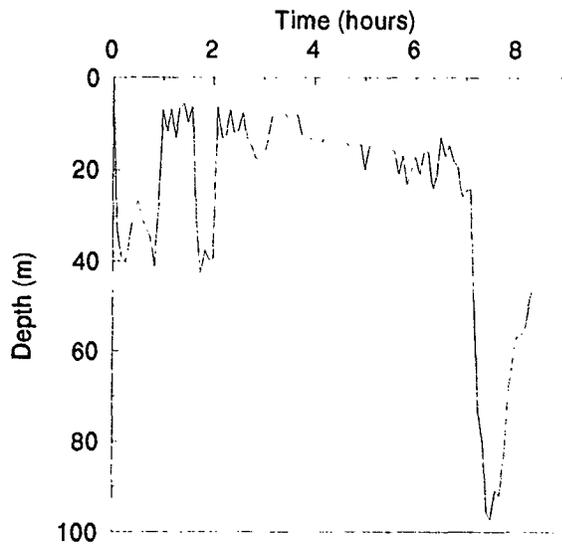
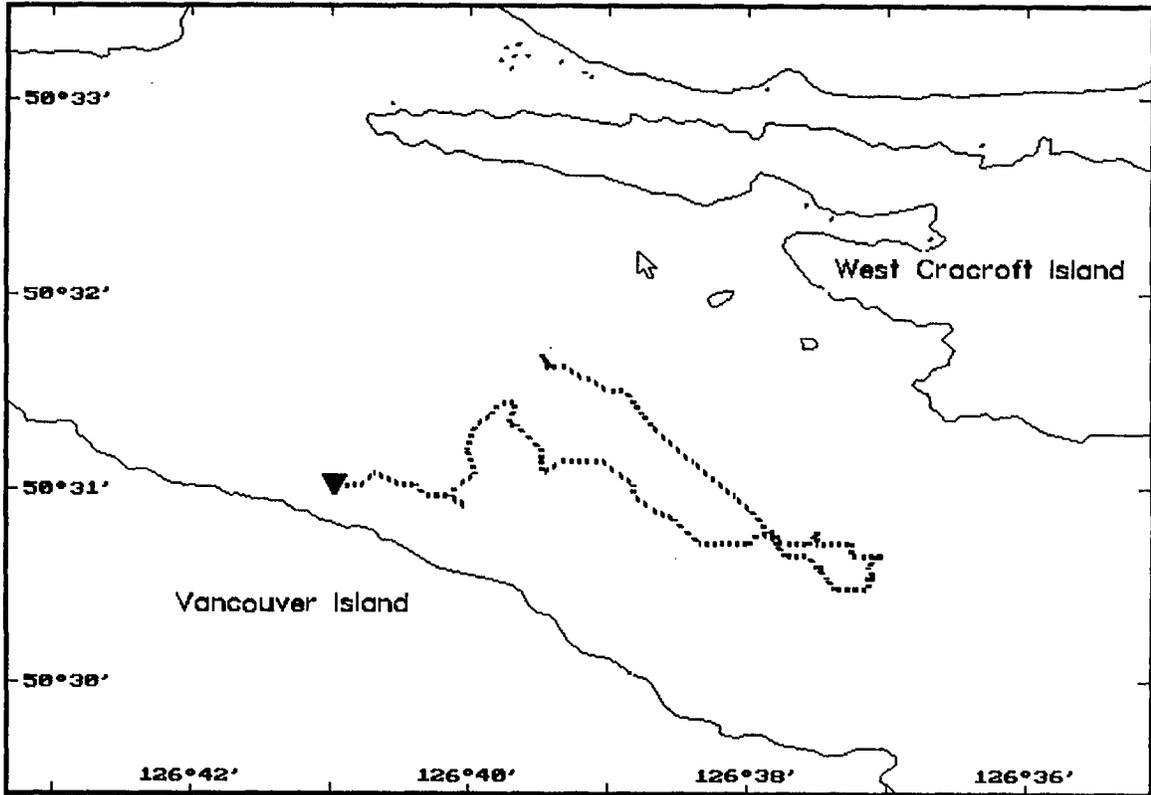
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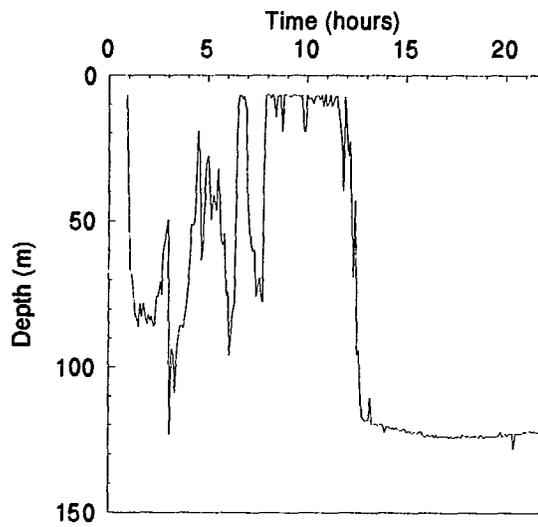
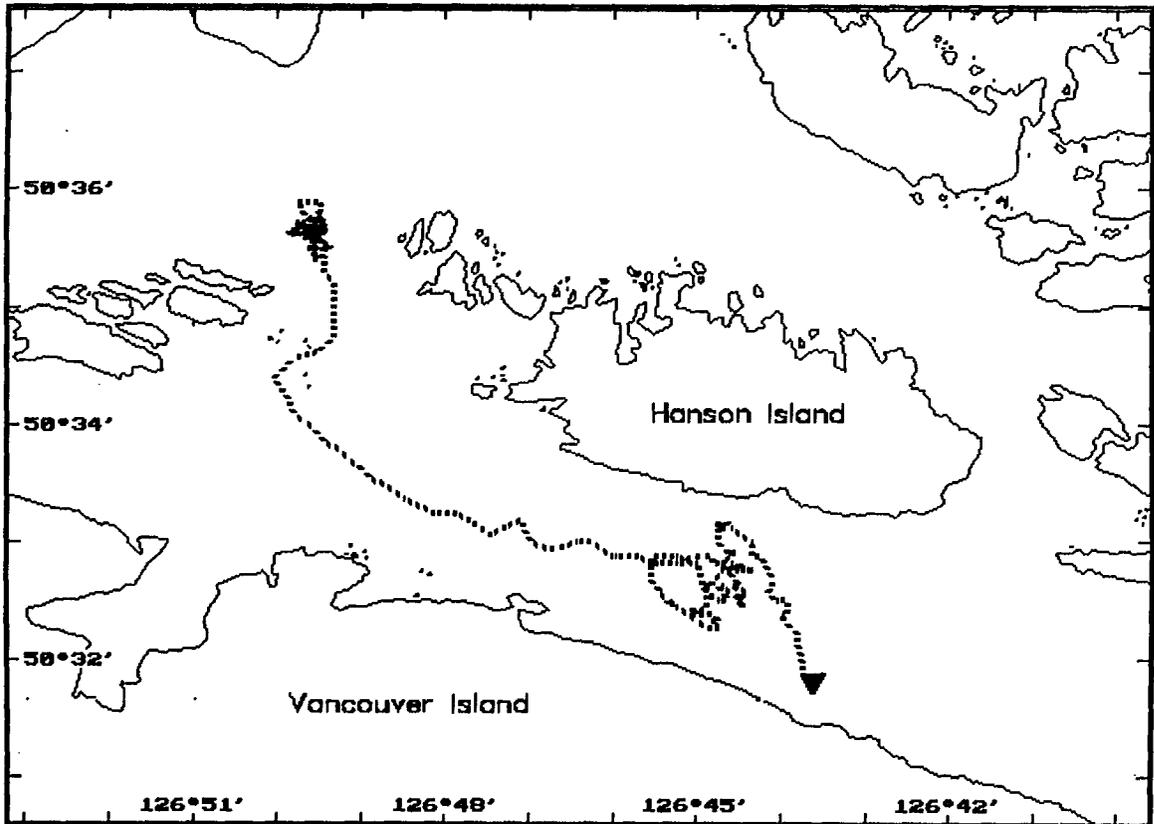
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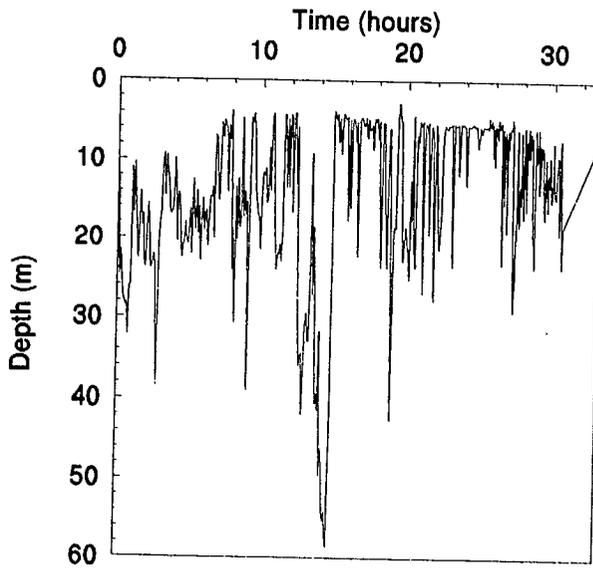
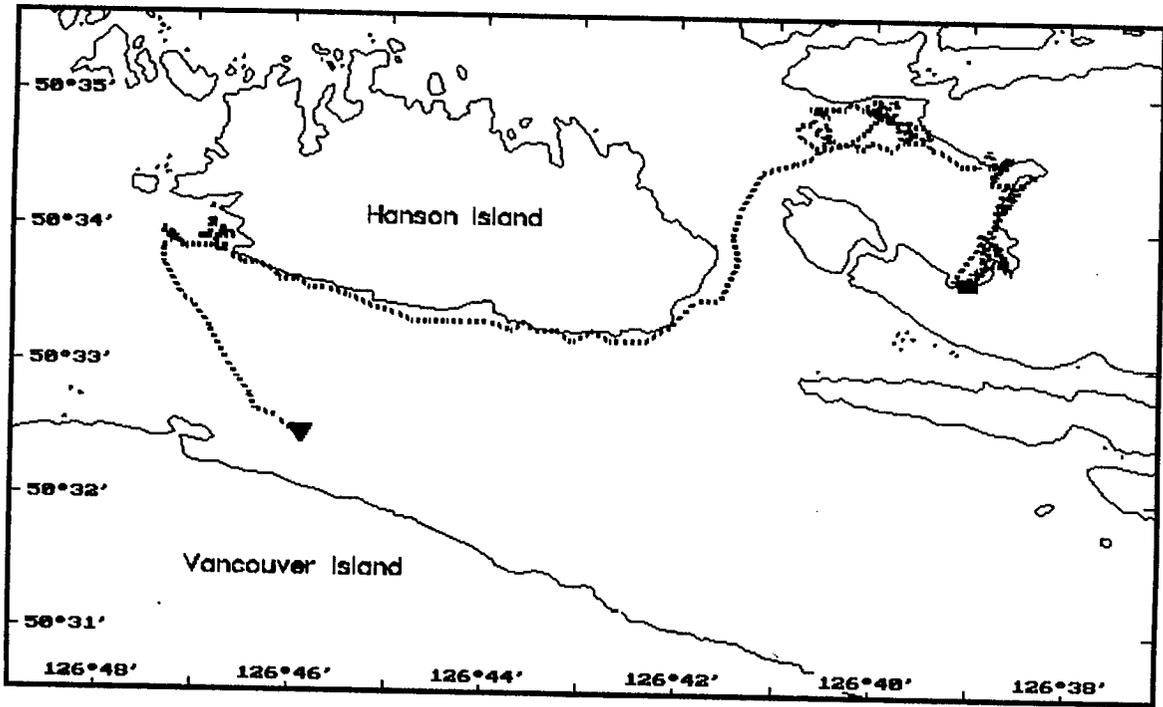
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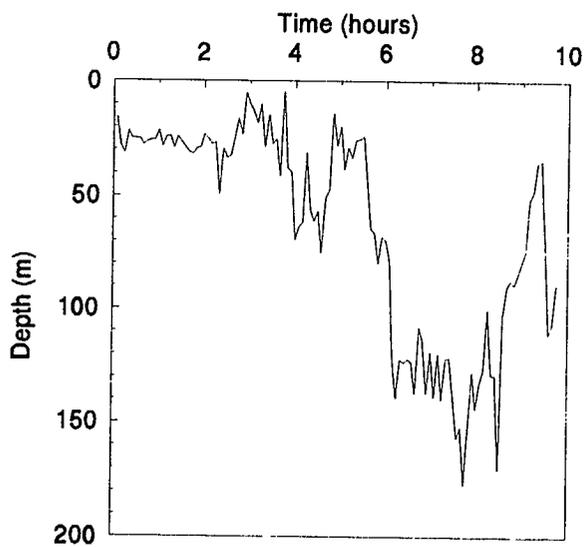
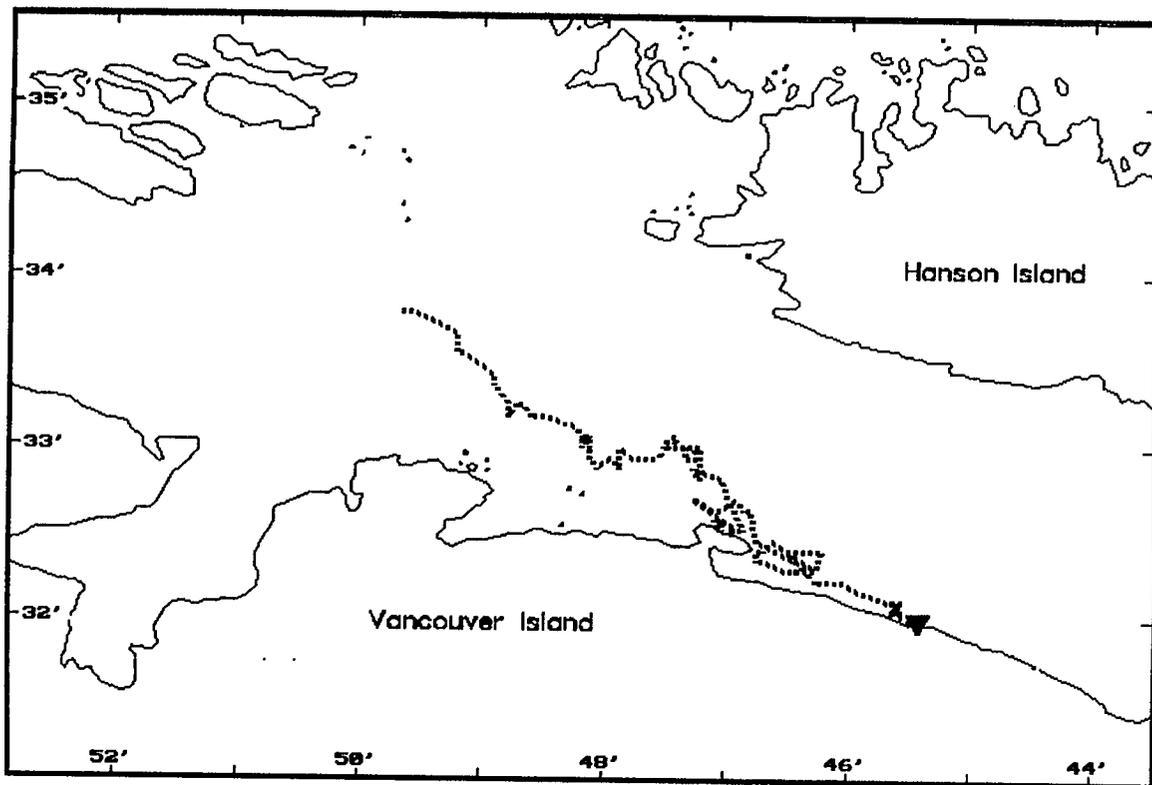
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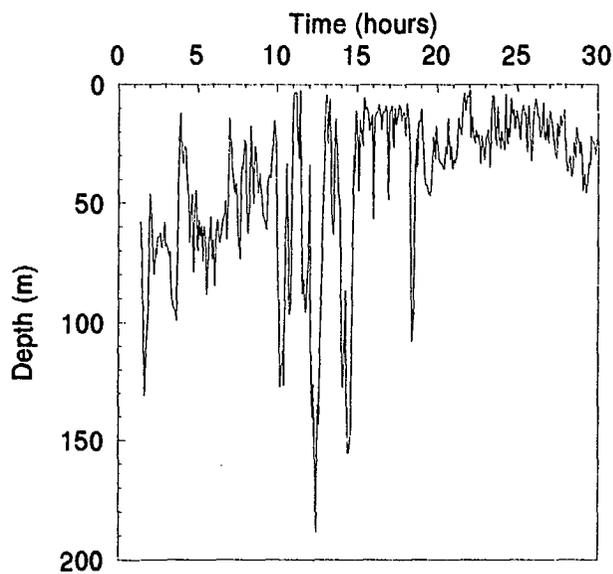
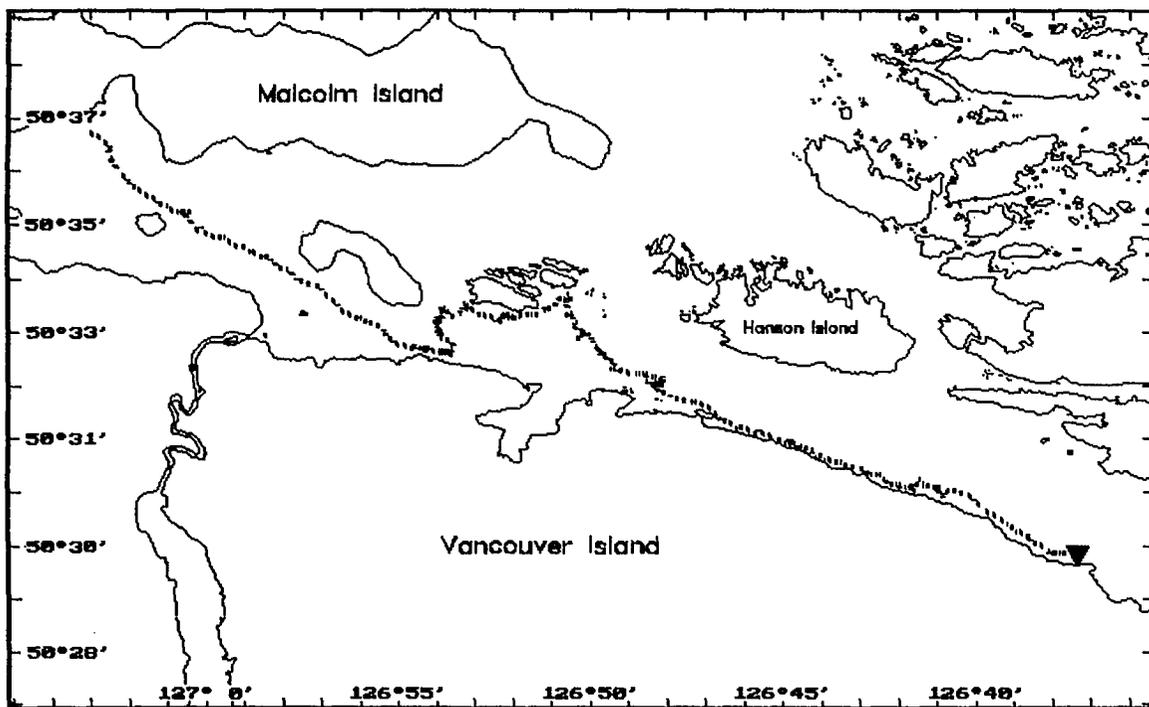
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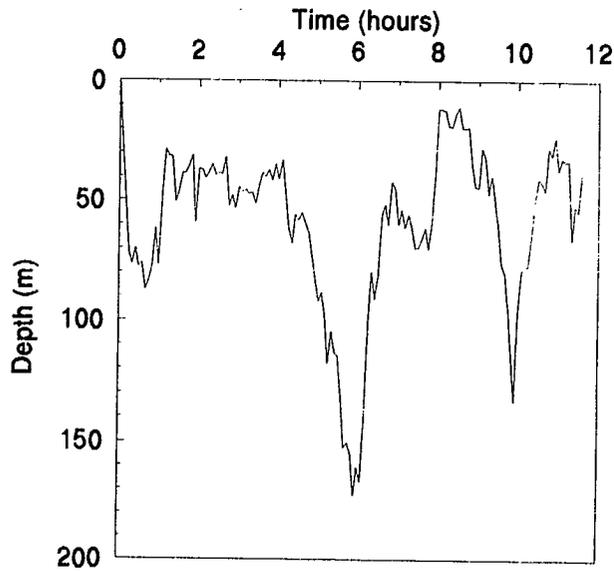
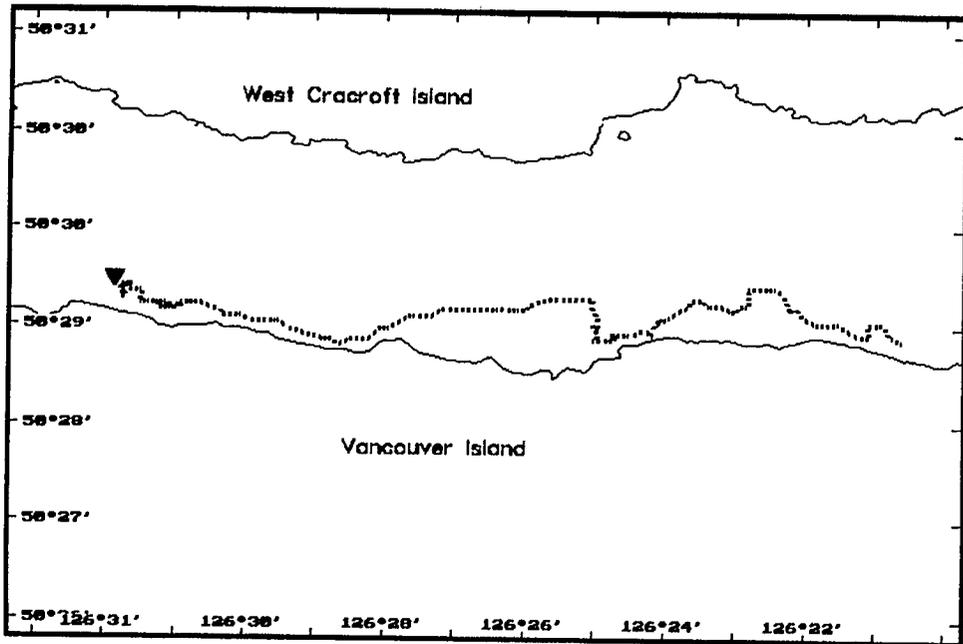
Sonic Track 9109



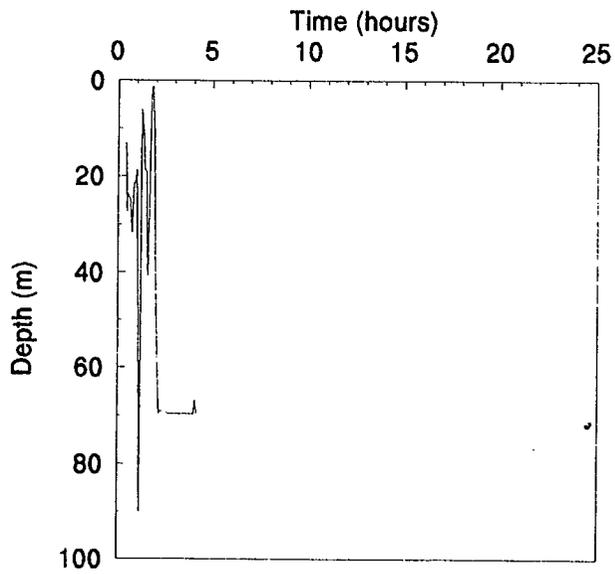
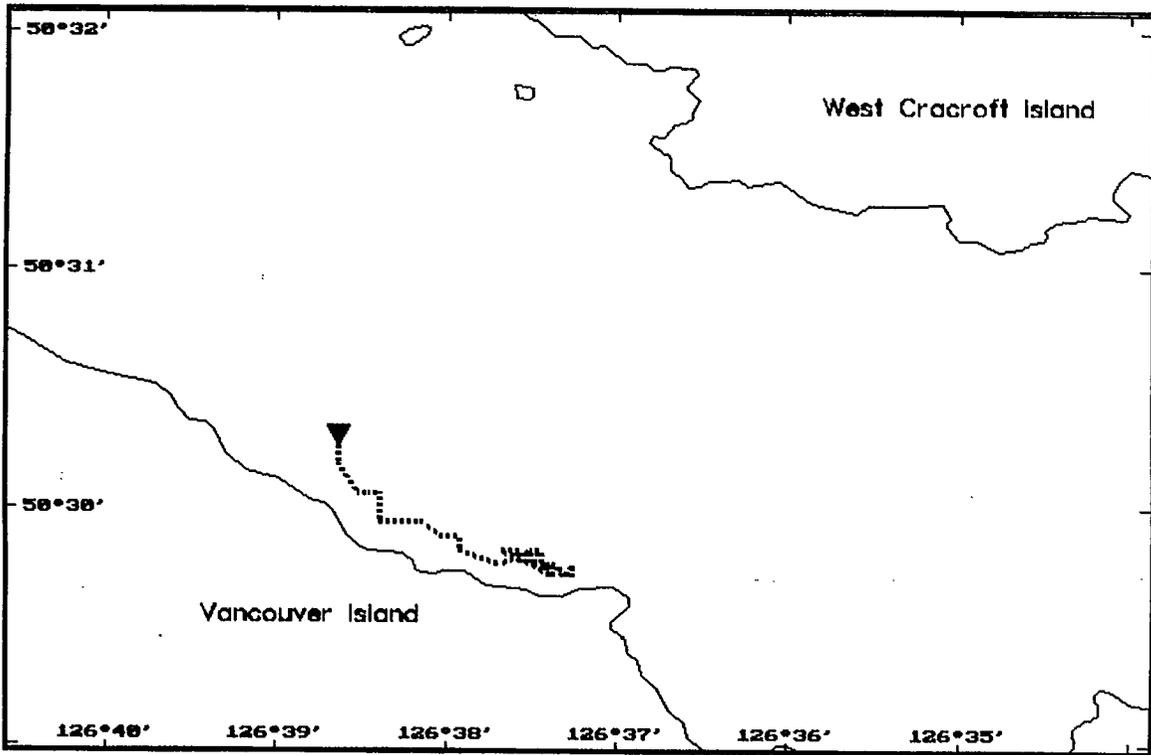
Sonic Track 9110



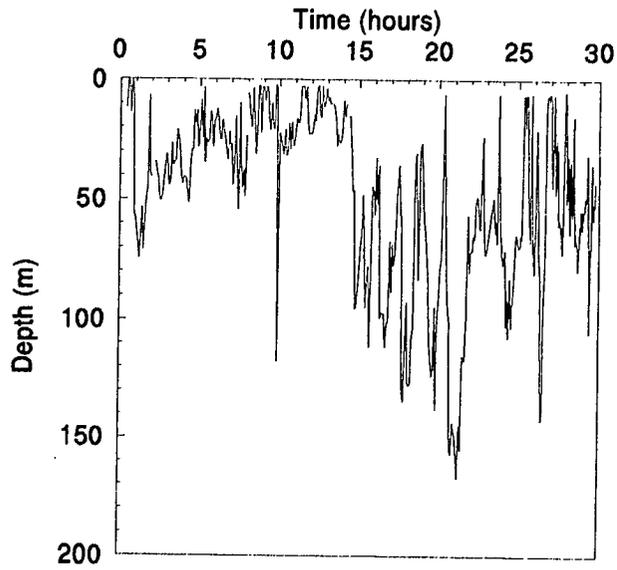
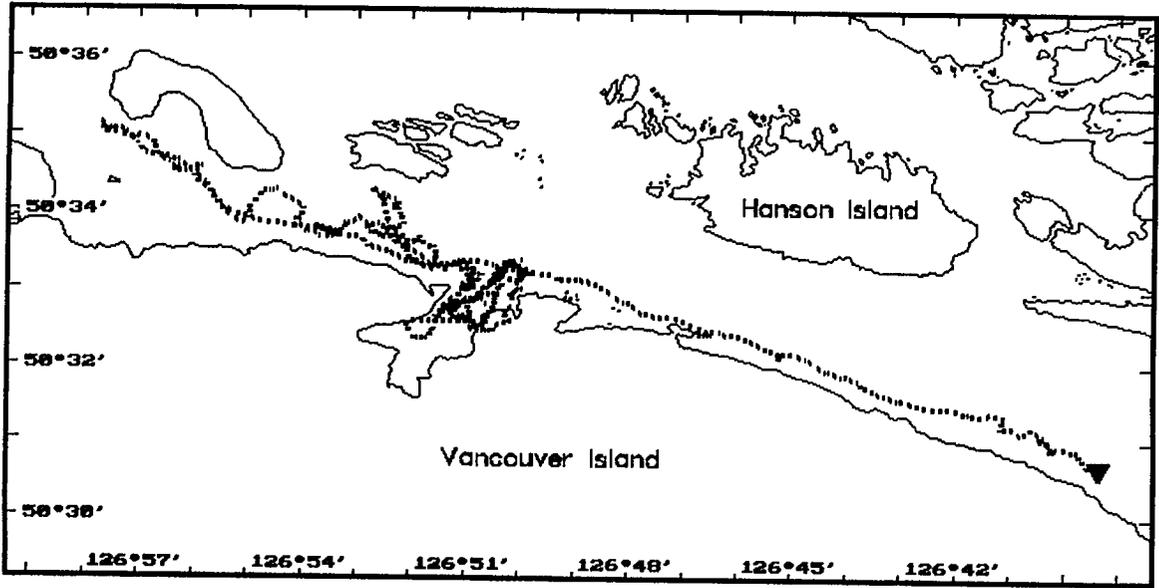
Sonic Track 9111



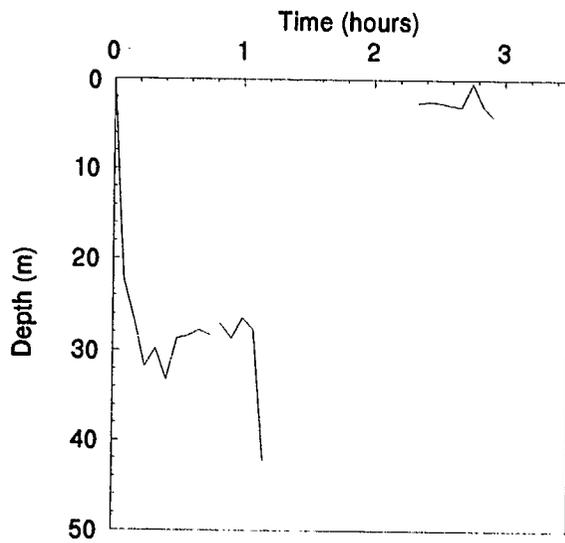
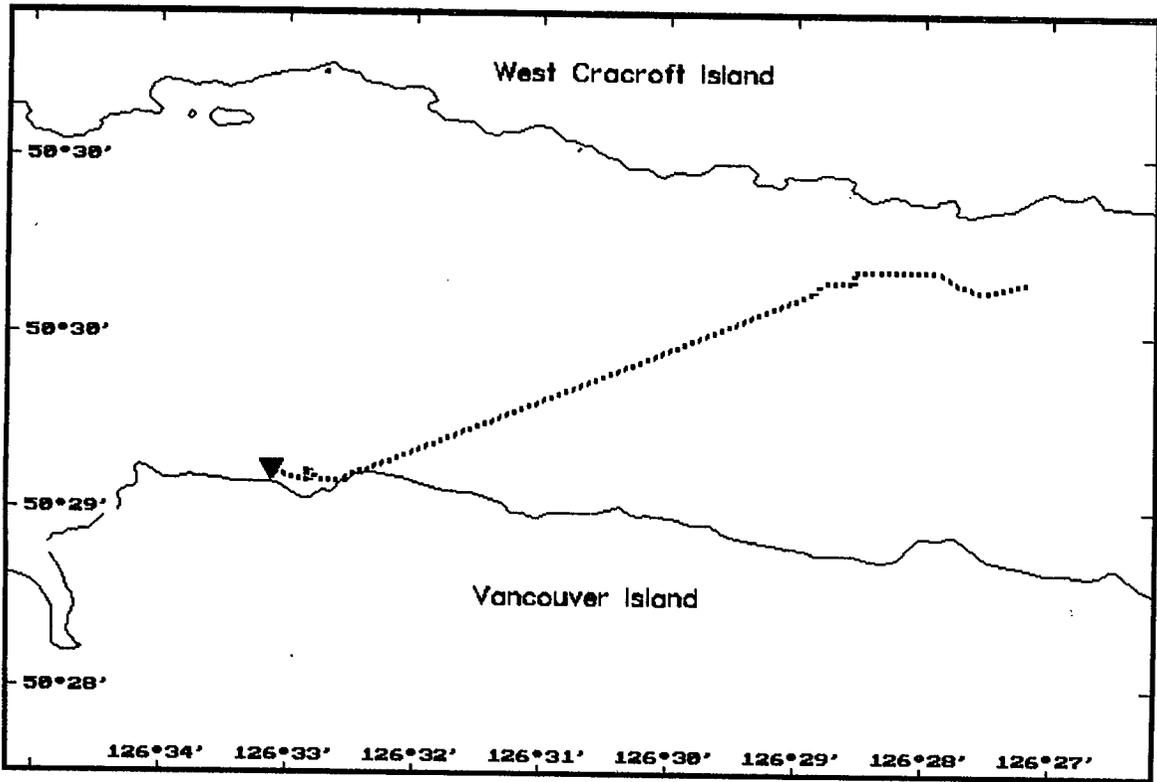
Sonic Track 9112



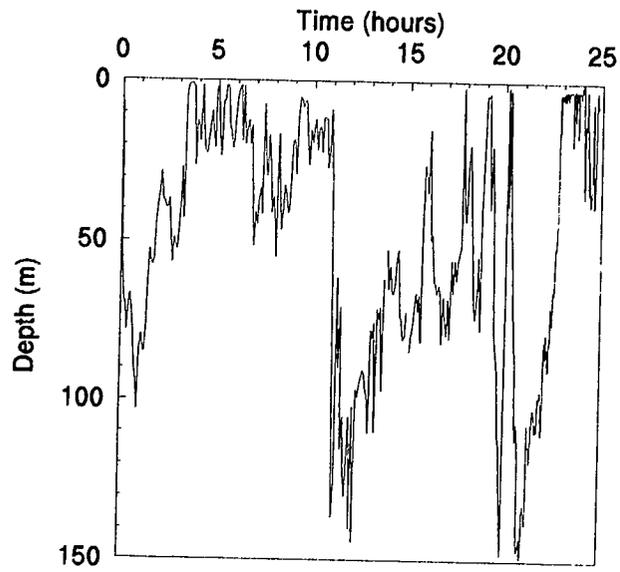
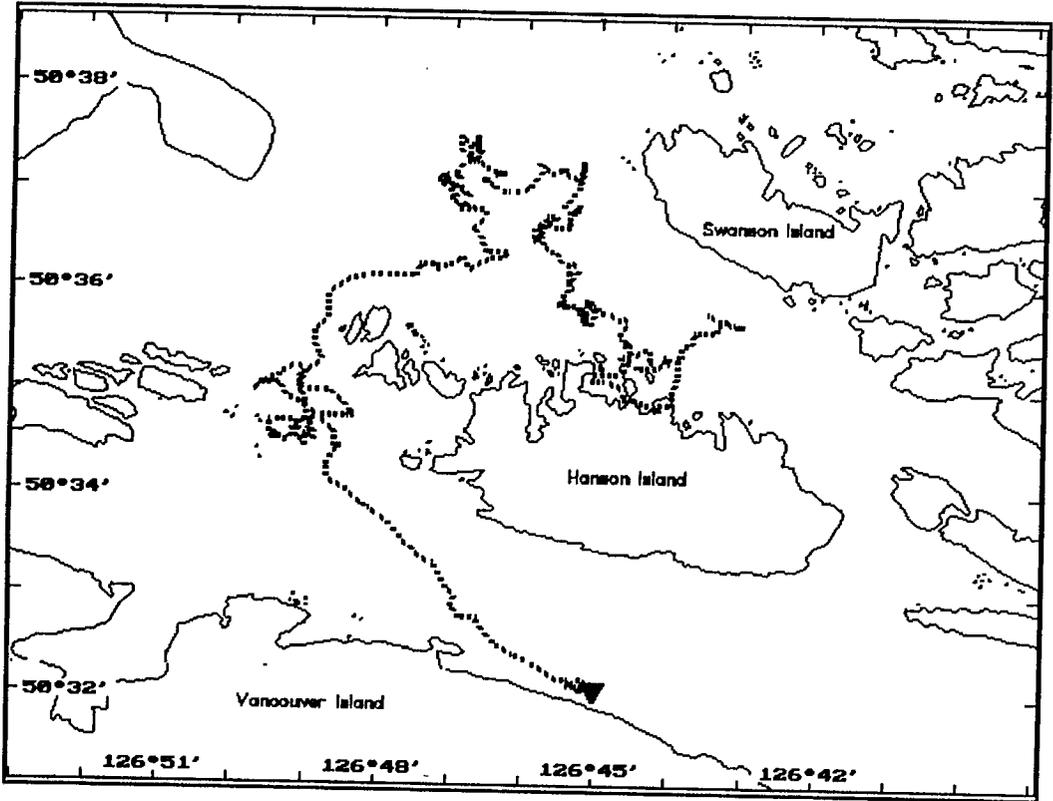
Sonic Track 9113



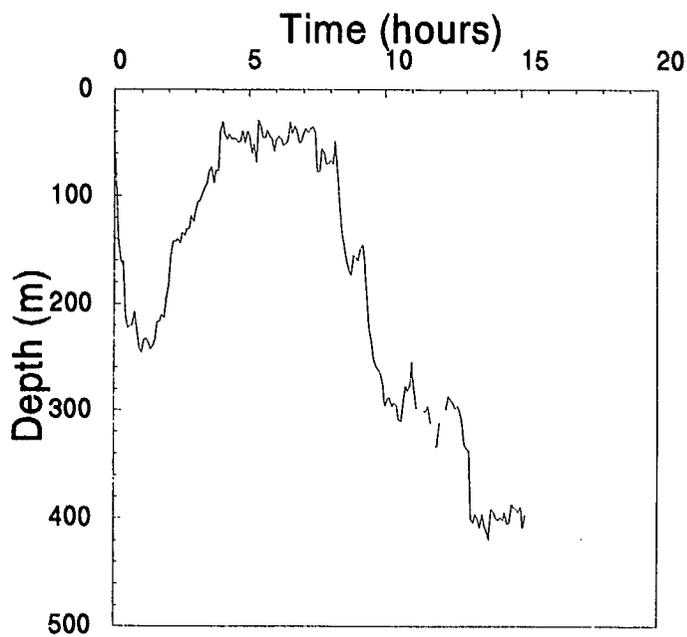
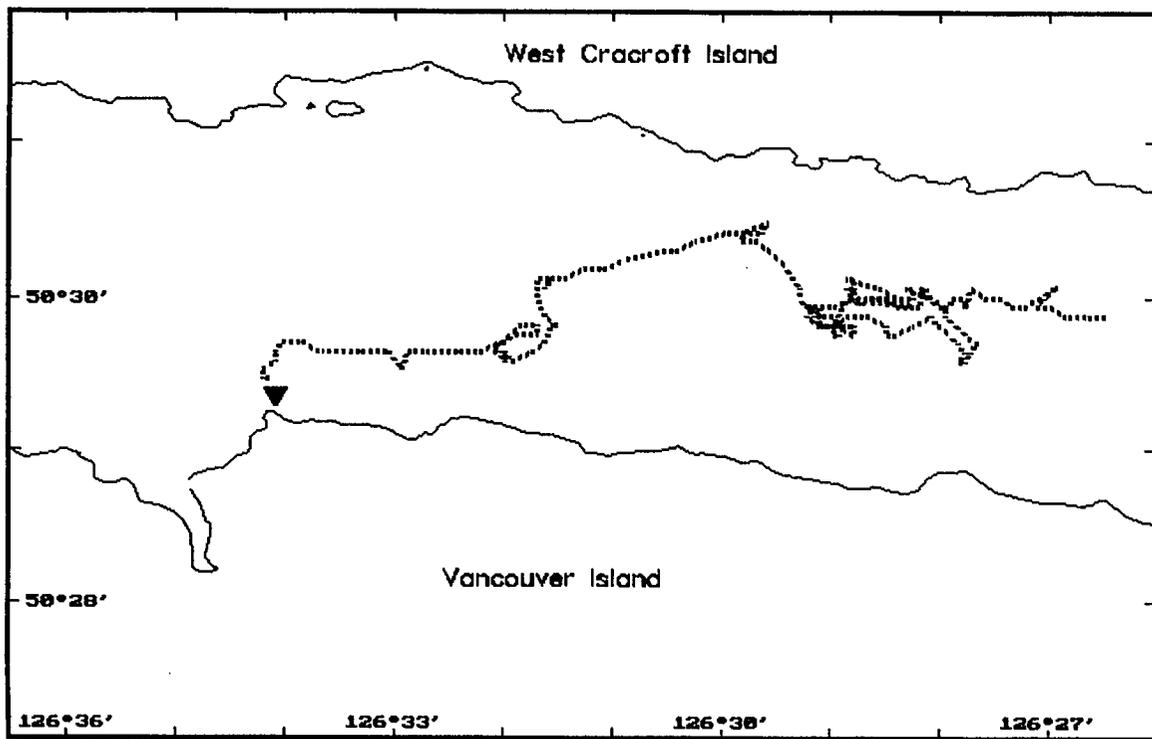
Sonic Track 9114



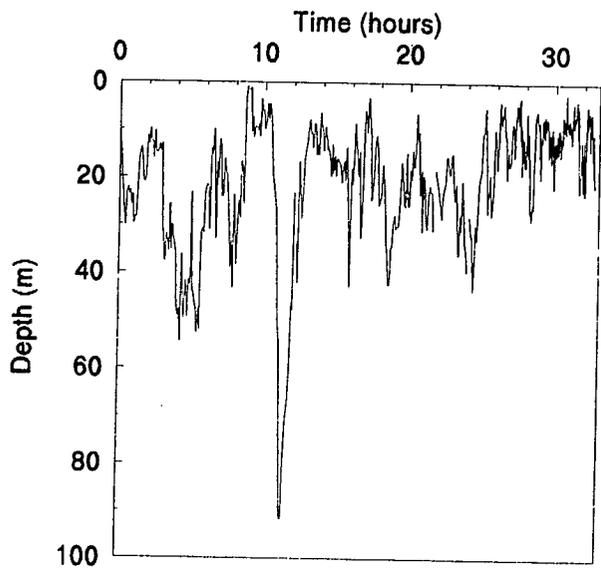
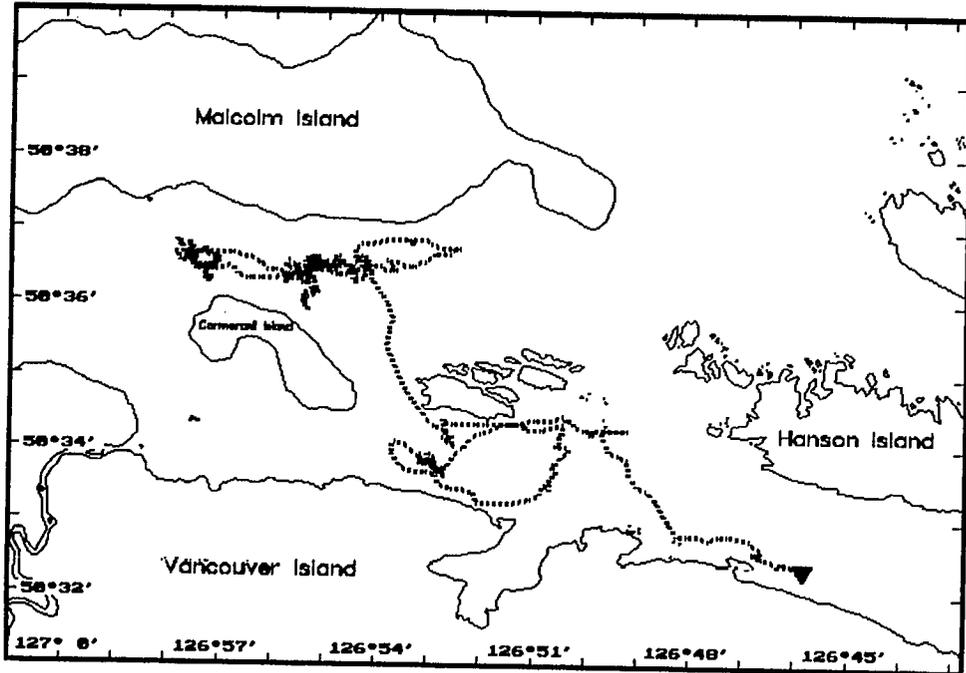
Sonic Track 9115



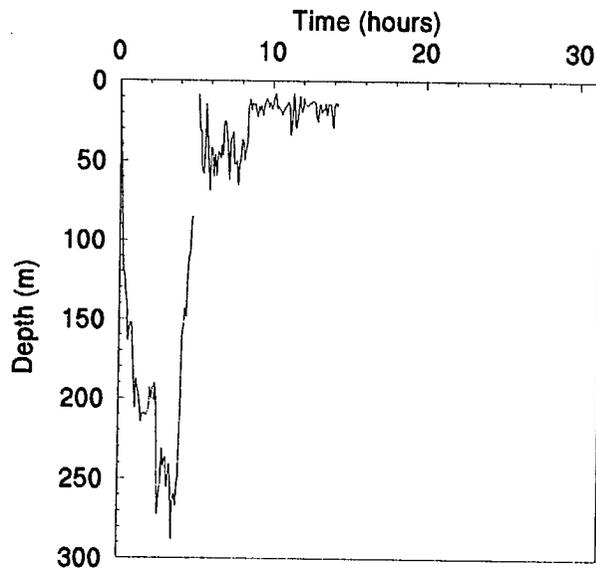
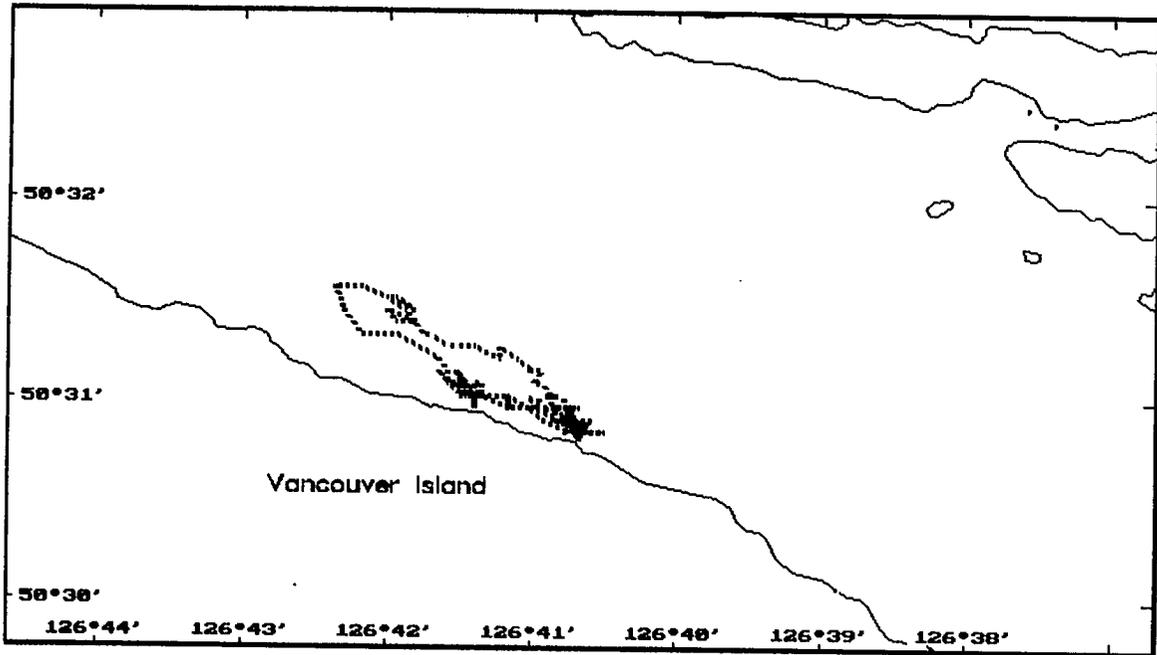
Sonic Track 9116



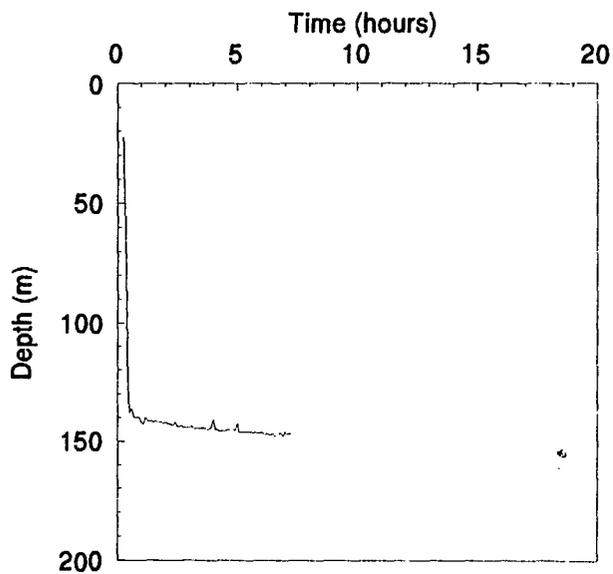
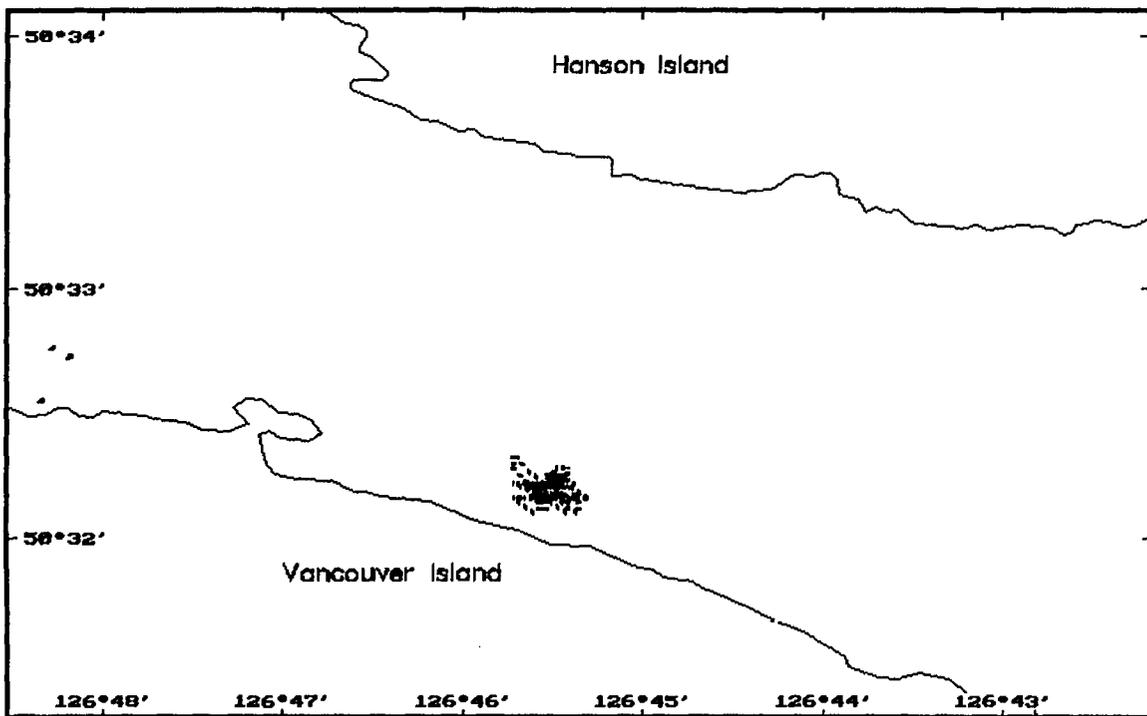
Sonic Track 9117



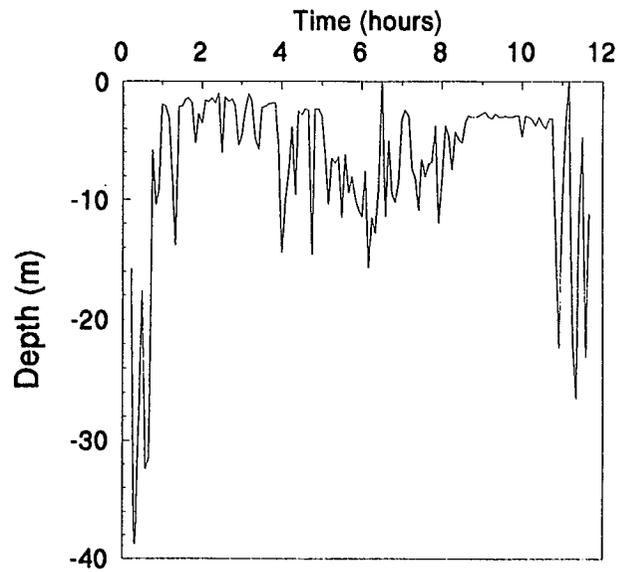
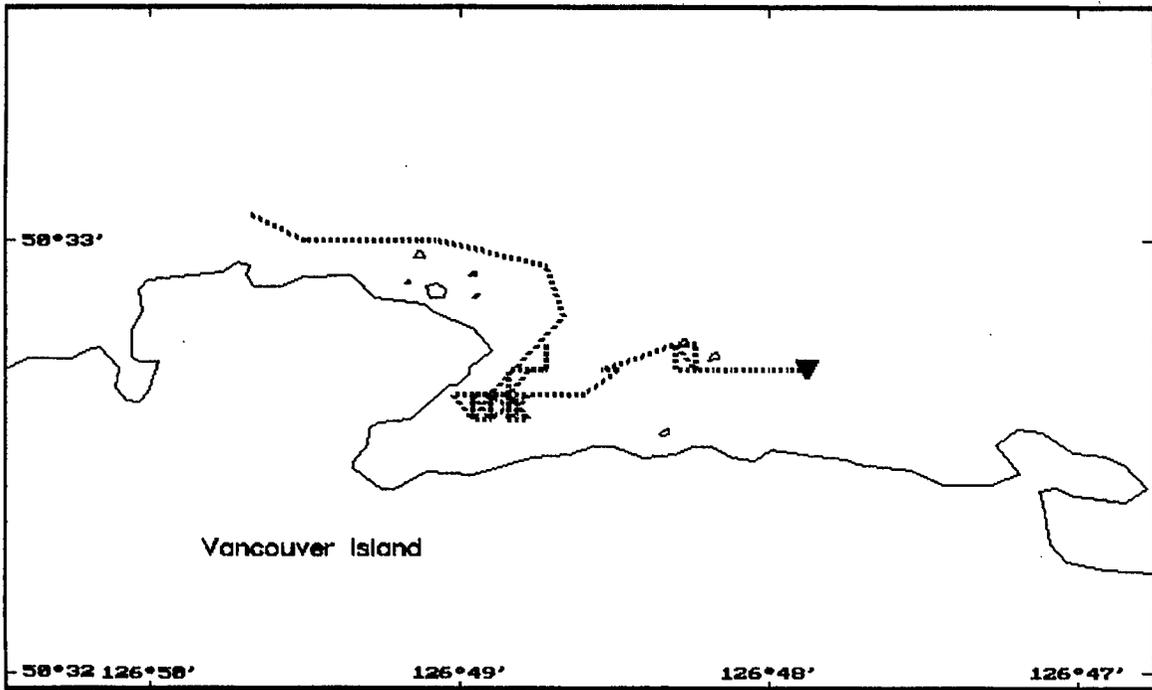
Sonic Track 9118



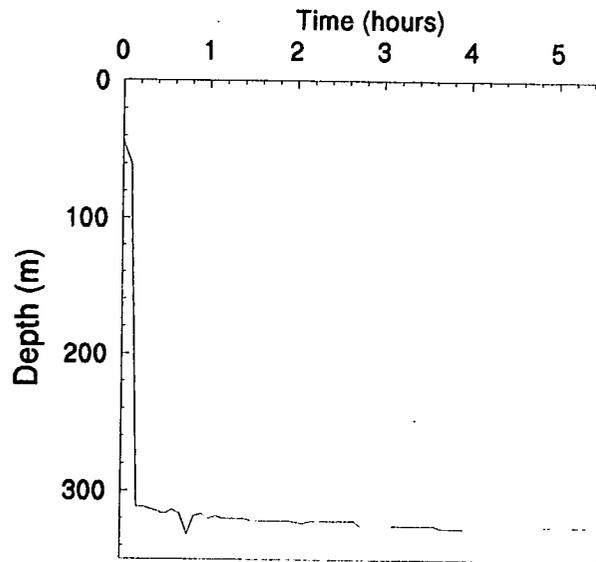
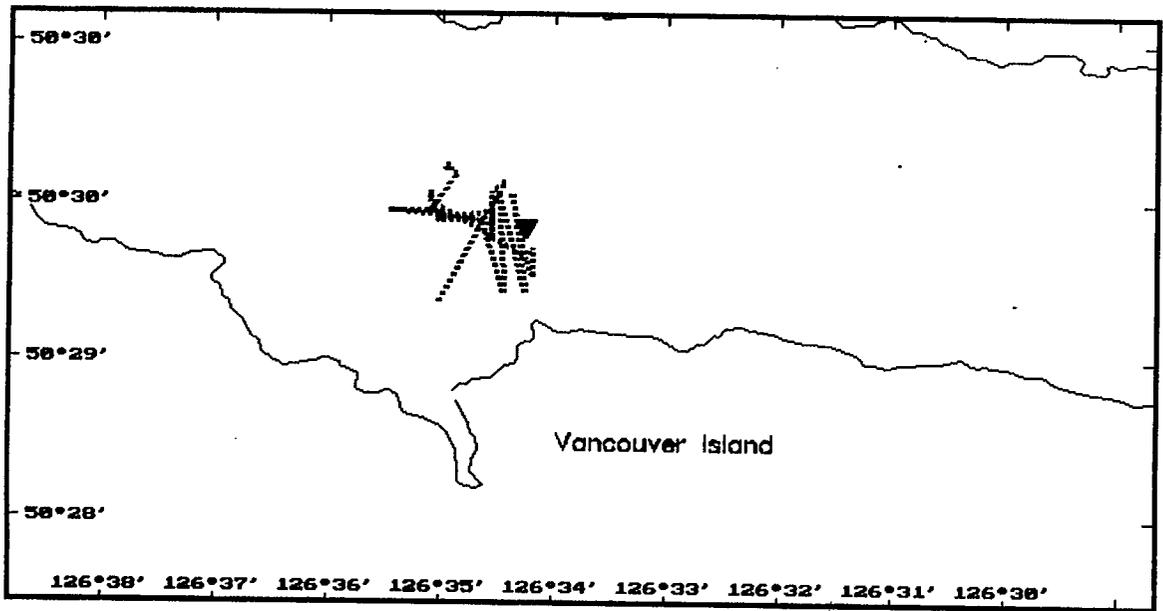
Sonic Track 9119



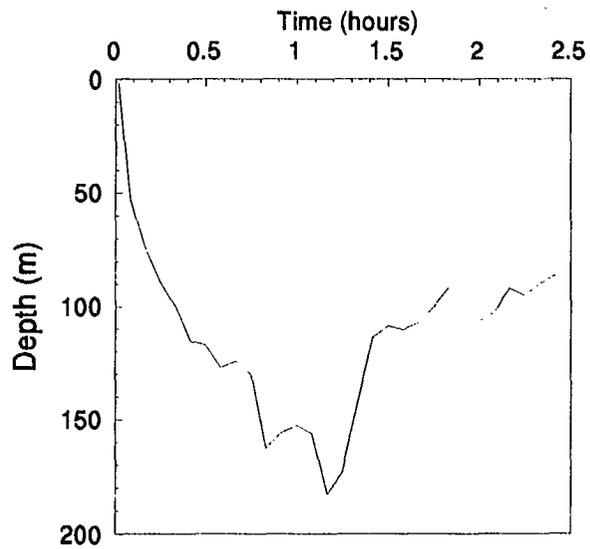
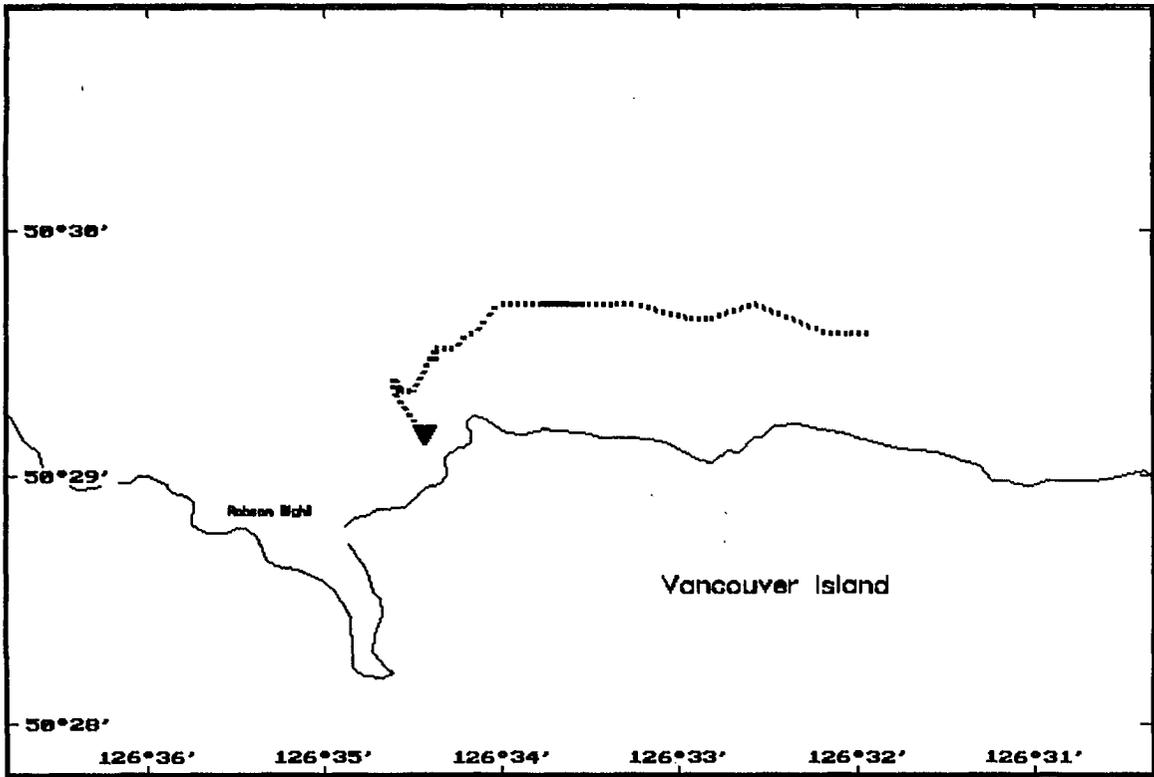
Sonic Track 9120



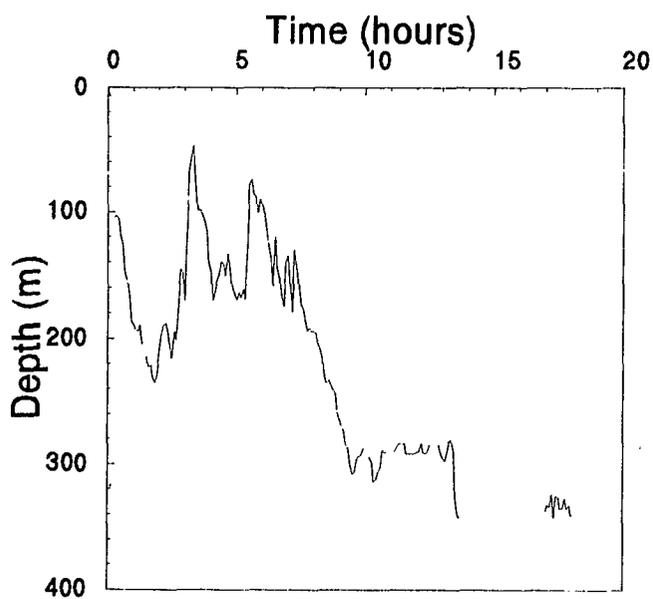
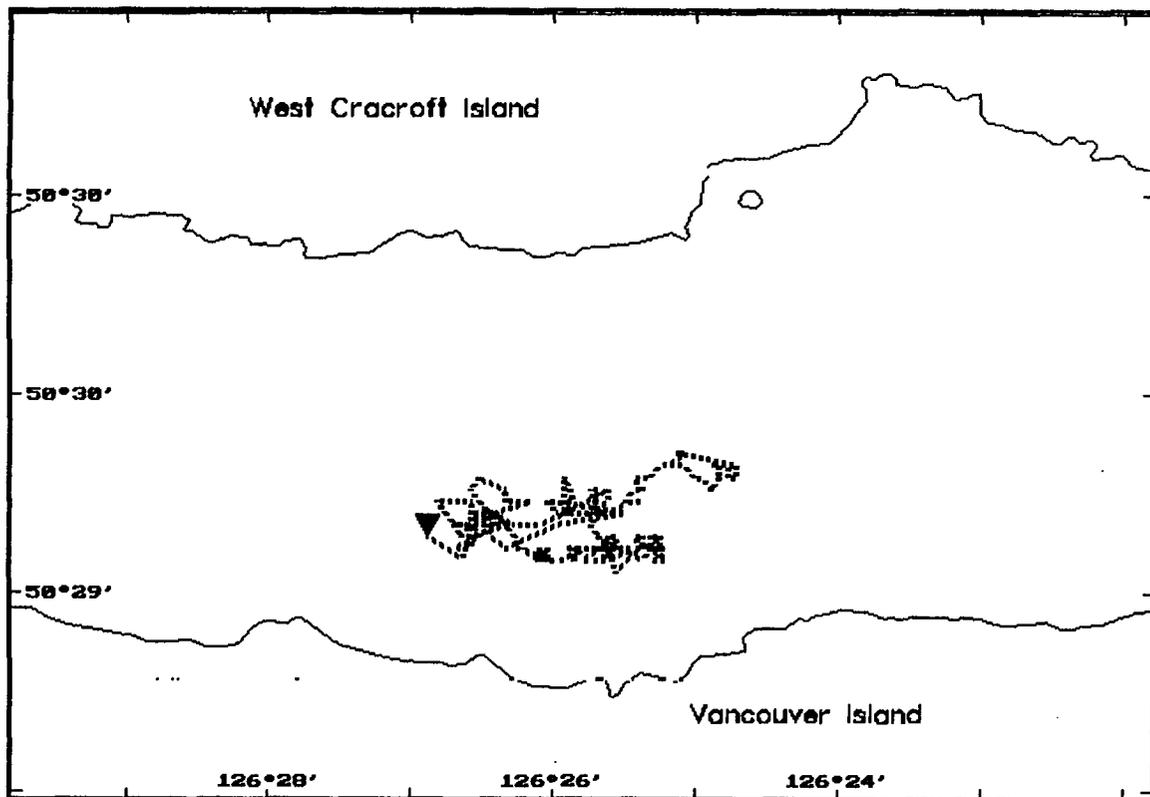
Sonic Track 9201



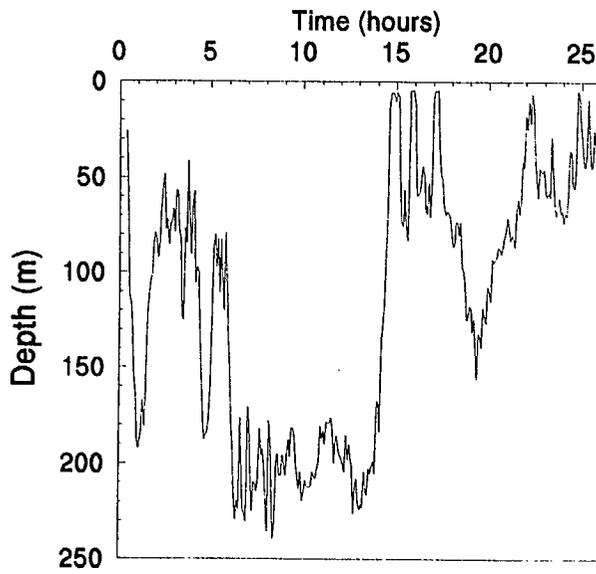
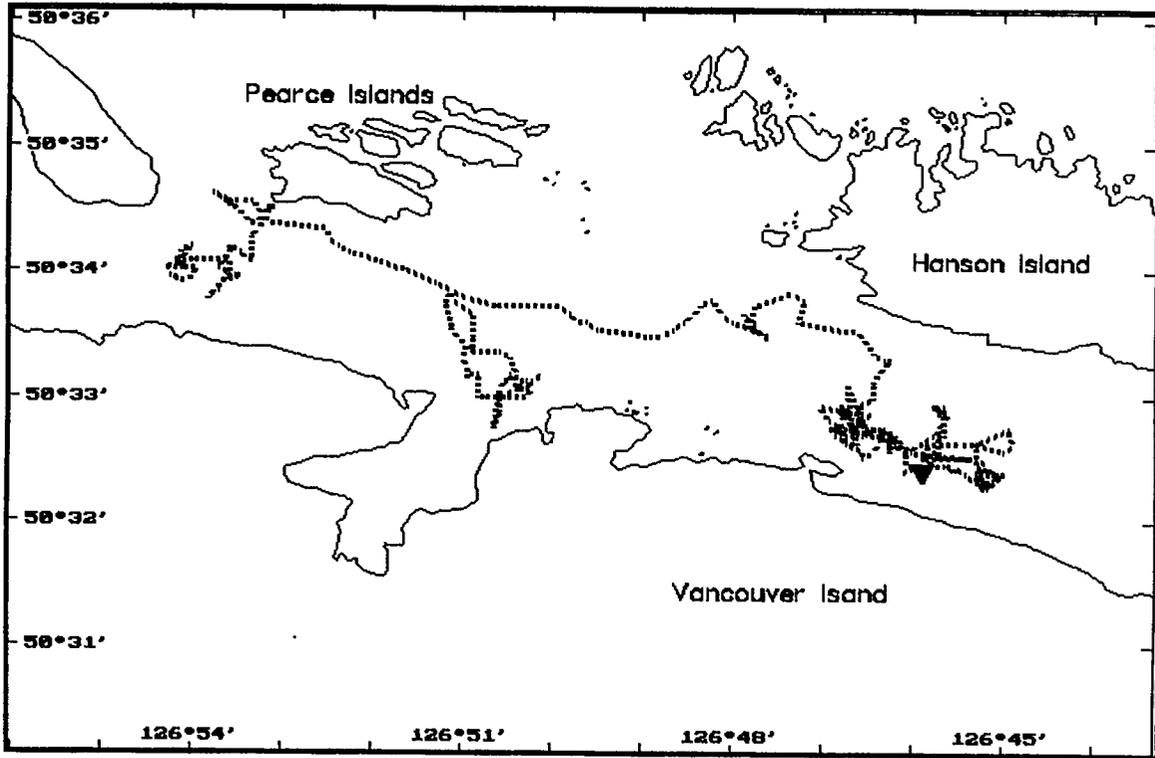
Sonic Track 9202



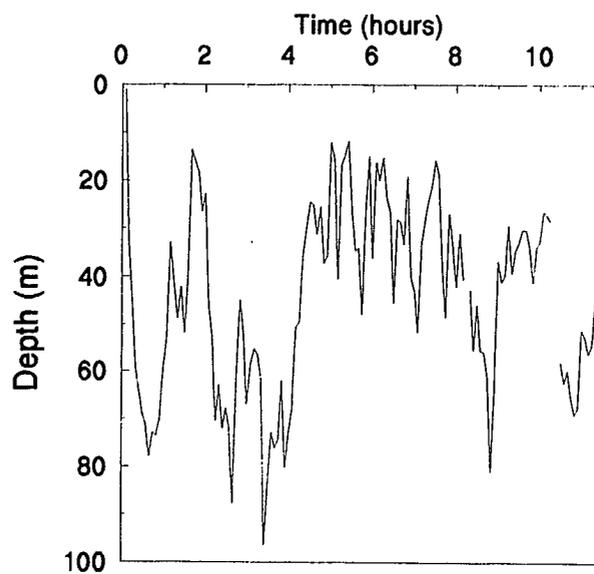
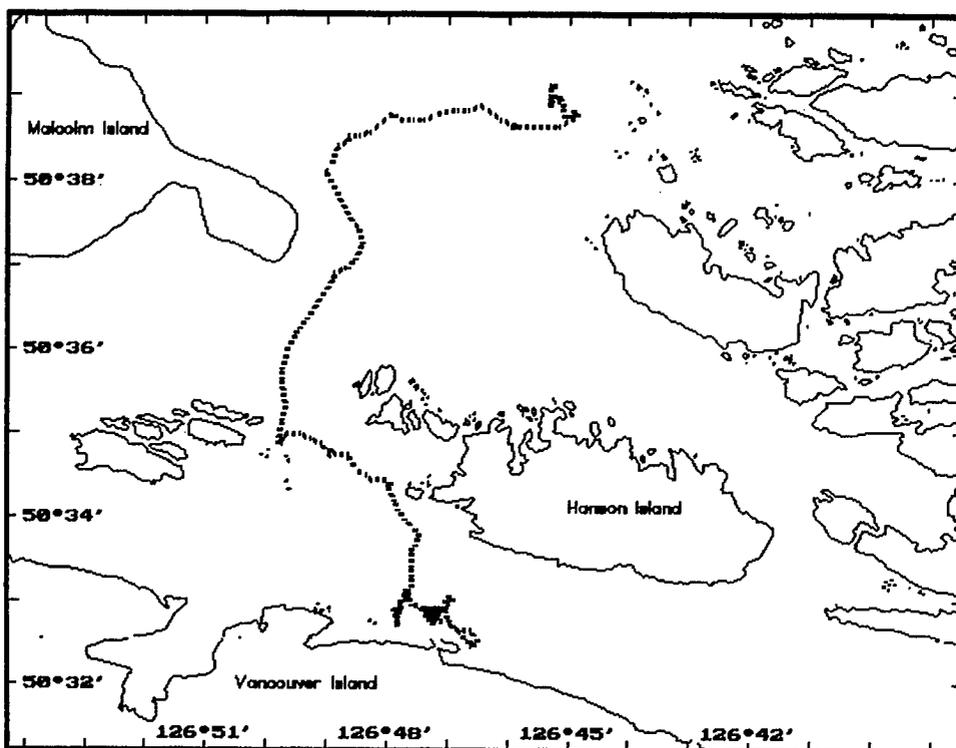
Sonic Track 9203



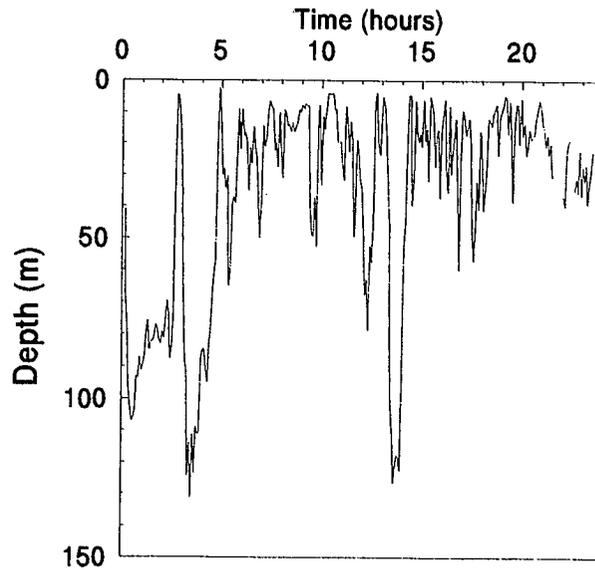
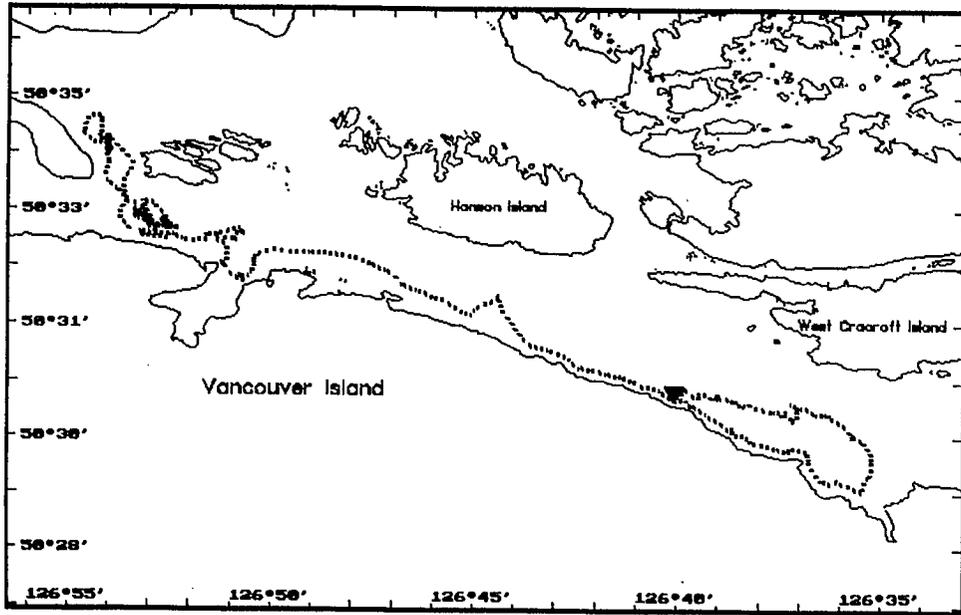
Sonic Track 9204



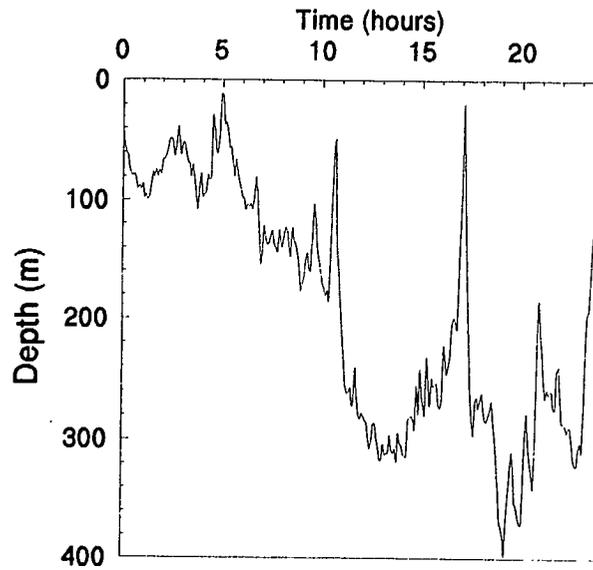
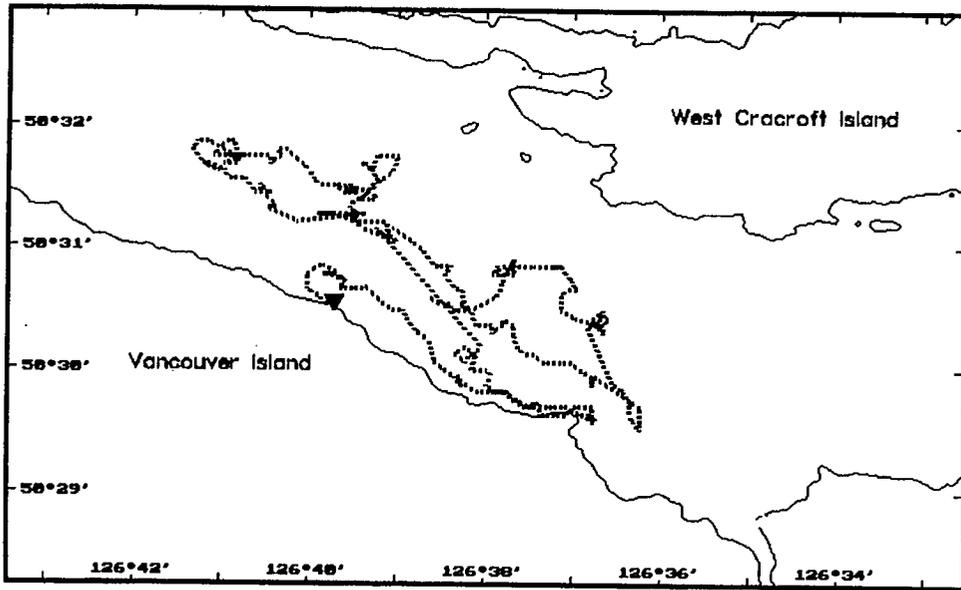
Sonic Track 9205



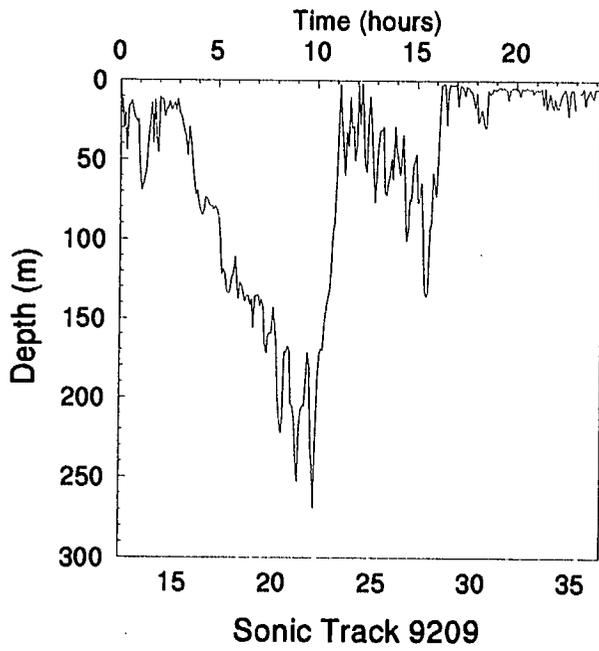
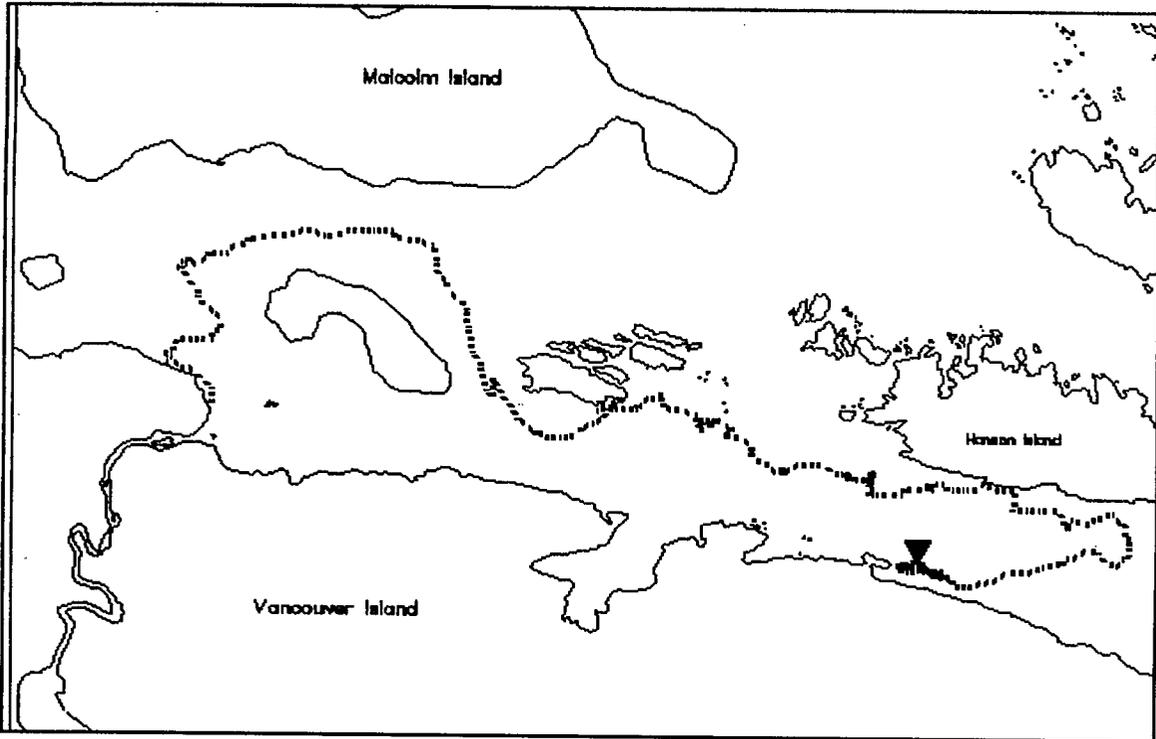
Sonic Track 9206

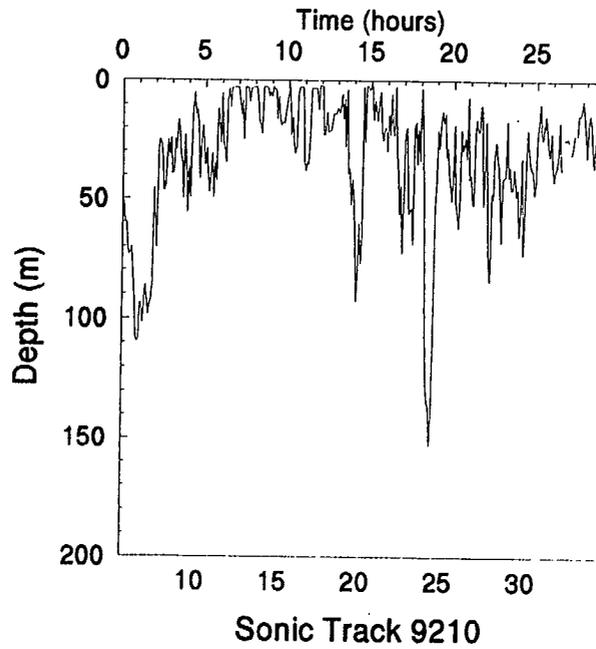
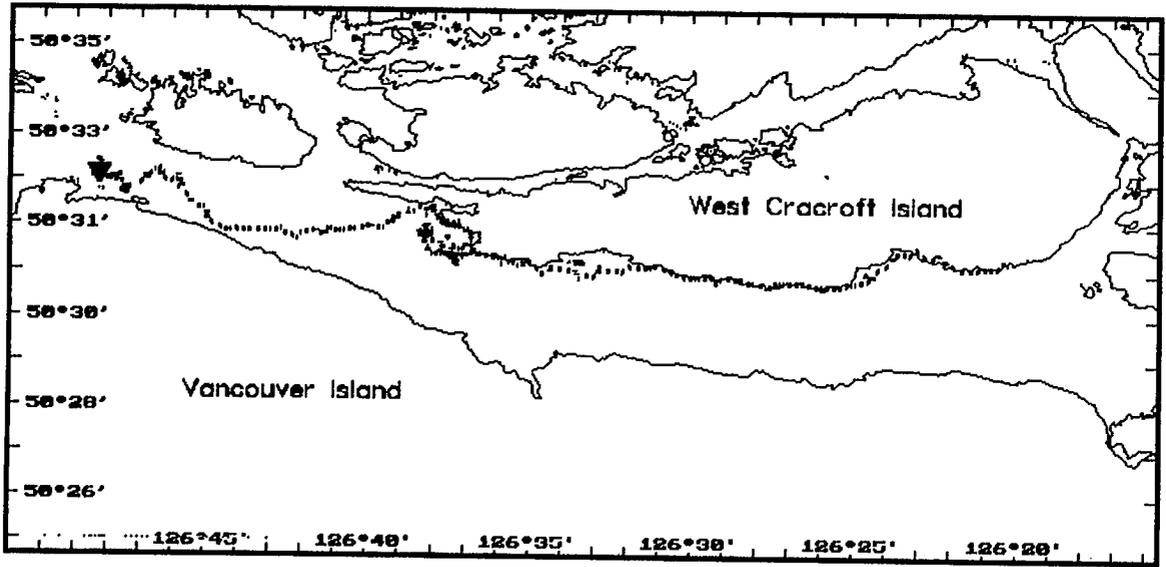


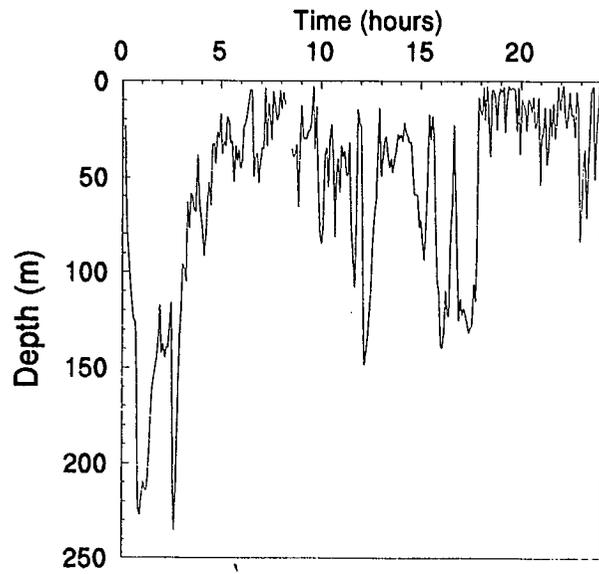
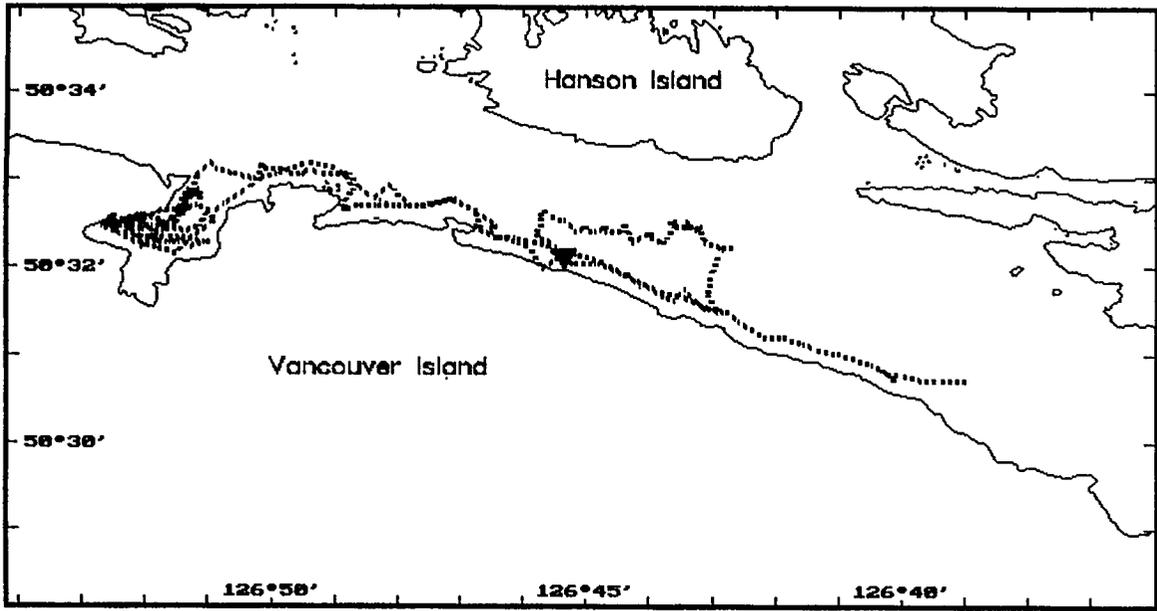
Sonic Track 9207



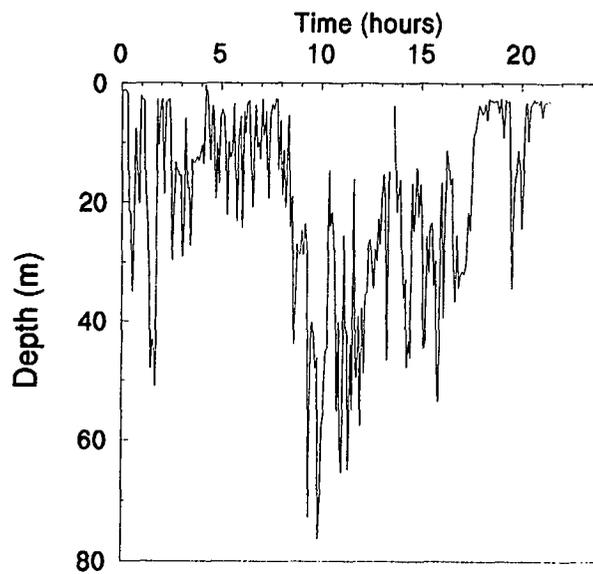
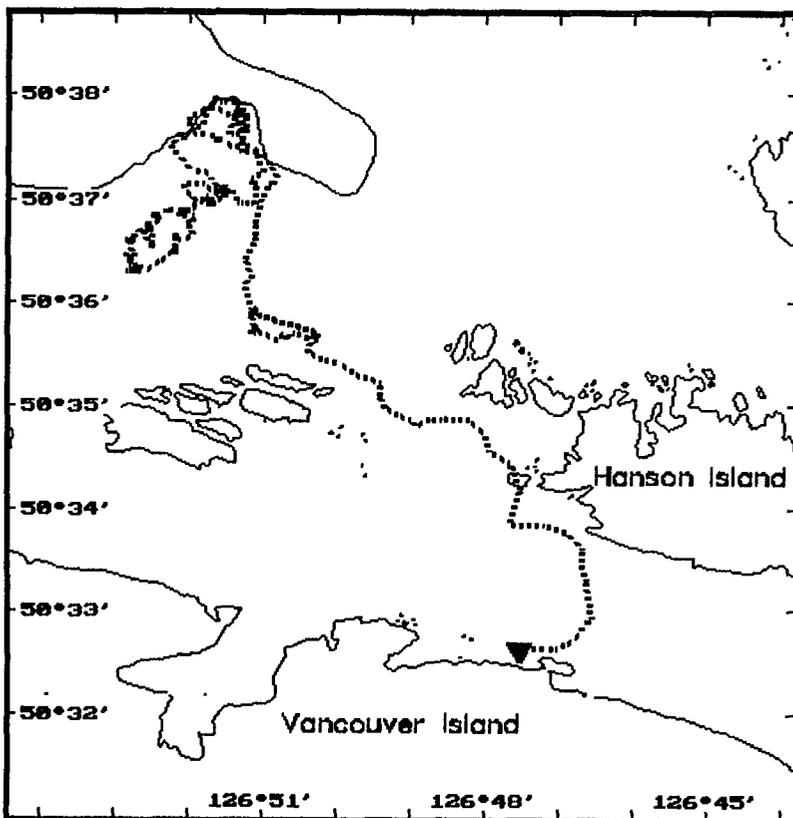
Sonic Track 9208



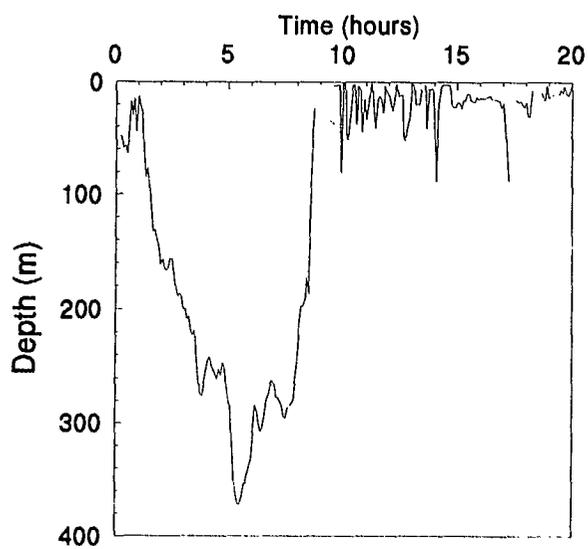
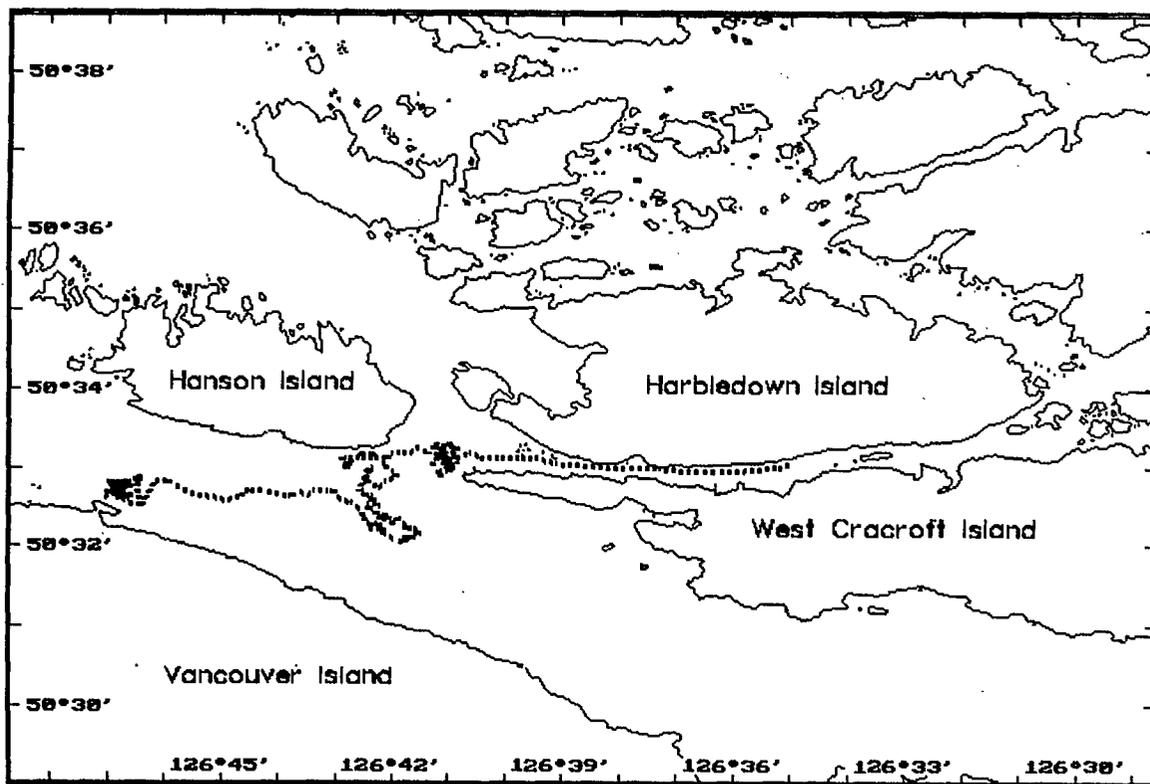




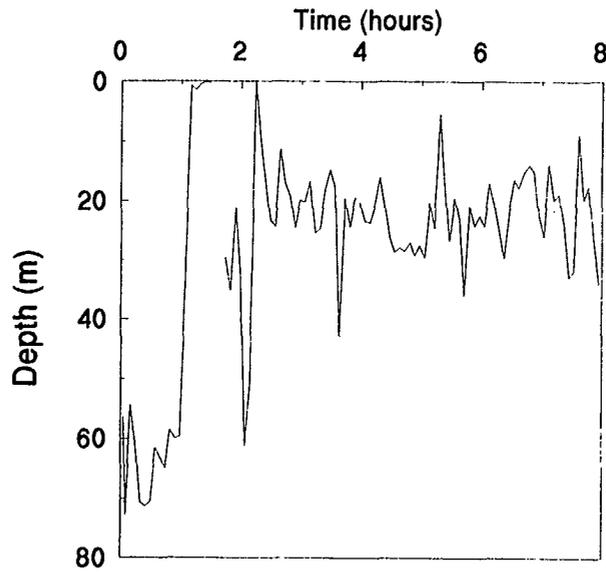
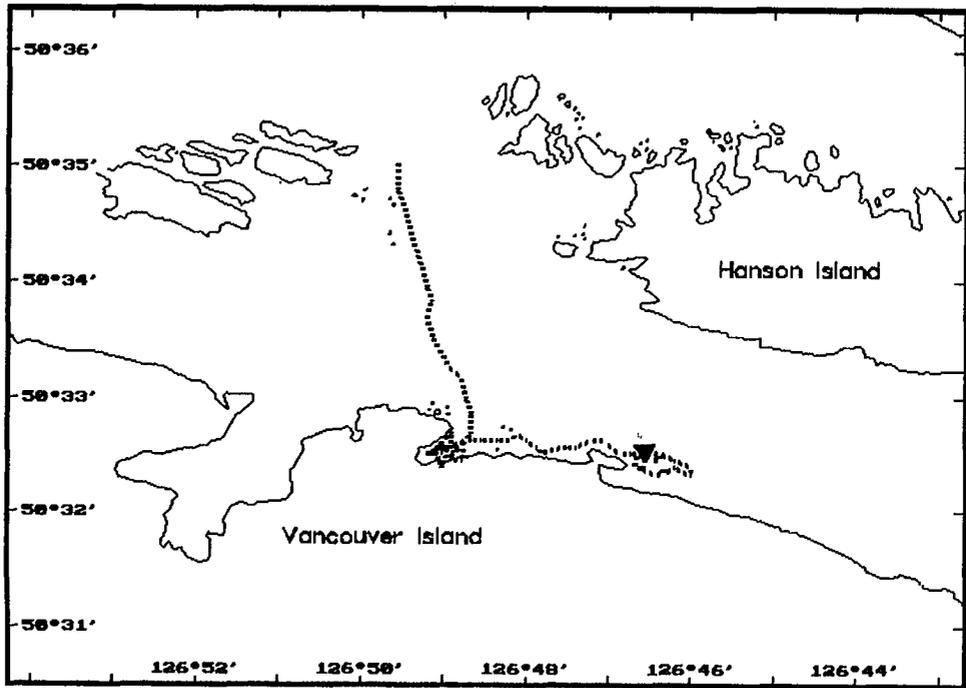
Sonic Track 9211



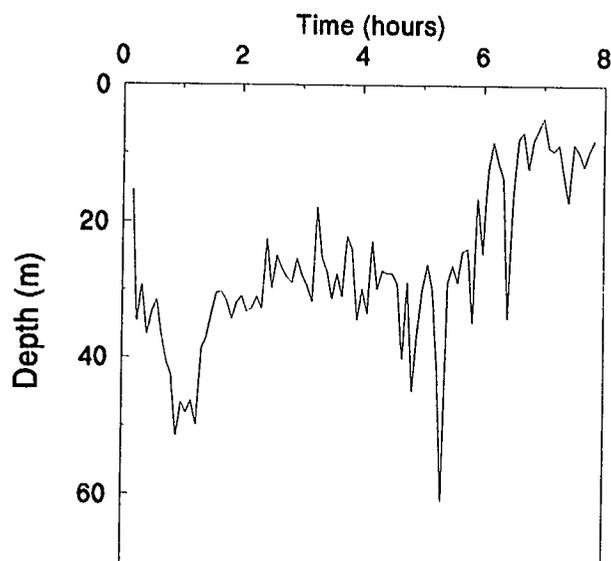
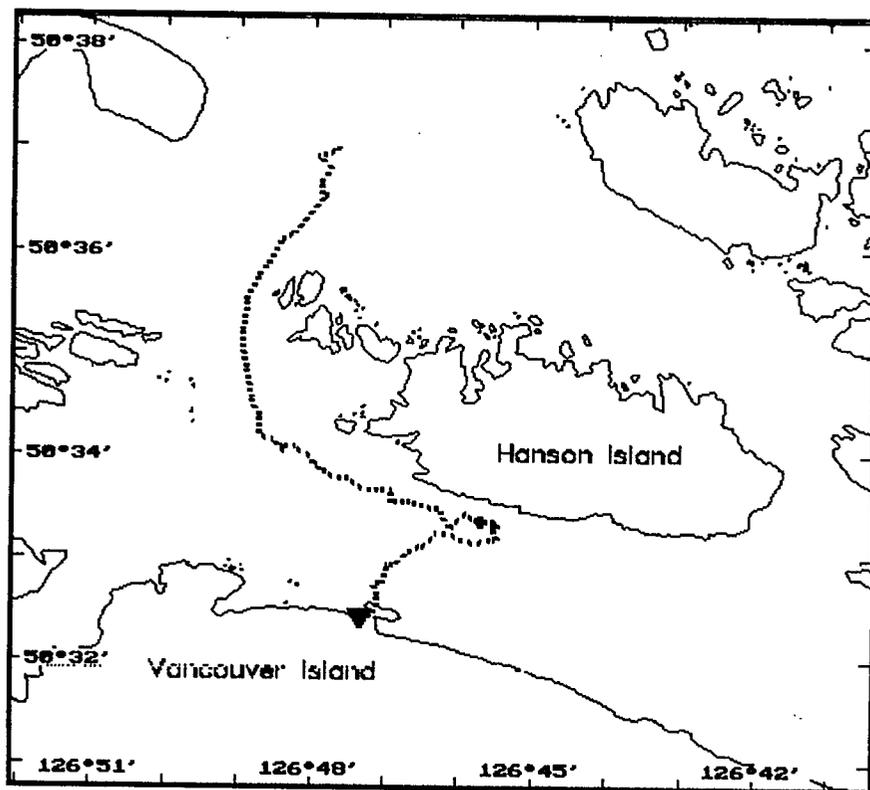
Sonic Track 9212



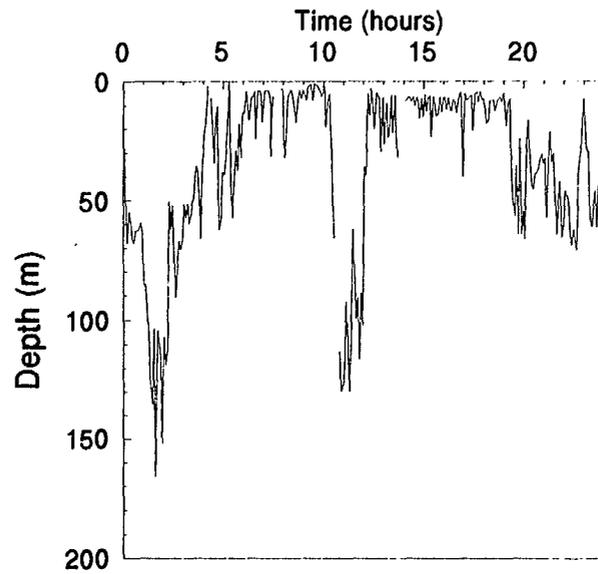
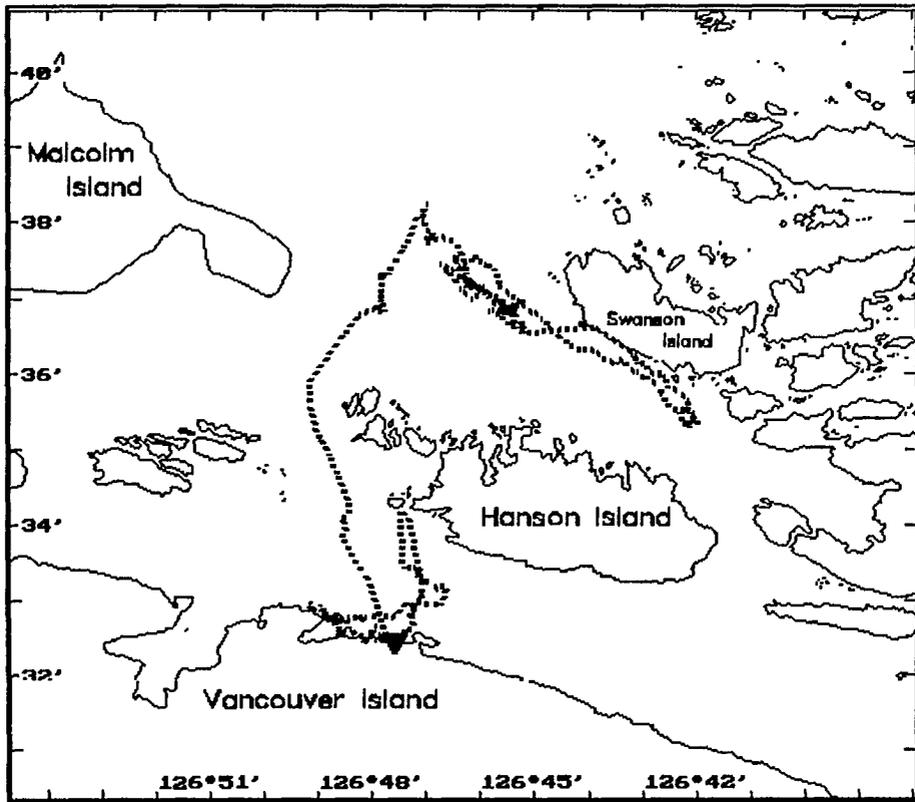
Sonic Track 9213



Sonic Track 9214



Sonic Track 9215



Sonic Track 9216

