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The American Lobster, *Homarus americanus*, fishery off of South-western Nova Scotia (Lobster Fishing Areas 34)

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Abstract

The status of the lobster fishery in Lobster Fishing Area (LFA) 34 is reviewed. Estimates of exploitation rate and levels of egg production per recruit (E/R) are presented. Projected impacts of conservation management changes currently in review are evaluated. Landings increased over 3X during the 1980’s and remained high and stable since 1990-91. Fishing grounds also expanded during the 1980’s to include the deeper water areas outside of 20km and the 55m depth contour, out to the 92km LFA 41 offshore line. Catch rates and size distributions in the nearshore fishery appear to be unchanged over the past decade. Exploitation rates are high and appear to be stable in the nearshore areas but over 70% of the landings are new recruits that have not spawned. Landings may have remained high in part due to increased fishing in the midshore areas and increased effective effort. A higher percentage of the landings are occurring earlier in the season, which is consistent with an increase in effective fishing effort. Size frequencies in deeper water midshore areas like German Bank, indicate a decline in proportion of mature females and exploitation rates appear to be as high as in the nearshore. Since the advent of the midshore fishery in the late 1970s the number of eggs per recruit may have declined by 2 to 8-fold for the entire LFA 34. Based on observation of the numbers of sublegal sized lobsters in traps, the recruitment since the late 1980s appears to be continually high. Results of the egg-per-recruit analysis indicates that the stock is recruitment over fished and increased egg production would help reduce the risk of recruitment failure.

Résumé

L’état de la pêche au homard dans la Zone de Pêche au Homard 34 (ZPH 34) est révisé. Des estimations du taux d’exploitation et des niveaux de production d’oeufs par recrue (O/R) sont présentées. Les impacts, résultant des changements dans la gestion de la conservation, sont évalués. Les débarquements ont augmenté 3 fois pendant les années 1980 et sont demeurés élevés et stables depuis 1990-1991. Les fonds de pêche, ont été élargis pendant les années 1980 pour inclure les zones plus profondes à l'extérieur du profil de la zone de 55 m de profondeur, jusqu’à la limite de la zone de pêche hauturière du homard (ZPH 41), à 92 km. Les taux de prises et la distribution des tailles dans la pêche côtière semblent inchangés depuis la dernière décennie. Les taux d’exploitation dans les eaux côtières sont élevés et semblent stables, mais plus de 70% des débarquements sont composés de nouvelles recrues qui ne se sont pas encore reproduites. Les débarquements sont peut-être demeurés élevés dû en partie à l'intensification de la pêche semi-hauturière et l’intensification de l’effort réel de pêche. Un plus grand pourcentage des débarquements à lieu au début de la saison, ce qui reflète une augmentation de l’effort réel de pêche. Des fréquences des tailles dans les zones de pêche semi-hauturière plus profondes comme le banc German reflète une diminution dans la proportion des femelles matures et les taux d’exploitation dans ces zones semblent aussi élevés que ceux dans les eaux cotières. Depuis le début de la pêche semi-hauturière, à la fin des années 1970, le nombre d’oeufs par recrue pourrait avoir diminué de 2 à 8 fois dans l’ensemble de la ZPH 34. Basé sur l'observation du nombre de homards de taille inférieure à la taille réglementaire dans les casiers dénote un recrutement qui paraît demeurer élevé depuis la fin des années 1980. Les résultats de l’analyse des oeufs par recrue confirment que le stock fait l’objet d’une surpêche des recrues et un accroissement de la production d’oeufs contribuerait à maintenir le recrutement.

The Fishery

The lobster grounds off of southwestern Nova Scotia are amongst the most productive in the world with landings in recent years exceeding 10,000mt (Table 1) and accounting for over 25% of Canada's lobster landings. The fishery is undertaken by 975 full time fishers (Category A license) and 7 part-time (Category B license).

The fishery is managed by an 81mm minimum size carapace length (CL), prohibition on landing egg-bearing females and effort controls consisting of limited entry, a season between the last Tuesday in November through to May 31, and a trap limit of 375 from November to March and 400 in March to May.

Lobster Fishing Area (LFA) 34, off Southwest Nova Scotia (Figure 1) is a diverse region between Digby Neck and Barrington Bay encompassing 21,000 km^2. Fishing takes place in shallow near-shore areas extending to deep water areas just inside the 92 km (50 nautical mile) offshore lobster line.

Commercial lobster fishing began in the mid-1800s and landings exceeded 12,000 tons in the late 1890s. Landings declined sharply in the late 1890s and reached a low of 1,700t in 1920. Landings remained between 1,000t and 4,500t until the early 1980s (Figure 2). During the 1980s, landings increased as part of a widespread recruitment pulse (Pezzack 1996) and peaked at 11,000t during the 1990-91 season. Landings remained high in LFA 34 and the remainder of the Gulf of Maine (LFA 35-41, Maine, New Hampshire and Massachusetts) (Figure 3). LFA 34 landings in 1997-98 increased to 11,747t the highest this century, 3.5 times the average for the 1960-1979 period.

Midshore Fishery

In the 1950s, the American offshore lobster fishery began after American vessels found lobster along the outer shelf and around Georges Bank (Schroeder 1955). The Canadian offshore fishery did not begin until 1972 and was restricted to areas of the continental shelf at least 92km (50 nautical miles) from shore. Historically, the inshore fishery took place in the coastal areas within 20 km and in waters less than 55m, so it was felt that the new line provided a wide buffer zone between the offshore and the inshore fisheries.

Inshore vessels began exploration of new grounds further from the shore and by the mid 1970s were fishing Browns Bank and German Bank. This deeper water fishery was referred to as the midshore fishery. The history of the midshore fishery was reviewed in 1995 (Duggan and Pezzack 1995) when, based on interview surveys of fishers, it was estimated that the midshore represented 10% of the license holdings and corresponded to 10-12% of the landings. Interviews indicated that some fishermen are active in the Midshore all season while others fish it only part of the season, moving nearshore when catch rates are higher there. The expansion of the midshore out to the offshore boundary line has resulted in them fishing the same lobster concentrations as the offshore fleet that fishes under a 720t Total Allowable Catch (TAC) outside the line.

Midshore fishing effort has continued to expand and though not documented may presently represent between 20-30% of LFA 34 landings.

Origin and development of the midshore lobster fishery

Pre-1970 (Figure 4a)

At this time traditional fishing grounds of the inshore lobster fishing fleet included area inside the 30 fathom contour with a limited amount outside this area towards German Bank.

Common fishing practices included:

- smaller boats, wooden traps, buoy gear (2 traps/buoy)
- fishing November to December and April-May with most traps landed during winter months

Early 1970's Vessels from Yarmouth and Wedgeport increase effort by extending lobster fishing grounds to German Bank and beyond.

Late 1971 Offshore lobster licenses were offered to 56 vessels displaced from the swordfish fleet. The offshore fishing area was delineated approximately 50 miles (92 km) from land. Initially, effort was centred on Georges Bank until productive grounds discovered in the Browns Bank area.

1975 (Figure 4b)

Two vessels from Cape Sable Island begin fishing Browns Bank just inside the offshore lobster limit and landed large catches of lobsters larger than those of traditional inshore catches. Fishers were showing increased concern over rising effort and landings by offshore fleet and a fear that it would have a negative impact on the inshore fishery

1976 At this time offshore licenses were frozen at eight, a 10 month season, 1000 trap limit and 408t quota were imposed in NAFO area 4x.

A total of eight inshore boats were fishing Browns Bank inside the offshore line. Several inshore lobster licenses from Cape Sable Island and Pubnico areas were transferred from smaller fishing boats to larger, 70-75 foot herring seiners.

1977 Inshore lobster vessel size restrictions were imposed (45'LOA, length overall)

1979 (Figure 4c)

Browns Bank Closed Area prevented fishing in this area and was imposed in order to protect an area believed to be an important spawning area hypothesized by Stasko. Two offshore and 8 inshore lobster vessels were displaced. The closure stopped 20-30 vessels fishing midshore which had intentions to fish Browns Bank next season

1981-84 New, larger modern vessels begin to expand into the midshore. Changes in fishing methods include:

- increased use of Loran C and hydraulic trap haulers
- introduction of the wire lobster trap
- shift to trawl fishing with 15-20 traps per trawl
- fishing from November to May and not landing gear in the winter as previously done

1983-84 (Figure 4d)

Aerial survey shows that effort in the midshore has expanded and increased on German Bank and out to the 50 mile offshore limit

1985-93 (Figure 4e)

In 1985-86 there were up to 100 vessels fishing the midshore seasonally and the results of 1993 survey showed that effort in this areas has increased and expanded.

1994 Reports by midshore fishers and fisheries officers of another increase in the number of vessels fishing the midshore during the fall inshore season.

1995-97 (Figure 4f)

Observations by midshore fishers, fisheries officers and from overflights by DFO surveillance aircraft indicate that over 200 vessels fish the midshore on a seasonal basis with highest effort between December and March

The midshore is an area of interest because it represents an expansion of exploitation into a portion of the stock previously not fished. This previously unexploited portion of the population may have served as a source of eggs and acted as a buffer in periods of poor recruitment. Information on landings and effort from the midshore is available only by word of mouth from interviews with fishers as landings are recorded by port location providing no information about the actual fishing location. Consequently, no documented or reliable information on fishing effort in the midshore exists. Without this information a full assessment is impossible as size frequencies cannot be weighed according to catch to determine an over all estimate of Fishing Mortality (F) nor can changes in spatial distribution of the catch be determined which may provide early indications of changes in abundance.

Biological Background

The American lobster, *Homarus americanus*, inhabits coastal waters from southern Labrador to Maryland, with major fisheries in the Gulf of St. Lawrence and the Gulf of Maine. Although lobsters are most common in coastal waters, they are also found in areas of warm deep water in the Gulf of Maine and along the outer edge of the continental shelf from Sable Island to North Carolina (Figure 5) to depths of 750m. In other areas lobsters are restricted to a band along the coast by cold bottom waters found at depth. In the Gulf of Maine, warm slope waters with year round temperatures of 6 to 9 degrees Celsius fill deep basins offering habitat for lobsters and allowing movement over long distances.

Lobsters make seasonal migrations moving to shallower waters in summer and deeper waters in winter. Tagging studies indicate that these movements often amount to a few kilometers in most regions, however, in the Gulf of Maine lobsters undertake long distance migrations of tens to hundreds of kilometers. Similar work has also shown site fidelity with some of these lobsters return to the same areas each year (Saila and Flowers 1968; Pezzack and Duggan 1986; Campbell 1986).

Current thinking is that the Gulf of Maine lobster population can be viewed as a metapopulation, meaning that a number of sub-populations are linked in various ways by movements of larvae via water currents and motion of adults. Exchange of genetic information occurs through the dispersal of larvae and adults. The dynamics of this relationship have not been fully evaluated with the number and distribution of these subpopulations remaining unknown.

To grow, lobsters must shed their exoskeleton through a process called molting. Lobsters exhibit continuous growth such that they continue to grow even after reaching morphometric maturity. In the region off SW Nova Scotia the size at 50% maturity is between 95 and 100mm carapace length (CL), at an average weight of 0.7 kg (1.5 lb.).

Mating occurs in midsummer, after mature females molt. The following summer she produces eggs that attach to the underside of the tail and are carried for 10-12 months, hatching in July or August. The larvae spend 30-60 days feeding and growing near the surface before settling to the bottom and seeking shelter. For the first 4-5 years lobsters remain in or near sheltered areas to avoid predation by small fish. Very young lobsters can molt 3-4 times a year, increasing 50% in weight and 15% in length with each molt. As they grow and have less chance of being eaten, they spend more time foraging in open areas and become more catchable in lobster traps.

In the waters off south-western Nova Scotia lobsters take 7-8 years to reach the legal size of 81 mm carapace length when they can be captured by the fishery. At this size they weigh 0.45 kg (1 lb.) and molt once a year. Larger lobsters molt less often, with a 1.4–2.8kg (3-6 lb.) lobster molting every 2-3 years.

Methodology

Landings information is obtained by Statistical Area from data compiled by the Statistics Branch of DFO based on sales slip (1947-1996) and self reporting sheets (1997-98). Catch and effort information is obtained from voluntary logbook records kept by the Index Fishers, and size information from sea samples collected on a trap by trap basis during regular lobster fishing operations.

The Index fishermen program was introduced in 1988 and at present there are 35 logbook holders recording daily catch and effort information. As analysis of logbook data can be biased by changes in the individual fisher participating in the program, only data from fishers present over the entire period (1988 to 1997) were included for analysis.

To better standardize comparisons between years the landings and catch rate or CPUE (kg/TH) were compared for the first 4 and last 3 weeks of the season. These periods should be indicative of actual trends as they account for over half of the total landings.

At-sea samples collect information from fishermen's catch during normal commercial fishing operation. The data collected includes: carapace length measured to the nearest millimeter (from the back of eye socket to the end of the carapace), sex, egg presence and stage, number, location and depth of traps.

Data has been obtained through at-sea sampling conducted during the second to fourth weeks of the fall season, and the last 3 weeks of spring season. Although, the time of sampling has remained relatively consistent, the number of areas and level of sampling has varied considerably over time (Figure 6a-c). The sampling effort peaked in 1985-86 with 21 samples, and between 11-15 samples per season from 1987 to 1993. The sample number was further reduced between 1993-1995, as a result of budget constraints, to 6-7 samples seasonally with greater emphasis placed on the springtime. During 1995-1997, the lowest level of sampling was reached with only 3 spring samples achieved.

Sampling of the midshore, deeper than 30 fathoms, has historically been sporadic. This fragmented record is in part due to the higher cost associated with these longer midshore samples, fishing effort taking place outside of the traditional sampling periods and in mid winter, the variability of times when vessels fish specific areas and the difficulty caused by short notice of sailing in the mid-winter period.

Faced with these short falls in the sampling program biologists designed a more frequent and intensive at-sea sampling program meant to supply information on both the temporal and spatial variation of size frequencies. The sampling strategy focused on a "corridor" approach (Figure 6c) with efforts concentrated on an area running from the coast off Lobster Bay, Nova Scotia out to Crowell Basin in Lobster Fishing Area 41. Samples are taken from four sub-areas: inside Lobster Bay, outside Lobster Bay, German Bank and outside German Bank to the 92 km offshore line, at least 4 times during the season beginning in December and ending in May. This transect was chosen as a number of index fishers hold historical fishing and temperature records for these sub-areas, the lobster rich nearshore grounds of Lobster Bay are included, and it is contiguous with the offshore grounds in Crowell Basin. Such a zone is also advantageous as it encompasses contrasting types of grounds and provides a cross section of the shelf.

At present areas outside the corridor, such as Port Maitland and Cape Sable Island, were only sampled once during the fall and spring season. Similar corridors or transects are proposed for the area extending from Cape Sable Island to LFA 40, and from Port Maitland to the offshore line. These additional samples would facilitate providing a better spatial picture of the population size structure.

During 1997-98 little fishing activity occurred in Lobster Bay during January through March, and likewise fishing in the Midshore during the same period occurred only on an opportunistic basis with no fishing after March. Four adjacent offshore samples were also taken during January, February, and March as part of the industry funded offshore lobster fishery sampling program.

Estimation of Fishing Mortality (F)

The 1996 Invertebrate Fisheries RAP recommended developing and using a common method of determining Fishing Mortality (F) rather then the 4 variations used in the 1996 assessment. The Length Cohort Analysis (LCA) was chosen as it is applicable to different areas, uses wide ranges of sizes and incorporates more information on growth and time at-size than the previously used length based methods.

The LCA, based on Pope's (Pope 1972) cohort analysis and developed by Jones (Jones 1974; Jones 1981), estimates instantaneous mortality (F) from a sequence of cohort abundances over several ages. This method assumes that abundance at the end of year 1 can be estimated by the initial abundance (Ni), a half year of natural mortality (M), a mid year catch (C) and natural mortality for the remainder of the year.

Natural mortality (M) is derived from the Idoine-Rago Egg and Yield per Recruit model (E/R) output. The E/R program uses estimates of hard shell (M=10) and molting (M=0.05) mortality to generate an overall M. The overall M may vary depending upon growth rates, maturity and egg production schedules in different populations.

$$C_i e^{T_c M \Delta t} + N_{i+\Delta t} e^{M \Delta t} = N_i$$

Jones (1974) included variable time intervals (Δt), which represents the duration of the intermolt period for each size class, into the model. In the present assessment, Δt was attained by simulating the progression of a cohort through its lifetime using LFA 34/41 growth parameters and calculating Δt at-size from outputs of the E/R program.

The method was then further modified by Cadrin and Estrella to include the time of the catch (Tc). The time of catch is the period in the year when the catch is taken. The year begins in August following the molt and Tc is set as the month in which cumulative landings reach 50% of the total. For example in LFA 34 Tc = 0.45.

Numbers in the catch at size were obtained by expanding the size frequencies from at-sea samples using monthly landing data. This was not possible for the German Bank and deep water areas outside of German Bank due the lack of reliable landing data required to expand the size composition data to numbers landed. For these areas, percentages at size from the at- sea samples were used.

The sizes are group into 5mm or 10 mm CL groups. The 10mm groupings are used at larger sizes when numbers in any size group becomes small or are absent. The smaller groupings are most critical at the smaller sizes where Δt has the largest changes.

Egg per Recruit Determination

Female lobsters have a complex reproductive pattern and non-continuous growth which are not easily accommodated by the traditional dynamic pool models (Beverton and Holt 1957) The egg per recruit analysis are based on the size structured egg and yield per recruit model developed by Josef Idoine and Paul Rago (National Marine Fisheries Service (NMFS)) and used in the NEFSC SAW 22 (North East Fisheries Science Center Stock Assessment Workshop) assessment (Anonymous 1996). The model is based on an earlier work by (Fogarty and Idoine 1988).

The model includes size specific annual molt increments, maximum intermolt period and probabilities, proportion mature and egg bearing, fecundity and weight. The model runs on ¼ year time steps with growth, mortality, and fishing applied in the appropriate quarter. For example natural mortality is applied as hard shell mortality throughout the year and a soft-shell mortality at the time of molt in the fourth quarter. Fishing mortality is assigned to the appropriate quarter through the input parameters giving the proportion of the catch by quarter.

In lobsters, growth is a function of the molt increment, maximum intermolt period and annual probability of molting. Molt increment is input as a distribution of increments at size based on tagging data results. Molt probability is based on observations of animals held in the lab at ambient Bay of Fundy temperatures (S. Waddy, unpublished) and tagging data (Campbell 1983; Pezzack 1990). Immature lobsters molted annually while mature lobsters had intermolt periods of 2 years increasing to a maximum, of 4 or 5 years at large sizes. Maturity values were based on published and unpublished results using the pleopod method and dissections.

Maximum size and v-notch protection measures are incorporated into the model with an input parameter to specify the level of compliance and/or participation by the fishing industry.

Input values are given in Appendix 1 and a more detailed description of the model is found in the 22nd SAW report.

Results and Discussion

Resource Status

Resource status is evaluated by examining trends in landings, size frequencies of the commercial catch, exploitation rates and trends in catch rate (CPUE) from voluntary logbook holders.

General Landings Trends

Commercial fishing began in the mid-1800s with landings exceeding 12,000t in1898. Concerns about the status of the fishery were raised as early as 1872 (Venning 1873) when a decline in the average size of catch was first observed. Following the peak in 1898 landings fell sharply to 6,600t in 1903 and 2800t in 1918. The landings remained low (1500-3500t) from the early 1920s until the late1940s. Over this period numerous Government Commissions reviewed the decline and recommended changes in regulations in attempts to prevent further decrease in size and to protect from further declines in the fishery (DeWolf 1974). Landings rose in the late 1940s and remained between 2200t and 4600t until the 1980s. Landings increased throughout the 1980s in response to both increased effort and as part of a western Atlantic wide recruitment pulse (Elner and Campbell 1991; Pezzack 1993). Landings peaked at 11,000t during the 1990-91 season.

Landings continue to be high in LFA 34 and the remainder of the Gulf of Maine (LFA 35-41, Maine, New Hampshire and Massachusetts) throughout the 1990s. The 1997-98 landings were 12,064t, the highest this century, or 3.6 times the average for the 1960-1980 period (Table 1, Figure 2).

Landings are highest in the southern portion of LFA 34 in Statistical Area 32-34 (Figure 8) and the largest increase have occurred in these areas (Figure 9)

Since the peak landings in 1990-91, high landings have been sustained but a greater proportion of the landings are taken in the first half of the season (Figure 10, 11). The increased removals during fall months suggest increased effort and efficiency (Figure 11).

Issues and uncertainties: Landings are not a reliable indicator of the size or reproductive health of the stock. High landings can be maintained through higher levels of effort, greater efficiency or through fishing down successive areas. Environmental conditions which influence distribution and catchability can also mask underlying changes in the population. The shift towards greater percentage of the catch in the fall suggest increasing effort or efficiency by the fleet.
To understand and interpret the dynamics of the landings, it is important to know the underlying spatial component. At present, crucial information about fishing location is unavailable. This makes it impossible to determine where the landings are coming from, whether landings are being maintained by a shift in effort from one area to another, or, if some areas exhibited signs of decline, even though the overall landings have remained high. These are questions that will only be answered with spatial data supplied through the co-operation of fishers

Catch and Effort: The patterns in catch and CPUE are similar in all parts of LFA 34 (Figure 12, 13a-b). CPUE, like landings, is very high at the beginning of the season but drops sharply over the first 2-3 weeks. Approximately 30-50% of the total season's catch is caught during this time. Temperature, is also an import factor in determining catch rates and CPUE, and part of the drop in CPUE during the first weeks of the season is due to declining water temperatures. (Figure 14). Catch rates remain low during the winter months and increase again in the spring as weather conditions improve.

Weekly catch rates at the beginning and end of the season (Figure 13a-b) do not show a clear pattern but appear to be remaining relatively constant or declining in spite of increasing landings

Issues and uncertainties: CPUE or catch rate can be used as an indicator of abundance but it must be done so with caution as may factors influence their level (Hilborn and Walters 1992). The relationship between CPUE and abundance is not necessarily linear and thus does not increase or decrease at the same rate as abundance. High CPUE levels can be maintained through increased efficiency and use of new technology, improved fishing gear and strategy. Such changes are difficult to monitor and quantify. CPUE can also remain higher in core areas of the stock sampled masking a contraction or expansion of stock area. CPUE can be strongly influenced by temperature and long term changes in temperature could mask changes in abundance.

Catch Size Structure

Size frequencies in the catch vary along the coast, with depth or distance from shore and with season (Figure 15-19). Using length based assessment methods requires knowledge of the overall size structure but this cannot be obtained without knowledge of the spatial and temporal patterns in size structure and landings. Earlier sampling lacked both the spatial components and even the new strategy introduced in 1997-98, only covers a portion of the fishery. Science is presently unable to provide a complete picture of the changes in size distribution of lobsters in LFA 34.

Trends in Size frequencies: Size frequency analyses of nearshore landings during the 1980s indicate that a pulse in new recruits to the fishery fueled the increased landings. The levels of pre-recruits in traps hauled increased throughout the 1980s even with the gradual introduction of escape vents, which allow smaller, sublegal lobsters to escape. (Pezzack 1993; Pezzack 1996b)

In the nearshore, between 1983-1995 (Figure 20a,b,c), a high but stable proportion (70%) of the overall catch was in the first molt group (81-92mm for females) indicating high but stable exploitation rates in nearshore areas.

The proportion of the catch in the first molt group varies between nearshore areas being highest in Statistical Area 33-34 (80-90%) and lowest in Statistical Area 32 (30-50%). The percentage of females in the first molt group is also highest nearshore and becomes progressively lower in the midshore and offshore areas (Figure 20c), though the proportion on German Bank is similar to nearshore levels. Since 1991, the percentage of lobsters in the first molt group has increased in Statistical Area 33-34 and decreased in 32. (Figure 20b).

German Bank was one of the first midshore areas to be fished and still serves as an important fishing location. The proportion of the catch in the first molt group in 1997-98 was similar to that of the nearshore areas. At sea sample size frequency data from this area is limited, but comparison of samples taken in 1981, 1994 and 1998, suggest a major shift in the size structure (Figure 21) with the fishery moving from one based on multi-molt groups (1981) to a recruit based fishery similar to the nearshore based on 1-2 molt groups (1994, 1998). The loss of mature sizes has a significant effect on egg production. By contrast, the size frequency has been relatively stable on the various offshore grounds since the offshore fishery began in 1972 (DFO 1997).

If the trend observed on German Bank is indicative of the overall trend in the midshore fishery, there has been serious reduction in the reproductive potential of the stock. Quantifying this would require more knowledge of landings from the different areas and relative stock sizes, but the expansion of the fishery in the midshore could have reduced the over all egg per recruit level by 50% or possibly more.

1997-98 Samples

The new corridor sampling strategy implemented during the 1997-98 season provides more detailed seasonal and spatial data on size frequencies. The results of sampling conducted shows several common trends among the five areas including: males are generally found at larger sizes than females, size ranges are wider in areas further from shore, low catch rates of berried females, and catch rate of sublegal sizes increases in the spring.

It is difficult to speak of general trends from one year of sampling but the patterns observed are:

Inside Lobster Bay (Figure 15a-b)

- males have a wider size range than females

- few females larger than 115mm
- catch of berried females very low in the fall but increases in May
- catch rate of sublegals increases dramatically in April and May

Outside Lobster Bay (Figure 16a,-b)

- catch rate lower than inside Lobster Bay
- berried female catch rates low in all months
- size range of males and females narrower than inside Lobster Bay
- no increase in catch rate of sublegal sizes observed in April or May

German Bank (Figure 17a-b)

- catch rate lower than inside areas
- size range wider in males than females
- catch rate of berried females low in all months, though slightly higher in May
- catch rate of sublegals increase in May

Outside German Bank and Crowell basin (Figure 18, 19)

- inshore and offshore size frequencies are very similar
- catch rates of females higher than males
- catch rate of berried females higher than inside areas but still low

Issues and uncertainties:

Fishermen's comments on size structure and abundance of berried females often differ from the sampling data. This may be due to the limited number of samples and the narrow time period when sampling occurs. It may also be that individual fishermen are observing higher catch rates of specific sizes and sexes in their local ground, which are not representative of the whole area. Resolving this difference would require more sampling

Fishing mortality and exploitation rate

The Length Cohort Analysis was originally developed for groundfish but modified for use in American lobster assessment (Cadrin and Estrella 1996). This model uses size frequency and growth data inputs to derive estimates of indicators of the status of the fishery (F and exploitation). LCA was used in the 1996 LFA 34 assessment but improvements in growth information have resulted in lower estimates for the nearshore, while new size data that have become available have resulted in higher estimates for the midshore.

Length Cohort Analysis (LCA) was used to estimate exploitation rate and fishing mortality (F) (Table 2) The output of the analysis is given in Appendix 1.

The current estimates of exploitation rate range from between 50-64% which are generally lower than were provided in earlier assessments which ranged from 60-80%. (FRCC, 1995)

The lack of information of the distribution of catches within this LFA makes it impossible to combine size data from the midshore and nearshore areas which is necessary to estimate an overall exploitation rate for LFA 34. As a result, separate estimates are given for the nearshore, the German Bank portion of the midshore and the deep water portion of the midshore. The exploitation rate for the Scotian Shelf portion of LFA 41 (offshore) is also provided.

Egg per Recruit Analysis

In November 1995, the Fisheries Resource Conservation Council (FRCC) presented a review of the conservation status of the Atlantic lobster fishery (FRCC, 1995). It was concluded that the present fisheries were operating at levels of exploitation which were too high, harvesting primarily immature animals and not allowing for adequate egg production. A new framework of seven large conservation units (Lobster Production Areas, LPA's) was proposed, within which measures should be taken to increase egg production. A threshold of egg production per recruit (E/R) equivalent to 5% that of an unfished population was recommended.

Despite general agreement by industry for the need to change there was no agreement on the FRCC target. As a result, an objective to double present E/R was selected. In December 1997, the Minister of Fisheries and Oceans issued a directive to Atlantic lobster fishers to implement new conservation measures, over a period of 4 years, which would achieve a doubling of egg production from current E/R levels.

The E/R values for nearshore and the German Bank area are 1-2% of the unfished conditions. Low values of E/R result in a higher risk of recruitment failure over the long term. The overall E/R values for LFA 34 cannot be determined because information on the relative sizes of the nearshore and midshore are not available as landings are not recorded by areas fished.

The stability of landings in the Gulf of Maine is likely due in part to the fact that a segment of the mature animals were not exploited and thus served as a recruitment source for nearshore areas. If the loss of mature sizes observed on German Bank is representative of a major portion of the midshore then LFA 34, E/R has been decreased to 10-50% of what it was in the 1970s. If the current level of exploitation is maintained, further reductions in E/R are likely which will increase the already unacceptably high risk.

Trends in E/R: As the exploitation rate has been relatively stable, the nearshore levels of E/R have been unchanged. The effects from a decline in mature sizes and higher exploitation rates in the midshore will ultimately reduce the overall E/R. The degree of reduction caused by exploiting a previously unexploited portion of the stock depends upon the relative sizes of the stock, the levels of exploitation and interchange between stock components.

Issues and uncertainties: The largest uncertainty is the relative sizes of the fishing areas delimiting the midshore and the nearshore. There is concern that any additional reduction of the contribution of other E/R values in the fishery could have long term impacts on recruitment. The fishery has been stable over its history, likely due in part to the fact that a portion of the mature animals were not exploited and thus served as a broad stock and buffer against shifts in effort and climate. Fogarty (1996) used a simple metapopulation model which indicated that a small population with a low exploitation rate could feed recruitment to a larger, more heavily exploited stock and could maintain that stock even at very high fishing mortality (F). If this is the role that the midshore stock has served in the past, the model predicts that applying high exploitation to both populations results in the collapse of both.

The **egg per recruit** analysis and the benefits of various management scenarios are based on an improved E/R model, developed since the FRCC review (FRCC, 1995). Remaining uncertainties in applying the model include:

1. The lower exploitation rates from LCA. There is uncertainty in these new estimates, and risk associated with the fact that they may lead to greater projected benefits from some stock conservation measures. For this reason, additional runs of the model were completed using a higher exploitation rate.

2. Appropriate time scales within which the increase in the egg per recruit resulting from a specific conservation strategy can be measured. For example, measures such as the maximum size do not provide the full projected increase in E/R for up to 40 years after introduction.

3. The LFA 34 lobster fishery resource needs to be considered in the broader context of the Gulf of Maine lobster stock or complex

Management Considerations

Consultations have been ongoing with LFA 34 lobster fishermen since the release of the FRCC report in October 1995 through direct mail-out of interpretative documents, community-level meetings, discussions at regular Lobster Advisory Committee meetings, and two workshops.

The options available to double egg production include combinations of v-notching, and minimum and maximum sizes limits. Adopting v-notching as a conservation measure would require wide acceptance over the entire LFA. In estimating the benefits of v-notching, it was assumed that 50% of the berried females caught would be notched. However based on current information from at-sea sampling it is assumed that berried females are not fully available to the fishery during the fishing season and catch rates are only 30% those of non berried females.

The combination of a minimum and maximum size increase allows more animals to reach maturity and reproduce while also establishing a pool of larger lobsters. As larger animals are able to carry more eggs, these could serve as a buffer during years of lower than average larval survival (Figure 22). A maximum size, with no change in mortality, applied only to females will have a reduction in yield and increase in E/R. An increase in the minimum size, with no change in mortality, will increase yield and E/R. It is possible that not protecting larger males could have a long-term effect on reproduction but it is felt that the faster growth rate of males, their ability to mate with a number of females each year and females ability to store sperm will prevent such limitation, though further study and monitoring will be necessary to confirm this assumption.

Conclusion

Landings have remained high and stable since the 1990-91 season. However, a higher percentage of the catch is landed earlier in the season, consistent with an increase in effective fishing effort. A potential reason for sustained high landings could be accounted for by a shift from fishing in the nearshore to increased pressure on the midshore. This is difficult to substantiate, as there is a lack of information on spatial distribution of catch and effort by virtue of the nature of the statistical collection method, which only includes port of landing. Information related to fishing location is crucial and inclusion of spatial data would improve prediction of the larger picture.

Catch rates and size distributions in the nearshore fishery appear to be unchanged over the past decade. Based on observation of the numbers of sublegal sized lobsters in traps, the recruitment since the late 1980s appears also to be continually high. Size frequencies in German Bank indicate that there is a major decline in the number of mature females and possibly a future failure in recruitment. Size frequencies in midshore areas like German Bank, indicate a decline in proportion of mature females and exploitation rates appear to be as high as in the nearshore. Additional monitoring will be necessary to document and analyze future shifts or changes.

Generally, exploitation rates are high and appear to be stable in the nearshore areas. A considerable proportion of the landings, over 70%, are new recruits that have not spawned. This is despite the movement of a portion of fishing effort out of the nearshore into the midshore. Exploitation rates are high in waters inside German Bank but still at relatively low levels outside this area.

Since the advent of the midshore fishery in the late 1970s, the number of eggs per recruit has declined by 2 to 8-fold for LFA 34. Results of the egg-per-recruit analysis suggest that the stock is recruitment over fished and would benefit from increased egg production in order to reduce the risk of recruitment failure.

ACKNOWLEDGMENTS

This paper is dedicated to the memory of Izabella M. Gutt. (May 3 1977- Aug 9 1999) a brilliant and hard working young biologist who died in a SCUBA diving accident off Nova Scotia. She started as a summer student but quickly became an important part of the team and a valued colleague. She worked long and hard hours, always with a smile and time for laughter. She took the lead in the estimating of exploitation rates and running and evaluating the E/R model, which was critical to this and other assessments. She questioned and challenged every assumption, and the assessment owes a great deal to her. She was an inspiration to all that knew her and she is missed greatly.

We thank the various LFA 34 lobster fishermen who have allowed us to sample their catches and who provide information on their catches and fishing effort over the years. Production of this assessment document was assisted by several students/interns/ casual employees (on both paid and volunteer arrangements) working with the Gulf of Maine Crustacean Fisheries Section during 1998: J. Dykens,. A. Spadafora, and J. Hunt. We also wish to thank Josef Idoine (NMFS) for is continued support in the technical aspects of the assessment, his insights into the fishery and for reviewing this document.

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Table 1. Lobster Fishing Area 34 landings 1947-1998.

Season	LFA34
1946-47	3130
1947-48	3284
1948-49	3761
1949-50	4172
1950-51	4420
1951-52	3887
1952-53	3973
1953-54	3480
1954-55	3282
1955-56	3441
1956-57	2706
1957-58	2268
1958-59	2215
1959-60	2606
1960-61	2305
1961-62	2548
1962-63	2896
1963-64	3221
1964-65	2851
1965-66	2708
1966-67	2710
1967-68	2844
1968-69	3888
1969-70	4580
1970-71	4066
1971-72	4037
1972-73	4457
1973-74	3771
1974-75	3973
1975-76	3914
1976-77	3463
1977-78	2813
1978-79	3037
1979-80	3229
1980-81	3060
1981-82	3663
1982-83	4546
1983-84	5138
1984-85	5938
1985-86	6891
1986-87	7673
1987-88	8479
1988-89	8201
1989-90	9449
1990-91	11069
1991-92	8876
1992-93	8919
1993-94	10308
1994-95	9646
1995-96	10263
1996-97	10473
1997-98	12064

Table 2. Estimates of fishing mortality (F) and exploitation rate for nearshore and offshore areas in LFA 34 as estimated by the LCA.

Area	F (Fishing Mortality)	Exploitation rate
Near shore	0.81 (0.70-1.01)	0.55 (0.50-0.64)
German Bank	1.08	0.66
Outside German Bank	0.35	0.30
Offshore Scotian Shelf	0.23	0.20

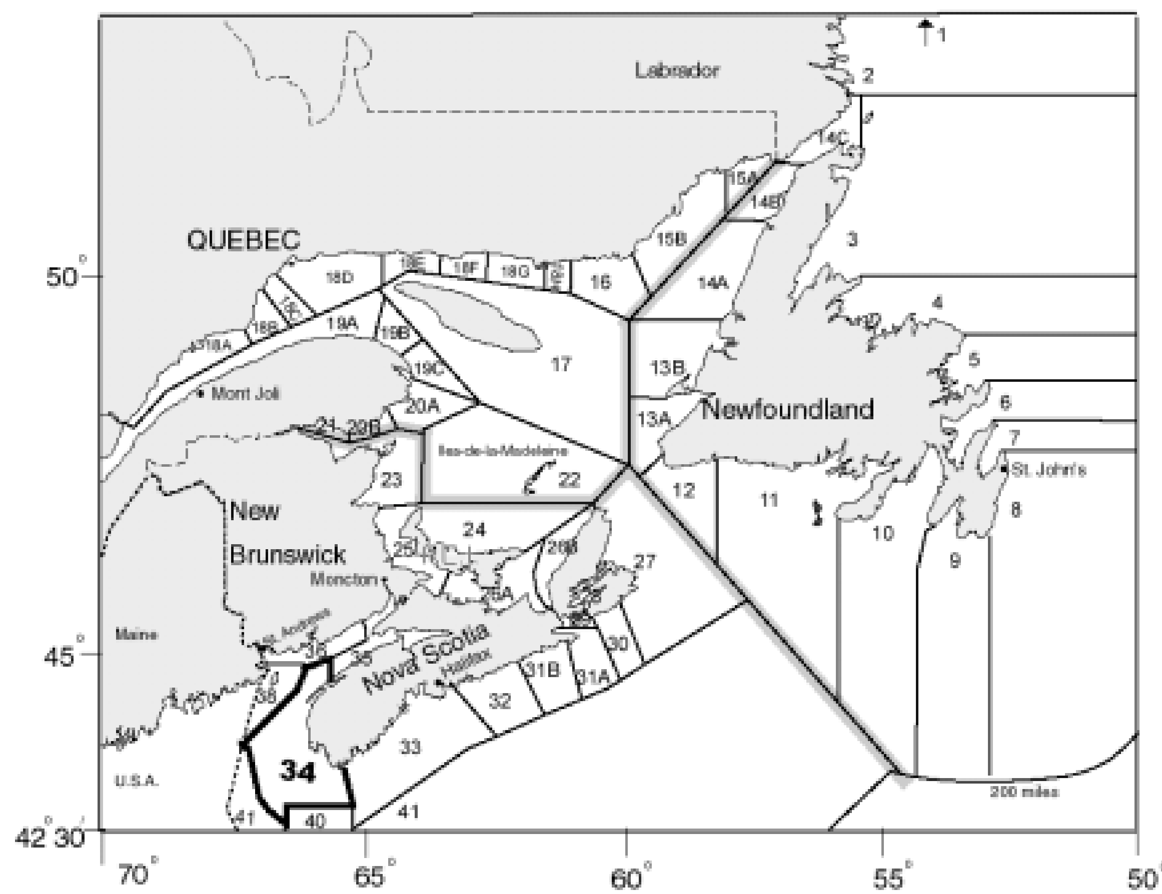


Figure 1. Canadian Lobster Fishing Areas (LFA).

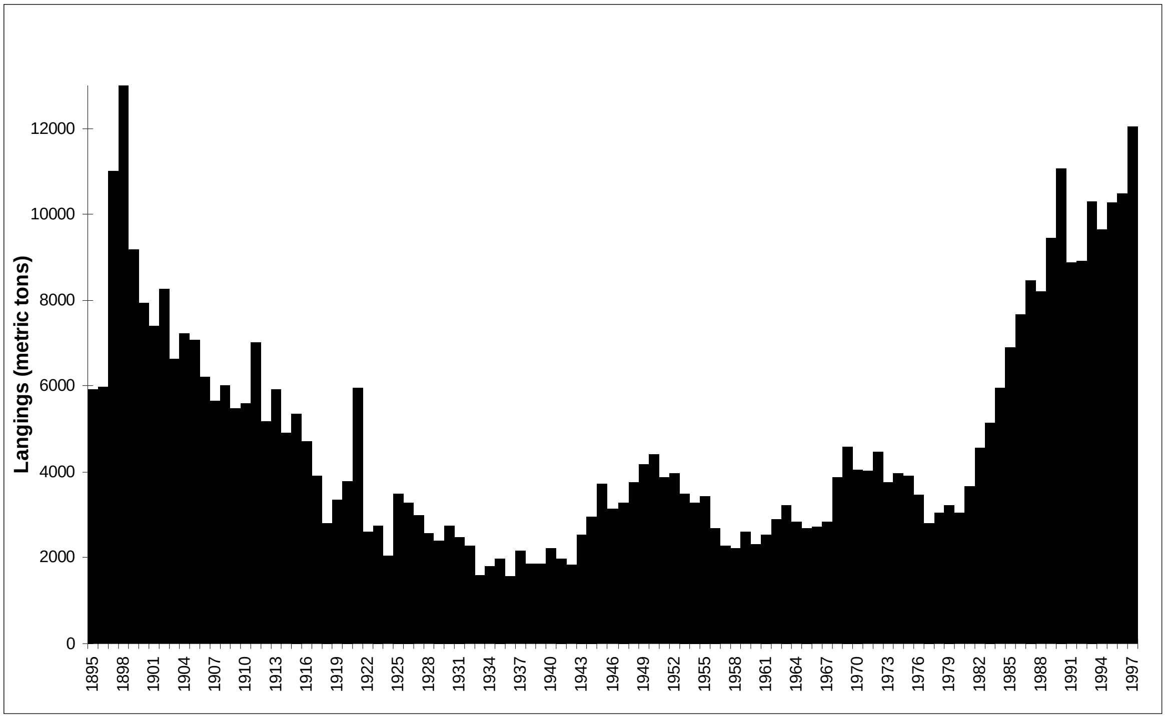


Figure 2: LFA 34 season landings 1890-98.

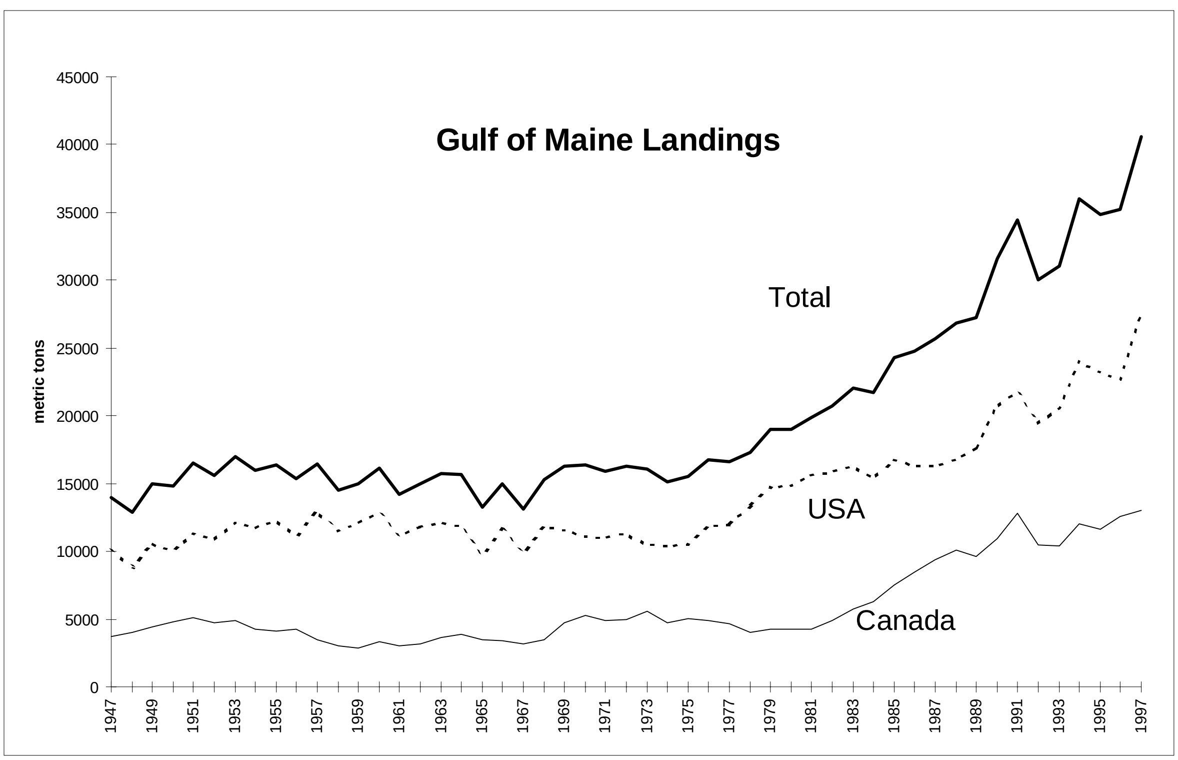


Figure 3: Canadian and USA annual landings (metric tons) from the Gulf of Maine region.

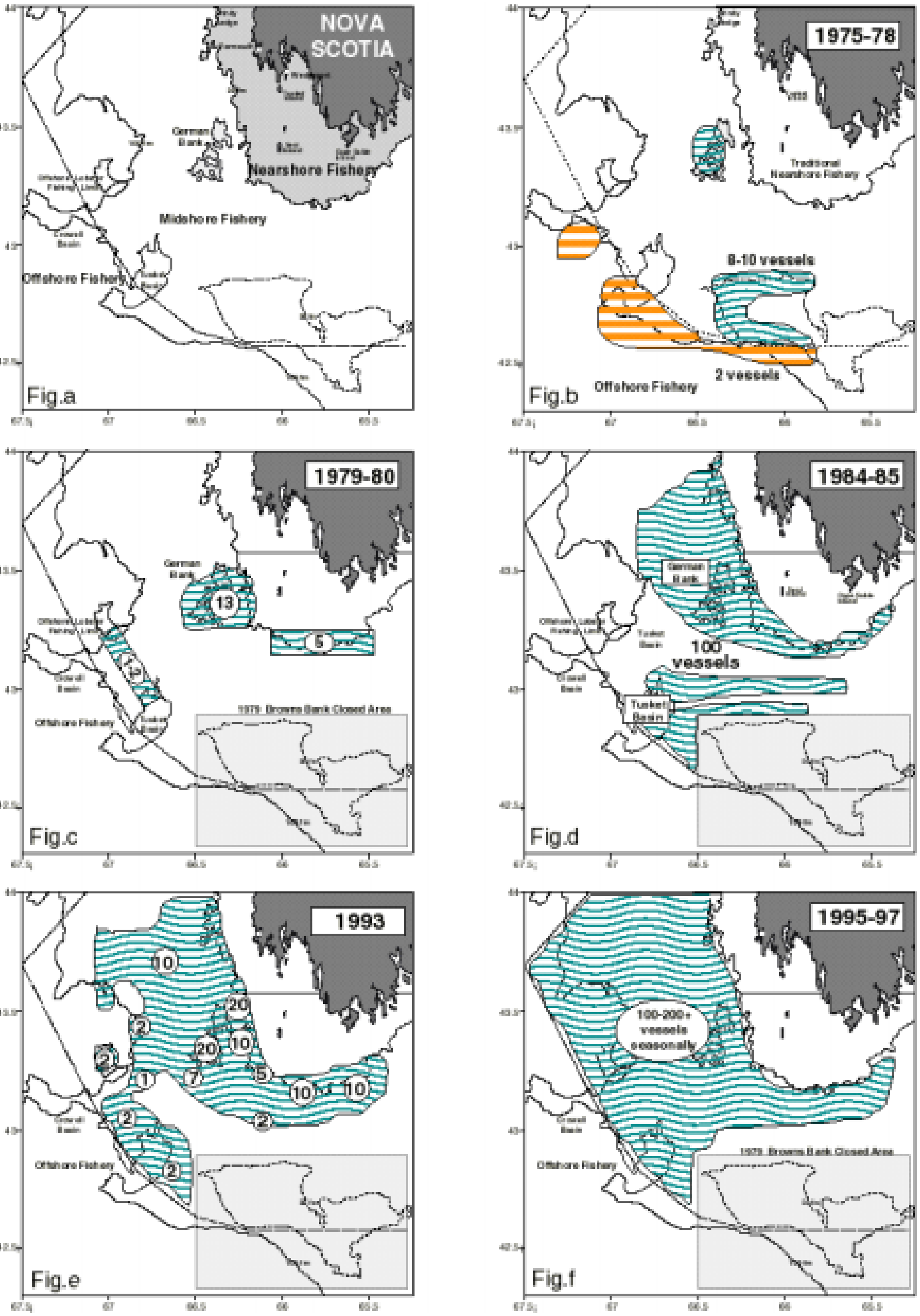


Figure 4. Progression of the development of the midshore lobster fishery in LFA 34 from the early 1970's until the present showing number of vessels and areas fished.

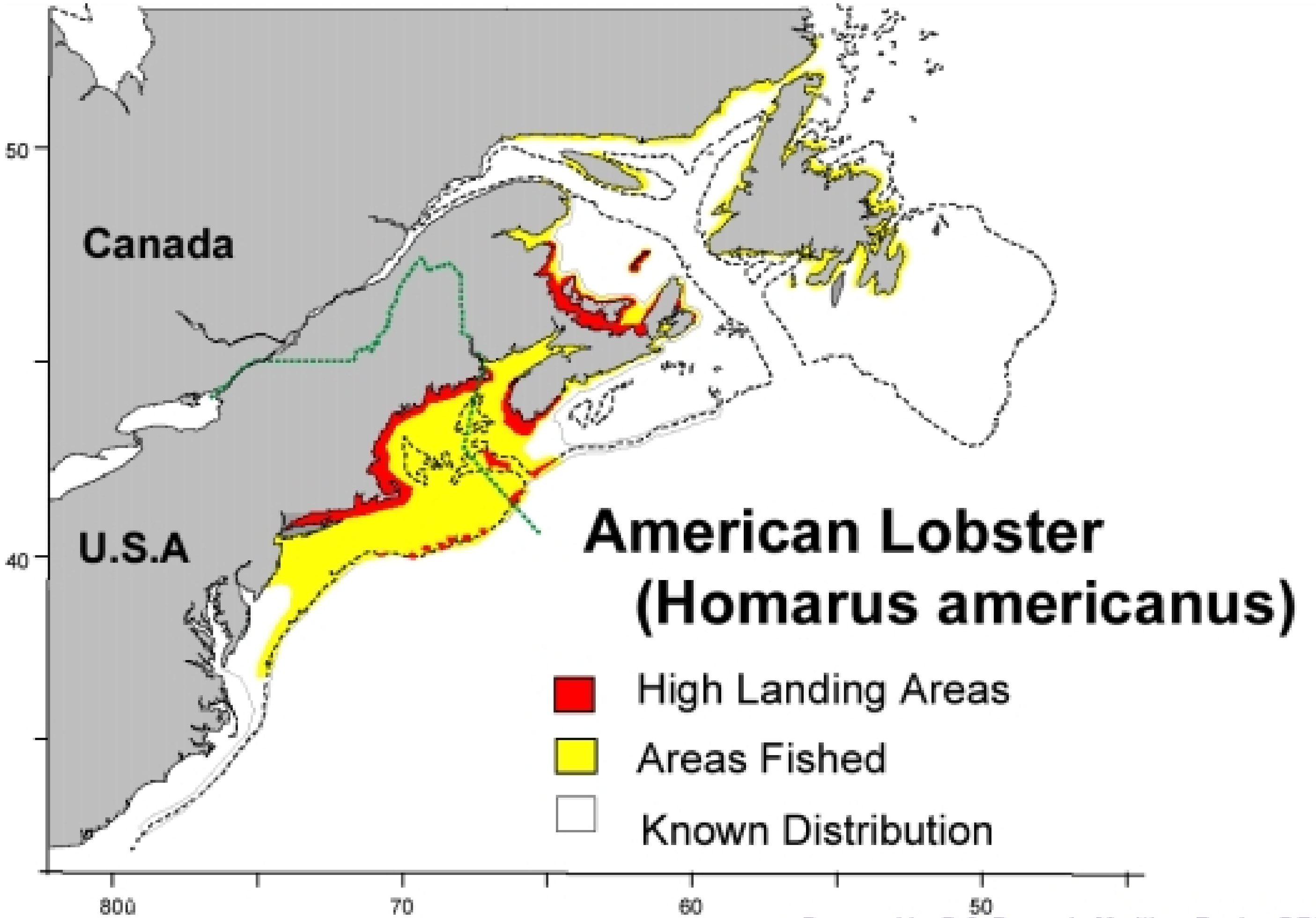


Figure 5. Known range of lobsters in the northeast Atlantic showing areas fished and those with higher landings.

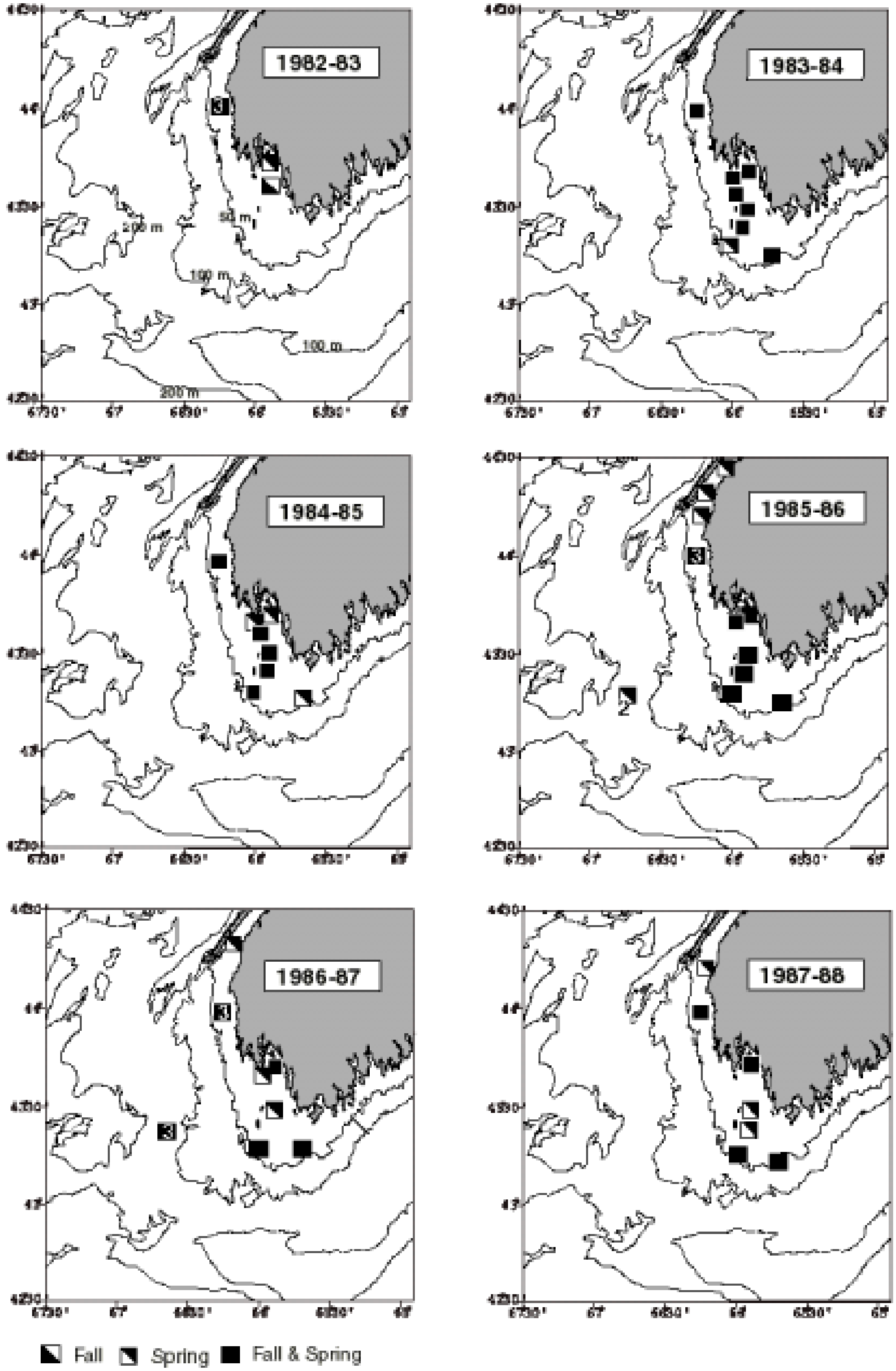


Figure 6a. Locations of lobster at sea samples in LFA 34 from the1982/83 until 1987/88 season.

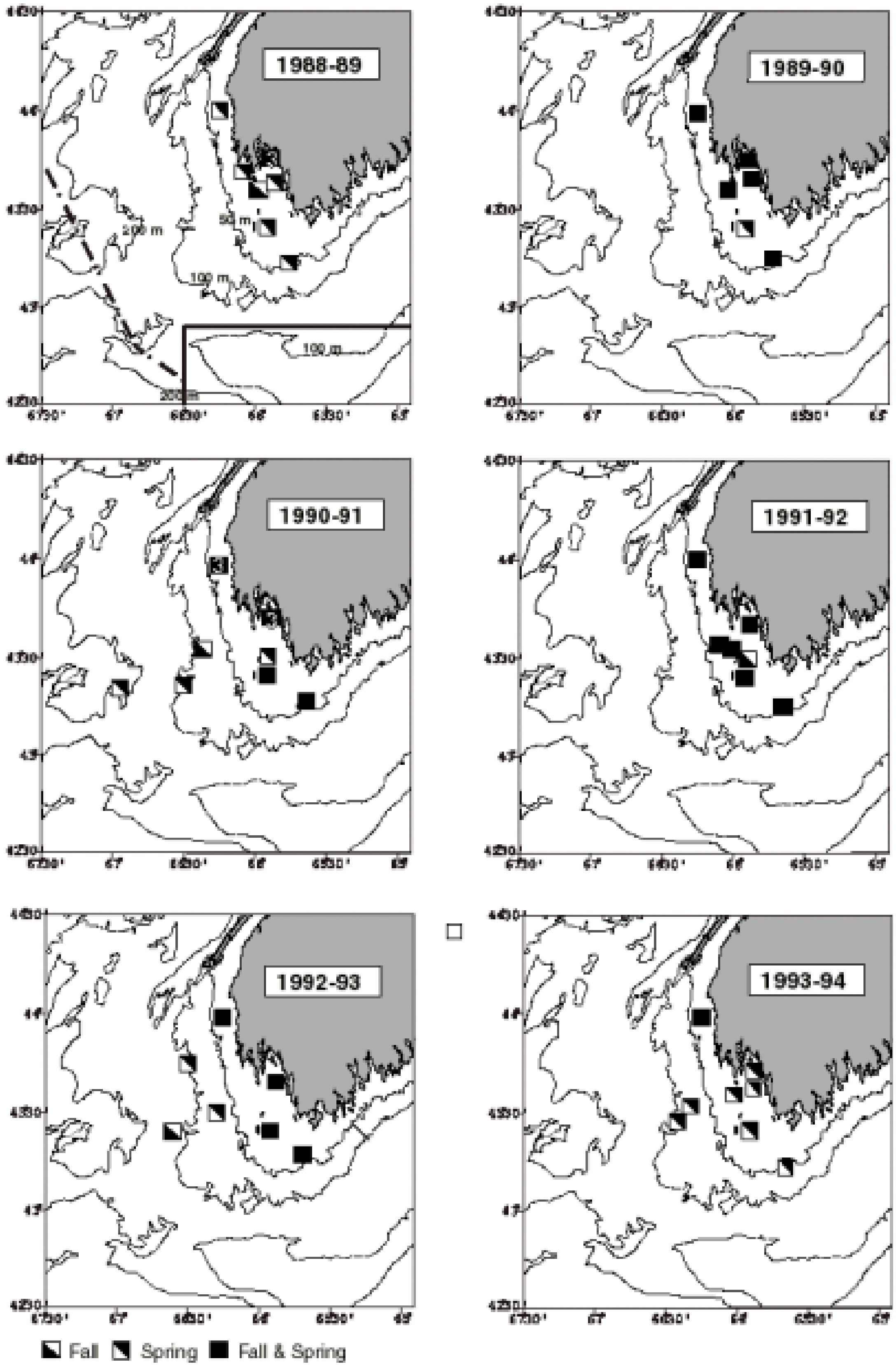


Figure 6b. Locations of lobster at sea samples in LFA 34 from the 1988/98 until the 1993/94 season.

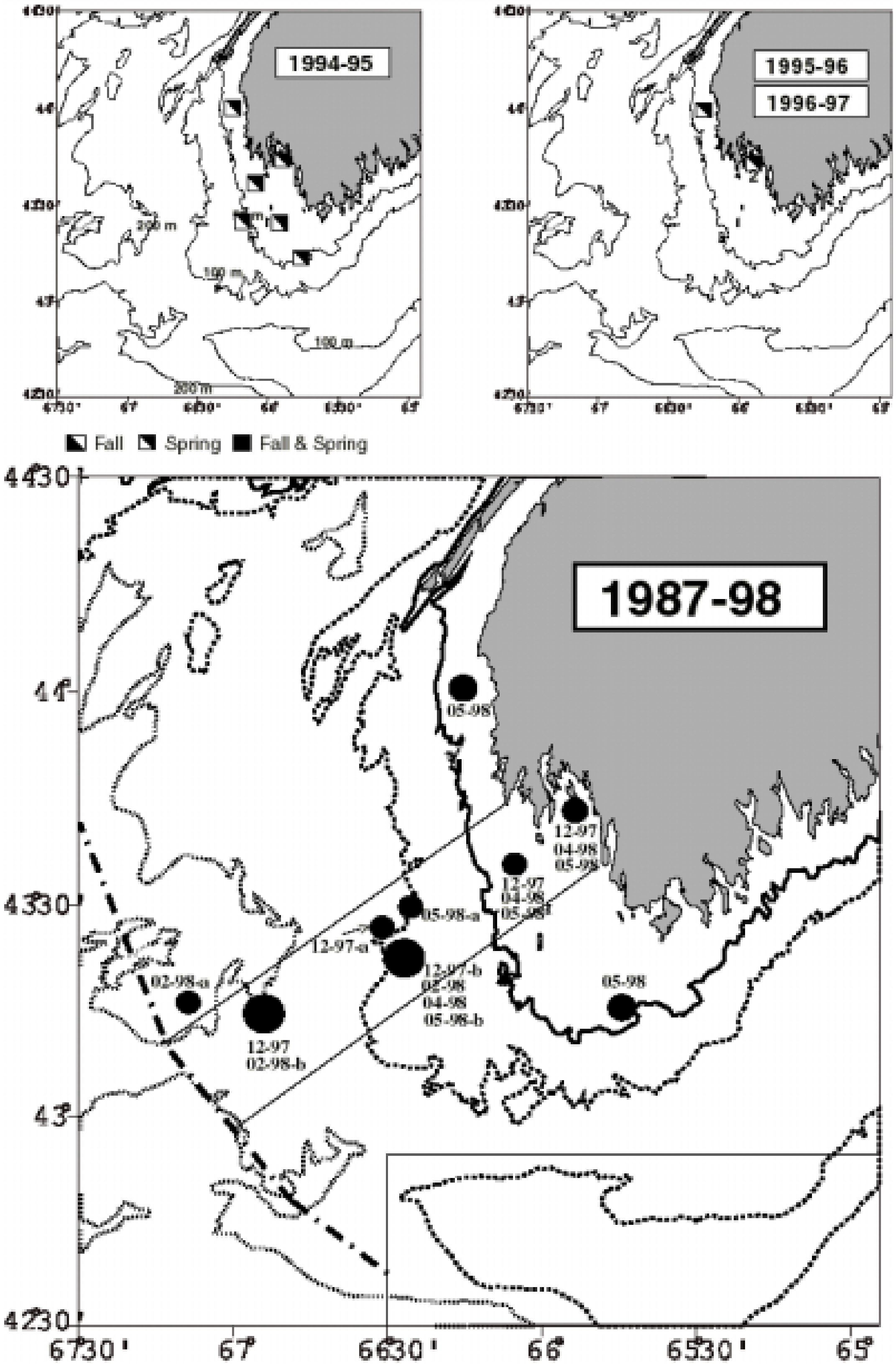


Figure 6c. Locations of lobster at sea samples in LFA 34 from the 1995/96 until 1997/98 season and the corridor sampling strategy implemented in 1997

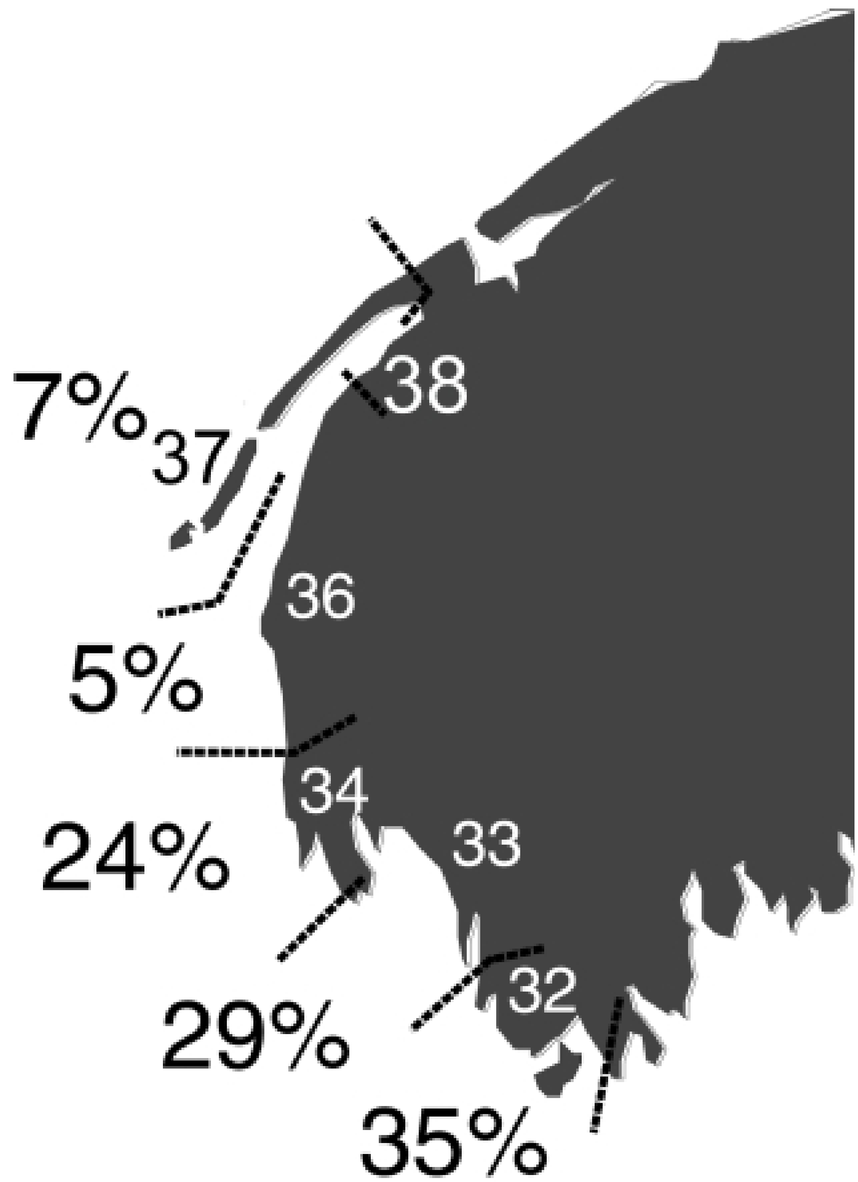


Figure 8: Lobster landings in LFA 34 in South West Nova Scotia by Statistical Areas.

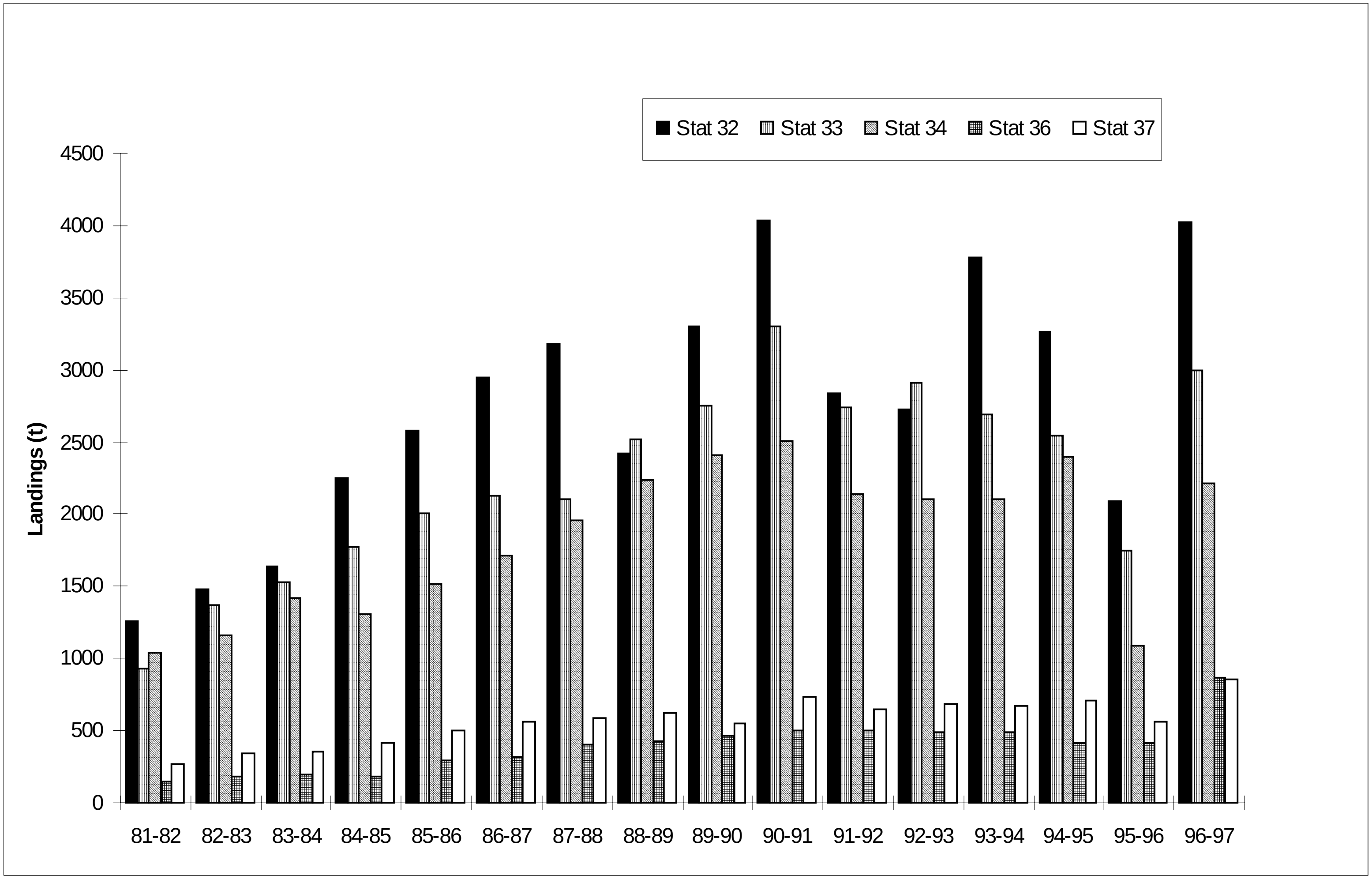


Figure 9. Season landings (metric tons) by Statistical Areas 32, 33, 34, 36, 37.

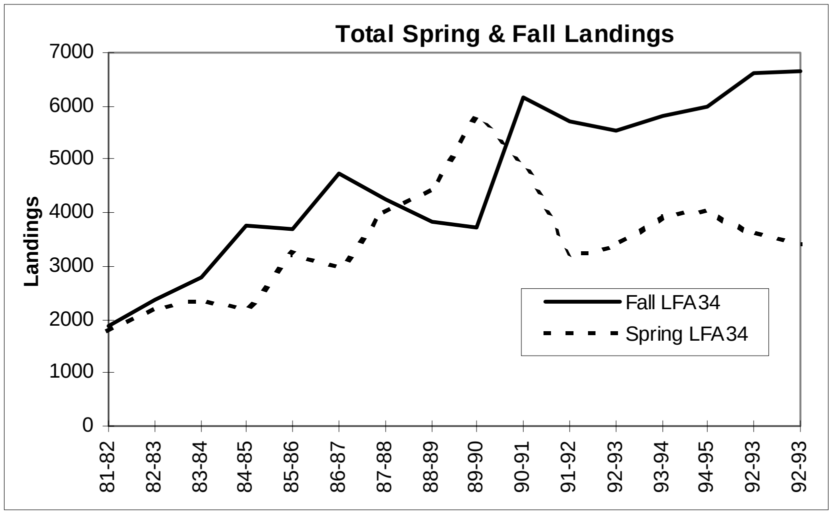


Figure 10. Fall and Spring lobster landings (metric tons) in LFA 34, 1981-82 to 1996-97

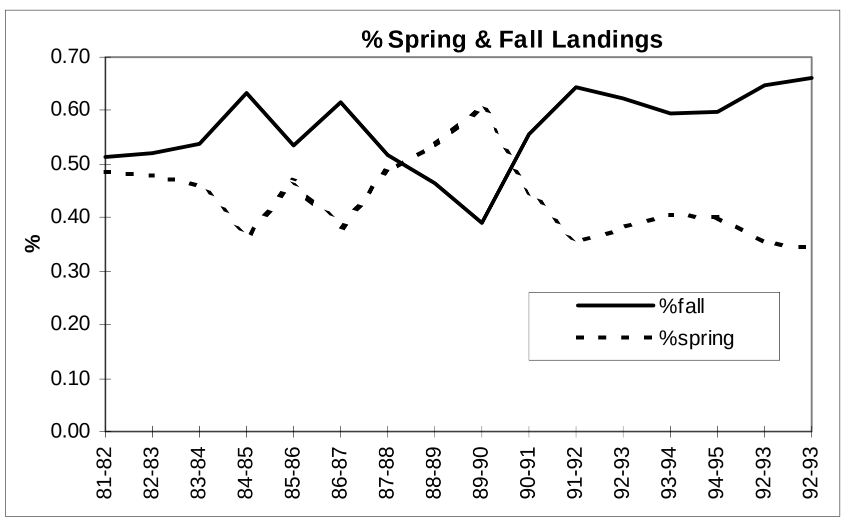


Figure 11. Percentage of total LFA 34 landings caught in the fall and spring, 1981-82 to 1996-97

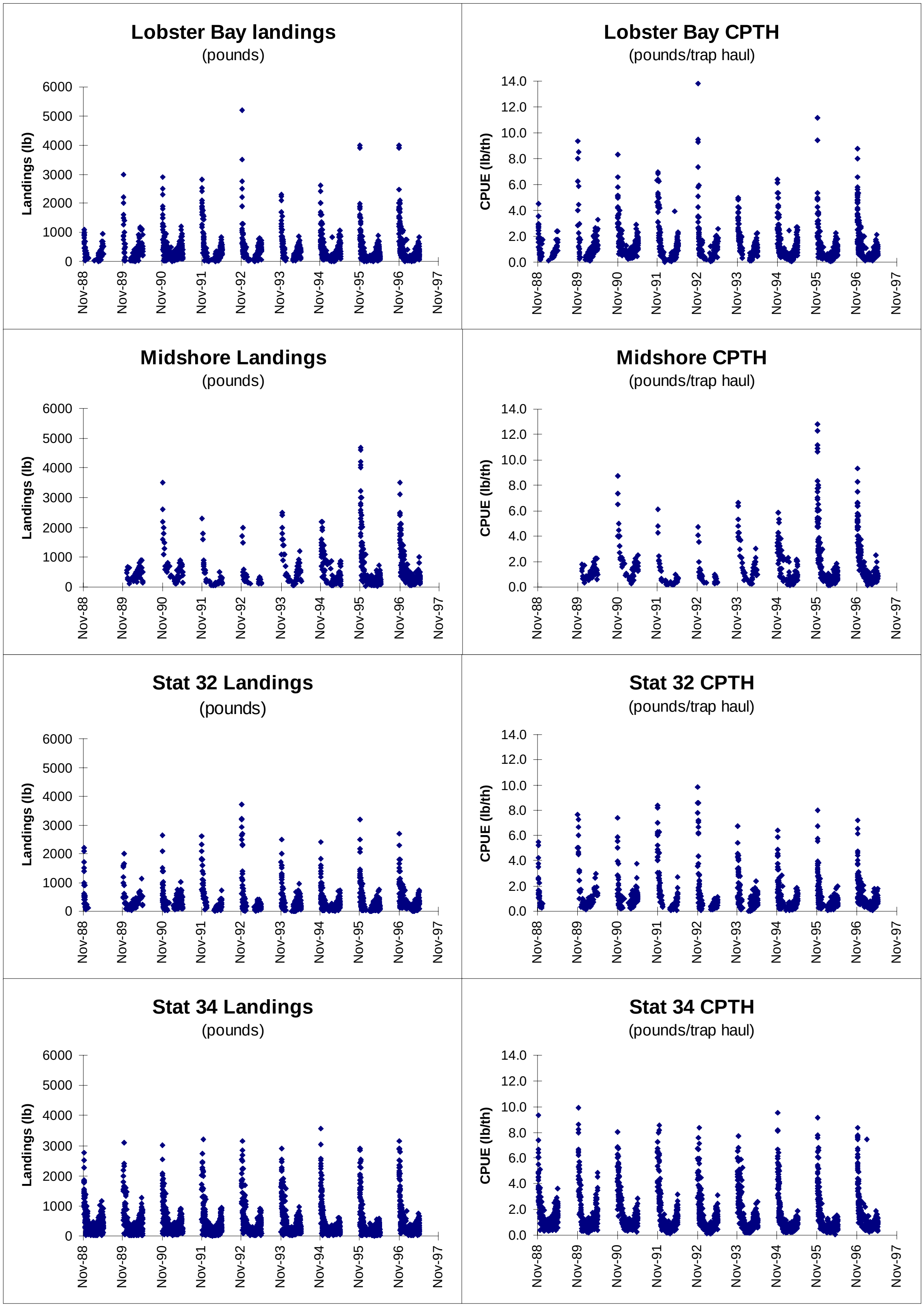


Figure 12. Seasonal pattern in daily landings and catch per unit effort for fishing areas in LFA 34.

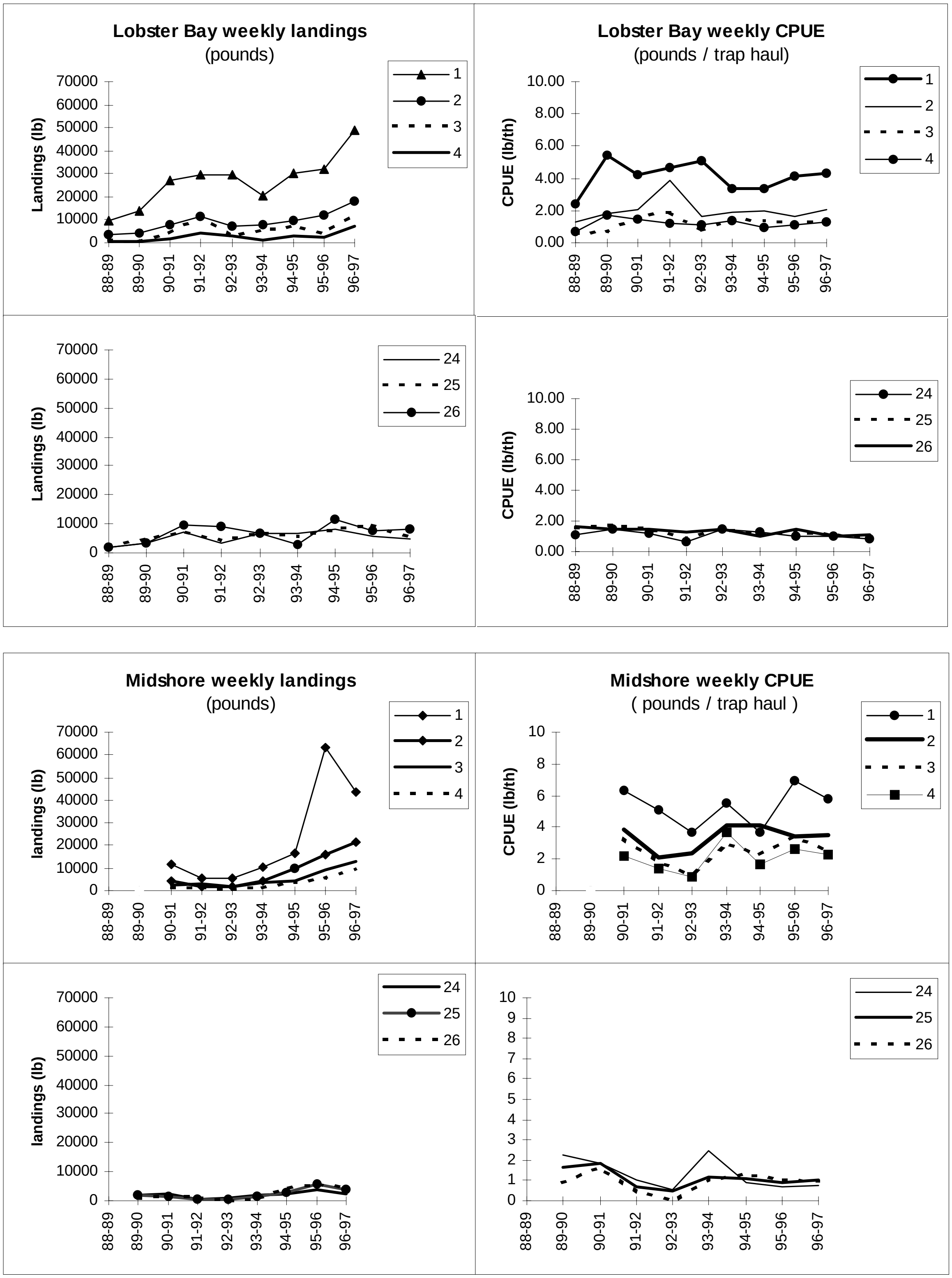


Figure 13a. Landings and CPUE for first four and last three weeks of lobster season in LFA 34

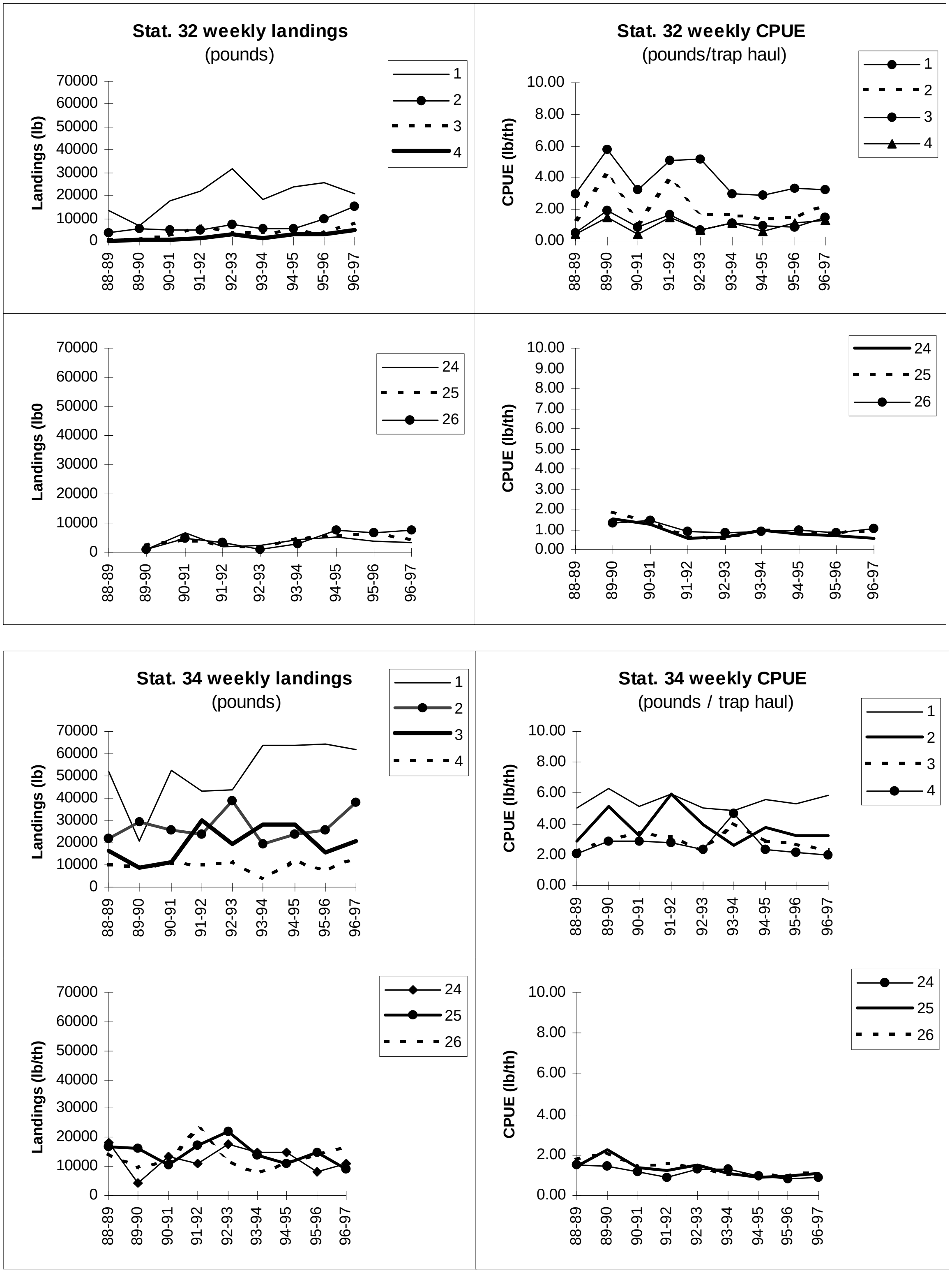


Figure 13b. Landings and CPUE for first four and last three weeks of lobster season in LFA 34

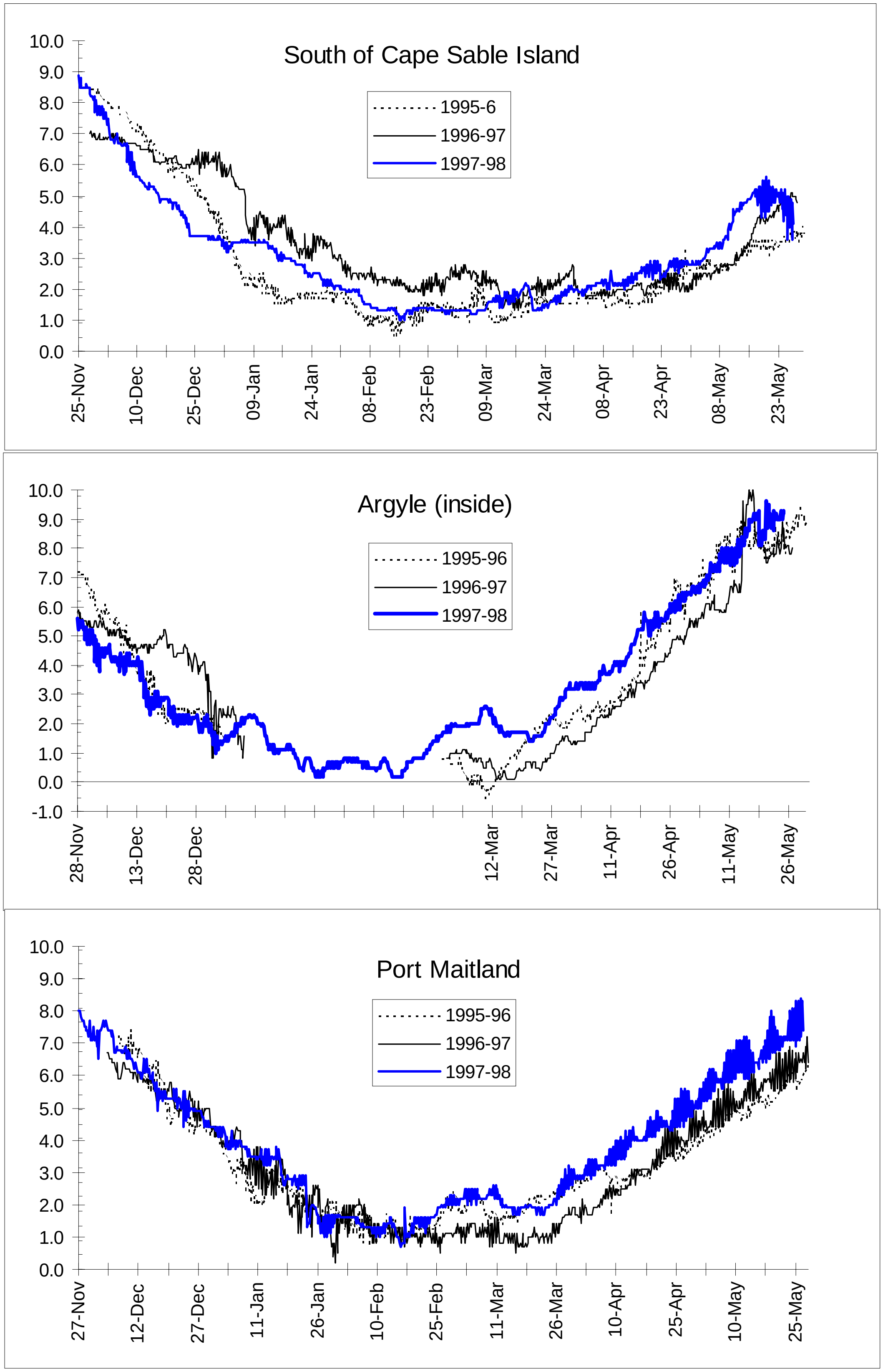


Figure 14. The water temperatures (degrees Celsius) of South of Cape Sable Island, Argyle and Port Maitland from 1995-97.

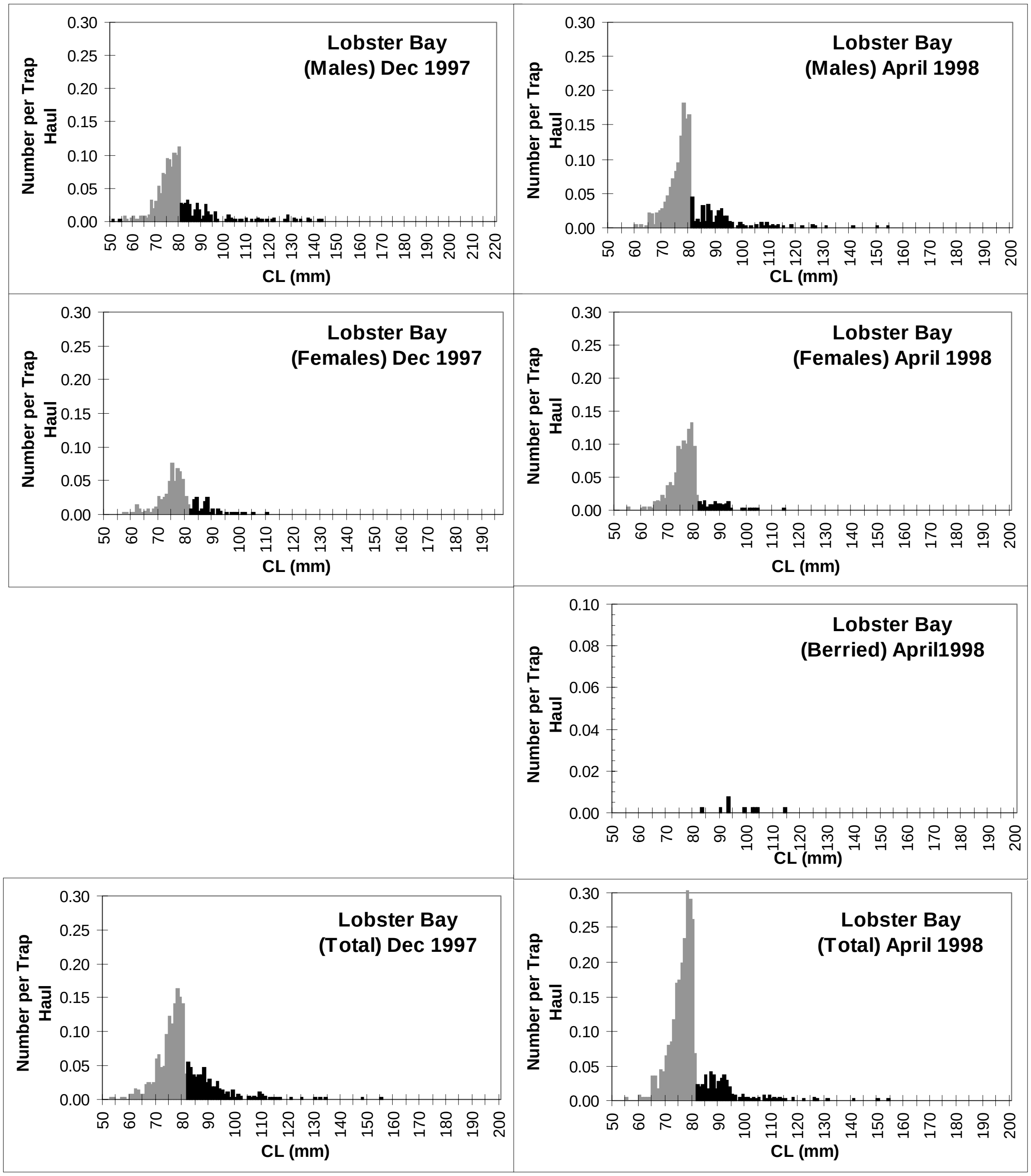


Figure 15a. Length frequencies of males and females from sea samples taken in Lobster Bay during the 1997-98 fishing season.

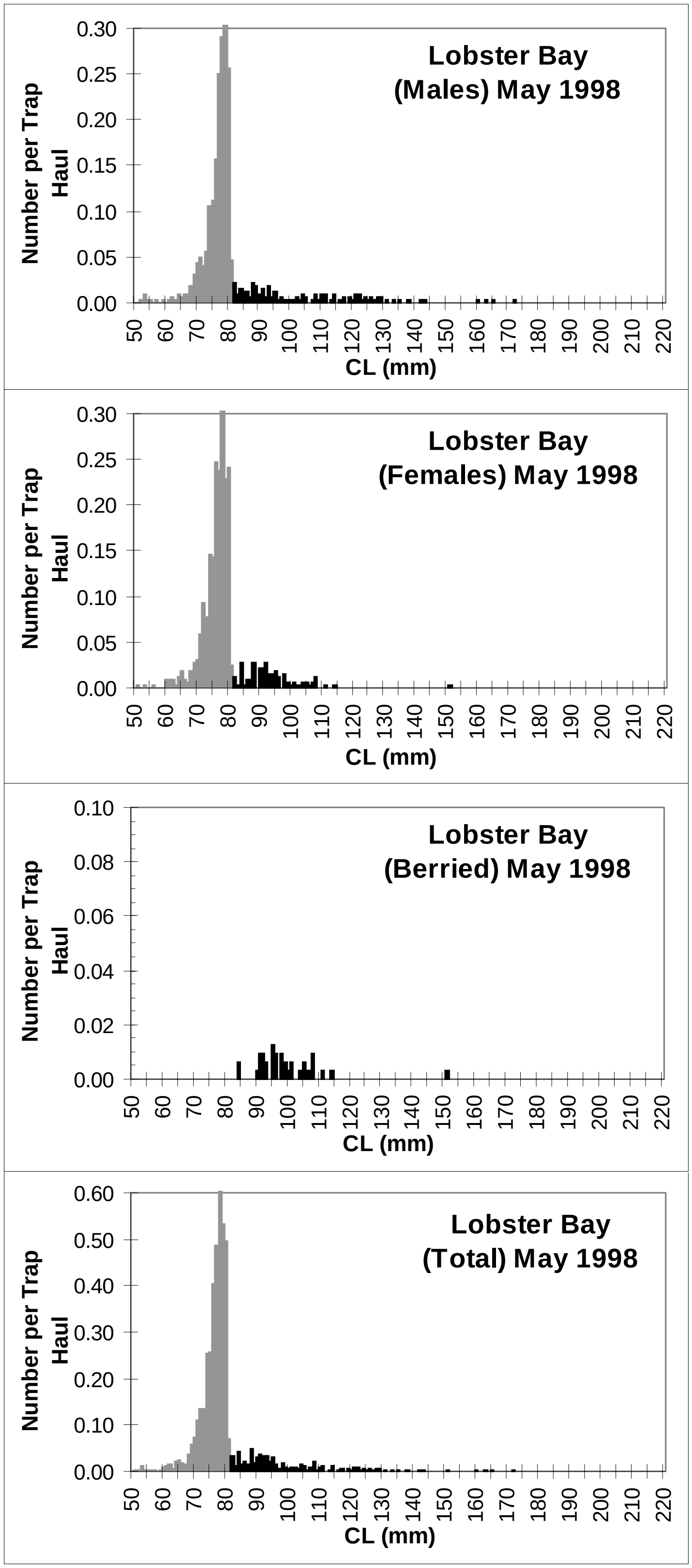


Figure 15b. Length frequencies of males and females from sea samples taken in Lobster Bay during the 1998 fishing season.

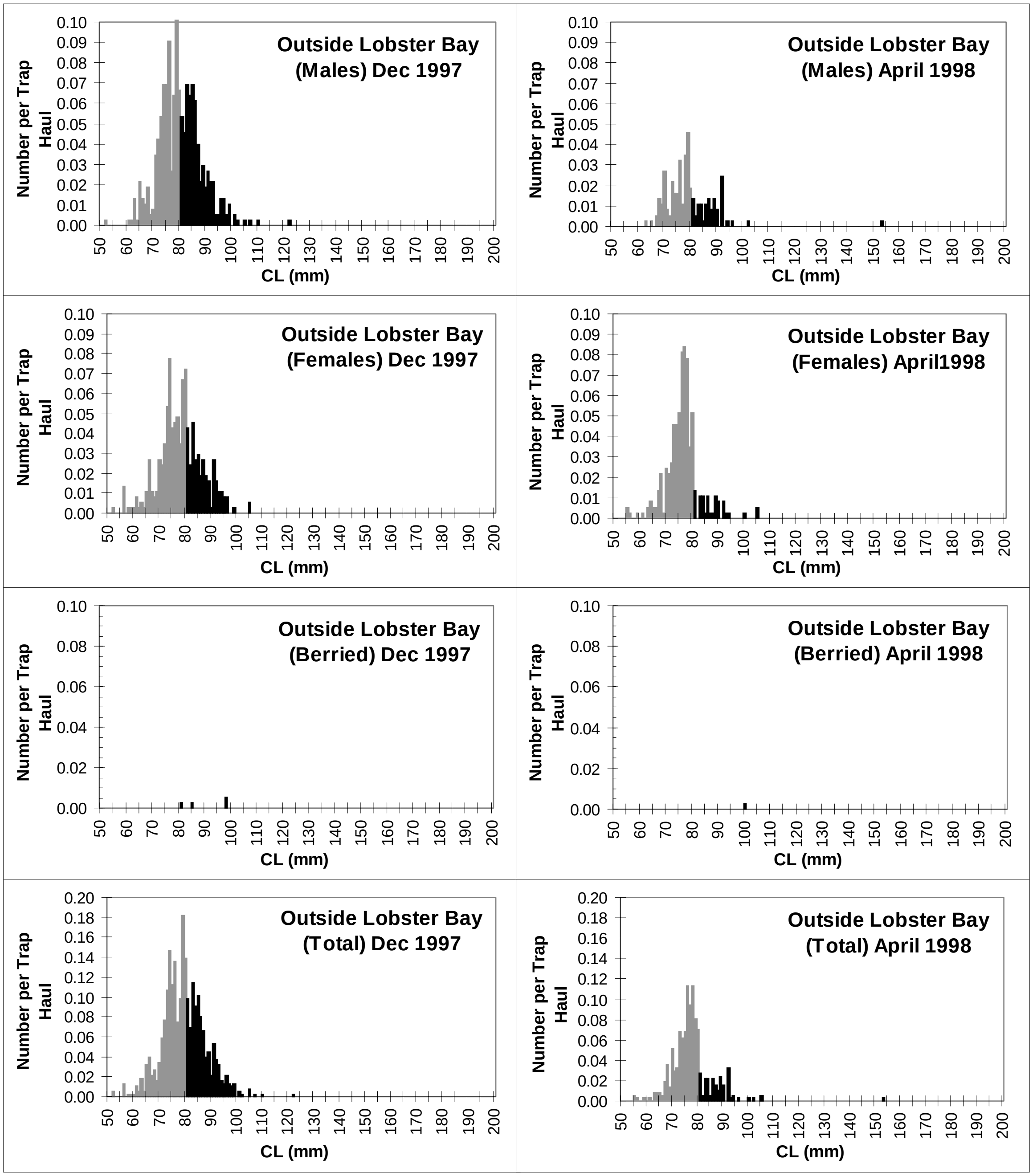


Figure 16a. Length frequencies of males and females from sea samples taken outside of Lobster Bay during the 1997-98 fishing season.

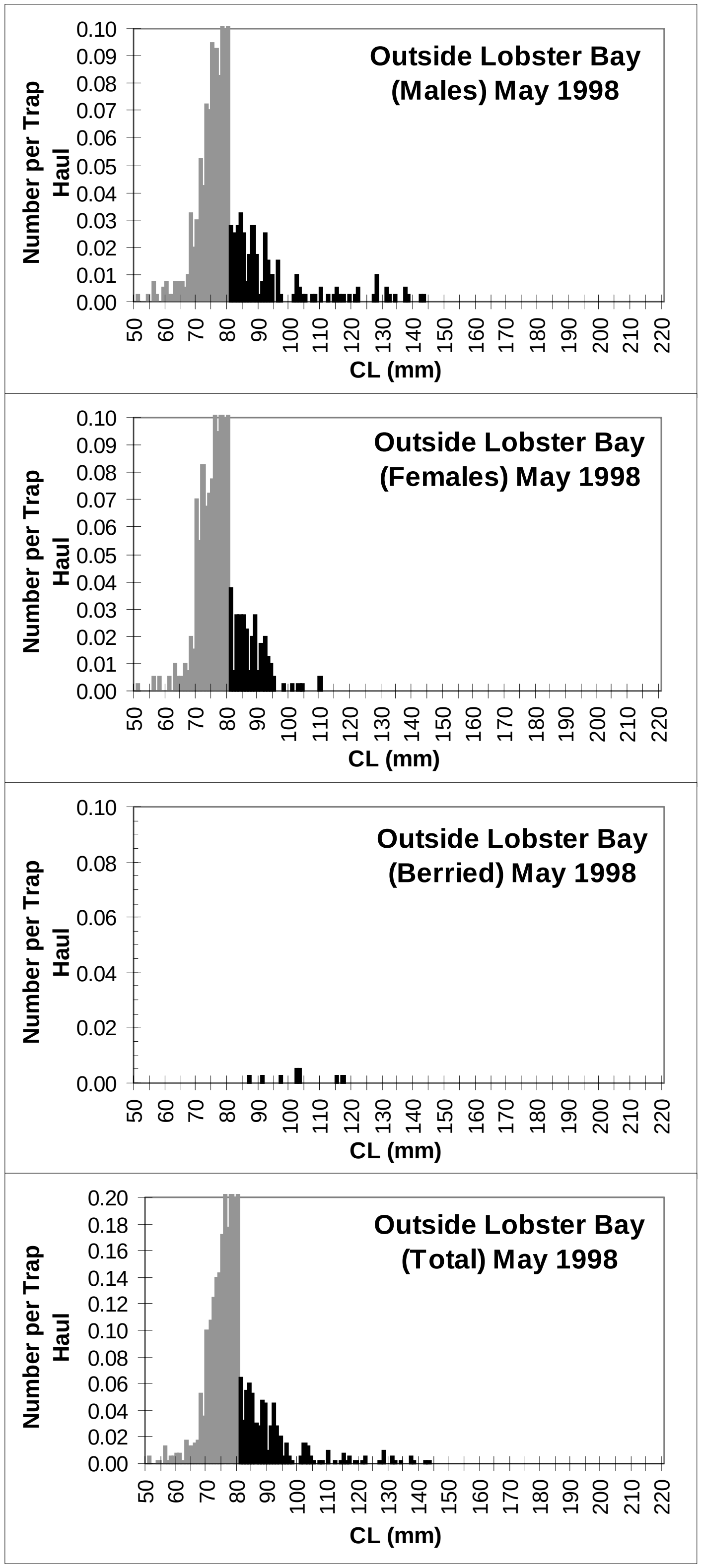


Figure 16b. Length frequencies of males and females from sea samples taken outside of Lobster Bay during the 1998 fishing season.

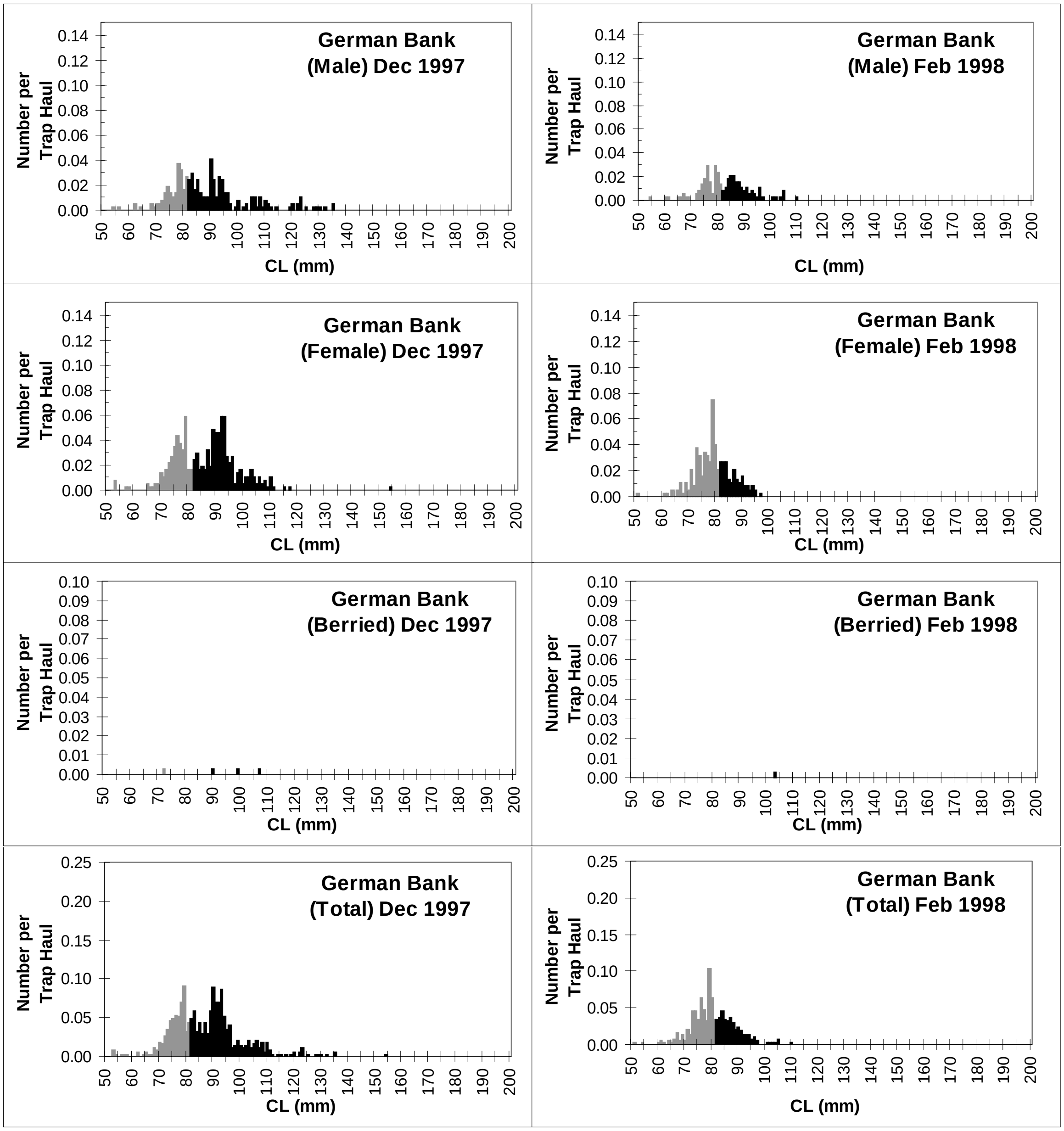


Figure 17a. Length frequencies of males and females from sea samples taken around German Bank during the 1997-98 fishing season.

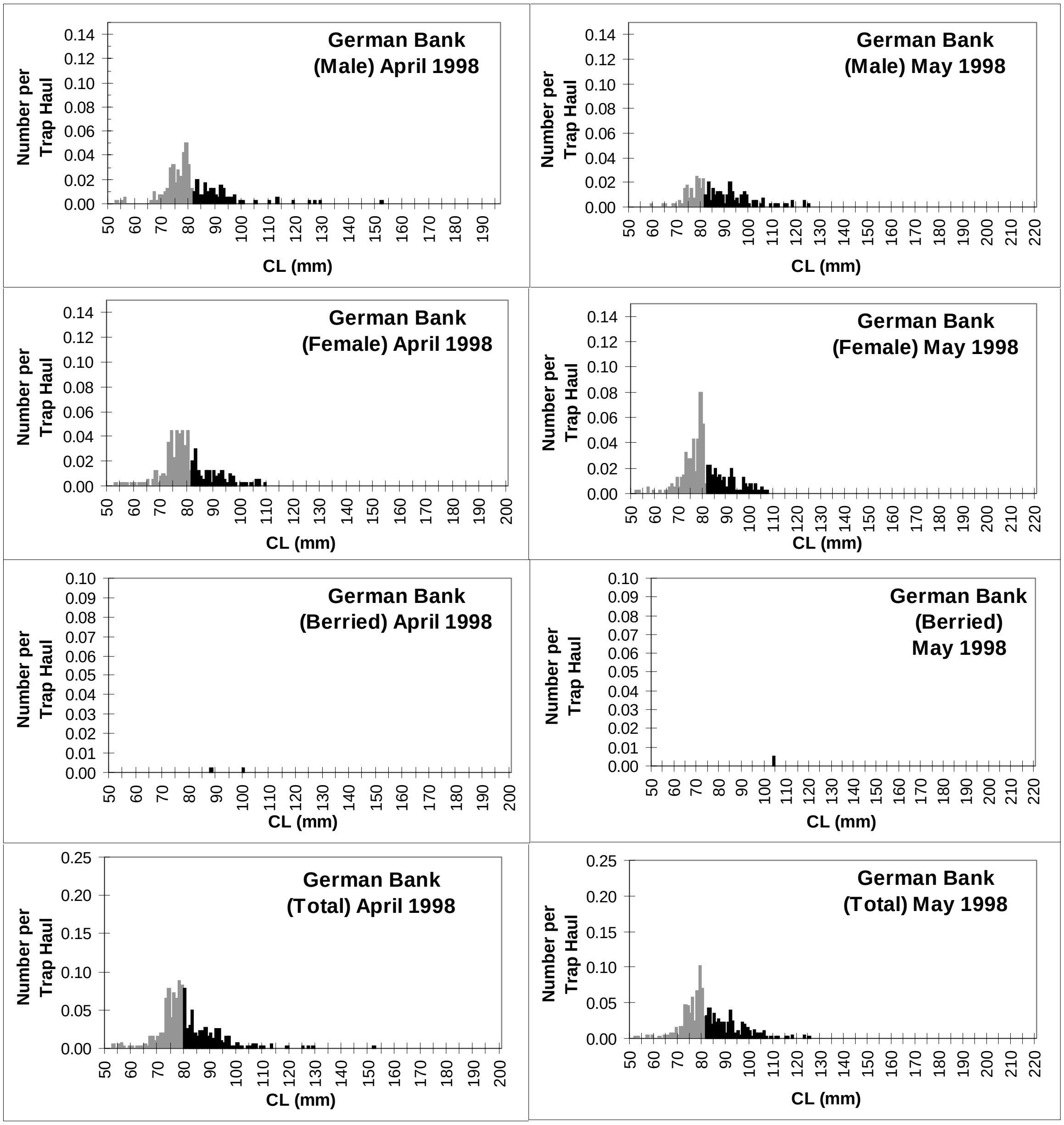


Figure 17b. Length frequencies of males and females from sea samples taken around German Bank during the 1998 fishing season.

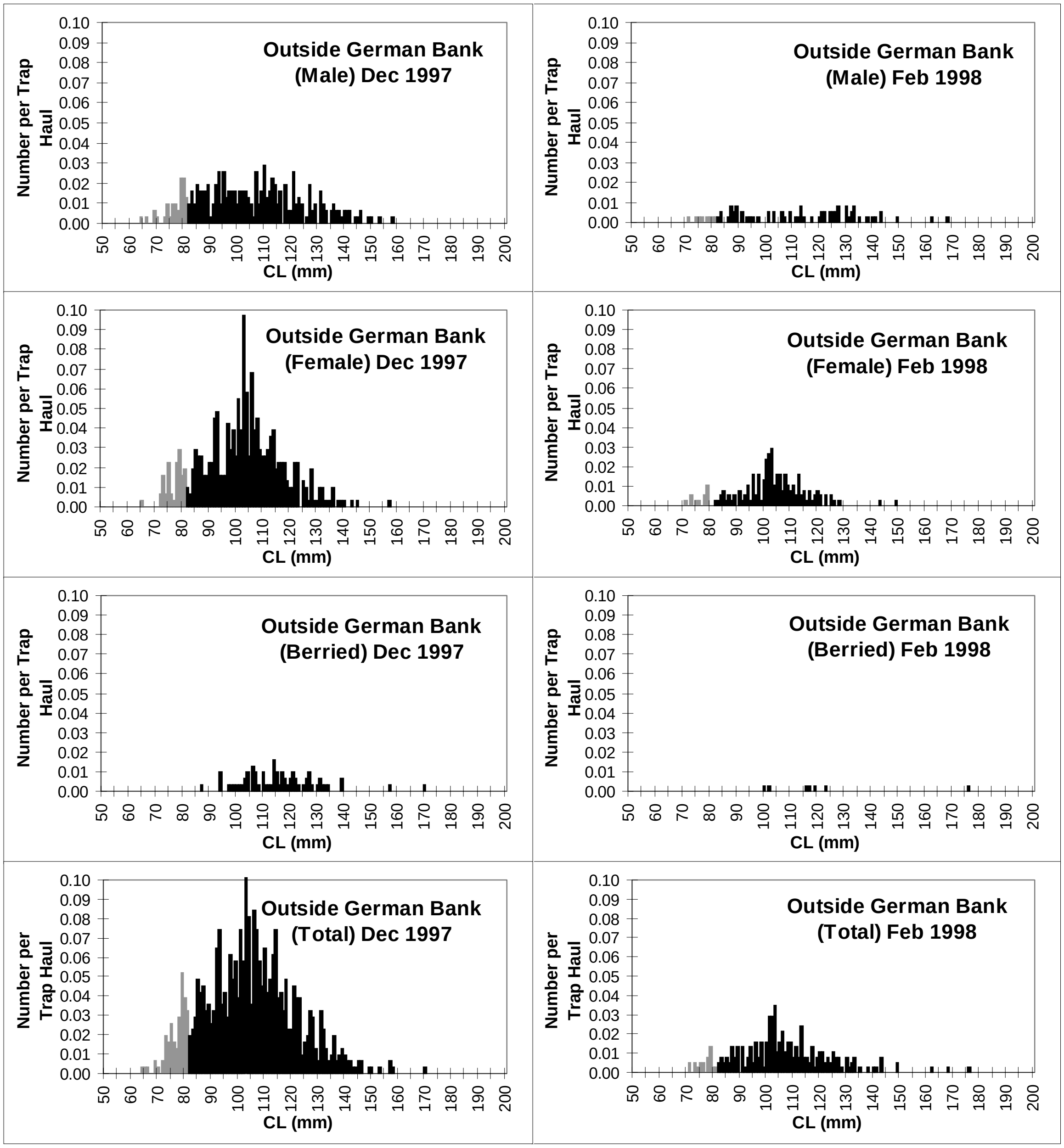


Figure 18. Length frequencies of males and females from sea samples taken outside of German Bank during the 1997-98 fishing season.

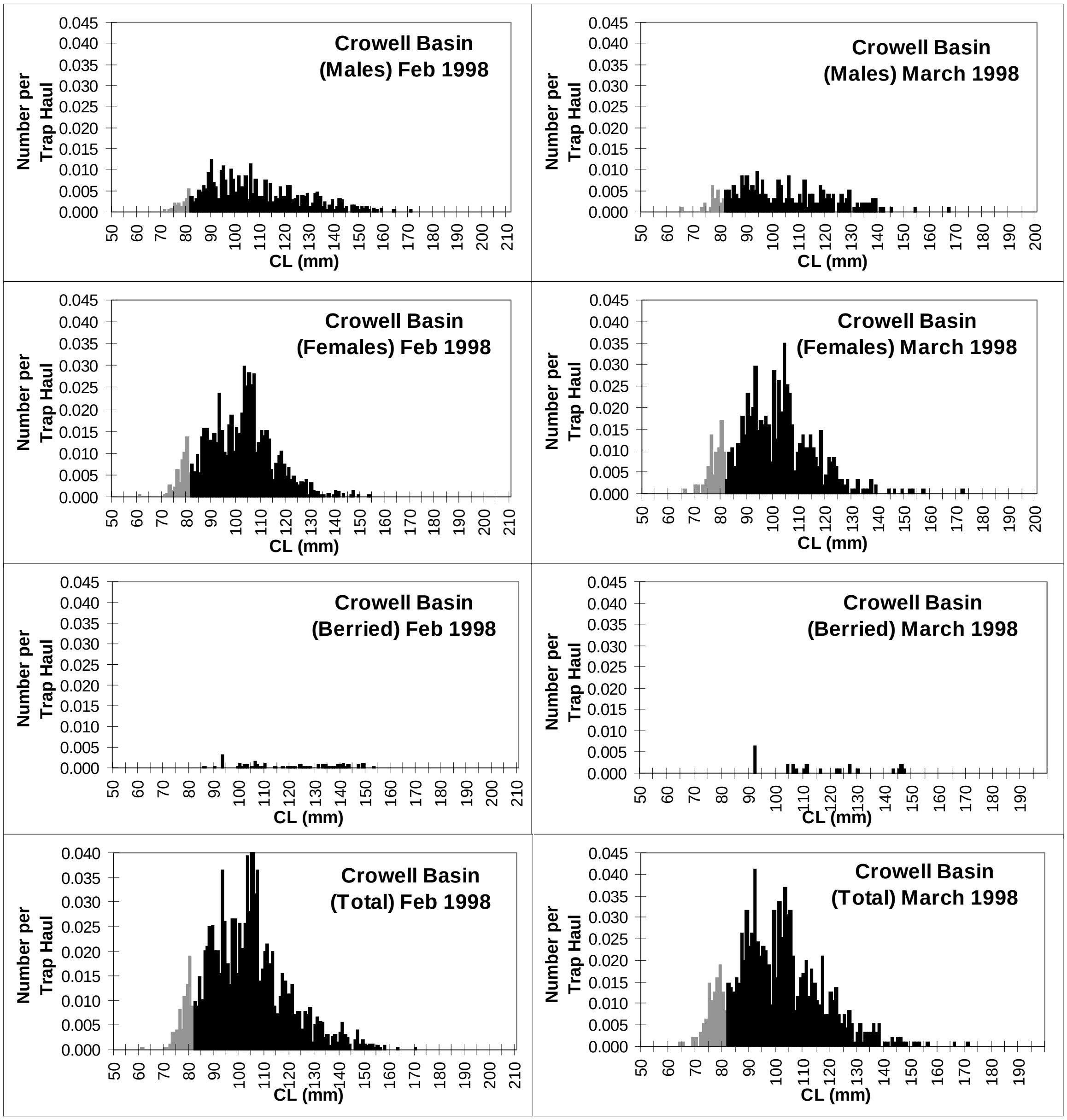


Figure 19. Length frequencies of males and females from sea samples taken from Crowell Basin(offshore) during the 1997-98 fishing season.

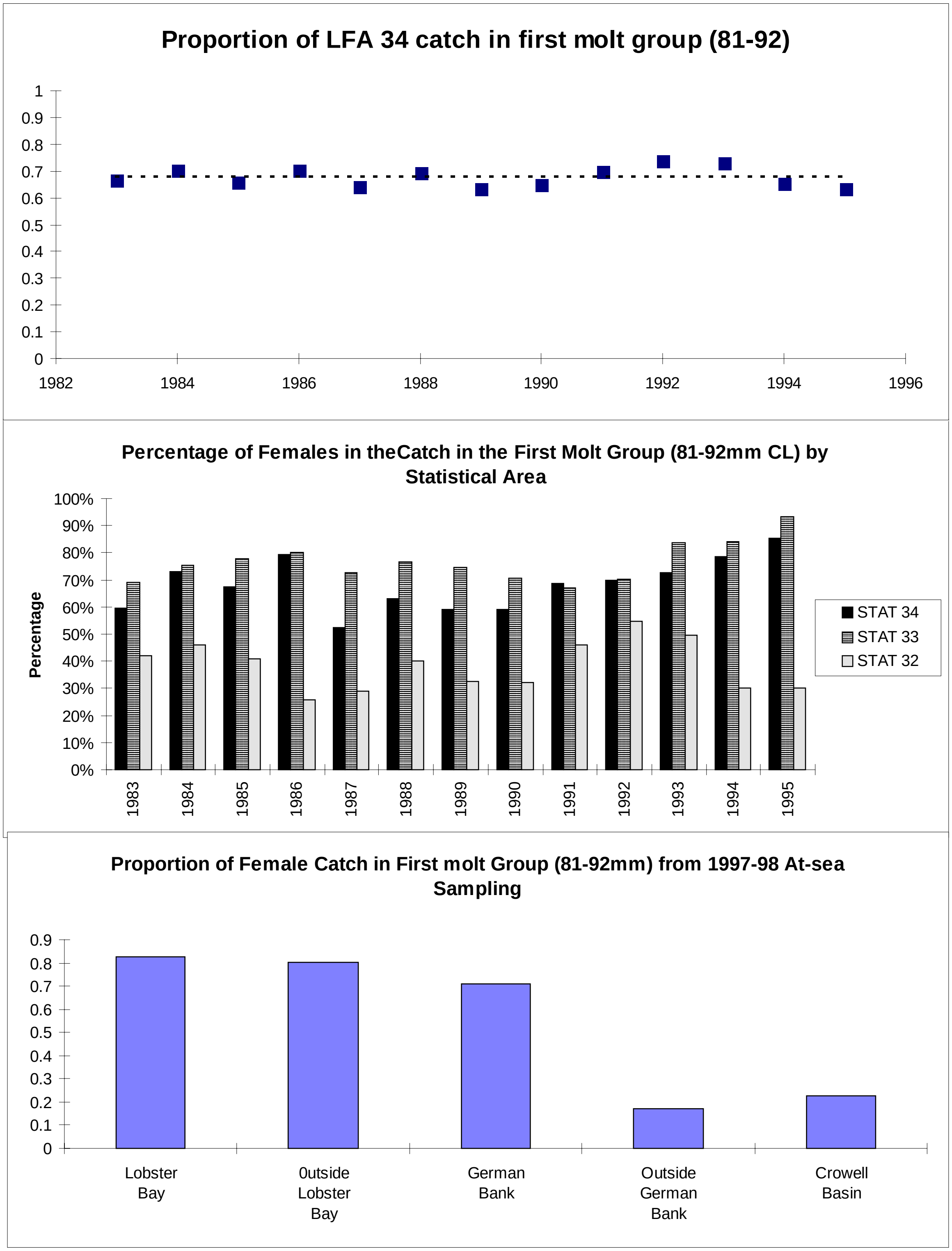


Figure 20 a. The proportion of lobsters landed in LFA 34 in the first molt group (81-92mm).
b. The percentage of females landed in Statistical Areas 32, 33, & 34 in the first molt group (81-92mm).
c. Female in the First Molt Group (81-92mm) from sea samples in Lobster Bay, outside Lobster Bay, German Bank, outside German Bank, & Crowell Basin

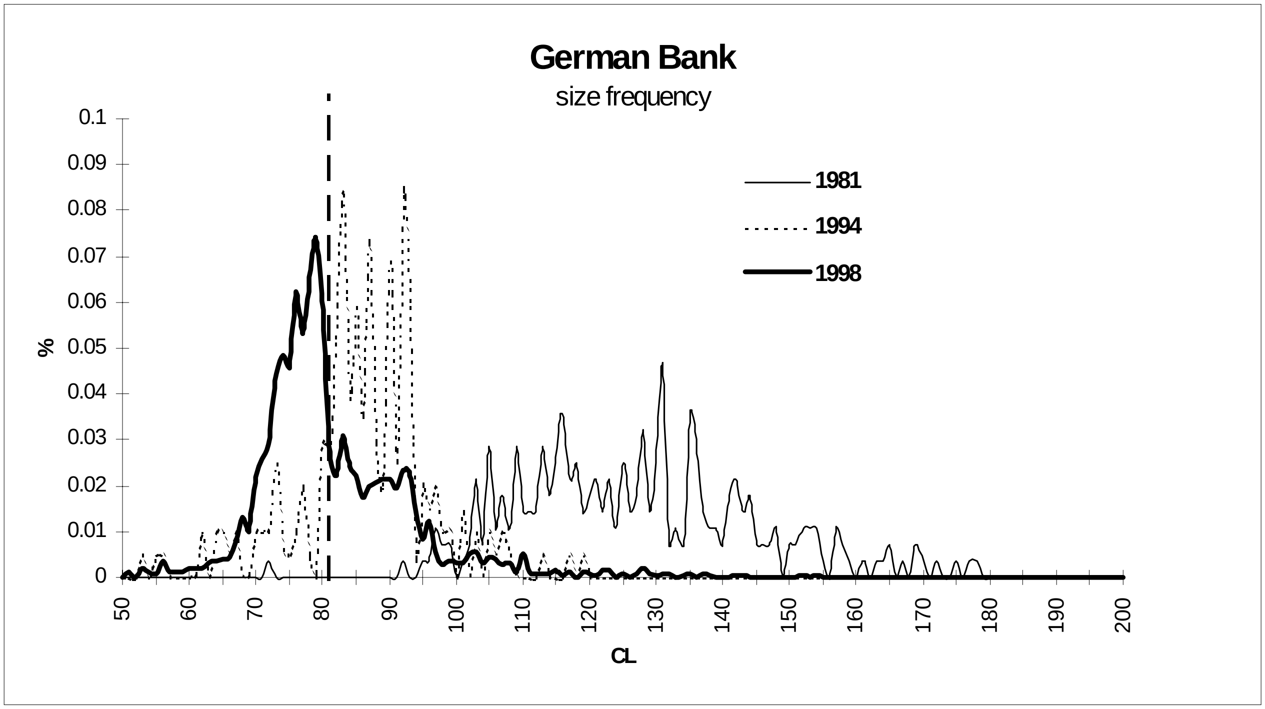


Figure 21. Size frequency changes in American lobster (*Homarus Americanus*) between 1981 - 1998 on German Bank.

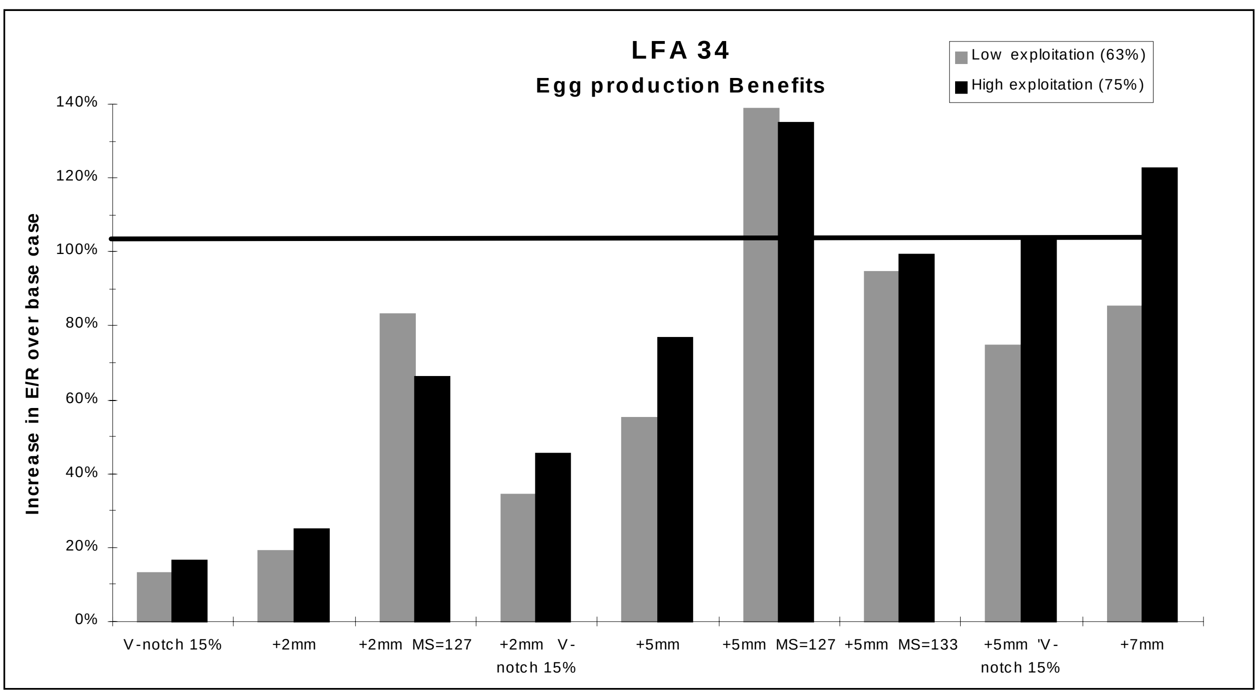


Figure 22. The predicted benefits of various strategies to increase egg production in LFA 34 based on output of the E/R model.

APPENDIX 1: E/R MODEL DESCRIPTION INPUTS

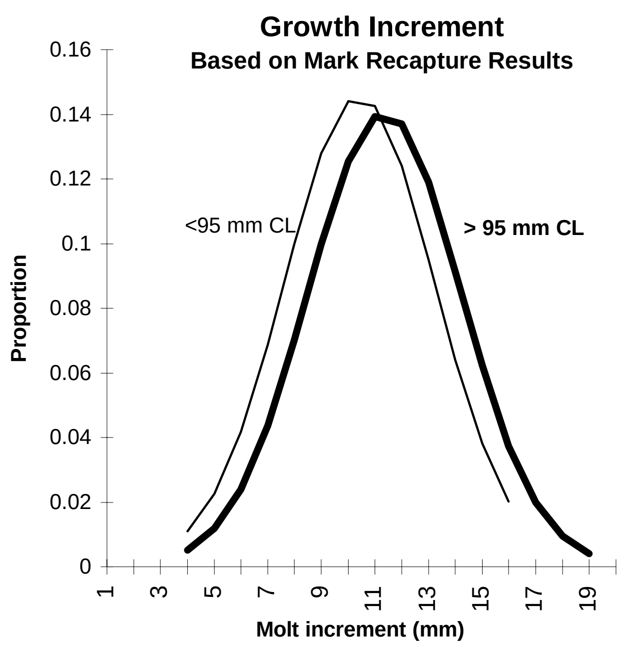
Category	Parameter	Description	Default
Model	**Years to run**	Maximum number of years the model will simulate	100 years
	Maximum size	Largest animals allowed in model (growth stops at this size but animals continue to reproduce until they disappear due to natural mortality or fishing)	300mm
	Starting size	Smallest size used in model	50mm
	Frequency of calculations	Frequency at which animals move between the seven states a female can be in.	1/4 year
Biology	**Size at maturity**	The relationship between size and maturity. Determine separately for each LFA as it varies with local temperature conditions	
	Number of eggs at size	The relationship between egg number and female size. A single relationship is used for all area	(Campbell and Robinson 1983)
	Weight at size	Weight in grams at size	varies between areas
	Natural mortality	Natural mortality is difficult to estimate and is likely size dependent. The model allows input of a hard shell mortality and a molting mortality.	Hard-shell 0.10 Molting 0.05
	Molt increment	The size increase with each molt. The model inputs this as a distribution rather than single point estimate. Different distributions can be entered for three different size ranges.	normal distribution mean of 11mm
	Intermolt period	The time between molting which varies with size Intermolt period is based on estimates from laboratory work that indicated that mature animals follow a molting schedule which is size dependent.(Waddy and Aiken 1991) The model does not allow double extrusions Double extrusion from a single molt have been observed in the lab (Waddy and Aiken 1986)but not confirmed in the field.	Immature animals molt at least once per year. Maximum intermolt i4 years
	Proportion double molting	At smaller sizes it is possible for animals to molt twice in a single year. The proportion of these at-size can be included in the model	Data is often lacking on double molting. Where available it is included.
Fishery	**Minimum size**	Minimum legal size	varies
	Maximum size	Maximum legal size	varies
	proposition of fishery using Maximum size	If all parts of the stock are not using a maximum legal size then this the proportion that are is entered	varies

Proportion of females lobsters caught by fishermen which will be v-notched	An estimate of the proportion of berried female lobsters that will be notched when caught. Must consider availability of females to the catch, and participation rate by fishermen	varies
Partial recruitment	Availability at size to the fishery. Generally a knife edge recruitment is used at the minimum legal size, but this gives the option of applying lower catch abilities at size or including some level of catch below the legal size	knife edge at minimum size

Sample of LFA 34 input file FORT8

```
1)    50 280 1.0 0.0 125 0.25
2)    0.1 0.05 81 300
3)    0.50 0.15 .35 0.0
4)    5 5 5 13 16 16
5)    0.013   0.028   0.052   0.0815  0.113   0.138   0.149   0.138   0.113   0.0815  0.052   0.028
        0.013
6)    0.0009  0.0284  0.0515  0.0806  0.1115  0.1365  0.1474  0.1365  0.1115  0.0806  0.0515  0.0286
        0.0144  0.0065  0.0026  0.0009
7)    0.0009  0.0284  0.0515  0.0806  0.1115  0.1365  0.1474  0.1365  0.1115  0.0806  0.0515  0.0286
        0.0144  0.0065  0.0026  0.0009
```

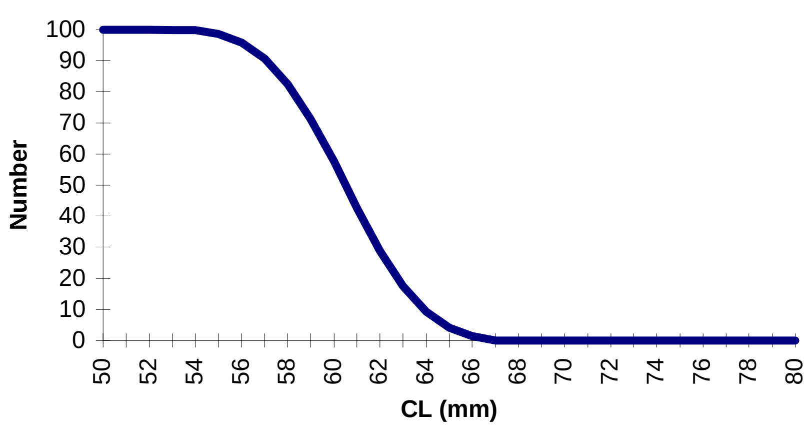
Line 1	50 min. starting size
	280 Max. size used in model
	1.0 % of fishery with max. size rule (set to 1 if n/a)
	0.0 % v-notching (% of animals caught which fishermen notch)
	125 Number of years model runs
	0.25 analysis done quarterly (3 month)
Line 2	0.1 Hard shell M
	0.05 soft shell M (only applied at molt)
	81 Minimum size
	300 Maximum size (in Maine this would be 127. It is set at 300 to be greater than maximum size in the model if there is no maximum size regulation)
Line 3	0.50 proportion catch in Q1 October-December
	0.15 proportion catch in Q2 Jan-March
	0.35 proportion catch in Q3 April-June
	0.00 proportion catch in Q4 July-Sept. (period of molting event)
Line 4	5 6 6 smallest molt increment for each of the 3 size ranges
	number of increments in the distribution molt increments
Line 5	distribution of molt increments first size range
Line 6	distribution of molt increments second size range
Line 7	distribution of molt increments third size range



Sample of LFA 34 input file FORT11
Tested fishing mortality (F) and starting size distribution

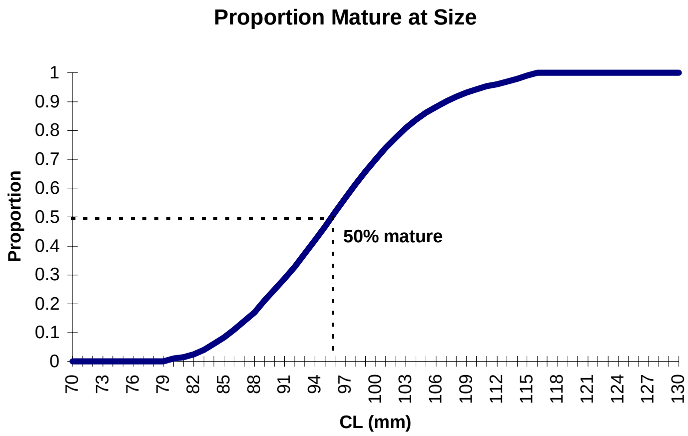
input	Description
0.0	***Test F***
gtst5500	***Specifies file out put name***
gtst55 Mort 0.10, F = 0.0	***Headings for output file***
50 17	***Starting size and number of size groups in starting population***
100 100 100 99.9 99.9 98.7 95.9 90.7 82.5 71.3 57.5 42.6 28.8 17.5 9.3 4.1 1.3	
	Distribution of animals within starting size groups
0.625	
gtst55625	
gtst55 Mort 0.010, F = 0.625	
50 17	
100 100 100 99.9 99.9 98.7 95.9 90.7 82.5 71.3 57.5 42.6 28.8 17.5 9.3 4.1 1.3	
0.675	
gtst55675	
gtst55 Mort 0.05, F = 0.675	
50 17	
100 100 100 99.9 99.9 98.7 95.9 90.7 82.5 71.3 57.5 42.6 28.8 17.5 9.3 4.1 1.3	

Starting Size distribution

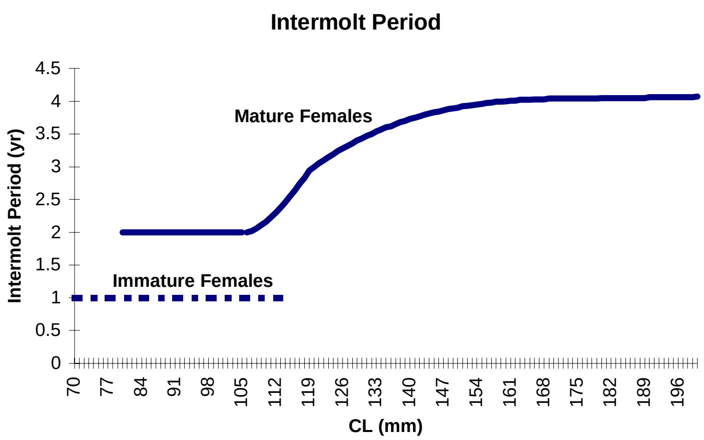


Sample of LFA 34 input file FORT99
Proportion mature, double molt, intermolt period, partial recruitment, fecundity, weight

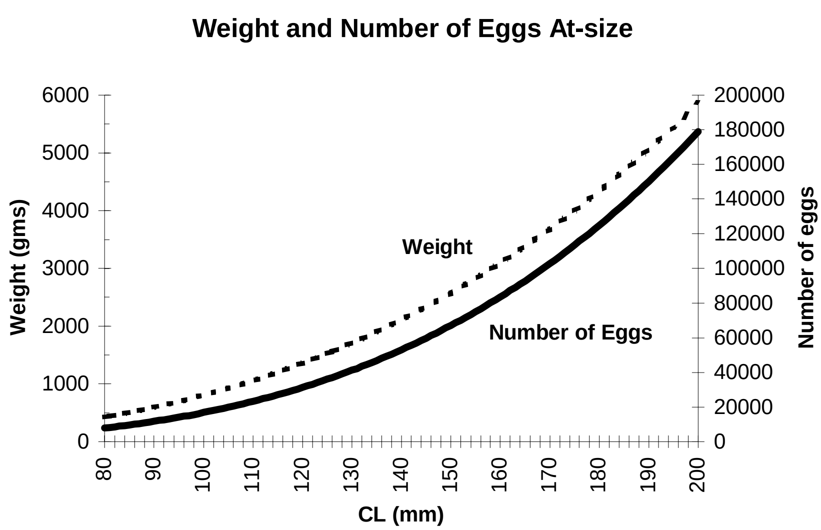
CL (mm)	Proportion Mature	Proportion Double Molting	Intermolt Period (yr.)	Integer intermolt	Partial Recruitment	Egg number	Weight (gm)
50	0	0	1	1	0	2193	111
51	0	0	1	1	0	2193	118
52	0	0	1	1	0	2193	124
...							
...							
78	0	0	1	1	0	7218	396
79	0	0	1	1	0	7538	411
80	0.01	0	1	2	0	7868	426
81	0.015	0	1.01	2	0	8209	441
82	0.025	0	1.02	2	0	8559	457
83	0.04	0	1.03	2	0	8920	473
84	0.062	0	1.04	2	1	9292	490
85	0.083	0	1.05	2	1	9675	507
86	0.109	0	1.06	2	1	10068	524
87	0.14	0	1.07	2	1	10473	542
88	0.17	0	1.08	2	1	10889	560
89	0.21	0	1.09	2	1	11316	578
90	0.249	0	1.1	2	1	11756	597
91	0.287	0	1.11	2	1	12207	616
92	0.329	0	1.12	2	1	12670	635
93	0.373	0	1.13	2	1	13146	655
94	0.42	0	1.14	2	1	13634	676
95	0.468	0	1.15	2	1	14135	697
96	0.517	0	1.17	2	1	14649	718
97	0.566	0	1.36	2	1	15176	739
98	0.613	0	1.42	2	1	15716	761
99	0.658	0	1.55	2	1	16269	784
100	0.701	0	1.65	2	1	16836	807
101	0.74	0	1.75	2	1	17417	830
102	0.776	0	1.85	2	1	18012	854
103	0.808	0	1.9	2	1	18621	878
104	0.837	0	1.95	2	1	19245	902
105	0.862	0	1.97	2	1	19883	928
106	0.883	0	2	3	1	20536	953
107	0.902	0	2.02	3	1	21204	979
...							
...							
118	1	0	2.83	3	1	29600	1295
119	1	0	2.94	3	1	30463	1327
120	1	0	3	4	1	31345	1359
121	1	0	3.05	4	1	32244	1392
122	1	0	3.1	4	1	33162	1425
123	1	0	3.15	4	1	34098	1459
124	1	0	3.19	4	1	35052	1493
125	1	0	3.24	4	1	36025	1527
126	1	0	3.28	4	1	37017	1563
...							
...							
...							
140	1	0	3.73	4	1	53014	2112
141	1	0	3.75	4	1	54316	2156
142	1	0	3.77	4	1	55640	2200
143	1	0	3.79	4	1	56988	2244
144	1	0	3.81	4	1	58358	2290
145	1	0	3.83	4	1	59751	2335
146	1	0	3.84	4	1	61167	2382
147	1	0	3.86	4	1	62607	2429
148	1	0	3.88	4	1	64071	2476
149	1	0	3.89	4	1	65559	2525



Proportion Mature at Size
Proportion
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
50% mature
70
73
76
79
82
85
88
91
94
97
100
103
106
109
112
115
118
121
124
127
130
CL (mm)



Intermolt Period
Intermolt Period (yr)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Mature Females
Immature Females
70
77
84
91
98
105
112
119
126
133
140
147
154
161
168
175
182
189
196
CL (mm)



Weight and Number of Eggs At-size
Weight (gms)
6000
5000
4000
3000
2000
1000
0
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Number of eggs
Weight
Number of Eggs
80
90
100
110
120
130
140
150
160
170
180
190
200
CL (mm)

Summary output table showing out put used:

fnom	Nominal F
vul_f	Vulnerable F
tot_m	Total M
vnotch	Number V-notched
tot_eggs	Total Eggs
%maxeggs	% of maximum Eggs (F=0.0)
YTE	Years to extinction

fnom	tot_z	tot_f	vul_z	**vul_f**	**tot_m**	**vnotch**	**tot_eggs**	**%maxeggs**	yield	**YTE**
0	0.1468	0	0.1444	0	0.1468	0	8.38E+08	1	0	102
0.1	0.1906	0.0427	0.2139	0.0684	0.1479	0	3.48E+08	0.4154	3075.46	71
0.2	0.2269	0.0785	0.2876	0.1414	0.1485	0	1.82E+08	0.2174	3866.36	55
0.3	0.2578	0.109	0.3654	0.2189	0.1488	0	1.07E+08	0.1278	4107.2	45
0.4	0.2844	0.1355	0.4473	0.3004	0.1489	0	67451450	0.0804	4167.79	39
0.5	0.3078	0.1588	0.5326	0.3857	0.149	0	44410430	0.053	4160.4	34
0.6	0.3286	0.1797	0.6208	0.4739	0.149	0	30212010	0.036	4126.76	30
0.7	0.3474	0.1985	0.7116	0.5647	0.1489	0	21081170	0.0251	4084.26	28
0.8	0.3644	0.2156	0.8043	0.6576	0.1488	0	15016670	0.0179	4040.48	25
0.9	0.3801	0.2313	0.8985	0.752	0.1487	0	10886090	0.013	3998.83	23
0.95	0.3874	0.2387	0.9463	0.7998	0.1487	0	9323469	0.0111	3979.3	23
1	0.3945	0.2459	0.9943	0.8478	0.1486	0	8013743	0.0096	3960.71	22
1.02	0.3973	0.2487	1.0136	0.8672	0.1486	0	7550287	0.009	3953.55	22
1.05	0.4013	0.2528	1.0423	0.896	0.1486	0	6911567	0.0082	3943.11	21
1.1	0.408	0.2595	1.0907	0.9444	0.1485	0	5980638	0.0071	3926.52	21
1.2	0.4205	0.2721	1.1878	1.0417	0.1484	0	4519159	0.0054	3896.22	19
1.3	0.4323	0.2841	1.2855	1.1396	0.1482	0	3454494	0.0041	3869.62	18