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The Iceland Scallop: A Fishery under Siege in Newfoundland

by

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Abstract

The recent fishery for Iceland scallop over the Grand Banks of Newfoundland has been driven by an accumulated virgin biomass, consisting largely of cohorts of old, possibly well-separated, year-classes with little potential for further growth. The high unit value combined with low annual production has led to rapid depletion of "new-found" aggregations, sometimes within a single season and preclude contemplated management or conservation measures. In practice, exploitation of Iceland scallop resources in Newfoundland has been based largely on short-term economics rather than considerations of resource sustainability *per se*. Declines in abundance indices, sometimes precipitous, and catch per unit effort have been exacerbated by high incidental fishing mortality. Exploitation rates on this highly aggregated species have in effect been substantially higher than the target 10% hitherto used to estimate appropriate catch levels from abundance indices. At current levels of fishing effort all known commercial aggregations could be severely depleted before significant recovery occurs. Fishing for scallops should be considered a low volume, high value activity.

Résumé

La pêche récente du pétoncle d'Islande sur les Grands Bancs de Terre-Neuve a été alimentée par une biomasse vierge accumulée surtout composée de cohortes de classes annuelles âgées, sans doute bien distinctes, présentant peu de possibilités de croissance ultérieure. La valeur unitaire élevée combinée à une faible production annuelle a donné lieu à un épuisement rapide des concentrations « nouvellement découvertes », parfois au cours d'une même saison, et interdit d'envisager des mesures de gestion ou de conservation. En pratique, l'exploitation des ressources en pétoncle d'Islande de Terre-Neuve a surtout été fondée sur les avantages économiques à court terme plutôt que sur le maintien du caractère durable de la ressource. Les déclins des indices d'abondance, parfois subits, et des prises par unité d'effort ont été exacerbés par la forte mortalité par pêche accidentelle. Les taux d'exploitation de cette espèce à concentrations élevées ont été passablement supérieurs à l'objectif de 10 % utilisé pour estimer des niveaux de capture appropriés à partir des indices d'abondance. Aux valeurs actuelles de l'effort de pêche, toutes les concentrations commerciales pourraient être appauvries de façon très importante avant qu'il n'y ait rétablissement appréciable. La pêche du pétoncle devrait être perçue comme une activité à production faible mais à valeur élevée.

Introduction

As histories go, the directed fishery for the Iceland scallop over the Grand Banks of Newfoundland (NAFO Div. 3LNO) is relatively recent (Table 1). While several resource surveys, both private and public, have been conducted over this very vast and highly productive area (see, for example, Dickie and Chiasson 1955, Somerville and Dickie 1957, McPhail and Muggah 1965, Rowell et al. 1966a,1966b) little commercial interest had developed. The earlier surveys by Maritime's-based vessels were primarily in pursuit of the sea scallop which by then had already been fully commercialized along the Atlantic seaboard by both Canada and the U.S. These surveys had encountered only the Iceland scallop, sometimes in commercial densities. A decade of declining catches from the more traditional areas especially Georges Bank, beginning in 1975 coupled with the uncertainty then surrounding the outcome of the Canada/U.S. jurisdictional dispute over Georges Bank, rekindled interest eastwards including the eastern Grand Banks. This interest was in part facilitated by the coming of age of mechanical extracting (shucking) devices that permitted efficient bulk extraction of meats (Naidu 1989). Quantitative information remained scant until formal surveys commenced beginning in 1982. The first, a contracted survey through an unsolicited proposal from Halifax-based Commar Management Consultants Ltd. was managed and costs co-shared by the then Branches of Fisheries Development from the Newfoundland and Scotia-Fundy Regions (Rodger and Davis 1982, Naidu and Cahill 1989). No sooner had the survey been concluded, the media was abuzz with reports of a major and significant discovery. In October 1982, the press heralded the find with headlines such as "Grand Bank Scallops Discovered in Survey" and "Rare Scallop find on the Grand Bank". Much of the hype then centered round a find purported to be some "1,100 sq. mi." near the Virgin Rocks, southeast of the Avalon Peninsula. None of the rich deposits along the edge of the Bank including the Canyons had been discovered at that time. In fact, much of the area that subsequently was found to contain the major aggregations was beyond the range of reliability for Decca, the navigational device then used by the two vessels participating in the contracted survey. Also, the Loran C transmitting station at Fox Harbour had not yet operational and together had resulted in undue problems for navigation. Much of the real estate to the southeast, including the Canyons therefore had not been adequately surveyed.

Test fishing commenced the following year (Naidu and Cahill 1989). Bonafide commercial activity for this "new-found" resource did not materialize until 1987 when a 9-day trip resulted in the harvesting of some 18,000 lb. meats mostly from areas previously unidentified. It was reported that shucking capacity (manual) frequently became limiting to the 18-man crew. Reportedly, up to 60 bushels were taken in a single tow with two 15ft offshore rakes (Capt. Allan Skinner, N.S. pers. comm.). Convinced of the commercial viability of the resource, several Canadian concerns poised themselves to take advantage of an apparent new opportunity. One of these purchased a state-of-the-art, purpose-

built factory trawler which at that time had been displaced from the Norwegian fishery because of resource depletion over the Bear Island and Spitzbergen grounds. During her maiden voyage to the Grand Banks, she completed some 2,084 tows over a twenty-day period. Catches were reported to be dismal. Only 6,000 lb. meats were taken (Naidu and Cahill 1989). The majority of catches had come from an area east of the Virgin Rocks and from the Lilly Canyon area (Capt. L. Otterhalls, pers. comm.) Everyone was stymied at the outcome. It was at this juncture, in 1989, that Science Branch (Newfoundland Region) decided to conduct systematic resource surveys over the eastern Grand Banks.

Because of the very large areas involved, we had judiciously chosen to complete the task in installments. NAFO Div. 3N had been selected for the first phase (Naidu and Cahill 1990). It was during this survey that two scallop aggregations, one each in the vicinity of the Lilly Canyon and Carson Canyon were first discovered (Naidu and Cahill 1990). Fishing began in earnest in 1993 with 10 vessels participating. Most of the early removals came from NAFO Div. 3L. Only one vessel had begun exploiting the rich deposits in 3N (Fig.1). Interest in the area soon mushroomed with fifty-seven vessels participating in the 3N fishery the following year. Also in 1994, a TAC regime was put in place for 3L (1,000 t) and for the areas encompassing the two Canyons (3,000 t) collectively labeled as LCC (Fig. 2, see also Table 2). The majority of removals (98%) in 1994 came from the highly productive areas near the Lilly Canyon/ Carson Canyon areas. Because of the accelerated growth of fishing activity in this area and the availability of improved distributional information on the resource, we were able to return to Div. 3N in 1994 and reassess the resource. As well, we completed a resource survey in 3L, an area to the north that had been located during the contracted survey in 1982 where fishing had first gotten underway in 1993. Aggregations trending northeast from the LCC were surveyed in 1995 (Naidu et al. 1996). After the 1994 fishing season fishermen recommended that two TAC zones be created, one within the Canyons and one to the north (3LN) between 45°30'N and 46°00'N. Science supported this recommendation because of a natural discontinuity in the resource distribution here (Fig. 2). Some of the early abundance estimates and fishery characteristics for the three referenced areas are summarized in Table 2.

The areas around the Lilly Canyon and Carson Canyon have attracted most of the effort. In part this is because catch rates here are higher than elsewhere on the Bank. More importantly meat weights at size are higher (lower count) (Table 3, Fig. 3) which fetch a premium price. Demands from participants in 1996 resulted in an early opening of the LCC (March 1996) before Science advice had became available. The fishery commenced in March 1996 with a management-sanctioned pre-emptive TAC of 1,000 t which was quickly taken. The interim quota was revised upwards to 2,000 t and the fishery reopened in May 1996. By mid-June the pre-emptive TAC had been exhausted and the LCC Box had been closed again, albeit temporarily. It was reopened for one week commencing September 10, 1996.

Meanwhile, declining catch rates to the north of the LCC, also under TAC, coupled with higher counts (smaller meats) forced the fleet to look elsewhere for new deposits along the edge of the Bank, particularly when the LCC Box was shut down. It was then that the Newfoundland fleet discovered a new, never-before fished aggregation to the southeast in Subdiv. 3Nf. By July (1996) many of the vessels had moved into this new area. Catch rates in 1996 were quite high (Table 4), well above any reported elsewhere over the Bank at any time in the year. Moreover, the majority of meats was large. By year end the nominal catch had reached nearly 3,500 t round, higher than any other area on the Bank including areas for which catch limits had been in place. As a precautionary measure research managers created a new zone south of Kettle Canyon, henceforth referred to in this Document as the "3Nf" Box. The area was closed in September 16, 1996 for the remainder of the year. The phenomenal success within these aggregations resulted in persistent and aggressive demands from industry to establish a catch limit in the range of 3,000-5,000 t, round for the following year (1997).

There were no research vessel survey data at that time for 3Nf. Based on log data we were able to determine that a total of 833 fishing days had been directed into these aggregations. Of this, 334 days (or 43%) was expended in a 40 sq. mi. area from which came approximately 1,130 t (or 43%). An additional 185 days (or 24%) was directed into an area to the southwest from where an estimated 719 t was taken (Fig. 4). Combined removals from these two aggregations in 1996 amounted to some 2049 t out of 3,106 t or 70% of the nominal catch in 1996. Of this, nearly 90% (2,685 t) came from a narrow strip of sea-bottom within the 50-100 fm contours, with the majority drawn from a preferred depth range between 50-70 fm (Table 5). Science considered the levels of removals to be inordinately high. Our concerns were reinforced by the very significant within-season declines in catch rates (Table 6). Based on estimated scallop habitat within the preferred depth zones (sq. mi.), relative to an adjoining area (LCC) for which we had more reliable information on scallop abundance, we had "ball-parked" carrying capacity within the total area (3Nf) to be in the neighborhood of 8,000 t round. Using the 10% exploitation rate we had suggested that a precautionary catch limit of 800 t to be more appropriate than the 3,000-5,000 t demanded by industry. Also, we were obliged to undertake a resource inventory within 3Nf before the following (1998) season.

An 11-day research mission into NAFO Div. 3N was completed in 1997. The resource base in the Lilly Canyon and Carson Canyon area, last surveyed in 1994, was updated. The new-found aggregation in Div.3Nf was also surveyed for the first time. All survey tows were completed over 1.0 mile with a 12 ft rake equipped with 3 in rings and interconnected to the top and bottom with three and four links respectively.

STOCK STATUS

NAFO Div. 3N: Lilly Canyon/Carson Canyon

In 1994 we had surveyed the canyons, an area approximating 867 sq. mi. The survey area was determined primarily by information on resource distribution from an earlier Science survey in 1989 (Naidu and Cahill 1989). Of this only 243 sq. mi. was considered to contain commercial densities of the Iceland scallop. Subsequent examination of the distribution of fishing effort and preliminary Roxann sweeps confirmed that the survey effort overlapped with areal distribution of fishing activity (Burns et al. 1995). The research survey in 1997 was therefore limited to the same general area as in 1994. A somewhat larger area was examined to reflect an enforcement-related "buffer zone" around the originally designated Box. This perimeter produced insignificant catches. Of the 77 randomly assigned stations, only 30 were within areas likely to support commercial effort. Depths fished, weights and numbers/tow and size characteristics are summarized in Tables 7 and 8. Abundance indices (mean weights and numbers) within comparable areas were down significantly. Estimates of abundance show that the minimum dredgeable biomass had declined by 70% (Table 9). Mean adductor muscle weight was down slightly as reflected by higher counts (Table 10).

Natural Mortality

Natural mortality within the Canyons computed as per Mercer (1974) and Naidu (1988) was up to 0.20 from 0.13 in 1994 (Table 11).

Starfish

One hundred out of 114 sets completed in the Lilly Canyon/Carson Canyon area (or 88%) contained Leptasterias sp. It was the most abundant echinoderm, reaching individual sizes and weights nowhere else seen (Tables 12 and 13). Next in relative abundance was Crossaster sp. occurring in 75% of sets. They were comprised of relatively large animals approaching sizes and weights encountered in 3Ps where a plague of starfish has been reported (Naidu et al. 1996).

NAFO Div.3Nf

Acoustic data over the area indicated that only about 110 sq.mi. (out of 570 sq. mi. or 20%) within the box was suitable scallop bottom (see Table insert in Fig. 5). A total of 59 sets was completed in a depth range of 58-173 m (32-94 fm). Four distinct aggregations were located within this zone (Fig. 5). As expected catch rates within each bed and between beds showed wide variation. The largest of the four designated beds (Bed No. 1, ~57 sq. mi.) produced an average catch of 16 kg/tow. The second largest area (Bed No. 4, 32 sq. mi.)

produced less than 6 kg/tow. Overall the best average catch (37 kg/tow) came from an aggregation (Bed No. 2) estimated at 11 sq. mi. A similar-sized bed (Bed No. 3) produced 10 kg/tow. The bulk of the real estate (460 sq. mi. or 80%) within the 3Nf Box is in waters ≤50 fms consisting of hard bottom and devoid of scallops. Distribution of sets and catch rates within these depth zones (Table 14) show that the better catch rates came from within the 70-79 fm isobaths, followed by the 50-59 fm contours. Bed No.1 (Fig. 5) contained nearly 60% of the biomass. With a mean catch at 11.7 kg (±25.7 kg), total MDB within the four aggregations was estimated at 800 t (Table 15). Using a gear efficiency of 20% (Caddy 1971), we estimate fishable biomass to be in the range of 1,700-6,200 t (Mean = 4,000 t, round). At 10% exploitation rate, the catch level (TAC) is estimated to be at 400 t. Unfortunately, the confidence limits (58%) are high. It is likely that many of the high-density aggregations have already been fished down and that the residual biomass is spread thinly over the 110 sq. mi. considered favourable for scallop.

Size Composition and Meat Yield

Size characteristics (Table 16) including frequency distributions (Fig. 6) in 3Nf were found to be similar to those observed to the north along the Canyons. Meat yield was somewhat lower (11.3% vs. 13%) and counts correspondingly higher (49 vs. 35/lb, Table 17). This no doubt reflects the better productivity in the Canyons. At a given size scallops from the Canyons consistently produce the heaviest meats (Table 3).

Natural Mortality

Allowing for the forced disarticulation during typical tows (Naidu 1988) overall annual natural mortality was estimated at 0.07 (Table 18), well below rates observed for aggregations elsewhere that have been long commercialized.

Starfish

Starfish numbers and weights/tow were low throughout (Table 12). Only 37% of survey tows contained Leptasterias sp., half the numbers/tow recorded for Crossaster sp. Mean weight per tow for both species were the lowest recorded for the four areas examined. Individual weights were lower and arm radii shorter than those recorded for the adjoining LCC Box just to the north (Table 13).

NAFO Div. 3LN

No new information

NAFO Div. 3L

No new information

COMMERCIAL

Historical catch statistics are summarized in Table 19. In just five years nominal catches here have surpassed 24,000 t round, a volume comparable to that harvested from the Gulf of St. Lawrence (NAFO Div. 4R) over a 25-yr period (Table 1). Removals offshore in 1997 by NAFO Divisions are summarized in Table 20. The analysis presented here is based on the combined logged catch of 3,480 t round. Much of the effort over the Grand Banks in 1997 continued to be directed into Div. 3N especially the highly productive Canyons which contributed to the majority (92%) of the total removals from the Grand Banks in 1997. Meat weight profiles are particularly attractive here (Table 3). Of the 292 t from 3L, only 4.6 t was drawn from the Eastern 3L Box. Coastal aggregations from 3L (west of 51° long.), mostly from beds along the Southern Shore, contributed to some 270 t (Fig. 2).

3N - Lilly Canyon/Carson Canyon: moderate declines in CPUE conceal real decline in availability

Nominal catch from the Lilly Canyon/Carson Canyon area is estimated at 2,842 t round or 95% of the 1997 allocation (Table 21). In anticipation of the quota being exceeded, the LCC Box was closed in mid-June. Catch rate indices, both within season and annual, continue to drift downwards (Table 22). Overall, CPUEs (kg/tow) have declined 20% since deposits here were first commercialized. Individual meat weight frequency distributions in 1997 (Fig. 7) suggest that new aggregations were probably targeted in 1997 (Fig. 8).

3Nf - Underperforms

After the extraordinary success in 1996 and the bullish outlook, fishers had fully expected that the catch limit of 800 t would be easily reached. In fact only 228 t (or 29%) of the 800 t allocation was taken. Within-season catch rates had already declined in 1996, the first year the 3Nf Box was targeted (Naidu et. al 1996). Further reductions in monthly CPUEs (kg/tow) were again evident in 1997 (Table 23). Overall, a reduction of 40% was recorded between 1996 and 1997. Total number of fishing days expended dropped dramatically to only 68 days from 833 days in 1996. Much of the reduced effort is probably related to the large-scale diversion of effort into underexploited aggregations in Canadian waters within 3Ps. These beds are much closer to shore than those in 3Nf and

consequently more attractive to the mid-distance fleet. Although meat counts improved somewhat in 1997 (Fig. 9) they nevertheless are among the lowest of any area (Table 3) and may have in part contributed to some of the exodus in effort.

3LN – Mostly ignored in 1997!

As in previous years much of the fishing effort here continued to be directed within the area between and 45°30' and 46°00'N. This swath of ground, however, accounted for only 211t of the nominal catch from the 3LN Box. Only an estimated 7% of the 1997 allocation (3,000 t) was taken. As in the TAC zone to the south (LCC), catch rates here also continue to decline (Table 24). Catch rate indices in the final three months (Aug.-Oct.) was only 57kg/tow versus 88kg/tow earlier in the season, a drop of 35% in the three-month moving average. Overall, annual CPUEs here have declined 40% from levels estimated in 1995.

3L - Ignored

Only an estimated 5 t round was taken from the TAC Box in 3L. High counts and a high epibiont load on the scallops compared to other aggregations. make this area relatively unattractive. Catch rate at approximately 54 kg/tow is among the lowest of the areas fished over the Grand Bank. No other data are available on fishery characteristics/performance.

In summary, with the exception of eastern 3L where directed effort is at best considered marginal, moderate to severe declines indices and catch rates are apparent for each of the areas examined (Table 4). In some cases, the severity of the estimated declines in abundance are not easily reconciled with reported removals. The broad-based declines reported for the aggregations that attract most attention are particularly worrisome. The need for caution in this nascent fishery was recognized early, soon after the deposits were first commercialized. However, the high unit value of this species clearly favours overexploitation. It should also be recognized that this fishery is driven by high-density scallop aggregations and not the biomass *per se*. Declines will continue unless fishing effort is reduced substantially. Otherwise catch rates will quickly drop to levels that would render fishing activity uneconomic. This will become accelerated if the high prices enjoyed over the last three years recede from present levels.

Past Advice re Exploitation Rates

During the early years (1980's) when catch levels had been first proposed for 3Ps, removals approximating 20% was considered to be consistent with $F_{0.1}$ exploitation of the resource. Yield/recruit considerations had then been based on faster-growing aggregations in shallower waters elsewhere (St. Pierre Bank).

The rates had been also applied to other beds within the Newfoundland Region. Based on more recent experience, including information from the directed fishery for the species in Iceland and Norway, we have revised downwards the recommended exploitation rate to 10%. Applying this to the estimated biomass, catch levels of 1,000 t and 3,000 t round had been proposed in 1994 for each of the areas in 3L and 3N respectively. Based on fishery performance and consultations with fishers/industry, these levels have remained unchanged between 1995 and 1997.

MANAGEMENT STRATEGY FOR ICELAND SCALLOPS

The fishery in each of the areas considered here appears to be driven by an accumulated virgin biomass consisting largely of cohorts of old, possibly well-separated yearclasses with little potential for further growth. It appears that exploitation rates on this highly aggregated species have in effect been substantially higher than the target 10% rate used to estimate appropriate catch levels from abundance estimates.

In practice, exploitation of Iceland scallop resources in the Newfoundland Region has been based largely on short-term economics rather than considerations of resource sustainability *per se*. High unit value combined with low annual production lead to rapid depletion of commercial concentrations, sometimes within a single season and pre-empt contemplated management or conservation measures. In general, recruitment tends to occur with sporadic strong yearclasses between which annual recruitment is low or negligible. Indirect (non-yield) fishing mortality contributes significantly to localized depletion. In addition, fishing causes heavy mortality to young, recently settled scallops through perturbation to the sea bottom reducing settlement potential and ultimately recruitment (Naidu et al. 1998).

A stock-recruitment relationship is unlikely to be of concern in this highly fecund species. As such, concerns over recruitment overfishing are diminished. About the only mechanism available to confer any degree of sustainability is to reduce catch levels severely throughout. This strategy is likely to reduce present catch levels to the order of hundreds of tonnes rather than levels permitted by the 10% target exploitation rate.

The kind of "pulse" fishing that has developed may be a viable strategy if depleted beds can be closed to fishing for the extended periods necessary for recovery while new aggregations are discovered and fished down. However, at the current levels of fishing effort, already one of the highest in the world, all known commercial aggregations could be severely depleted before any significant recovery of this very slow growing species. Fishing for scallops should be considered a low volume, high value activity.

It is suggested that managers and stakeholders consider the concept of establishing closed areas (refugias) to reduce continuous, large-scale perturbation to the sea bottom. Closure of some areas for extended periods might help to rehabilitate the stock.

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Table 1. Nominal catches (t, round) of sea scallops (offshore 3Ps only) and Iceland scallops from Newfoundland, 1969-97.

Year	4R	3Ps Iceland scallops (all SPB)		Sea scallops	Div. 3LNO		
					3L	3N	3O
1969	248						
1970	192						
1971	167						
1972	2,596						
1973	2,189						
1974	244						
1975	-						
1976	-						
1977	-						
1978	-			191			
1979	450			8			
1980	1,133			291			
1981	1,530			-			
1982	349			5,951			
1983	371			4,930			
1984	1,523			3,428			
1985	2,546			440			
1986	1,942			1,270			
1987	1,141			448			
1988	447			8,176			
1989	155	36		2,756			
1990	88	507		1,270			
1991	457	755		1,112			
1992	1,296	5,967		556	20	2	0
		Core	Non-core				
1993	2,122	-	667	1,079	489	325	3
1994	2,294	-	440	407	86	3,844	11
1995	1,497	230	31	564	101	6,400	0
1996	1,204	224	82	-	406	9,048	0
1997	1,205	125	5,245	-	292	3,188	0

Table 2. Summary of abundance estimates, TACs and removals of Iceland scallops for the Grand Banks of Newfoundland, NAFO Div. 3LNO, 1994-97.

Year	3L	3LN	LCC	3Nf
1994				
Abundance Estimate	4,000-15,000 (Mean = 1,500 t)	n/a	20,000-38,000 (Mean = 29,000 t)	n/a
TAC	1,000 t	nil	3,000 t	nil
Nominal catch	91 t	280 t	4,200 t	0
1995				
Abundance Estimate	n/a	15,000-45,000 (Mean = 30,000 t)	n/a	n/a
TAC	1,000 t	nil	3,000 t	nil
Nominal catch	174 t	2,913 t	3,023 t	0
1996				
Abundance Estimate	n/a	n/a	n/a	n/a
TAC	1,000 t	3,000 t	3,000 t	nil
Nominal catch	146 t	967 t	2,970 t	3,483
1997				
Abundance Estimate	n/a	n/a	6,000-12,000 (Mean = 9,000)	344-1,250 (Mean = 800)
TAC	1,000 t	3,000 t	3,000 t	800 t
Nominal catch	5 t	211 t	2,842 t	228 t

Table 3. Size-specific meat weights (g) for Iceland scallops computed from shell height/meat weight regression for (A) the northeastern Gulf of St. Lawrence (4R) and (B) Lilly Canyon/Carson Canyon (3N), (C) 3L, and (D) 3Nf , (E) 3Ps and (F) 3LN.

Shell Height (mm)	4R (Gulf of St. Lawrence A		3N (Lilly / Carson Canyons B		3L C	3Nf D	3Ps (Strat, 911) E	3LN F
	1995	1997	1996	1997	1994	1997	1991	1995
40	1.9	1.6	1.8	1.7	1.4	1.5	1.3	1.3
45	2.5	2.2	2.5	2.3	2.0	2.0	1.9	1.9
50	3.2	2.9	3.4	3.1	2.6	2.6	2.6	2.6
55	3.9	3.8	4.5	4.1	3.4	3.3	3.4	3.4
60	4.8	4.9	5.8	5.3	4.3	4.1	4.4	4.4
65	5.8	6.1	7.3	6.7	5.3	5.0	5.6	5.6
70	6.7	7.5	9.0	8.2	6.5	6.0	6.9	7.0
75	8.0	9.1	11.0	10.0	7.9	7.1	8.5	8.6
80	9.3	10.3	13.3	12.1	9.4	8.4	10.3	10.4
85	10.7	12.9	15.8	14.4	11.1	9.7	12.3	12.4
90	12.2	15.2	18.7	17.0	12.9	11.2	14.5	14.7
95	13.8	17.6	21.8	19.8	15.0	12.8	17.0	17.2
100	15.5	20.4	25.3	23.0	17.2	14.6	19.8	20.1

A. 4R:
1995: log W = 2.2938 log SH - 3.3962 (r^2 = 0.65), DFO Atl. Fish. Res. Doc. 96/49
1997: log W = 2.7957 log SH - 4.2826 (r^2 = 0.85), CSAS Res. Doc. 98/148.

B. Lilly/Carson Canyons:
1995: log W = 2.8960 log SH - 4.3889 (r^2 = 0.91), DFO Atl. Fish. Res. Doc. 95/136.
1997: log W = 2.8726 log SH - 4.3843 (r^2 = 0.93), CSAS Res. Doc. 98/149.

C. 3L:
1994: log W = 2.7239 log Sh - 4.2112 (r^2 = 0.87), DFO Atl. Fish. Res. Doc. 95/136.

D. 3Nf:
1997: log W = 2.4773 log SH - 3.7914 (r^2 = 0.88), CSAS Res. Doc. 98/149.

E. 3Ps:
1991: log W = 2.9383 log SH - 4.58 (r^2 = 0.96), CAFSAC Res. Doc. 92/31.

F. 3LN:
1995: log W = 2.9548 log SH - 4.6070 (r^2 = 0.91), DFO Atl. Fish. Res. Doc. 96/76.

Table 4. Mean daily catch (kg, round) per tow by month over selected grounds on the Grand Bank of Newfoundland, 1996.

Month	Lilly/Carson Canyon (Mean ± S.D)	3N (north of LCC) (Mean ± S.D)	3LN (Mean ± S.D)	3Nf (Mean ± S.D)
March	94.4 (±47.4)	72.4 (±53.7)	72.4 (±53.7)	-
April	103.1 (±75.2)	97.7 (±65.8)	97.7 (±65.8)	-
May	85.4 (±44.8)	51.1 (±34.5)	49.5 (±34.9)	21.7
June	105.9 (±32.6)	82.2 (±41.2)	93.2 (±77.1)	277.8 (±153.6)
July	-	146.0 (±54.4)	146.0 (±54.4)	200.4 (±257.9)
August	40.2 (±23.5)	98.6 (±82.1)	95.7 (±81.0)	80.1 (±49.2)
September	90.0 (±101.5)	102.3 (±74.6)	99.8 (±75.0)	66.4 (±21.0)
October	90.2 (±48.9)	108.7 ± (86.4)	110.3 (±83.7)	-
November	-	107.5 (±155.4)	114.0 (±129.8)	-
Overall	94.3 (±66.0)	92.9 (±77.3)	95.3 (±81.9)	154.7 (±198.6)

Table 5. Relationship between preferred water depth (fm) and scallop removals from 3Nf, 1996.

Depth range (fm)	Removals (%)
51-59	1,066 t (39.7)
60-69	1,165 t (43.4)
70-79	400 t (14.9)
80-89	55 t (2.1)
90-100	0 t
Total	2,686 t

Table 6. Monthly CPUE estimates for the Southeast 3N zone (3Nf), 1996.

Month	Removals[1] (t, round)	Fishing days	CPUE (kg/tow)
March	-	-	-
April	-	-	-
May	0.4	1	22
June	410	79	235
July	1,735	392	166
August	944	353	75
September	17	8	68
October	-	-	-
November	-	-	-
Overall	3,107	833	124

[1] sum of daily log estimates x9.2

Table 7. Mean number and weights (kg) of Iceland scallops per tow mile in Lilly/Carson Canyons area of NAFO Div. 3N, 1994 and 1997.

Year	Area surveyed (n mi^2)	Depth fished (m)		No. of sets	Mean no. (±S.D.)	Mean weight (±S.D.)
		Mean	Range			
1994	867	76.5	61-174	178	2026 (±557.3)	17.3 (±45.5)
1997	867	81.1	65-172	77	105.4 (±138.9)	9.9 (±12.9)

Table 8. Mean and modal shell heights (mm) of Iceland scallops in Lilly/Carson Canyon area of NAFO Div. 3N, 1994 and 1997.

Year	N	Mean shell Height (mm) (±S.D.)	Modal shell height (mm)	Range	
				Maximum	Minimum
1994	12,995	82.7 (±8.8)	85	110	10
1997	5,271	83.2 (±9.3)	85	108	12

Table 9. Estimates of minimum dredgeable biomass (MDB) for two commercial beds of Iceland scallops in Lilly/Carson Canyon area of NAFO Div. 3N.

Year	Area (n mi^2)	No. of sets	MDB (t, round)
1994	243	58	3,926-7,583 (Mean = 5,754)
1997	243	30	1,141-2,337 (Mean = 1,739)

Table 10. Biological meat yields, average and weights and meat counts of Iceland scallops from Lilly/Carson Canyon area of NAFO Div. 3N, 1994 and 1997. Weights not adjusted for epibiont load.

Year	N	Whole weight (kg)	Meat weight (kg)	Mean meat weight (g)	Count (#/500 g)	Yield (%)
1994	3,822	361.04	52.16	13.6	36.6	14.5
1997	1,186	117.30	15.28	12.9	38.8	13.0

Table 11. Natural mortalities for Iceland scallops in the Lilly/Carson Canyon area of NAFO Div. 3N computed from ratio of cluckers to live scallops, 1994 and 1997. Clucker numbers are adjusted by a factor of 1.221 to allow for tow-induced disarticulation.

Year	Live	Cluckers	M
1994	14,050	1,120.8	0.13

Table 12. Mean numbers and weights (kg) of four starfish species in the main commercial fishery areas for Iceland scallops in the Newfoundland area.

Area	# of sets	Leptasterias sp.		Crossaster sp.		Asterias sp.		Solaster sp.	
		mean #/tow (±S.D.)	mean wt./tow (±S.D.)	mean #/tow (±S.D.)	mean wt./tow (±S.D.)	mean #/tow (±S.D.)	mean wt./tow (±S.D.)	mean #/tow (±S.D.)	mean wt./tow (±S.D.)
4R	148	124.6 (±198.1)	11.7 (±18.9)	42.6 (±80.1)	3.5 (±7.9)	<0.1	<0.1	1.2 (±3.4)	0.2 (±0.7)
LCC	106	105.5 (±113.8)	23.3 (±25.2)	19.3 (±24.0)	2.4 (±2.9)	0.1 (±0.9)	<0.1	2.8 (±6.0)	0.8 (±2.0)
3Nf	59	4.3 (±9.4)	0.8 (±1.7)	15.4 (±20.4)	1.7 (±2.4)	0.1 (±0.5)	<0.1	2.7 (±5.6)	0.9 (±2.3)
3Ps Strat. 22	42	107.2 (±96.8)	15.8 (±14.1)	67.5 (±60.5)	9.4 (±8.7)	30.4 (±108.5)	1.7 (±7.6)	1.2 (±1.3)	0.5 (±0.5)

Table 13. Weight and size (arm radii) characteristics of populations of starfish in 4R (1997), compared with those from 3Ps (1996) and the Grand Banks of Newfoundland, NAFO Div. 3N (Lilly Canyon/Carson Canyon and 3Nf, 1997).

	Leptasterias sp.				Crossaster sp.				Asterias sp.				Solaster sp.			
	4R	LCC	St. 22	3Nf	4R	LCC	St. 22	3Nf	4R	LCC	St. 22	3Nf	4R	LCC	St. 22	3Nf
Weight Sampled (kg)	380	1104	272	42	147	220	21	9	<1	<1	21	9	10	90	18	53
Nos. Sampled	4093	5114	1884	255	1838	1922	623	7	1	14	623	7	61	356	46	159
Mean Individual weight (g)	90	215	145	165	80	115	30	21	80	22	30	21	160	253	270	335
Mean arm radius (cm)	8	12	10	11	7	7.5	6	4	8	4	6	4	10	11	13	11
No. of tows completed in area (#s with starfish)	148 (132)	114 (100)	98 (41)	59 (22)	148 (134)	114 (85)	98 (22)	59 (4)	148 (1)	114 (5)	98 (22)	59 (4)	148 (28)	114 (55)	98 (25)	59 (24)

Table 14. Distribution of research sets, catch rates (weights and numbers) by depth zones within NAFO Div. 3Nf (July 1997).

Depth range (fm)	# of sets	Size (n mi^2)	Percent of 3Nf	Mean catch kg/tow (±S.D.)	Mean no./tow (±S.D.)
<50	14	471	82.6	0.1 (±0.3)	0.86 (±2.21)
50-59	9	30	5.3	13.2 (±13.9)	135.78 (±151.59)
60-69	12	20	3.5	9.8 (±13.8)	102.75 (±152.07)
70-79	15	17	3.0	27.7 (44.8)	359.73 (±632.49)
80-89	7	15	2.6	4.6 (±5.0)	64.14 (±75.53)
90-99	2	17	3.0	1.1 (±1.1)	14.00 (±14.14)
Total	59	570	100.0	11.7 (±25.7)	141.36 (±350.42)

Table 15. Estimates of minimum dredgeable biomass (MDB) of Iceland scallops for NAFO Div. 3NF, July 1997.

'Bed'	Area (n mi^2)	# of sets	Mean catch (kg) Per tow	MDB (t, round)
1	56.5	24	15.7	55-842 (Mean = 448)
2	10.8	5	37.4	0-494 (Mean = 205)
3	10.8	7	9.7	21-85 (Mean = 53)
4	31.8	10	5.7	4-179 (Mean = 91)
5	460.1	13	0	0
Combined	570.0	59	11.7	344-1,250 (Mean = 797)

Table 16. Mean and modal shell heights (mm) of Iceland scallops in NAFO Div. 3Nf, during a research vessel survey July 1997.

Area	N	Mean shell height (±S.D.)	Modal shell height	Range	
				Max.	Min.
3Nf	4,226	83.6 (±8.1)	88	119	8

Table 17. Average meat weights, biological meat weights, and meat counts of Iceland scallops in NAFO Div. 3Nf, July 1997. No corrections made for epibiont load.

Area	N	Whole wt.* (kg)	Meat wt. (kg)	Mean meat wt. (g)	Count (nos./lb.)	Yield (%)
3Nf	383	31.50	3.57	9.3	49	11.3

* whole weight = weight of scallops as caught. No barnacles/epibionts cleaned off shells.

Table 18. Natural mortalities of Iceland scallops in NAFO Div. 3Nf from ratio of cluckers to live scallops, July 1997. Clucker numbers are adjusted by a factor of 1.221 to allow for tow-induced disarticulation.

Area	Live	Cluckers	M
3Nf	4,341	179.5	0.06909

Table 19. Nominal catch (t, round) and effort (no. vessels) in the fishery directed at Iceland scallops in NAFO Div. 3LNO, 1992-97.

Year	No. of vessels	Div. 3L	Div. 3N	Div. 3O	Total Div. 3LNO
1992	1	20	2	0	22
1993	10	489	325	3	817
1994	57	86	3,844	11	3,941
1995	48	101	6,400	0	6,501
1996	52	406	9,048	0	9,454
1997	52*	292	3,188	0	3,480
Totals	-	1,394	22,807	14	24,215

* Figures for 1997 are preliminary; not all logs have been returned.

Table 20. Summary of Iceland scallop effort, landings and distribution of effort within NAFO Div. 3LNO, 1997.

NAFO Div.	No. of boats	No. of fishing days	Landings[1] (kg, round) (% of total)
3L	25	252	291,935 (8.4)
3N	37	1,207	3,188,107 (91.6)
3O	1	1	0
Offshore only (east of 51° long.)	37	1,217	3,201,542 (92.0)
Total 3LNO	52	1,460	3,480,042

Table 21. Summary of TACs, effort and removals from NAFO Div. 3LNO, 1997.

Area	TAC (t)	No. of fishing days	Log estimates (kg)	Dockside monitoring
Eastern 3L (EPL)	1,000	5	5,610	4,832
3LN (3LN)	3,000	124	249,022	211,155
Lilly/Carson Canyons (LCC)	3,000	920	2,494,915	2,842,123
3Nf (3Nf)	800	68	181,317	228,027
Remainder of 3LNO (R3LNO)	-	343	550,178	687,268
Total	-	1,460	3,480,042	3,973,405

Table 22. Monthly non-standardized CPUE estimates (kg/tow, round) for the Lilly/Carson Canyon area of NAFO Div. 3N, 1997. Corresponding estimates for 1995 and 1996 are included.

Month	Removals[1] (t, round)	Fishing days	CPUE (kg/tow)
April	414	172	81
May	1,564	562	78
June	517	186	70
Overall 1997	2,495	920	77
1996	2,696	904	86
1995	3,023	977	98

[1] sum of daily log estimates x9.2

Table 23. Monthly non-standardized CPUE estimates for 3Nf, 1997. Corresponding estimates for 1996 are provided.

Month	Removals[1] (t, round)	Fishing days	CPUE (kg/tow)
April	21	6	90
May	47	15	98
June	53	16	95
July	43	21	57
August	15	9	44
September	2	1	58
Overall 1997	181	68	75
1996 estimates	3,107	833	124

[1] sum of daily log estimates x9.2

Table 24. Monthly non-standardized CPUE estimates (kg/tow, round) for NAFO Div. 3LN, 1997. Corresponding estimates for 1995 and 1996 are included.

Month	Removals[1] (t, round)	Fishing days	CPUE (kg/tow)
April	17	5	96
May	35	7	189
June	30	21	50
July	-	-	-
August	31	13	57
September	95	61	53
October	32	14	75
Overall 1997	240[2]	121	65
1996 estimates	1,292[3]	534	79
1995 estimates	2,913	998	110

[1] sum of daily log estimates x9.2

[2] This total represents 97% of all removals from the 3LN zone.

[3] This total represents 92% of all removals from the 3LN zone.

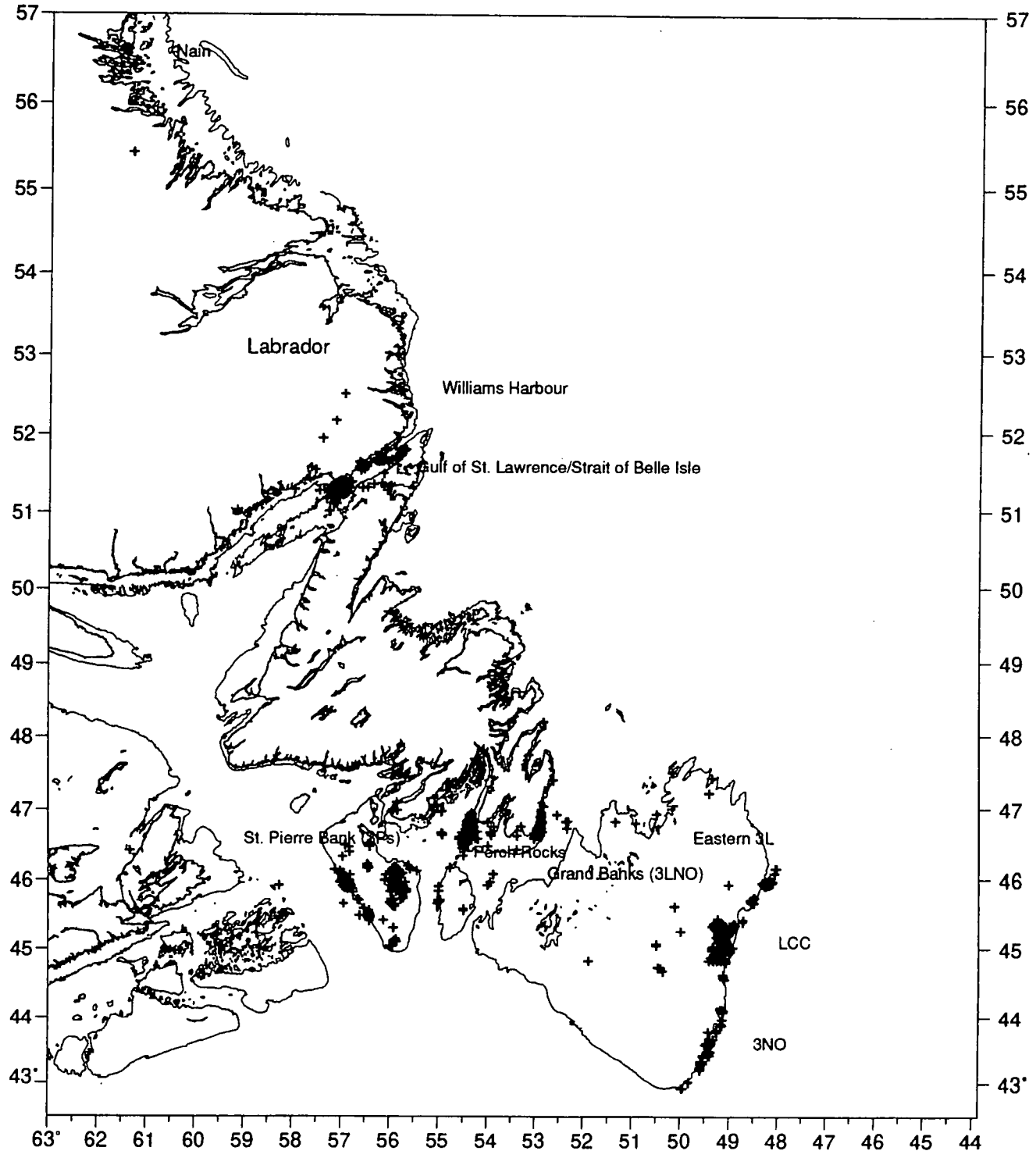


Fig. 1. Iceland scallop aggregations fished in Newfoundland, 1997.

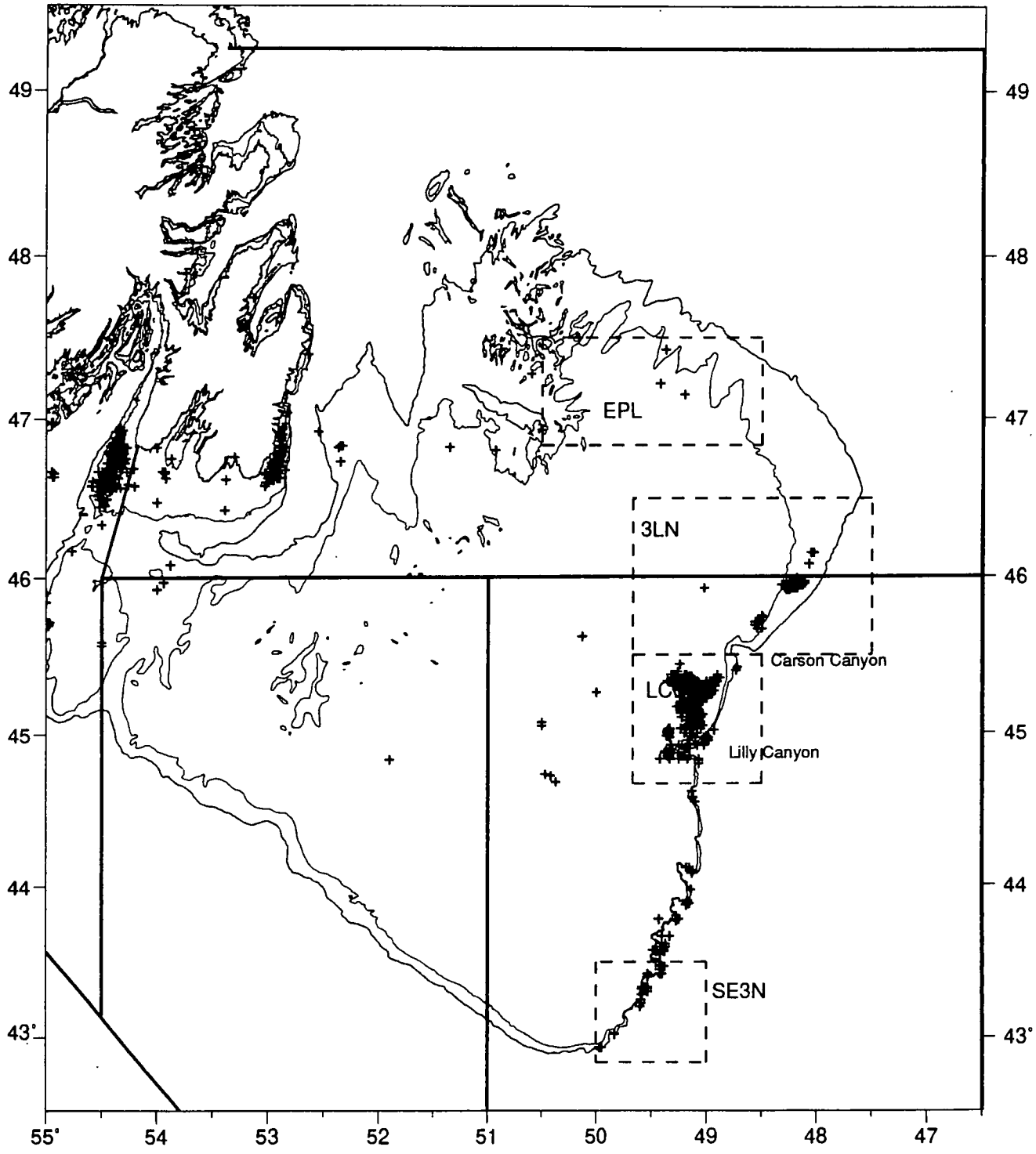


Fig. 2. TAC zones for Iceland scallop over the Grand Bank of Newfoundland, 1997.

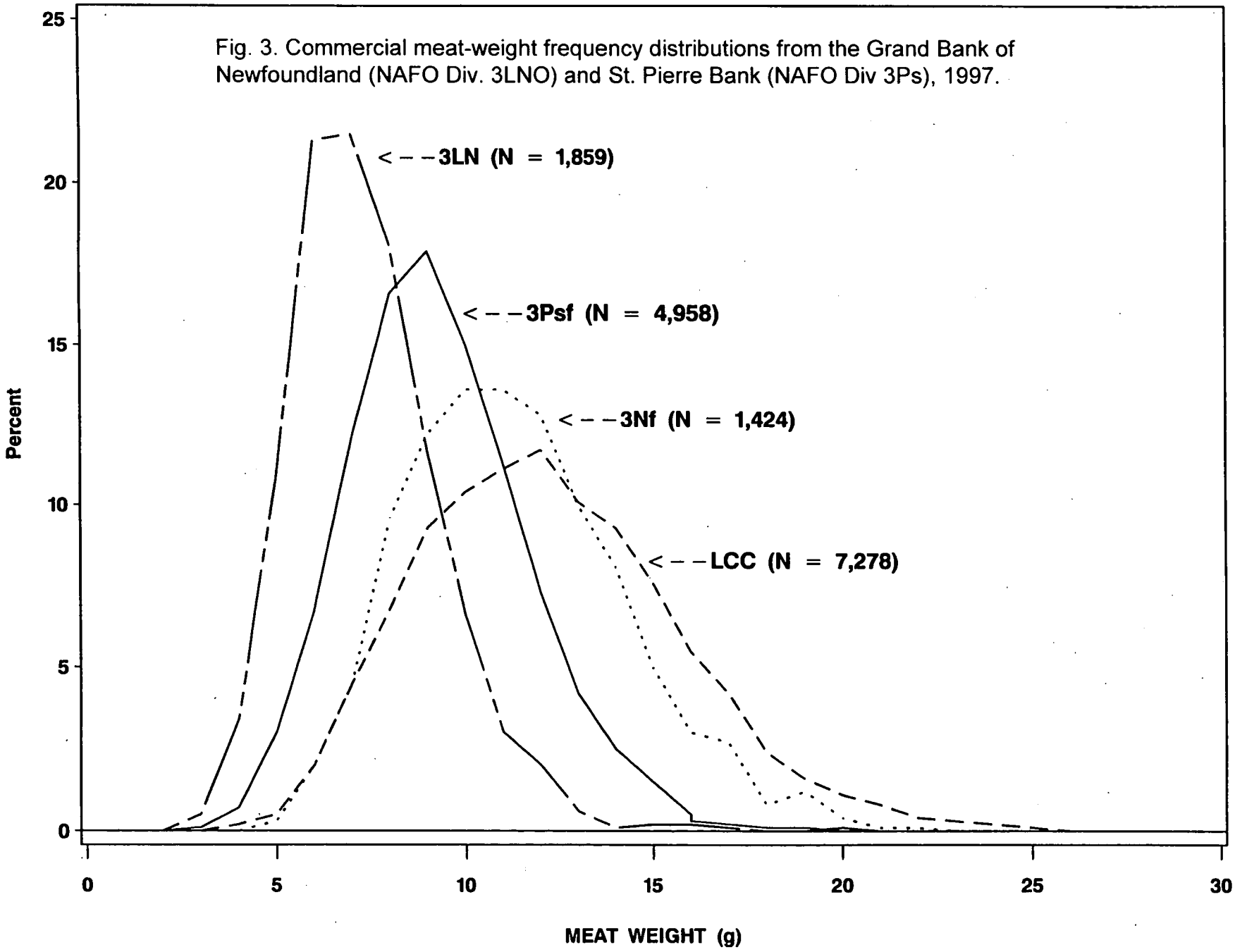


Fig. 3. Commercial meat-weight frequency distributions from the Grand Bank of Newfoundland (NAFO Div. 3LNO) and St. Pierre Bank (NAFO Div 3Ps), 1997.

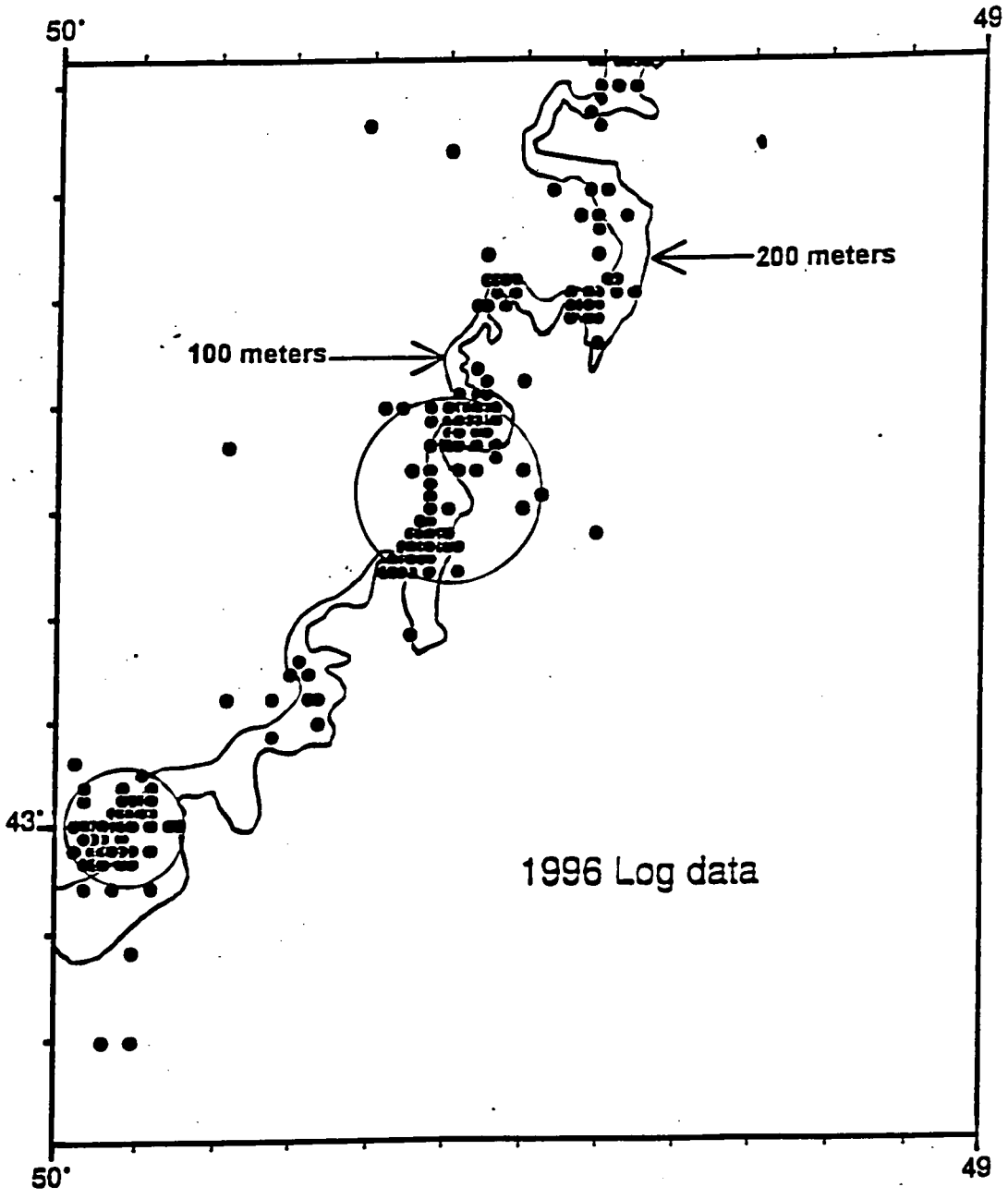
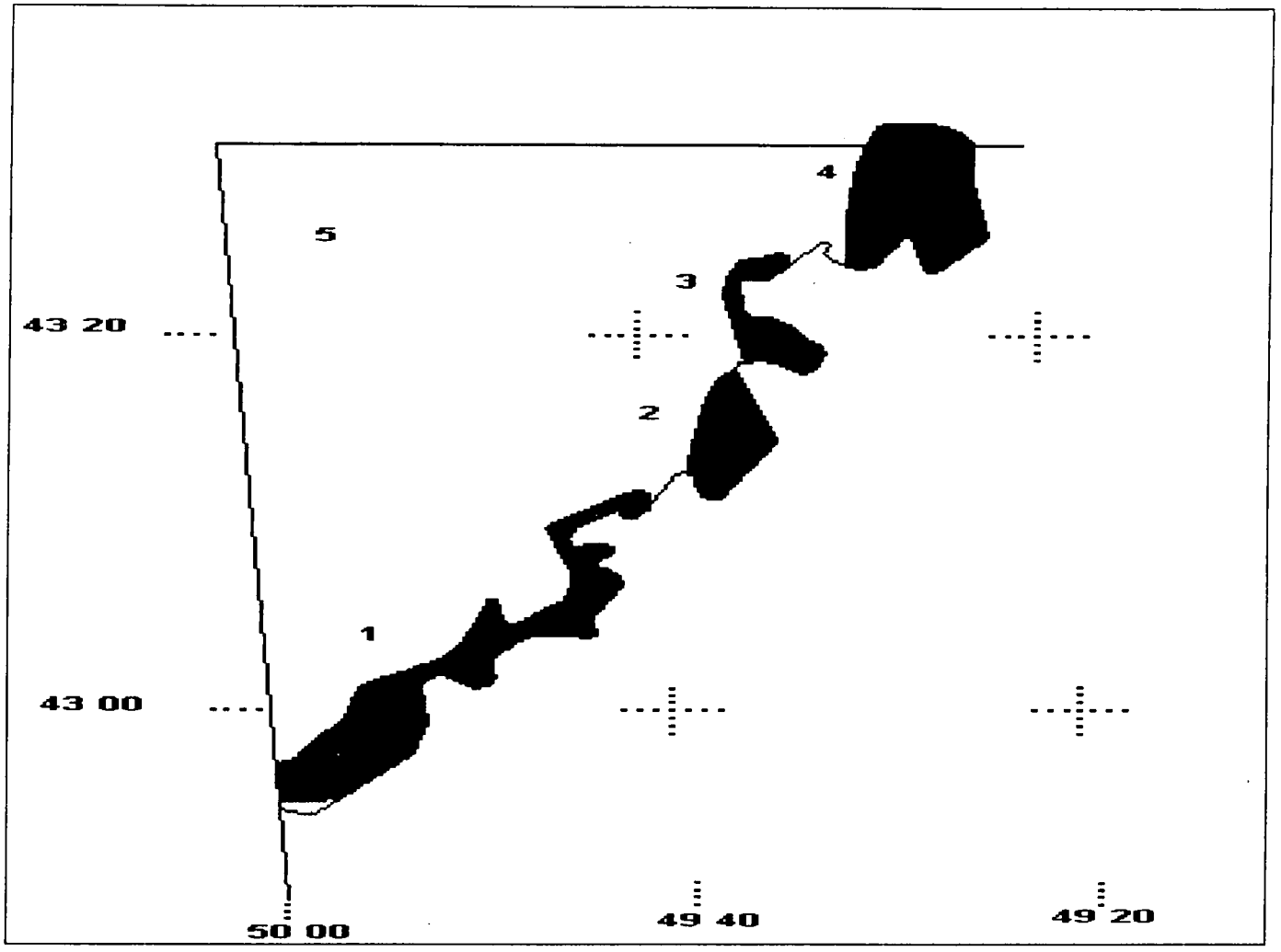


Fig. 4. Distribution of commercial effort in NAFO Div. 3Nf, 1996.



	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	Total
# SETS	24	5	7	10	13	59
TOTAL CATCH (kg)	375.83	186.9	67.8	56.60	0	687.13
MEAN CATCH (kg)	15.7	37.4	9.7	5.7	0	11.7
# TRACK POINTS (SCALLOP & SCALLOP BOTTOM)	6343	1166	1206	2031	57	10803
% SCALLOP & SCALLOP BOTTOM	86.7	95	53.6	64.9	1.7	62.3
# TRACK POINTS (HARD & SOFT BOTTOM)	973	61	1044	1100	3366	6544
% HARD & SOFT BOTTOM	13.3	5	46.4	35.1	98.3	37.7
TOTAL TRACK POINTS	7316	1227	2250	3131	3423	17347
AREA (Square nautical miles)	56.53	10.8	10.8	31.82	460.05	570
% OF TOTAL AREA SURVEYED	9.9	1.9	1.9	5.6	80.7	100

Fig. 5. Distribution of scallop beds in NAFO Div. 3Nf as configured in 1997 and summary of parameters used in estimating fishable biomass.

Fig. 6. Research shell-height frequency of Iceland scallop in NAFO Div. 3Nf, July 1997.

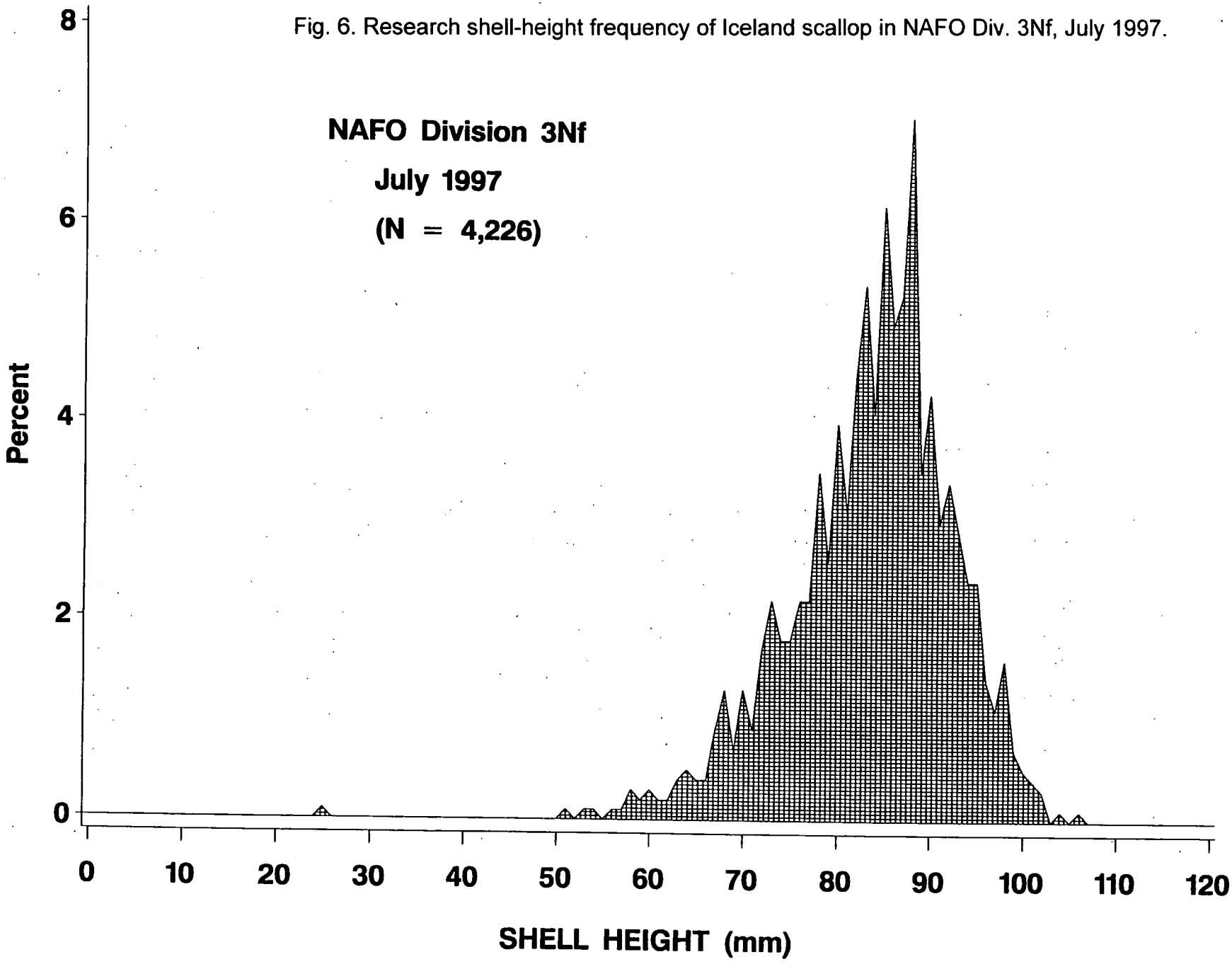
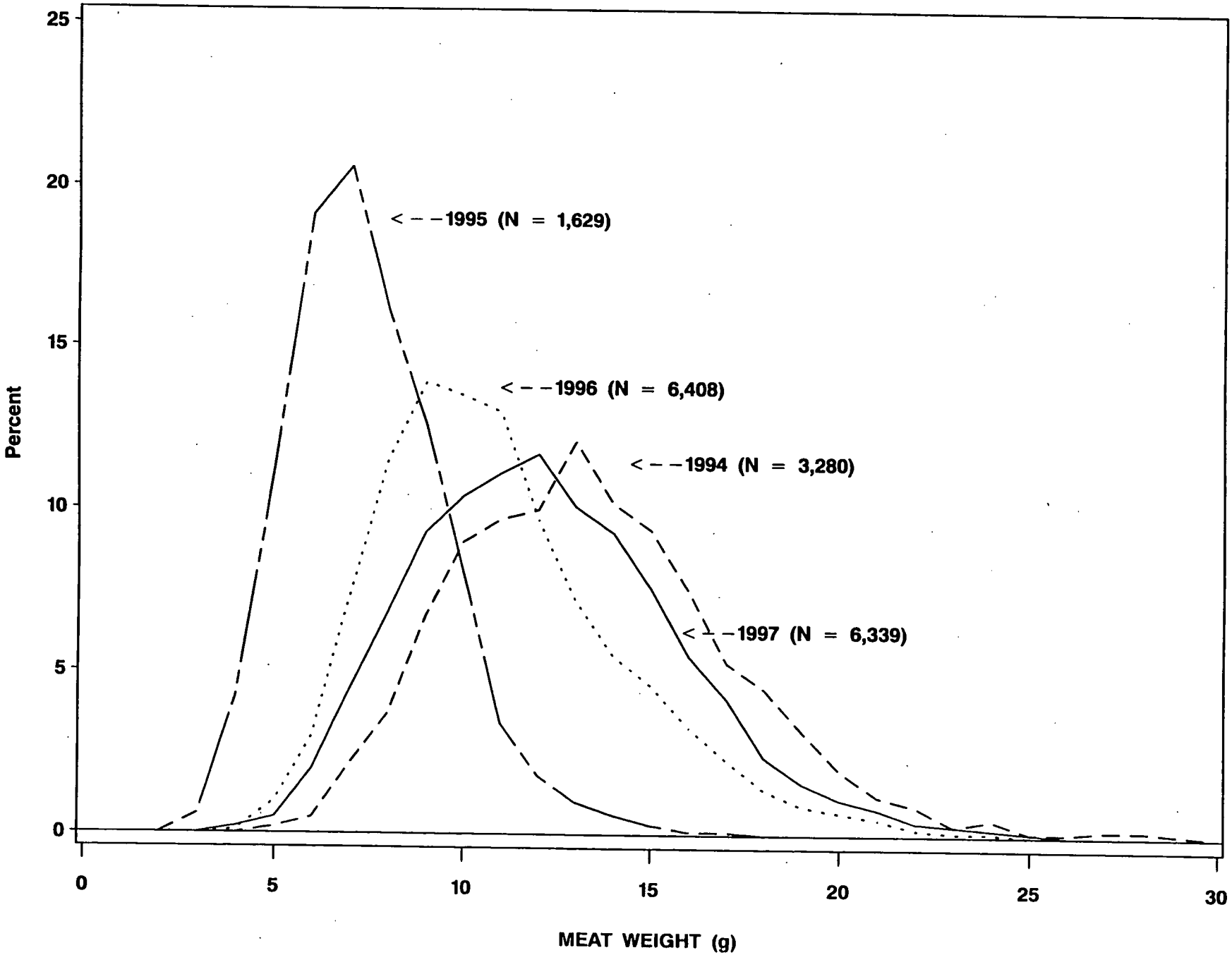


Fig. 7. Commercial meat-weight frequency distributions from the Lilly Canyon/Carson Canyon area, 1994-1997.



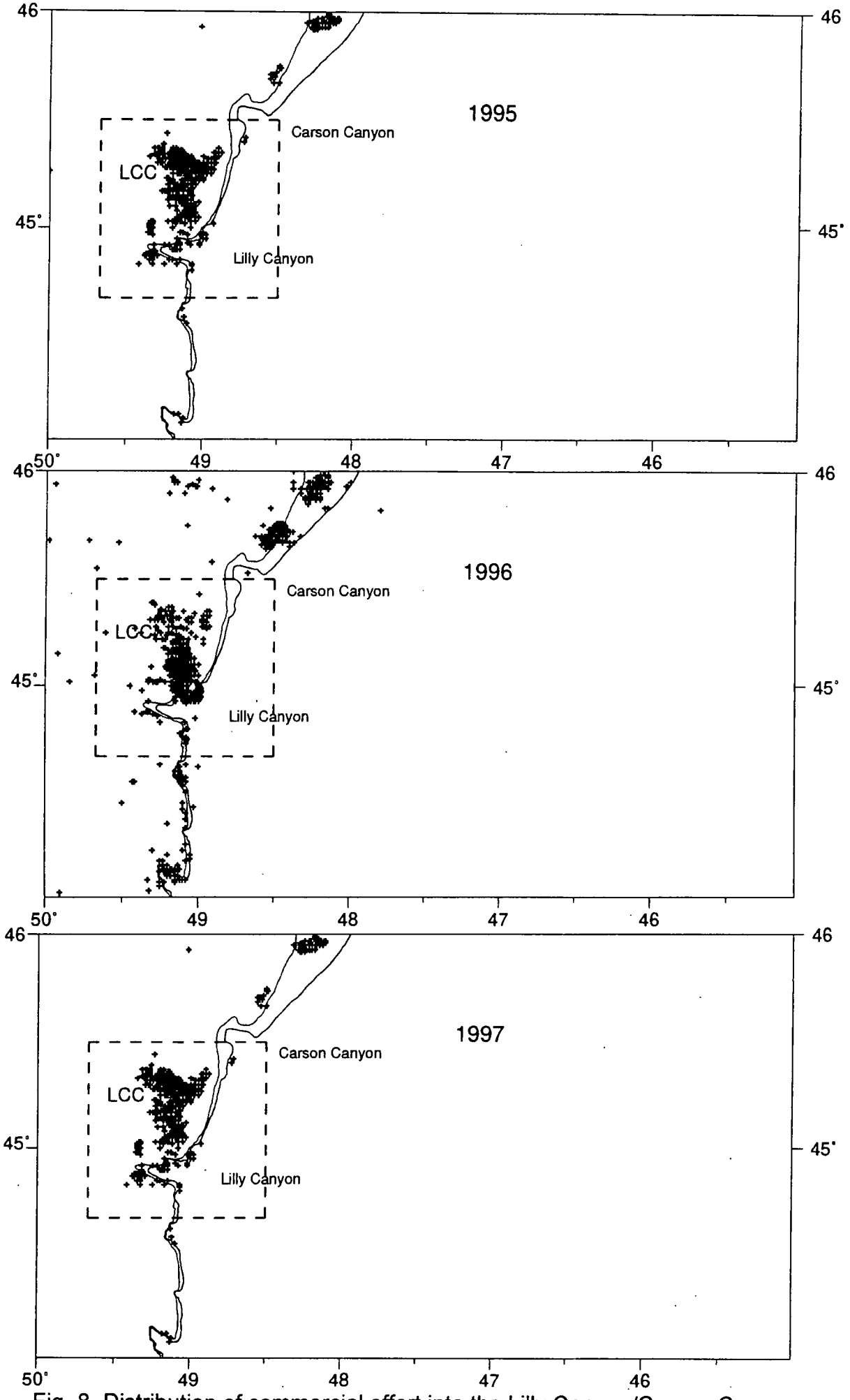


Fig. 8. Distribution of commercial effort into the Lilly Canyon/Carson Canyon areas, 1995-97.

Fig. 9. Commercial meat-weight frequency distributions from NAFO Div. 3Nf, 1996-97.