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Seasonal Distribution of Harp Seals, *Phoca groenlandica*, in the Northwest Atlantic

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Abstract

Our understanding of the seasonal distribution and migratory behaviour of harp seals is based primarily on surveys of whelping and moulting concentrations, catch data, tag returns and anecdotal observations which may be biased by the location of the observer. To determine the seasonal distribution of harp seals in detail, satellite transmitters were deployed on 22 newly moulted, adult harp seals captured in 1995 (n=11) and 1996 (n=10) along the coast of Newfoundland and southern Labrador. Seals were tracked for periods of 22 - 356 days and provided a total of 13,309 transmissions. Locations were obtained on an average of 34.6% (SE=4.7, range 4.3 – 90.6%) of the days. Seasonal movements varied greatly among individuals and between years; there were no differences between males and females. Harp seals ranged from the northern Scotian Shelf and Grand Banks of Newfoundland in the spring and winter, north to Baffin Bay, southeastern Greenland and Hudson Strait in the summer. The Grand Banks appeared to be an important wintering area in both years. Much of their time was spent in offshore areas where they are rarely observed using traditional techniques. The occurrence of seals on the southern Grand Banks, Flemish Cap and Scotian Shelf may indicate a southern shift in distribution in recent years. The timing of the annual migrations in 1996 was similar to those reported previously. Both the northward and southward migrations occurred earlier in 1995 than in 1996, but the differences were not significant. This study illustrates the complexity of movements in a wide-ranging pelagic species such as the harp seal.

Introduction

Knowledge of the distribution of a species is necessary to understand its role in the ecosystem, particularly when trying to quantify interactions among predators and their prey. In the Northwest Atlantic, harp seals are the most abundant marine mammal predator with a total population estimate between 4.5 and 4.8 million in 1994 (Shelton et al. 1996). In order to determine the potential impact seals may have on commercial fish stocks, the amount of prey consumed can be estimated by incorporating data on abundance, energy requirements of individuals, geographical and seasonal variation in the diet, and distribution (Stenson et al. 1995; Hammill and Stenson 1997). Although considerable research has been conducted on various aspects of their biology, relatively few details are known about the seasonal distribution of this pelagic species.

The general migratory patterns of harp seals were described by Sergeant (1965, 1991). During the summer, the majority reside in the Arctic, occurring as far north as Thule in northwest Greenland and Lancaster Sound in the Canadian Arctic, and extending as far west as Hudson Bay (Fig. 1). In the autumn, they migrate southward along the coast of Labrador, usually reaching the entrance to the Gulf of St. Lawrence by early winter. There they split into two groups, one moving into the Gulf and the other remaining off the coast of Newfoundland and Labrador. The latter disperse across the continental shelf to feed until early March when they form large whelping concentrations off southern Labrador or northeast Newfoundland. Following mating, the seals disperse to feed, and in late April, they again congregate in large numbers on the ice to moult. Harp seals are thought to remain in Newfoundland waters into June at which time they migrate northward to the Arctic feeding grounds.

Our concepts of harp seal movement have been based on information from catch statistics, returns of traditional flipper tags, anecdotal sightings and surveys of whelping and/or moulting concentrations. Unfortunately, these often tell us more about where the observers are than where the majority of the seals go and thus, are insufficient to quantify the seasonal distribution of this population. In addition, they do not allow us to estimate the importance of individual or annual variation in movements that have been observed (Fisher 1955; Greendale and Brousseau-Greendale 1976; Stenson and Kavanagh 1994). Such variations can have a significant impact on the estimates of prey consumption (Shelton et al. 1995).

Recently, satellite telemetry has been used to monitor the movements of free-ranging hooded seals and provide new insights into their seasonal distribution (Stenson and Hammill 1993; Folkow and Blix 1995; Folkow et al. 1996). The objective of this study is to document the detailed movements of harp seals in the northwest Atlantic to improve our understanding of their seasonal distribution.

Methods

Moulting harp seals were captured during two trips to the pack ice off Newfoundland and Labrador in late April 1995 and again in early May 1996. In 1995, twelve seals were captured off the northeast coast of Newfoundland near Cape Bonavista (48° 42'N, 53° 05'W), while ten seals were caught off the southern coast of Labrador (approximately 54° 00'N, 57° 00'W) in 1996. The seals were caught on the ice by approaching them on foot and ensnaring them in a throw net. Once caught, they were brought on board a ship and transported to the Ocean Sciences Centre at Memorial University in St. John's, Newfoundland where they were held until they completed their moult. Based on their pelage patterns, all of the seals were greater than 3 years (Sergeant 1991; Roff and Bowen 1986).

Once their moult was completed, each seal was weighed and immobilised using tiletamine hydrochloride and zolazepam hydrochloride (Telezol, A. H. Robins Company, Richmond, VZ, USA) administered intramuscularly. Satellite linked time-depth recorders (SLTDRs) were attached to the new hair at the back of the seal's neck approximately 5 cm from the base of the skull using quick-drying epoxy resin. After ensuring that the transmitters were firmly attached, the seals were released near St. John's (47° 37'N, 52° 35'W) between mid May and mid June (Table 1).

All of the transmitters deployed were 0.5W SLTDRs (Wildlife Computers, Seattle Washington, USA), measuring 9.1 X 12 X 2.5 cm and weighing 700 g. Each transmitter had an expected depth tolerance of >1000 m and was equipped with a conductivity switch to ensured that the transmissions were stopped when the unit was submerged. The expected transmission capacity of each unit was 100,000 transmissions with a repetition rate between 45 and 50 seconds. To ensure that the transmitters had sufficient power to last a full year, the daily transmission allowance was varied from a maximum of 200 (1995) or 300 (1996) transmissions·day^{-1} during the summer (July, August) to 500 transmission·day^{-1} during the winter months (October - February) and spring (May, June). In 1995, one transmitter (3020) had a daily maximum transmission allowance of 400 transmission throughout the year. In 1995 the transmitters were allowed to transmit every day while in 1996 they were subjected to a duty cycle of 3 days on and 1 day off.

Data from the transmitters were processed by the Argos Data Collection and Location System (CLS/Service Argos 1989). If a sufficient number of transmissions were obtained during a pass of the satellite, Service Argos also provided a location along with an estimate of the accuracy of the position referred to as 'location class' (LC). Location classes range from LC 3 (best) to LC 0 (poorest) with the latter further subdivided into 'location indicators' (LI) depending upon the number of transmission received during a satellite pass. Location classes of LC 1 – LC 3 have been determined to be accurate within 1000 m or better, while the reliability of LC 0 has not been determined (CLC/.Service Argos 1989). LC 0 locations were considered to be sufficiently accurate for a study of seasonal movements provided they were not located over land or could be reached by a seal travelling 3 m·sec^{-1} or less since the last location.

For each day on which a position was obtained, the single, highest quality location was plotted. If more than one location of the same class were available, the first location of the day was used. For descriptive purposes, the locations were assigned to one of seven geographical areas (Fig. 1). The **Grand Banks** of Newfoundland was defined as the area of the banks within the 200-m depth contour. The **Southern Labrador Shelf** consisted of the continental shelf out to the 1000 m contour from the Grand Banks to the north edge of Hamilton Bank (approximately 55°N) while the **Northern Labrador Shelf** was defined as the area from Hamilton Bank to Cape Chidley (60°N). Locations around southeastern Baffin Island, including those in the Hudson Strait, were considered to be within the **Davis Strait** area while those north of the southern entrance to Disko Bay (>69°N) were classified as being in **Baffin Bay**. Seals were considered to be around **Greenland** if they were located within the 200 m continental depth contour. Positions located outside of the 1000 m contour were classed as being in the **Labrador Sea**.

Statistical comparisons between years and sexes were made using StatView (Abacus Concepts Inc., Berkeley, CA, USA).

Results

Of the twelve transmitters deployed in 1995, one stopped functioning immediately, while the remaining units operated for an average of 224 (SE = 18.4; range 128-356) days (Table 1). In 1996, all ten transmitters provided some data after release. However, longevity was more variable than in the previous year, ranging from 22 – 353 days and averaging 170 (SE=33) days (Table 1). Although this was less than in 1995, the difference was not significant (t=1.47, df=19, p=1579). There was no difference between males (184.1; SE=29.3) and females (214.6; SE=23.9; t=0.8, df=19, p=0.436). Two of the seals released in 1996 were shot in Greenland waters; 17909 on 25 August, 1996 and 17903 on 19 November, 1996.

A total of 13,309 transmissions were received during the two year study. In 1995 there was an average of 3.12 transmissions · day^{-1} (SE=0.52) while in 1996 it increased to 4.96 (SE=0.59; t=2.35, df=19, p=0.03). These transmissions resulted in 2,026 locations in 1995 and 1,289 in 1996, an average of 2.9 (SE=0.2) locations per day. There were no significant differences between years (t=0.47, df=19, p=0.64) or between sexes (t=0.97, df=19, p=0.34).

The proportion of locations that were considered to be reasonably accurate (CL 1-3) was slightly greater in 1996 (0.17, SE=0.02) than in 1995 (0.11, SE=0.02; t=2.19, df=19, p=0.04) although when CL 0 locations were included the difference was not significant (0.297 vs. 0.293; t=0.06, df=19, p=0.95).

The percentage of days on which a location was obtained varied from 4.3 – 50.7 % (mean=28.3 SE=5.6) in 1995 (Table 1). After taking into account the duty cycle, the percentage of days on which a location was obtained in 1996 was greater (12.4 – 90.6 %, Table 1), although the difference was not significant (t=1.43, df=19, p=.17). Similarly, there was no difference between males (38.1, SE=7.6) and females (30.8, SE=5.5; t=7.26, df=19, 0.46). Overall, locations were obtained on 34.6 % (SE=4.7) of the total possible days.

Seasonal Migration

Examination of the migratory patterns of the 21 seals tagged indicate that general movements of individuals are highly variable and that harp seals spent much of their time in offshore areas where they are rarely observed (Figs. 1-2). In 1995, the majority of the seals moved to the Grand Banks following their release and remained there for periods up to one month (Fig. 1a,b,e,f,g,h, Table 2). Although the timing varied greatly among individuals, harp seals did not move north of the Southern Labrador Shelf until July or August. Based on the six seals which provided locations, the average day on which the seals moved north of 55°N was estimated to be July 20 (SE=12.4 days; Table 3).

By late July or August, the majority of the seals had moved north of 60^{0}N, although one individual did remain along the North Labrador Shelf until November (21213_95, Table 2). Three of the seals moved into Hudson Strait (Fig 1b,g,h) although only one was located west of 75°W. Most harp seals appeared to spend the summer and early autumn in the Davis Strait area around southeast Baffin Island, or in southern Baffin Bay.

Three of the eleven seals, all female, spent time in the waters off Greenland. The timing and movement patterns, however, varied greatly. Two seals (Fig 1f,k) migrated to the waters along the southwest coast of Greenland in July and September, respectively while the third (Fig 1a) swam to southeast Greenland in late June, crossing the Labrador Sea directly from the Grand Banks.

The movements of nine of the seals during the late fall and winter period were documented. With the exception of one seal that remained in Greenland until the transmitter stopped in December (3020_95, Fig 1a), the seals moved south of 62°N by late September or early October (Table 2). By mid November (mean = November 13, SE=10.2 days, n=7, Table 3) harp seals had migrated southward into the Southern Labrador Shelf region. During December and January, the seals that returned to Newfoundland were located on, or near the Grand Banks (Fig.1c,g,h,i,j) or Scotian Shelf (Fig. 1f,g).

Only a single transmitter continued past February 1996 (21210_95, Fig. 1h). This seal, an adult female, remained along the southern Grand Banks (~45°N, 55°W) during the whelping period in March. It is unknown if she gave birth but there was no increase in the number of high quality locations which may be expected if she was hauled out on the ice nursing a pup. By the time the transmitter stopped on May 5 (presumably due to the moult), the seal had returned to the area off

Northeast Newfoundland (~49°N, 52°W), close to the location she had been captured the previous year.

The general migratory pattern of harp seals released in 1996 was similar to that of the previous year (Fig. 2). However, the timing of movements was different and only a few seals moved to the offshore areas of the Grand Banks following their release. Instead, the majority moved northward almost immediately and were located on the Southern Labrador Shelf during May and early June (Table 4). By late June most of the seals had migrated to the Northern Labrador Shelf. The average date on which seals had moved north of 55°N was three weeks earlier in 1996 (June 28, SE=7.1) than in 1995, although the difference was not significant (t=1.57, df=19, p=0.14). One seal migrated northward to the Hamilton Bank area in June, but returned to the area off the Grand Banks and Flemish Cap (~45°N 44°W) before the transmitter stopped in early July.

As in 1995, most of the seals spent the summer in the Northern Labrador Shelf and Davis Strait areas. The majority remained between 60°N and 67°N, although two individuals went into Baffin Bay (Fig. 2c,d). The most northerly position obtained was 75° 25'N. Two of the seals visited west Greenland, although they were farther north than the seals observed in 1995 (Fig. 2b,c). Both of these seals were shot by hunters while in the nearshore waters of Greenland.

The seals migrated southward later in 1996 than in 1995. In 1996, seals did not return to the Southern Labrador Shelf area until November or December (mean = December 1, SE=12.9). As in 1995, the seals which were present during the winter remained on, or near the Grand Banks (Fig 2d,f,g,h).

Data from the spring period was obtained from only one seal in 1997. During the breeding period in late March, this male remained near the northeast slope of the Grand Banks (Fig. 2f). The transmitter stopped functioning in late April by which time it had moved to the traditional moulting area off the northeast coast of Newfoundland.

Although migratory patterns are usually considered to be a simple northward movement in the spring and southward movement in the fall, double migrations were observed in both years. Seals 8198_95 (Fig. 1c) and 21208_96 (Fig. 2e) made two fall migrations; moving from the Arctic to southern Labrador in late summer or early fall, and then returning to Davis Strait for an additional month prior to migrating southward again in December (Tables 2 and 4).

Discussion

The use of satellite telemetry has provided us with detailed information on the seasonal movements of free-ranging harp seals. The general patterns we observed are consistent with the traditional concepts of movements for this species (e.g. Sergeant 1965, 1991). However, there was a considerable amount of geographical and seasonal variation among individuals. Also, in contrast to our previous ideas harp seals were found to spend much of their time in offshore areas including the Labrador Sea, where they are rarely observed using traditional techniques.

Satellite tagged seals ranged from the southern Grand Banks north to Baffin Bay, and from southeastern Greenland to Hudson Strait. Although harps have been reported in Hudson Bay (see review in Sergeant 1991) and as far north as Lancaster and Smith Sounds, (Mansfield 1967, Greendale and Brousseau-Greendale 1976, Tuck unpublished in Sergeant 1991), none of the animals we followed extended to these areas. In contrast, a few of the seals were found south of their traditional range on the northern Scotian Shelf or off the Grand Banks near the Flemish Cap (47°N 45°W). This may represent a shift in their range southward or simply be part of their historical range than had not been previously examined. A southward shift in range would agree with the increased number of harp seal strandings reported on Sable Island, off the coast of Nova Scotia (Z. Lukas, personal communication), and in the northern United States (Slocum et al. 1995) during the 1990s. Such an extension may be related to changes in food availability, possibly related to environmental conditions. Frank et al. (1996) found that capelin (Mallotus villosus), a preferred food of harp seals (Lawson et al., in prep.), occurred on the Scotian Shelf beginning in the late 1980s and on the Flemish Cap beginning in the early 1990s. This occurrence was concomitant with lower than normal ocean temperatures and a decline in capelin abundance off Newfoundland.

Following their release in 1996, the majority of seals moved northward without delay whereas in 1995, many of the seals remained on the Grand Banks or the southern Labrador Shelf well into July and even August. Throughout the early 1990s, fishermen have reported the presence of harp seals around the coast of Newfoundland during the summer and large numbers of seals were caught during the nearshore and offshore (Grand Banks) groundfish gillnet fishery (Sjare and Stenson, unpublished data). The earlier spring migration observed in 1996 is similar to that observed during the 1950s - 1980s (Sergeant 1965, 1991) when seals were thought to move northward in May and June, shortly after their moult was completed. These differences in timing may be related to the anomalous environmental conditions observed during the early 1990s (Colbourne et al. 1994). Extensive ice coverage and cool water temperatures were present on the southern Labrador Shelf throughout this period. By 1995 these conditions had moderated somewhat and in 1996, ice coverage was below normal along the east coast of Newfoundland (Colbourne 1996). Although harp seals spend much of the year in areas where ice is absent, if their migratory patterns are influenced by environmental or prey conditions reflected by ice cover, it would account for the earlier movements northward in 1996. Fisher (1955) suggested that a reported change in the timing of the fall migration between the 1920s and 1950s may have been due to warmer conditions during the later period. It is possible that environmental conditions may also result in annual variation in migratory timing.

The difference observed in the movements of the seals following release between the two years of the study may also have been affected by the requirement to hold the animals at the Ocean Science Centre until their moult was completed. In 1995, the seals were released within 1° latitude of the capture site while in 1996 the seals were originally captured much further north. However, we do not feel that this significantly affected the results since they were released close to the traditional moulting areas for harp seals (Sergeant 1991) and seals were reported near the release area in May and June of both years.

Considering the highly variable nature of the movements observed among individuals, it is unlikely that capturing seals in a single moulting patch biased our results. Relatively few concentrations of moulting seals were found by surveillance flights in both years and the amount of suitable ice available was limited, suggesting that the seals from throughout the Newfoundland area were present within the capture area. Also, although the captures were made within a day in 1995, there was an attempt to move within the moulting concentration in 1996. There was no evidence that seals held together continued to associate after release in either year, even if released at the same time. Comparing locations indicates that various individuals may have been close to one another at some time during the year, but these possible associations did not appear to last longer than a few days and none occurred during the period immediately after release. Instead they suggest that individuals may have been utilising a common area or food source rather than forming long term associations during migration.

The largest catches of harp seals in the Arctic occur in the Cunningham Inlet area of south-east Baffin Island (Stewart et al. 1986) and along the Southwest Greenland coast of Davis Strait (Kapel and Rosing-Asvid 1996). Although catches reflect hunting effort to some extent, this area of the Davis Strait appears to be important for summer feeding and was heavily frequented by seals in both years of the study. Samples from seals collected off Baffin Island (Smith et al. 1979) and Southwest Greenland (Kapel 1995) indicated that Polar cod (*Boreogadus saida*), capelin, sandlance (*Ammodytes* sp.), euphausiids, and other pelagic crustacea are important prey of harp seals in this area. Shrimp (*Pandalus borealis*) and small Greenland halibut (*Reinhardtius hippoglossoides*), important prey of harp seals in more southern waters (Lawson et al. 1995, Lawson and Stenson 1995, 1997), are also common in this area (Atkinson and Bowering 1987, Squires 1990).

The northeast Grand Banks and southern portion of the Labrador Shelf appear to be important feeding areas for harp seals during December and January when adults are feeding heavily to build up energy stores for the breeding and moulting periods (Chabot et al. 1996). Annual fall groundfish surveys of southern Labrador and the northern Grand Banks (Lilly 1996) found that the largest catches of capelin, the major prey of harp seals during the winter in offshore waters (Lawson and Stenson 1997), occurred in the area where seals were observed most often.

The presence of harp seals wintering on the Grand Banks was reported in early accounts (Robinson 1897, Chafe 1923), but thought unlikely by Sergeant (1991). However, the results of offshore sighting surveys conducted in the early 1990s suggested that large numbers of harp seals were present in these areas (Stenson and Kavanagh 1994). It is unclear if these results represent a change in distribution or improved coverage, but our results indicate that these offshore areas are still important for harp seals during the winter.

With the decline and apparent lack of recovery of many groundfish stocks in the Northwest Atlantic (Anon 1997a,b), it is increasingly important to understand the role predators such as the harp seal may be having on fish stocks. In an effort to begin this process, Stenson et al (1995) and Hammill and Stenson (1997) attempted to estimate the amount of prey consumed by harp seals in the NAFO areas 2J3KL which may be approximated by the Grand Banks and Southern Labrador Shelf areas used in this study. Because of the lack of information on the residency time of seals in this area, they assumed that seals were present for a fixed period of 212 days, entering on November 15 and leaving on June 15. In order to test the importance of this assumption, Shelton et al. (1995) varied the dates from October 15 to December 1 in the fall and between June 1 and July 15 in the spring for a residency period between 182 and 272 days. Using estimates of residency within this range and varying the other assumptions related to the proportion of the population present similarly, resulted in consumption estimates that varied by 12%. A mean residency period of approximately 228 days (November 21 - July 6) was obtained by combing the two years of data in this study which were not significantly different. The observed variance resulted in a residency period between 199 and 257 days which is well within the range of estimates already considered in the consumption models.

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Table 1. Details of satellite transmitters deployed on harp seals in the Northwest Atlantic.

Year	PTT	Sex	Wt (kg)	Start	End	#Days	# Total Locations	% Location Days [1]	# Total Transmission
1995	3020	F	60.0	May 19	Dec 18	214	309	32.2	702
	3022	M	60.0	May 21	Nov 21	185	76	20.0	394
	8198	M	74.8	May 15	Jan 23/96	254	166	22.4	737
	8199	M	66.0	May 18	Oct 18	154	14	3.2	91
	17909	F	50.0	May 18	Dec 16	213	111	20.6	567
	21208	F	66.2	May 10	Feb 12/96	279	28	4.3	393
	21209	M	62.4	May 12	Feb 23/96	288	263	39.6	1308
	21210	F	73.0	May 20	May 9/96	356	153	16.8	900
	21211	M	65.0	May 21	Jan 8/96	233	440	39.3	1474
	21212	M	86.4	May 21	May 21	0			
	21213	F	60.2	June 16	Jan 26/96	225	381	50.7	972
	21214	F	77.3	June 16	Oct 21	128	85	31.2	312
	Mean (SE)					224.4 (18.4)	184.4 (43.4)	28.3 (5.6)	713.6 (128)
1996	17902	M	75.4	May 23	July 3	42	101	90.6	240
	17903	F	51.4	Jun 17	Nov 19	156	208	47.0	673
	17909	M	83.6	May 8	Aug 26	111	169	57.8	641
	17910	F	49.2	May 8	Jan 30/97	267	86	17.0	598
	21208	M	49.6	May 17	Jan 19/97	247	155	32.4	891
	21209	M	73.6	May 8	Apr 26/97	353	81	12.4	625
	21210	F	63.2	May 22	Dec 17	210	107	27.2	562
	21211	M	45.6	May 22	Dec 3	196	192	40.1	682
	21213	F	62.2	May 23	Aug 28	98	184	60.8	483
	21214	M	87.4	May 23	Jun 13	22	6	29.4	64
	Mean (SE)					170.2 (33.0)	128.9 (20.0)	41.5 (7.4)	545.9 (74.7)
Overall Mean (SE)						198.6 (19.0)	157.9 (24.9)	34.6 (4.7)	633.8 (76.5)

[1] Percentage of total possible days; 1996 data adjusted for duty cycle of 3 days on, 1 day off.

Table 2. Periods during which individual seals were resident in different geographical areas during 1995/96. Seals could not be assigned to areas during dates not listed.

PTT	Sex	Start	Grand Banks	SLS	NLS	Lab Sea	Davis Strait	Baffin Bay	Greenland	NLS	SLS	Grand Banks	End
3020	F	19/05	19/05-07/06			15/06-22/06			23/06-end				18/12
3022	M	21/05	21/05-28/06		22/08		23/08-25/10			26/10-01/11	02/11-end		20/11
8198	M	15/05		26/06			11/07-18/09			19/09-24/09	27/09-23/10		
							16/11-07/12			08/12-15/12	16/12-22/12	24/12-end	23/01/96
8199	M	18/05					13/08-15/08				18/10		18/10
17909	F	18/05	18/05-30/05				27/07-15/08	06/09-21/09		11/10-12/10	27/10-end		16/12
21208	F	10/05	10/05-30/05						28/07-30/07	10/10-11/10		30/01-end	11/02/96
21209	M	12/05	12/05-13/05	14/05-24/05									
			25/05-26/06		18/07-21/07		22/07-13/10			14/10-25/10	22/10-end		22/02/96
21210	F	20/05	20/05-23/05	24/05-08/06			07/10			01/12-15/12	16/12-31/12	01/01-16/01	
											30/01-05/02	22/02-03/05	
											04/05-end		09/05/96
21211	M	21/05	21/05-22/05	23/05-16/08	17/08-28/08		29/08-11/09	12/09-23/09					
							24/09-05/10			06/10-13/10	14/10-19/12	22/12-end	07/01/96
2113	F	16/06	16/06-17/06	18/06-02/08	03/08-01/11		02/11-24/11						
						25/11-02/12					03/12-11/12	12/12-15/01	
											16/01-end		25/01/96
21214	F	16/06	16/06-17/06	18/06-04/08		05/08-12/08			06/09-end				21/10

Table 3. Estimated day when individual seals moved north of, or south into, the Southern Labrador Shelf (SLS)[1] area.

Year	PTT	Sex	Start	North of SLC	South of SLC	Last Location
1995	3020	F	May 19	June 9		Dec 18
	3022	M	May 21		Nov 2	Nov 20
	8198	M	May 15	July 5	Sept 27[2]	
				Oct 27[3]	Dec 16	Jan 28/96
	8199	M	May 18			Oct 18
	17909	F	May 18		Oct 27	Dec 15
	21208	F	May 10			Feb 11/96
	21209	M	May 12		Oct 22	Feb 22/96
	21210	F	May 20		Dec 16	May 9/96
	21211	M	May 21	Aug 26	Oct 14	Jan 7/96
	21213	F	June 16	Aug 3	Dec 3	Jan 25/96
	21214	F	June 16	Aug 4		Oct 21
	Mean (SE[4])			July 20 (12.4)	Nov 13 (10.2)	
1996	17902	M	May 23			July 3
	17903	F	June 17	July 6		Nov 19
	17909	M	May 8	June 10	Dec 5	Aug 27
	17910	F	May 8	June 15		Jan 20/97
	21208	M	May 17	June 23	Aug 25[2]	
				Oct 26[3]	Dec 27	Jan 3/97
	21209	M	May 8	June 15	Jan 1/97	April 26/97
	21210	F	May 22	Aug 7	Nov 2	Dec 17
	21211	M	May 22	June 15	Nov 1	Aug 25
	21213	F	May 23	July 28		Aug 28
	21214	M	May 23	June 13		June 13
	Mean (SE)			June 28 (7.1)	Dec 1 (12.9)	
Overall Mean(SE)				July 6 (6.7)	Nov 21 (8.1)	

[1] Defined as 55°N or off the continental shelf
[2] Not used in average, assume last movement in
[3] Not used in average, assume first movement out
[4] Days

Table 4. Periods during which individual seals were resident in different geographical areas during 1996/97. Seals could not be assigned to areas during dates not listed.

PTT	Sex	Start	Grand Banks	SLS	NLS	Lab Sea	Davis Strait	Baffin Bay	Greenland	NLS	SLS	Grand Banks	End
17902	M	23/05	23/05-24/05	25/05-06/06	07/06-13/06								
				15/06-25/06								26/06-end	03/08
17903	F	17/06	17/06-24/06	25/06-06/07	07/07-18/07	19/07-25/07	26/07-24/09		25/08-27/08				
							07/09-16/09		17/09-16/10				
							17/10-end						19/11
17909	M	08/05		29/05-10/06	11/06-13/06				28/06-25/07				
								26/07-01/08	02/08-end				27/08
17910	F	08/05	08/05-09/05	10/05-15/06	16/06-26/06		20/09-18/10	19/10-26/10			14/12-07/01	08/01-20/01	30/01/97
21208	M	17/05	17/05-20/05	21/05-23/06	24/06-02/07	03/07-06/07	07/07-09/08						
						10/08-16/08				17/08-24/08	25/08-26/10		
					27/10-10/11		11/11-08/12			09/12-26/12	27/12-end		03/01/97
21209	M	08/05		08/06-16/01	16/06-20/06		04/08-06/09			07/09-30/12	01/01-end		26/04/97
21210	F	22/05	22/05	23/05-23/06									
			24/06-13/07	14/07-07/08			23/08-20/09			24/10-01/11	02/11-15/11	16/11-06/12	
											07/12-end		17/12
21211	M	22/05	22/05-29/05	30/05-15/06	16/06-10/08		11/08-02/09			03/09-02/11	01/11-07/11	08/11-25/11	
											26/11-end		03/12
21213	F	23/05	23/05-04/06	05/06-12/06									
			13/06-05/07	18/07-28/07	29//07-05/08		06/08-end						28/08
21214	M	23/05	23/05-24/05	25/05-12/06	13/06								13/06

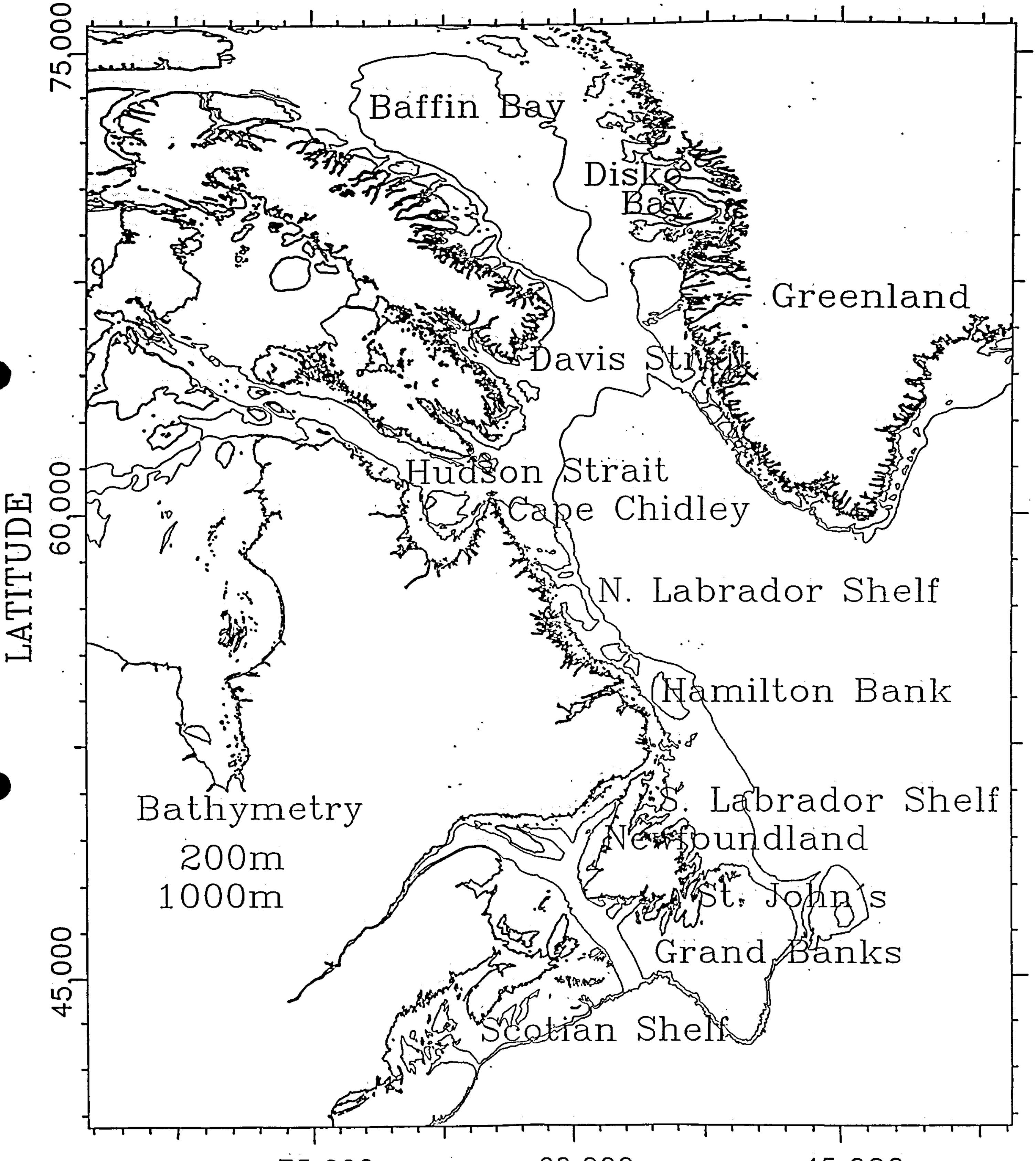


Figure 1: Map of the study area

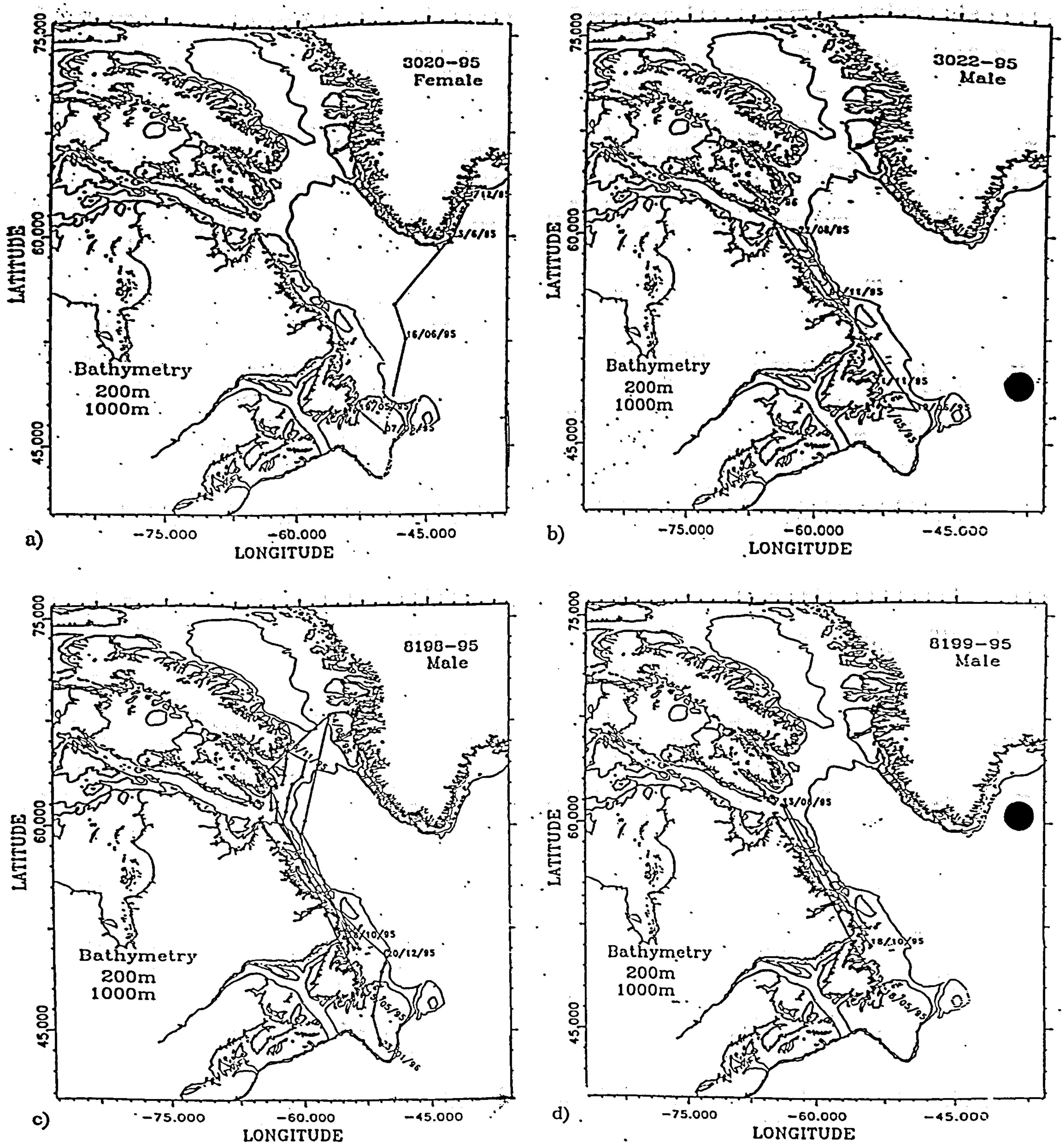


Figure 2: Movements of individual harp seals in the Northwest Atlantic during 1995/96

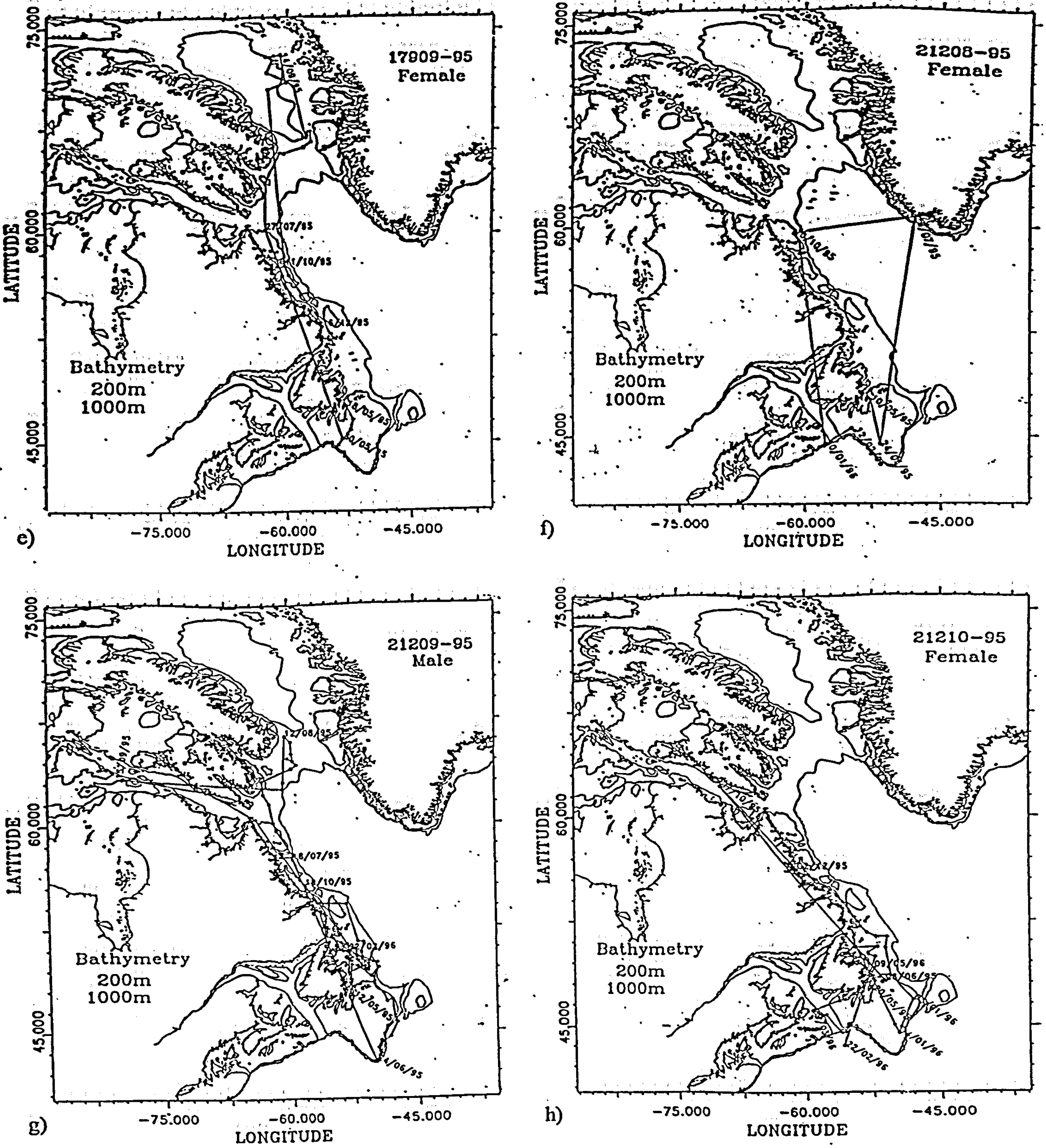


Figure 2: continued

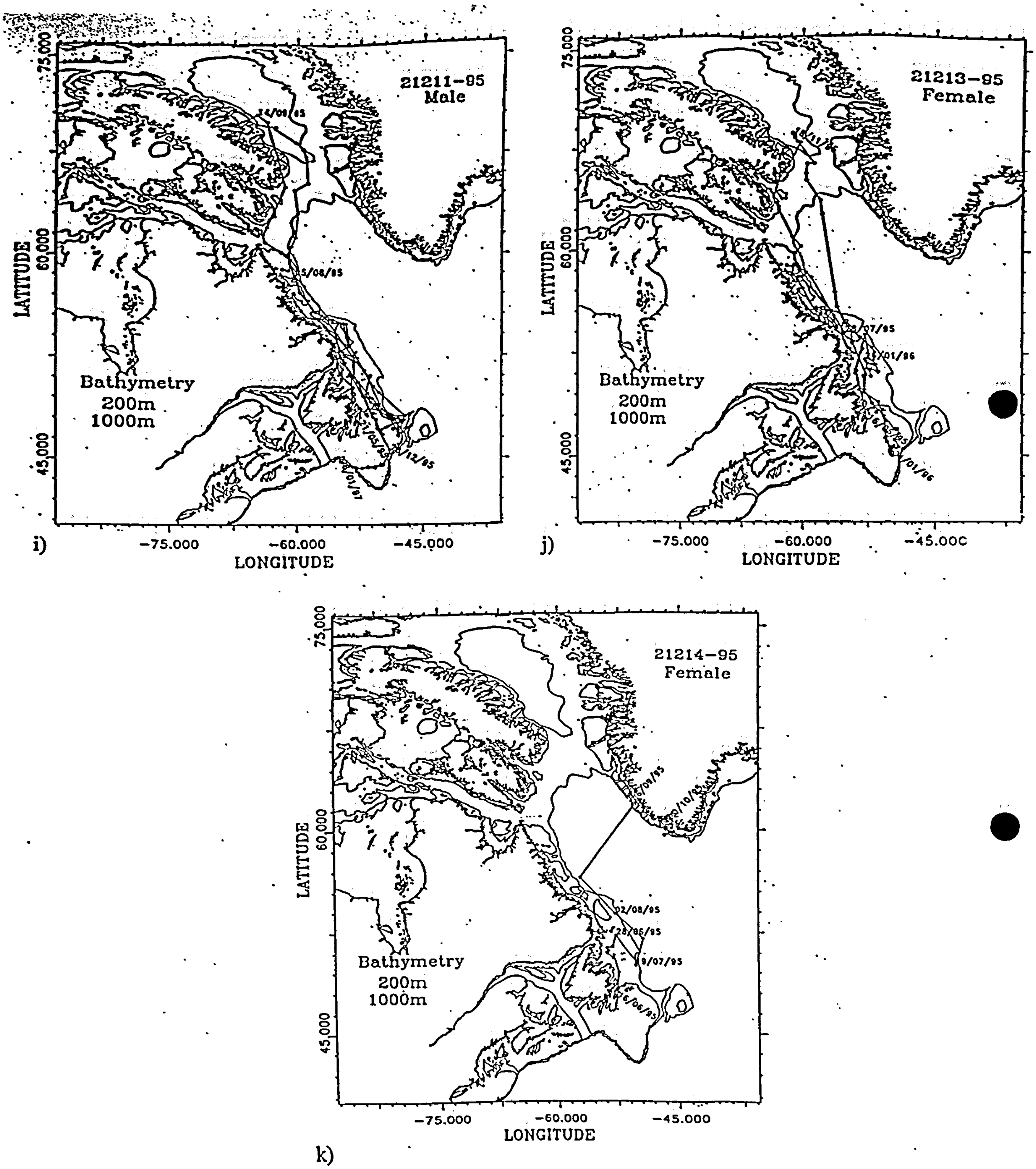


Figure 2: continued

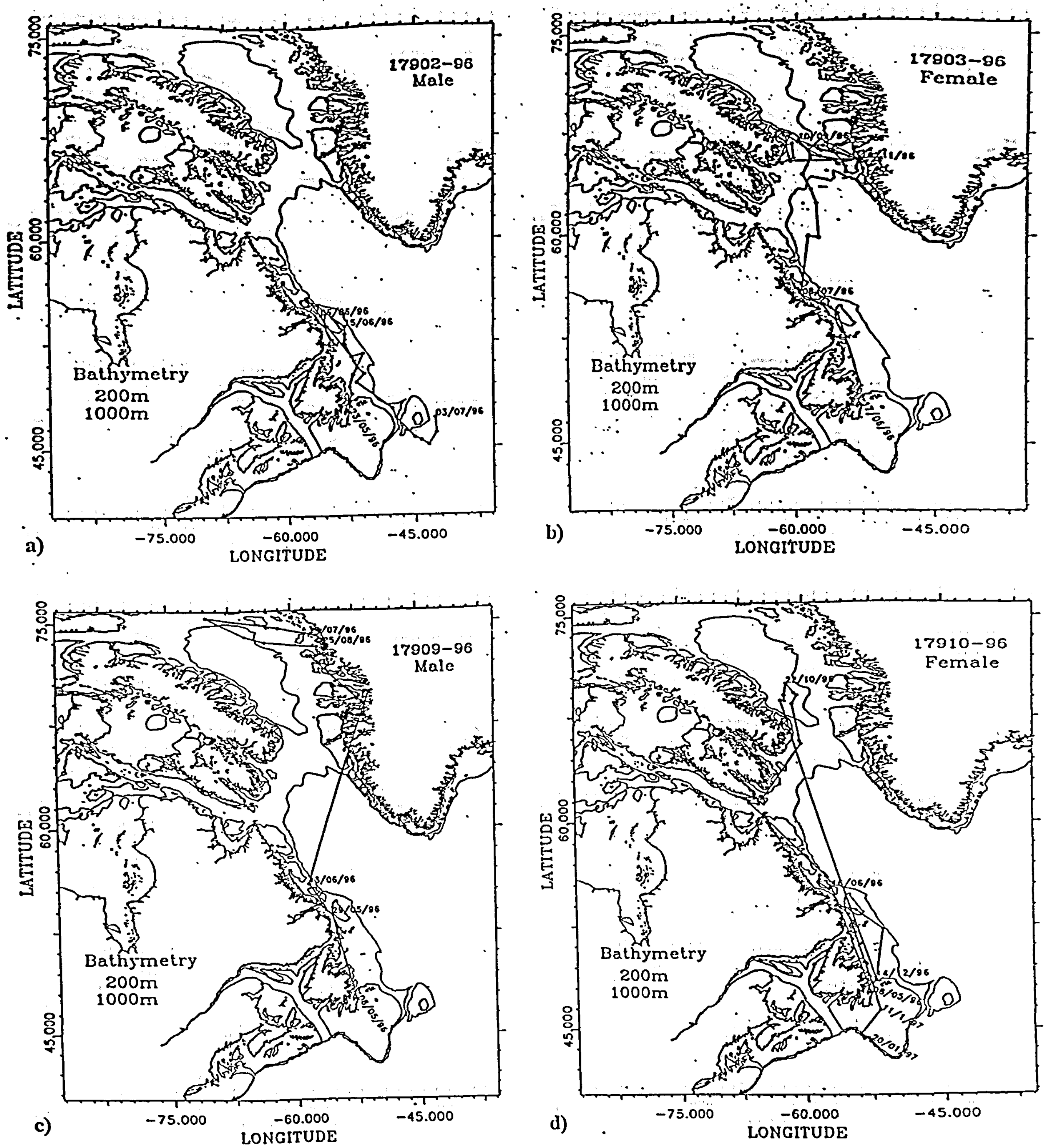


Figure 3: Movements of individual harp seals in the Northwest Atlantic during 1996/97

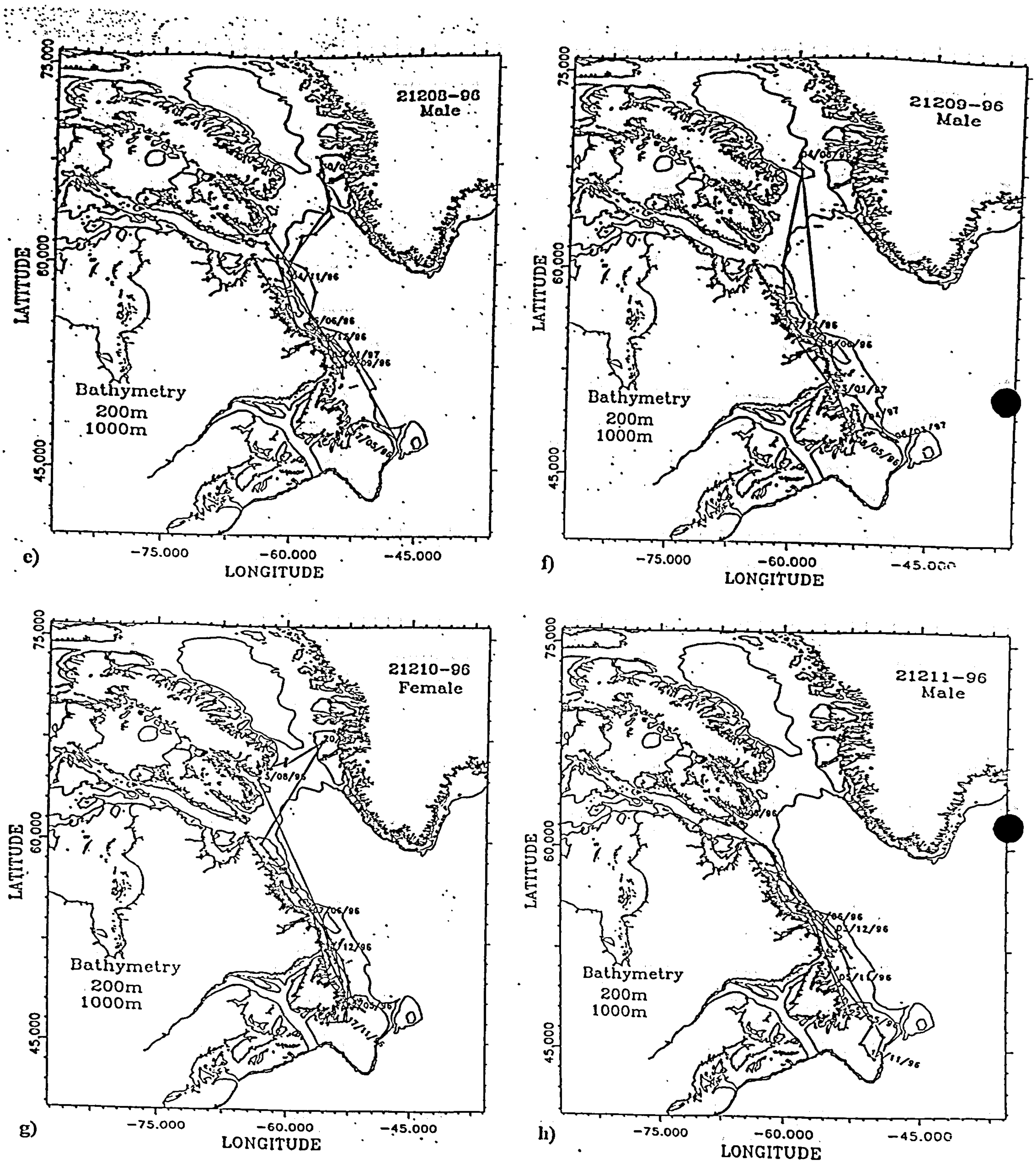
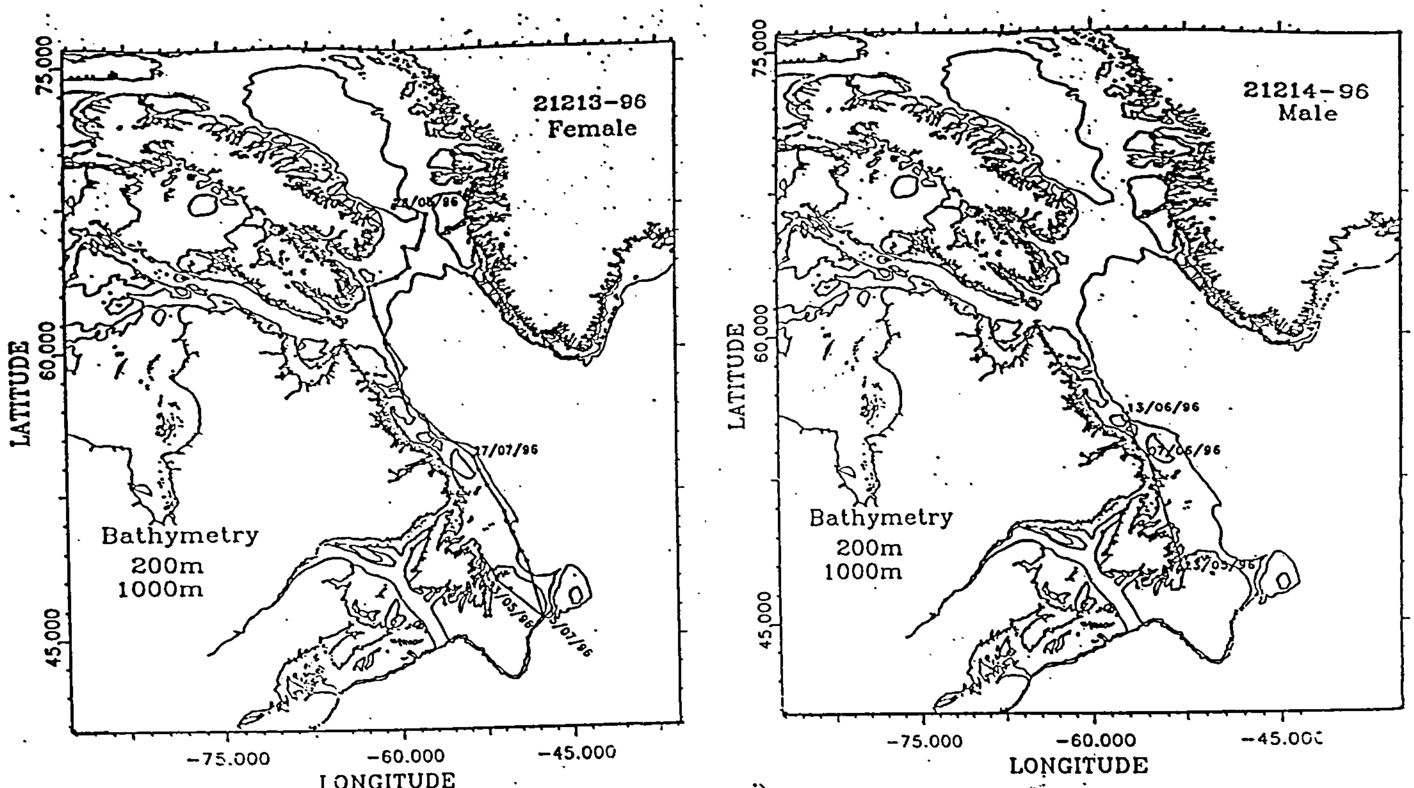


Figure 3: continued



i) j)

Figure 3: continued