DFO Atlantic Fisheries
Research Document 96/138

MPO Pêches de l'Atlantique
Document de recherche 96/138

Review of the Canadian Exploratory Offshore Fishery for Red Crab, *Chaceon quinquedens*

D.R Duggan[1] and P. Lawton[2]

Marine Invertebrate Fisheries Division
Science Branch
Department of Fisheries and Oceans
Maritimes Region

[1]Halifax Fisheries Research Laboratory, PO Box 550, Halifax, N.S. B3J 2S7

[2]Biological Station, St. Andrews, N.B. E0G 2X0

ABSTRACT

The catch history and management framework for an exploratory offshore fishery for the red crab, *Chaceon (=Geryon) quinquedens*, in Canadian waters of the Scotian Shelf and Georges Bank is reviewed from the inception of sporadic trapping in the late 1960's to the current development phase which has five exploratory licenses. The offshore red crab fishing grounds are now considered to be fully exploited, based on examination of monthly landings, and catch rates from log books, sales slips and dockside monitoring documents, together with sampling of commercial catch length frequencies, mainly from port sampling.

Catch rates (CPUE) decreased progressively from initial levels of up to 20 kg per trap haul (kg/th) in 1984, but may have stabilized in the last two years at between 5-10 kg/th. Total effort has increased, particularly in 1995 and 1996, where between 10,000-20,000 trap hauls were made monthly in the spring (April-July), as compared to approximately 5,000 trap hauls per month in previous years. While average size (carapace width, CW) of crab measured in port samples has not declined since the fishery began, crab landed from Emerald and LaHave banks tends to be smaller than that from Georges and Browns banks.

The original commercial biomass estimate, and total allowable catch (TAC) of 1300 metric tonnes (mt) under which the current fishery operates did not consider Georges Bank. If landings from Georges Bank are excluded (approximately 30% of current landings), expanded levels of fishing effort in the areas of initial biomass estimation have not yielded landings anywhere near original expectations. Preliminary resource surveys and initial catch rates on LaHave Bank indicate that red crab will enter traps in high numbers, so current low monthly CPUE's and annual landings may reflect lower population abundance, and unrealistic assumptions in the original scientific assessment. While the harvest experience to date indicates the potential for a permanent fishery, conversion of existing exploratory licenses to permanent ones is considered premature in 1997. This fishery should be managed conservatively, perhaps with a precautionary cut to the existing TAC to better match the emerging landings pattern. A revised TAC cannot presently be determined on a biological basis until additional information on red crab biology and stock dynamics becomes available.

RÉSUMÉ

Les prises historiques et la structure de gestion pour une pêcherie hauturière de crabe rouge, *Chaceon quinquedens*, dans les eaux canadiennes du plateau Néo-écossais et du Banc George sont révisées à partir du début sporadique de cette pêcherie, tard dans les années 1960, jusqu'à la phase présente de dévelopement avec cinq permits actifs. Basé sur les prises mensuelles, les taux de capture à partir des livres de bord, les documents de vente et du programmes de vérification au quai, en plus des échantillons de fréquence de taille principalement messurés au quai, les fonds de pêche au crabe rouge sont maintenant tous exploités.

Les taux de capture (PPUE) ont diminués à partir de taux élevés, jusqu'à 20 kg par casier levé (kg/cl) en 1984, et ont semblé se stabiliser entre 5 et 10 kg/cl durant les deux dernière années. Inversement l'effort total à augmenté, en particulier en 1995 et 1996, durant lesquelles entre 10000-20000 casiers ont été levés mensuellement durant le printemps (avril-juillet), en comparaison avec approximativement 5000 casiers levés par mois durant les années précédentes.

La taille moyenne (largeur de la carapace, LC) des crabes messurés au port n'a pas diminué depuis le début de cette pêcherie. Par contre la taille des crabes provenant des bancs Emerald et LeHave est généralement plus petite que celle provenant des bancs George et Browns. La taille minimale canadienne (100 mm LC) a été établit d'après des études faites dans la partie sud de l'habitat du crabe rouge et devrait être révisée en se basant sur la taille à maturité de crabes provenant des fonds canadiens de pêche.

L'estimation initiale de la biomass, et la dérivation des prises totales allouées (TPA) de 1300 t, sous lesquelles les cinq bateaux de pêche sont maintenant gérés, n'incluent pas le banc George. Si les débarquements du banc George sont enlevés, l'expension du niveau d'effort de pêche dans les région initale de l'estimation de biomass a produit des débarquements pas du tout près du quota original. Des études initiales des taux de capture sur le banc LeHave indiquent que le crabe rouge est capable d'entrer dans les casiers en grand nombres. Donc, la diminution des débarquements annuels et des PPUE mensuelles pourrait refléter une diminution d'abandance dans la population.

Jusqu'à date, même si l'expérience de cette pêcherie démontre un potentiel pour une pêcherie permanente pour un nombre limité de bateaux, la conversion de cette pêcherie est peut-être prématurée pour la saison de 1997. On devrait pas continuer à géré cette pêcherie on se basant sur un TPA jusqu'à ce que des meilleurs estimations de stock peuvent être disponible.

INTRODUCTION

Biological Background

The deep-sea red crab, *Chaceon (=Geryon) quinquedens*, is found in the western Atlantic from Nova Scotia to Argentina (Rathbun, 1937; Scelzo and Valentini, 1974). The species occurs at depths between 40 m and over 2,000 m on mud, sand or hard bottom where temperatures range from 3.6 - 12.7° C. However, populations are more abundant from 300 to 900 m, ranging between 5-8°C.

The red crab is an active, agile crab with moderately long legs relative to its carapace size. Males and females have similar external proportions and features except for the abdomen (Fig. 1). The abdomen of the female changes in shape and relative size at maturity (Haefner, 1977); its broad bulk serving to shield the extruded eggs. Males reach a maximum carapace width (CW) of 178 mm, and wet weight of 1.7 kg. Females may reach 136 mm CW and 0.7 kg, but are commonly less than 120 mm CW and 0.5 kg (McElman and Elner, 1982).

Although the red crab is an important member of the deep-water benthic community on the continental shelf and the slope of the western Atlantic, the ecology and behaviour of this crab are poorly understood. In a review of the biology of the deep-sea red crab, Elner (1986) noted that this crab had been observed on a "mud-clay base with sea anemones" habitat (Cooper and Uzmann, 1980). The fact that red crabs have been observed digging suggests that burrowing animals may be incorporated into the diet (Elner, 1986). Recent observations from a manned submersible at a continental slope site at 712m depth (Auster et al., 1991) revealed *Chaceon quinquedens* to be distributed randomly across the range of microhabitat types sampled, indicating a capability to forage widely.

Laboratory observations on the mating behaviour of the red crab show that the male initiates protection of the female as many as 13 days before the female molt (Elner et al., 1987). Copulation, with the newly-moulted female inverted under the male, may continue for 11.5 d. Egg-bearing females are present year-round off New England, with a peak incidence in November (Haefner, 1978). Between 90,000 and 210,000 eggs are carried (Caddy et al., 1974). Egg hatching off New England is most prevalent from January to June but may continue through the summer months (Haefner, 1978; Lux et al., 1982). The larvae develop through a prezoeal stage, four zoeal stages and one megalopa stage before settling to the bottom. Substantial numbers of larvae have been collected between Georges Bank and Halifax in coastal waters, and out to 270 km offshore, at surface temperatures ranging from 6-19°C, and salinities from 29 to 33 °/oo (Roff et al. 1986). The duration of the larval stages is temperature dependent. Total planktonic development time for the larvae is estimated between 23 d and 125 d for temperatures of 6-10 °C and 25°C, respectively (Rosowski, 1979; Kelly et al., 1982).

Larval settlement is thought to occur at the base of the continental slope (Wigley et al., 1975; Kelly et al., 1982). Immediately after the larval settlement an upslope migration to warmer water (>6°C) probably occurs to enhance growth rates. Laboratory studies suggest that the red crab would require 5.3 years at 15°C, or 6.0 years at 9-12°C to attain 114 mm CW (Van Heukelem et al., 1983), the minimum legal size in the United States fishery.

Soft-shelled, newly molted, crabs may be encountered year round (Gerrior, 1981), but there is some evidence that moulting periods are offset between the sexes, with males moulting from mid-December through January, and females moulting in July and August (Gray, 1988). Egg-bearing females as small as 70 mm CW have been captured on the edge of the Scotian Shelf. However, based on sampling of red crabs from off New England, sexual maturity is thought to occur between 80-91 mm CW for females, while males are reputed to mature "at a relatively small size" (Haefner, 1977).

Following initial studies in the 1980's, a considerable body of research and assessment work has emerged on Gulf of Mexico populations of *Chaceon quinquedens*, with studies on larval distribution (Perry et al.,

1991); reproduction (Erdman et al., 1991); trapping surveys (Lockhart et al., 1990; Waller et al. 1995), and *in-situ* observations from submersibles (Lindberg and Lockhart 1993).

Fisheries Development

Interest in red crab as a commercial species has been intermittent over the last three decades. A number of surveys by both provincial and federal fisheries departments were carried out before the current phase of exploratory fishing began off the coast of Nova Scotia (Table 1). The earliest commercial fishery activity started in the late 1960's when sporadic trapping occurred off Nova Scotia. Fishing ceased in the mid-1970's due to unfavorable economic conditions. Trawling surveys by the Department of Fisheries and Oceans in the early 1980's indicated the potential for a commercial red crab fishery along the continental slope, adjacent to LaHave and Emerald banks. Commercial landings resumed in 1984, initially as by-catch to a pilot offshore Jonah crab fishery (Elner and Robichaud, 1985), then subsequently two large vessels had a directed fishery for red crab during 1984 and 1985.

A preemptive total allowable catch (TAC) was set at 1,300 mt, based on 50% exploitation of an estimated biomass of 2,600 mt , derived from a trapping survey using effective fishing area techniques (McElman and Elner, 1982). The use of a target exploitation rate of 50% was based on prevailing scientific advice provided by the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) for snow crab fisheries (Elner and Robichaud, 1985).

Due to low profitability the fishery was once again stopped after two years. In 1983, the fishery was revived when a small one-vessel experimental fishery began in the same offshore areas. The current phase of exploratory fishing has continued to expand and there are now five vessels fishing from Emerald Bank to Georges Bank, along a narrow depth range of the continental slope.

Current regulations include a TAC of 1300 mt (unchanged from scientific advice presented to management in the mid-1980's), a minimum CW of 100 mm, no retention of females, retention of male Jonah crabs with a CW > 130 mm, and a 450 trap limit. To minimize by-catch of other commercial crustaceans, fishers are restricted to depths greater than 200 fathoms (360 m).

METHODS

Fishery Data

Landings, fishing effort (trap hauls (th); days fished), and trapping location information were obtained from several sources as the current exploratory fishery developed. Compulsory logbooks have been required from 1984 to date, and sales slip information is available from 1985 to 1994. In 1994, a dockside monitoring program replaced both log and sales slip reporting. A voluntary scientific logbook program was implemented for the 1996 fishery.

Landings, location, trap hauls and days fished are accurately reported on the present dockside monitoring document (DMD) which is completed for each fishing trip. The scientific log provides greater detail on the above information, as well as an account of the catch that is not retained (discards; soft crab, females and small males). Fishing effort (trap hauls, th), and catch per unit of effort (CPUE) provide relative indices of fishery activity, and abundance of the commercial stock by fishing area. In view of the small number of participants in this exploratory fishery, high resolution data on effort and CPUE by specific geographical location is not presented, rather the present review is based on aggregate data for relatively broad assessment areas.

Size Structure of the Commercial Catch

Population size structure is monitored through port samples of the commercial catch. The port sampling program attempts to sample each vessel, each month in which there is fishing activity, with a minimum of 300 animals being sampled. There is only limited sea-sampling coverage; this report includes samples from two of the fishing areas. At-sea samples measure crabs from every trap, every second or third trap (frequency based on catch rates and the ability of the sampler to accurately measure what is being caught). Carapace width, sex and egg stage (if present) are recorded. Sample sizes range from 500-3500 crabs.

Assessment Areas

Scotian Shelf deep-sea red crab data has traditionally been reported by NAFO subareas 4X and 4W. During the mid-1980's, fishing was directed to the LaHave Bank area. When red crab fishing began again in 1993, this area was targeted once again and in 1994 effort expanded to an area south of Emerald Bank. Changing fishing patterns in the mid 1990's opened new grounds for exploitation, and further subdivisions of fishery data were made. Fisheries data are now analyzed by 5 assessment areas; Georges Bank, Browns Bank, LaHave Bank, Emerald Bank, and Western-Sable Island Bank (Fig. 2). Fishery data prior to 1994 has been re-analyzed to conform to these new reporting areas as closely as possible. It should be recognized that these assessment areas do not necessarily represent biologically-defined stock units, rather they represent relatively discrete areas where exploratory fishing has concentrated.

Reporting Periods

The fishery operates on a calendar year basis. Fishery data received up to September 30, 1996 has been used in the present report.

RESULTS AND DISCUSSION

Fishing Patterns

From 1984 to 1994, fishing effort off Nova Scotia was directed to areas along the continental slope adjacent to LaHave and Emerald banks, as the fishery was restricted to an area east of 64°30' and to a minimum depth of 250 fathoms (460 m). In 1995, the fishing area was enlarged to include Georges Bank and a minimum depth of 200 fathoms (370 m). Currently, most effort is being directed to the Georges Bank and LaHave-Emerald Bank areas (Figure 2; Table 2). Georges Bank has seen a dramatic increase in trapping effort and landings from 1995, when fishing operations began and 69 metric tonnes were landed (9.4% of 1995 landings), to the current year where landings from this area account for 32% of landings up to September 30, 1996 (Table 2). In contrast, landings from Brown Bank, also initially exploited in 1995, represent 18% and 16% of the 1995 and 1996 (year to date) totals, respectively.

Catch and Effort

In aggregate, catch rates (CPUE) have decreased progressively from the initial high rates of up to 20 kg/th experienced at the inception of exploratory fishing in 1984 (Figure 3). Catch rates were generally within the range of 5-10 kg/th for the 1995 and 1996 fishing seasons, but dropped below 5 kg/th on several banks in some months (Figures 4 - 6). Conversely, total effort in the exploratory red crab fishery has increased, particularly in 1995 and 1996 (to date), where between 10,000 - 20,000 trap hauls were made monthly in the spring months (April - July), as compared to approximately 5,000 trap hauls during 1985, and again in 1993.

Although there was an indication of a seasonal pattern in CPUE at the outset of the current exploratory fishery, with highest rates observed in the Sept-Jan period (during 1984-85), monthly CPUE's during the

1990's show much reduced seasonal amplitude. The longest catch series, available for LaHave Bank (Figure 4), shows this trend, as well as a second, in that the highest catch rates were experienced during the initial exploitation of this area. Thus, catch rates reached 20 kg/th during July - December, 1993, when fishing once again resumed in the area after a hiatus of seven years.

None of the areas where new developmental activity has begun during the 1990's have supported initial catch rates as high as those initially reported on LaHave Bank. Initial catch rates on Emerald Bank (Figure 5) reached 10kg/th in September - December, 1994, but have since fallen to approximately 5kg/th during the same months in 1995 and 1996. Similar catch rates were experienced on Georges and Browns banks (Figure 6), again with a suggestion of a seasonal reduction in catch rates in the months of June-July. Based on a cursory review of logbooks from the 1996 fishery on Georges Bank, there was an increase in the numbers of soft crab reported during the period July 18 - September 7. Other red crab fishers indicate that July - September is when they see more soft crabs in their catches (D. Duggan, pers. obs.).

As red crab fishers tend to remain in areas where catch rates are high, yet occasionally test other fishing areas with a limited amount of gear, deciphering the influence of molt condition on catch rates is problematic, and could only be achieved through a detailed analysis of logbooks, which has not been possible to date. A better understanding of the seasonal availability of crab on the fishing grounds, and the annual recruitment cycle, is required to distinguish between these factors and possible cumulative depletion of fishing grounds.

Based on initial fishing experience in the 1980's, catch rates would be expected to increase in the winter period, relative to the June-July period. This was not observed during winter 1995 on LaHave Bank (Figure 4), although catch rates on Emerald Bank (Figure 5) did increase in January and February 1996. Emergence of a recurrent seasonal pattern to catch rates (indicative of annual recruitment) would provide a stronger foundation for conversion to a permanent fishery than the current pattern of landings (which may reflect intermittent recruitment and cumulative depletion of remaining crab on the grounds). Countering the hypothesis of seasonal cycles in catch rates related to recruitment, catch rates on LaHave Bank during June and July, 1993, at the commencement of the current developmental fishery phase (Figure 4) were approximately 20kg/th. Catch rates did not rise above 15 kg/th in 1994, nor above 10 kg/th since 1994, suggesting depletion of harvestable crab biomass.

Size Composition

Port sampling (Figures 7-10; Table 3) shows that the median carapace width, CW, landed from each area has not changed substantially since the fishery began its current phase. However, median sizes of crabs landed from Emerald and LaHave banks are marginally smaller than those landed from Georges and Browns banks. This variability in the landed catch is most likely attributable to market preferences which red crab fishers are targetting.

The current Canadian minimum size limit is 100 mm CW, and the percentage of landed catch between this size and the US measure (114 mm CW) has varied from a low of 4% (from Browns Bank; Table 3) to as high as 47% (from Emerald Bank; Table 3). A comparison of the at-sea sample from Georges Bank in October 1996 (Figure 11) with port samples from September 1995-July 1996 (Figure 10) suggests that highgrading is occurring from this fishery area. Highgrading may also be occurring on Browns Bank which has the highest median sizes from port samples. The limited availability of concurrent at-sea and port samples precludes full assessment of fishing strategies, but if a portion of the fleet is targetting crabs >114 mm CW this has implications for Canadian management measures.

Resource Status

The biological basis for determining current resource status is restricted to monthly landings and catch rates, together with sampling of commercial catch length frequencies, principally from port sampling. There is a dearth of biological information on red crab biology from the Canadian portion of the species'

range. Very little new biological information has been generated for red crabs since the overview of species biology provided by Elner (1986).

The principal signal from the available information on the fishery is a reduction in monthly catch rates from initial fishing conditions. Although initial catch rates have not been sustained, it appears that catch rates may have stabilized at approximately 5kg/th. Determining whether or not this represents an economic level of harvest for offshore vessels to pursue is not a biological issue. Certainly, against this current experience, participants in the present exploratory fishery have requested that this fishery be changed to a permanent fishery.

A possible explanation for this pattern of landings, and the fact that the annual TAC of 1,300 metric tonnes has not been met, may be that initial commercial biomass on the Browns to Emerald banks, derived from exploratory trapping surveys, using the method of effective fishing area (McElman and Elner, 1982) may have been overestimated. Their trap survey, conducted in September 1980, yielded a total of 3643 crabs from 573 trap hauls, with mean catch rates per string as high as 50 crabs/trap. The authors considered the distribution of red crabs to be patchy, with no measured parameter from their trap survey accounting for crab distribution or abundance. Their biomass estimate was derived using an estimate of effective fishing area (EFA) of 2300 sq m/trap. In a recent study of the harvest potential of *Chaceon quinquedens* in the north central Gulf of Mexico which also used EFA techniques (Waller et al., 1995) the range of estimates of the number of trappable crabs on the grounds ranged from 3.7×10^6 to 10.7×10^6 depending on the value of EFA used in the analysis. In addition to the choice of EFA used, population estimation using this procedure is also sensitive to assumptions on the total fishing area, and stratification of sub-areas by depth and/or catch rate. Additionally, a comparative study of population estimation procedures for the red crab *Chaceon (=Geryon) maritae* stock off the South West African coast suggests that EFA techniques overestimate biomass (Melville-Smith, 1988). The size and density of this red crab population, between latitudes 19 degree 20' and 19 degree 10'S and 400 - 900 m depth, was estimated by a tag-recapture technique. Results were then compared with estimates of stock density in the same area by three other methods (trawling, photography and EFA)). Tagging and photography yielded similar estimates of crab population size (21.6 and 19.5 million crabs respectively) whereas trawling (1.9 million) and EFA techniques (81.4 million) apparently under- and over-estimated stock size respectively.

Given the uncertainties over the initial biomass estimate, obtained during the early 1980's, and the fact that the initial biomass estimate of 2,600 mt did not include Georges Bank, from which 32 % of the current harvest is now being taken, it would be prudent to reduce the TAC (as a precautionary measure) to better match the emerging landings pattern, or manage the fishery conservatively without recourse to a TAC. Until a fuller biological assessment can be provided (which will require additional information on red crab biology and stock dynamics), there is no biological basis for recommending a specific TAC.

CONCLUSIONS

While the harvest experience to date indicates the potential for a permanent fishery, the following factors suggest that a cautious management approach should be adopted:

1. There are uncertainties in the current assessment of resource status:
a. Our longest time series (LaHave Bank) shows a progressive reduction in monthly CPUE's, and a dampening in the seasonal variation of landings;
b. From inception of the latest phase of exploratory fishing on LaHave Bank in July 1993 there are only three "years" of fishery data. For Emerald Bank there are two full years, while from Georges and Browns Bank there is less than two years of fishery information;
c. The initial biomass estimate (and derived TAC) did not include Georges Bank, and the relevance of that assessment, conducted over ten years ago, is problematic. If landings from Georges Bank are not considered, current, expanded levels of fishing effort in the areas of initial biomass estimation have not yielded landings close to original expectations. Based on earlier resource surveys, and initial catch rates on

LaHave Bank, it is known that red crabs will enter traps in high numbers, so these lower annual landings and monthly CPUE's may reflect a lower population abundance;
d. Research on red crab fisheries in S. Africa suggests that EFA-based trapping approaches may over-estimate biomass, compared to survey techniques such as underwater photographic/video transects, and mark-recapture programs.

2. The fishery is prosecuted within a narrow depth range, and based on the distribution of fishing effort (Figure 2), most of the available commercial grounds are now being exploited by the existing five exploratory licenses. No additional access to this fishery should be allowed until the next science assessment is completed.

3. Given the above factors, management should consider lowering the TAC, or managing the fishery on an alternative conservative basis, at least as an interim measure, until more experience is gained on the seasonal and annual pattern of landings and catch rates from which to specify the level of sustainable harvest.

4. The rapid expansion of effort and landings from Georges Bank is of concern, particularly as this area was not included in the initial biomass estimation on Canadian offshore fishing grounds, yet now contributes substantially to annual catches. During 1996 (to September 30) Georges Bank has provided 32% of total landings, representing 171 mt.

5. Attention needs to be placed on the minimum size regulation in the fishery. Minimum size has changed over time, with the biologically-defined size being set by reference to literature from other stocks of red crabs. Size at maturity estimates should be obtained from crabs sampled on Canadian fishing grounds. Recent port sampling information suggests a market preference for a larger minimum size. From a biological perspective, stock conservation would not be compromised if industry wished to increase minimum size for marketing reasons. However, it would be preferable to delay any change in minimum size until newly-initiated maturity studies are completed in 1997.

6. An improved scientific understanding of stock dynamics is required to allow for a more robust scientific assessment of resource status. In particular:

a) Finer resolution spatial and temporal analysis of catch rates for specific geographical locations to provide greater insight into relative abundance of red crabs;
b) As opportunities are presented, an increased scientific effort to obtain fishery-independent estimates of red crab densities on fishing grounds;
c) Determination of biological parameters such as growth rates and size at maturity for the Scotia Slope population which is at the northern end of the species range;
d) Assessment of seasonal migration of crabs up and down the continental slope, and horizontal movements between contiguous fishing areas to determine if the current assessment areas are biologically realistic;
e) Studies on recruitment processes in these offshore crab populations.

RECOMMENDATIONS

While the harvest experience to date in the exploratory offshore red crab fishery suggests that there is potential for a permanent fishery for a limited number of vessels, the following factors suggest that management should take a cautious approach:

1. The fishery is prosecuted within a narrow depth range, and based on the distribution of fishing effort most of the commercial grounds are now exploited.
2. The initial TAC set for the exploratory phase of the fishery has never been met and may reflect unrealistic assumptions on available commercial biomass. Current year landings (to September 30, 1996)

are 533 mt, of which 171 mt, or 32% is from Georges Bank, which was not included in the initial biomass estimate. It would be prudent to cut the present TAC (as a precautionary measure) to better match the emerging landings trends, or manage the fishery on an alternative basis. There is no biologically-defined revised TAC which can be presented at this time.
3. Given the above, the fishery is no longer exploratory, and there should not be any increase in fishing effort. No additional access to this fishery should be considered until the next scientific assessment.
4. Recent port sampling information indicates a market preference for a larger minimum size. From a biological perspective, a minimum size increase for marketing purposes would not compromise stock conservation. However, any change further changes to minimum size should be deferred until size at maturity information is available for the Canadian portion of the species' range.
5. The scientific understanding of stock dynamics needs to be improved to allow a more realistic assessment of sustainable harvest levels.

ACKNOWLEDGMENTS

We thank Michel Comeau, Trevor Kenchington and Michael Longmire for reviewing a draft working paper presented at the Fall 1996 Regional Advisory Process (RAP) meeting for the Maritimes Region, Halifax, N.S., October 1996, and other RAP participants for their comments on improving the documentation. We also wish to thank W. Young-Lai for undertaking a preliminary review of the literature on red crabs; captains of the red crab vessels for their cooperation in filling out voluntary science logs, and plant owners for their assistance during port sampling and support for sea samples.

REFERENCES

Auster, P. J., R. J. Malatesta, and S. C. LaRosa. 1991. Microhabitat use by continental slope megafauna. Am. Zool. 31:127A

Caddy, J. F. , R. A. Chandler, and D.G. Wilder. 1974. Biology and commercial potential of several underexploited molluscs and crustaceans on the Atlantic coast of Canada. A paper presented to the Federal-Provincial Fisheries Committee meeting on Utilization of Atlantic Resources, Montreal, 5-7 February. p. 57-106

Cooper, R. A., and J. R. Uzmann, 1980. Ecology of juvenile and adult *Homarus*, p. 97-142. *In* J. S. Cobb and B. F. Phillips (eds.) Biology and Management of Lobsters, Vol. II. Academic Press, New York, N.Y.

Erdman, R. B., N. J. Blake, F. D. Lockhart, W. J. Lindberg, H. M. Perry, and R. S. Waller. 1991. Comparative reproduction of the deep-sea crabs *Chaceon fenneri* and *Chaceon quinquedens* (Brachyura: Geryonidae) from the northeast Gulf of Mexico. Invertebr. Reprod. Dev. 19: 175-184.

Elner, R.W. 1986. Overview of biology for the deep-sea red crab, *Geryon quinquedens*, in the Northwest Atlantic

Elner, R. W., Koshio, S. & G.V. Hurley. 1987. Mating behavior of the deep-sea red crab, *Geryon quinquedens* Smith (Decapoda, Brachyura, Geryonidae). Crustaceana, 52:194-201

Elner, R.W. & D.A. Robichaud. 1985. The Scotian Shelf fisheries for Jonah crab, *Cancer borealis*, and deep-sea red crab, *Geryon quinquedens*, 1984. CAFSAC Res. Doc. 85/6, 23 pp.

Gerrior, P. 1981. The distribution and effects of fishing on the deep-sea red crab, *Geryon quinquedens*, Smith, off southern New England. M.Sc. thesis, Southeastern Massachusetts University, MA, USA, 130 pp.

Gray, G.W. 1988. Investigation of the basic life history of the red crab (*Geryon quinquedens*). R.I. Division of Conservation, P.L. 88-309; Project 3-46-R. 35 pp.

Haefner, P.A. 1977. Reproductive biology of the female deep-sea red crab, *Geryon quinquedens*, from the Chesapeake Bight. Fishery Bull. 75 (1) 91-102

Haefner, P.A. 1978. Seasonal aspects of the biology, distribution and relative abundance of the deep-sea red crab *Geryon quinquedens* Smith, in the vicinity of the Norfolk Canyon, Western North Atlantic. Proc. Nat. Shell. Assoc. 68: 49-62

Kelly, P., S.D. Sulkin, and W.F. Van Heukelem. 1982. A dispersal model for larvae of the deep-sea red crab *Geryon quinquedens* based upon behavior regulation of vertical migration in the hatching stage. Mar. Biol. 72:35-43.

Lindberg, W. J., and F. D. Lockhart. 1993. Depth-stratified population structure of geryonid crabs in the eastern Gulf of Mexico. J. Crust. Biol. 13:713-722.

Lockhart, F. D., W. J. Lindberg, N. J. Blake, R. B. Erdman, H. M. Perry, and R. S. Waller. 1990. Distributional differences and population similarities for two deep-sea crabs (family Geryonidae) in the northeastern Gulf of Mexico. Can. J. Fish. Aquat. Sci. 47:2112-2122.

Lux, F.E., A. R. Ganz, and W.F. Rathjen. 1982. Marking studies on the red crab, *Geryon quinquedens* Smith, off Southern New England. J. Shell. Res. 2(1): 71-80

McElman, J.F. and R.W. Elner. 1982. Red crab (*Geryon quinquedens*) trap survey along the edge of the Scotian Shelf, September 1980. Can. Tech. Rept. Fish. Aqua. Sci., 1084

Melville-Smith, R. 1988. Comparative population size estimates for a portion of the red crab *Geryon maritae* stock off the South West African coast. S. Afr. J. Mar. Sci. 6:23-31.

Perry, H. M., R. Waller, L. Stuck, K. Stuck, R. Erdman, N. Blake, F. Lockart, and W. Lindberg. 1991. Occurrence of *Chaceon* larvae in plankton samples from slope waters of the northeastern Gulf of Mexico. Gulf Res. Rep. 8: 313-315.

Rathbun, M.J. 1937. The Oxystomatous and allied crabs of America. United States National Museum Bulletin 166, i-vi + 278p.

Roff, J. C., L. P. Fanning, and A. B. Stasko. 1986. Distribution and association of larval crabs (Decapoda: Brachyura) zoeas and megalopas of the Scotian Shelf. Can. J. Fish. Aquat. Sci. 43: 587-599.

Rosowski, M.C. 1979. The effect of temperature on growth and dispersal of larvae of *Geryon quinquedens* Smith (Brachyura: Geryonidae). M.Sc. Thesis, U. Delaware, 81 pp.

Scelzo, M.A., and A. Valentini. 1974. Presencia de *Geryon quinquedens* Smith en aguas del Oceano Atlantica Sud occidental (Decapoda, Brachyura, Geryonidae). Physis, section A, 33(87): 557-567.

Smith, S. I. 1879. The stalk-eyed crustaceans of the Atlantic Coast of North America, north of Cape Cod. Trans. Connecticut Acad. Art Sci. 5: 27-136, plates 8-12.

Van Heukelem, W., M. C. Christman, C. E. Epifanio, and S. D. Sulkin. 1983. Growth of *Geryon quinquedens* (Brachyura: Geryonidae) juveniles in the laboratory. Fish. Bull. 81: 903-905

Waller, R., H. Perry, C. Trigg, J. McBee, R. Erdman, and N. Blake. 1995. Estimates of the harvest potential and distribution of the deep sea red crab, *Chaceon quinquedens*, in the north central Gulf of Mexico. Gulf Res. Rep. 1995 9(2): 75-84.

Wigley, R.L., R. B. Theroux, and H.E. Murray. 1975. Deep-sea red crab, *Geryon quinquedens*, survey off northeastern United States. Mar. Fish. Rev., 37:1-21

Table 1: Chronology of Research Surveys, and Exploratory Offshore Fishing Activity for Red Crabs

1966 Canadian trawl survey from Sable Island Bank to Georges Bank

- few red crabs encountered
- highest catch was 18 crabs per 60 minute tow southwest of LaHave Bank in 330 - 470 m

1969-1971 Trapping surveys by N.S. Dept. of Fisheries along Continental Slope from Sable Island Bank to Browns Bank

- similar results to 1966 trawl survey
- greatest concentration found to southwest of Emerald Bank
- survey found commercial concentrations of offshore lobster

late 60's-early 70's Intermittent commercial trapping off Nova Scotia using top-entry conical traps and large square steel traps

- processing by boiling, quick freezing and shaking meat out
- fishing ceased in mid-1970's due to poor economic conditions

1973 Commercial US landings of red crab begin as by-catch to the offshore lobster fishery

- Average US commercial by-catch of 1200 t in mid-70's

1975 Comprehensive US survey indicated commercial biomass (>114 mm CW) of 27,000 t on Continental Slope from Maryland to Corsair Canyon

- no red crab catches from two stations on Canadian side of Georges Bank (new boundary)

1978 Canadian trap survey along Continental Slope from Sable Island Bank to to Georges Bank (conical top-entry traps)

- highest catch rates (22-52 crabs/trap) in 360-540 m, south of LaHave Bank, and to southwest of Emerald Bank
- lower catch rates obtained southeast of Baccaro & Browns Banks

1980 Canadian trap survey along Continental Slope from Emerald Bank to Fundian Channel

- (five different types of traps; only catches from large offshore traps used in results)
- highest catch rates (11-14 crabs/trap) obtained in 296-322 m, southwest of Emerald Bank
- lower catch rates south of Baccaro & southeast of Browns Banks
- using EFA techniques, conservative estimate of 2600 t (>114 mm CW)

1983 Pilot Jonah crab fishery (with a by-catch of red crab) begins

- trapping in LaHave and Emerald Basins and adjacent edge of the Scotian Shelf

1984 US commercial red crab by-catch average 3000 t / yr. Canadian red crab landings begin again in August 1984 after the Jonah crab fishery ceases due to gear conflicts and gear loss

- 2 vessels direct exclusively for red crab; 1 - 30 m wooden, 1-36 m converted steel herring seiner equipped with refrigerated seawater system
- modified side-entry offshore lobster traps (no trap limit), typically fished in strings of 80 traps
- minimum CW of 115 mm

Table 1 (cont.): Chronology of Research Surveys, and Exploratory Offshore Fishing Activity

1984 Canadian red crab fishing activity and regulations (cont.)

- no retention of berried females
- logs required
- TAC of 1300 t
- fishing on slope adjacent to LaHave and Emerald Banks in 457-640 m; firm clay-mud bottom
- 16.4 kg/ trap haul
- 2 vessels land 120 t

1985 Red crab landings of 468 t

- fishing ceased again due to low profitability and some gear loss

1987 Federal Minister of Fisheries issues 4 exploratory offshore lobster and red crab licenses for NAFO 4W

- later revoked due to pressure from inshore fishers

1990 Draft Red Crab Management Plan

- maximum of 4 vessels
- outside 50 mile limit; fish only east of 64°30'W
- limited no. trips to Georges Bank with separate trip and license conditions
- conical, top-entry traps only
- minimum legal CW (115 mm)
- no retention of berried females
- 325 t / vessel quota (TAC = 1300 t); no season restrictions
- no fishing activity

1993 Three exploratory licenses issued (1 in June, 2 more in fall)

- logs required
- total landings = 31 t

1994 Experimental Red Crab licenses issued

- 100 mm CW minimum size
- no retention of female or soft crabs or lobsters
- fish to the east of 64°30 w' and > 200 fm
- logs required
- 3 vessels land 345 t

1995 No changes to regulations

- one vessel permitted to fish Georges Bank
- 100% DMD begins in fall
- 5 vessels land 734 t

1996 Science logs introduced in spring

- as of Sept. 30, 5 vessels land a total of 533 t

Table 2: Summary of Trapping Effort, Annual Catch and Annual Catch per Unit of Effort from Different Offshore Banks

Year	Measure	Georges	Browns	LaHave	Emerald	Western
1984	Landings (kg)	0	0	119600	0	0
	% of total	0	0	100	0	0
	Trap Hauls (th)	0	0	5826	0	0
	% of total	0	0	100	0	0
	CPUE (kg/th)	0	0	20.5	0	0
1985	Landings (kg)	0	0	468400	0	0
	% of total	0	0	100	0	0
	Trap Hauls (th)	0	0	52363	0	0
	% of total	0	0	100	0	0
	CPUE (kg/th)	0	0	8.9	0	0
1993	Landings (kg)	0	0	30771	0	0
	% of total	0	0	100	0	0
	Trap Hauls (th)	0	0	3609	0	0
	% of total	0	0	100	0	0
	CPUE (kg/th)	0	0	8.5	0	0
1994	Landings (kg)	0	0	168815	175078	0
	% of total	0	0	49.2	50.8	0
	Trap Hauls (n)	0	0	21464	16688	0
	% of total	0	0	56.3	43.7	0
	CPUE (kg/th)	0	0	7.9	10.5	0
1995	Landings (kg)	69025	133101	236033	294962	611
	% of total	9.4	18.1	32.2	40.2	0.1
	Trap Hauls	8700	20850	34638	40697	410
	% of total	8.3	19.8	32.9	38.7	0.4
	CPUE (kg/th)	7.9	6.4	6.8	7.2	1.5
1996 (to 30/09)	Landings (kg)	171713	85324	112128	163830	0
	% of total	32.2	16.0	21.0	30.7	0
	Trap Hauls (n)	24375	11645	27634	33047	0
	% of total	25.2	12.0	28.6	34.2	0
	CPUE (kg/th)	7.0	7.3	4.1	5.0	0

Table 3: Length frequency samples (at-sea and port).

Date	Sample Area	Type of Sample	Number sampled	Percentage catch <115mm CW
17/06/93	Emerald Bank	at-sea	492	21*
27/10/94	"	port	275	35
01/11/94	"	"	298	31
16/11/94	"	"	275	43
25/01/95	"	"	298	41
10/05/96	"	"	315	47
25/05/96	"	"	360	23
18/06/96	"	"	375	25
05/07/96	"	"	374	26
07/08/96	"	"	425	29
21/08/96	"	"	321	26
08/06/95	LaHave Bank	port	315	19
26/03/96	"	"	337	40
10/05/96	"	"	368	27
20/06/96	"	"	379	30
22/08/96	"	"	347	27
17/05/96	Browns Bank	"	367	12
20/06/96	"	"	294	05
26/06/96	"	"	295	04
15/08/96	"	"	297	07
01/09/95	Georges Bank	port	278	26
05/10/95	"	"	299	24
29/05/96	"	"	391	12
21/06/96	"	"	338	17
26/07/96	"	"	342	23
04/10/96	"	at-sea	3202	24*

* these numbers represent the percent of males (only) between 101-114 mm CW.

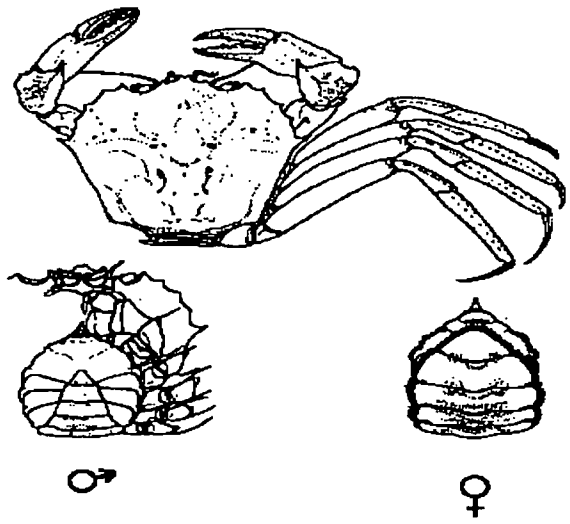

Figure 1: Dorsal view of red crab, *Chaceon quinquedens,* showing general carapace shape, morphology and relative size of body appendages, together with ventral views of male and female abdomens showing sexual differentiation. Adapted from Smith (1879).

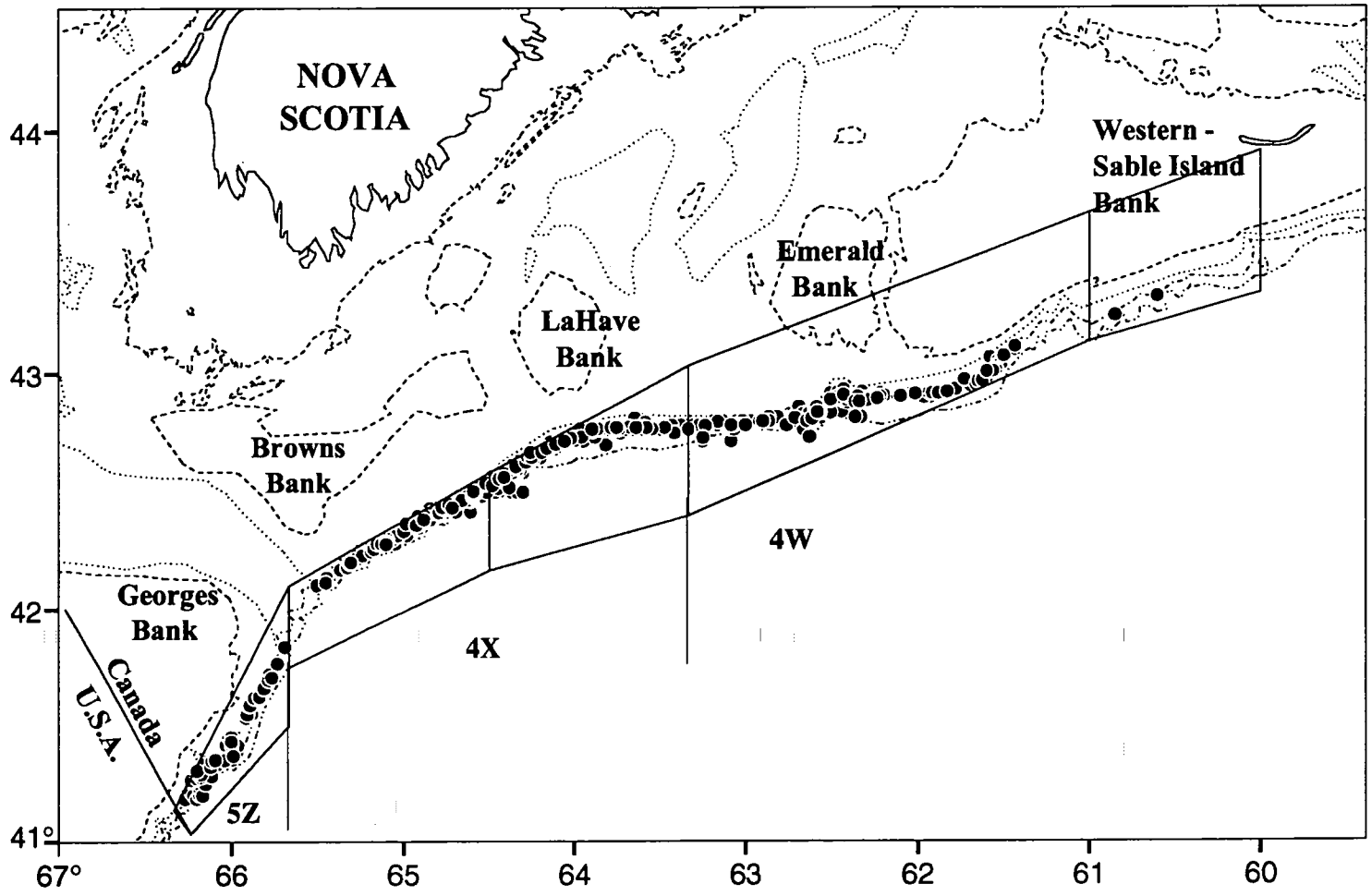

Figure 2. Distribution of fishing effort for red crabs along the continental slope, with breakdown of areas used for assessment.

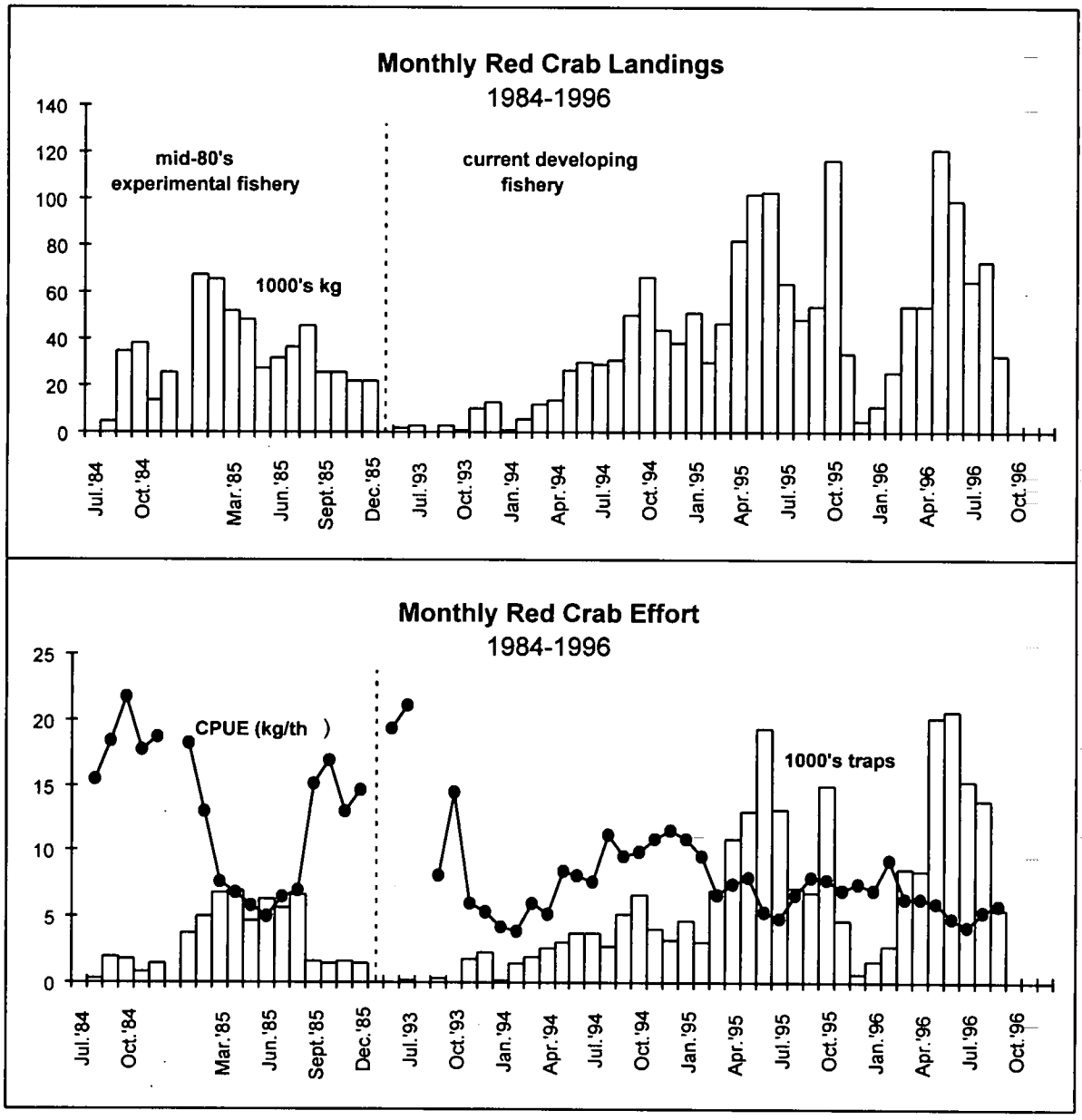

Figure 3. Evolution of aggregate monthly landings, effort, and catch per unit effort (CPUE) in the exploratory offshore fishery for red crabs. Top panel shows monthly landings (000's kg; histogram). Lower panel shows monthly effort (000's trap hauls; histogram) against monthly CPUE (kg/th; line). Note the break in the timeline after December 1985.

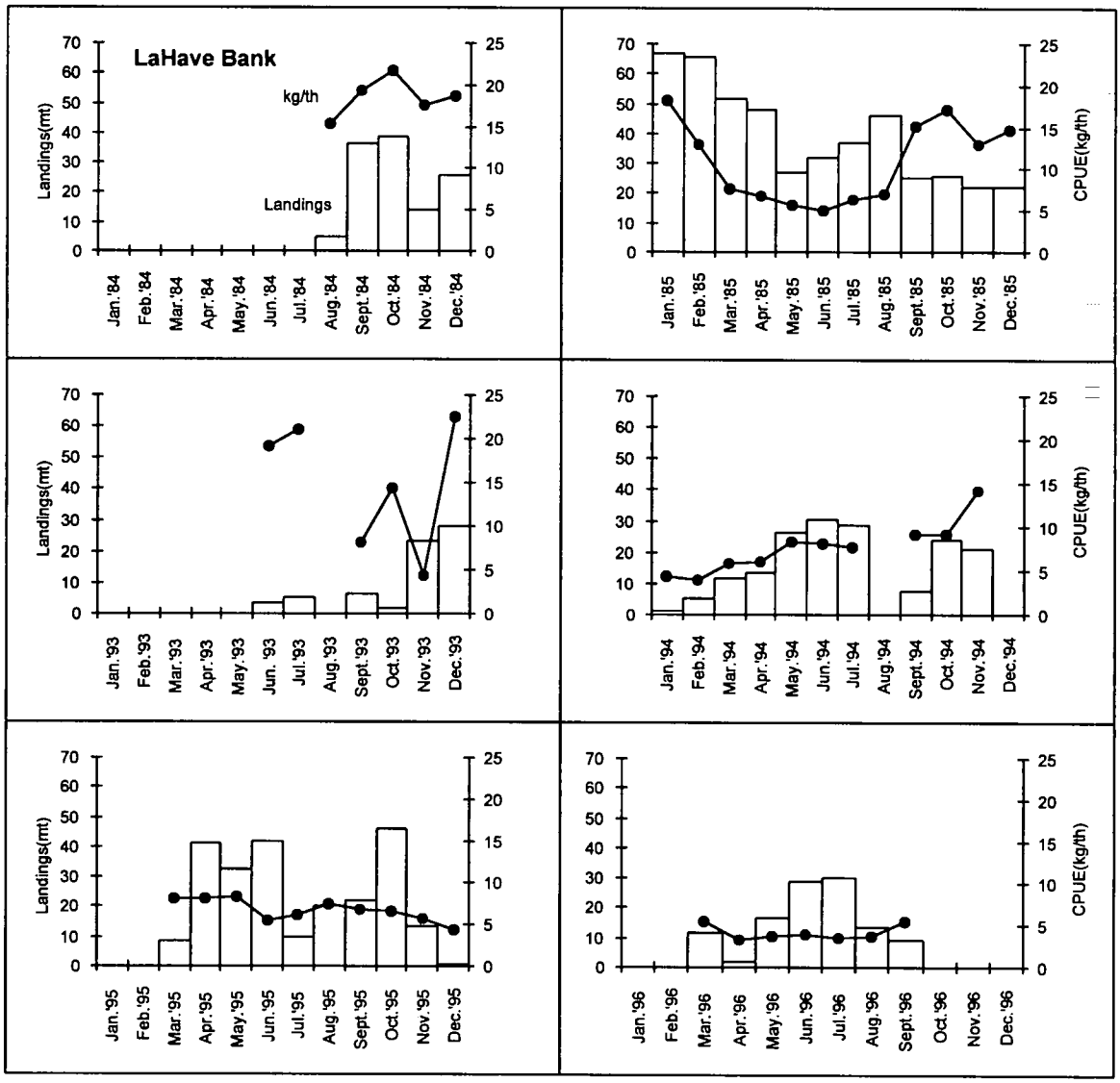

Figure 4. Evolution of monthly landings and catch per unit effort for LaHave bank

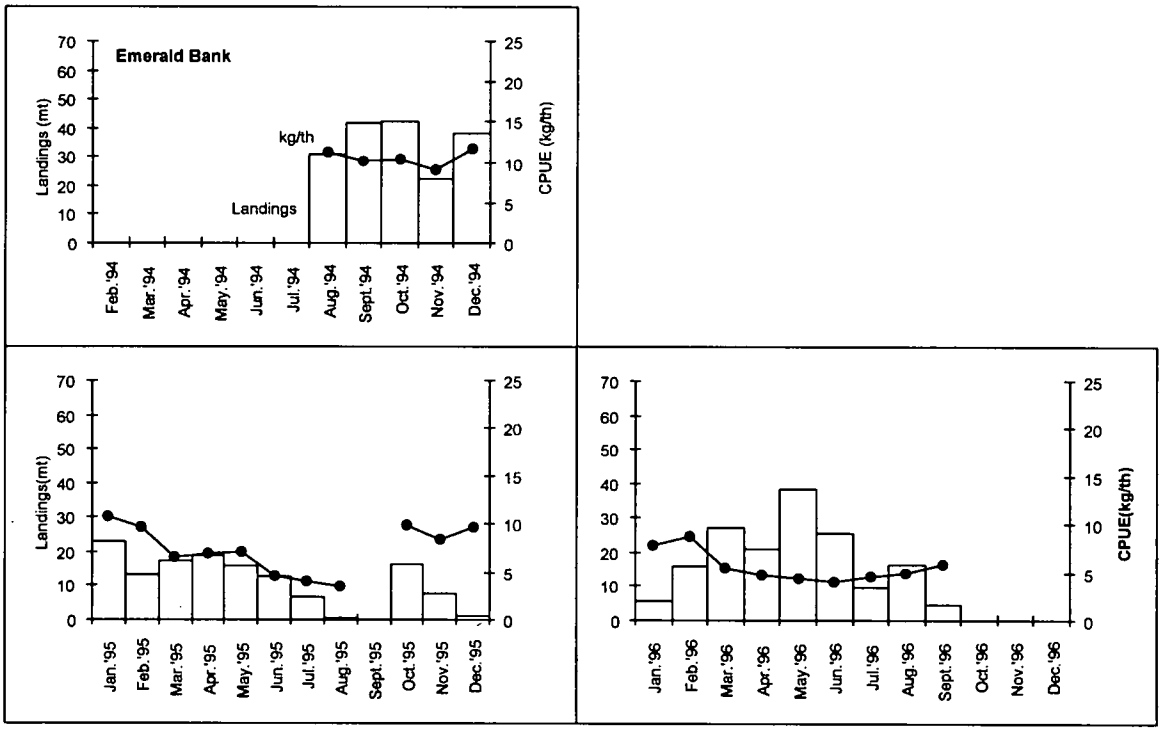

Figure 5. Evolution of monthly landings and catch per unit effort for Emerald Bank

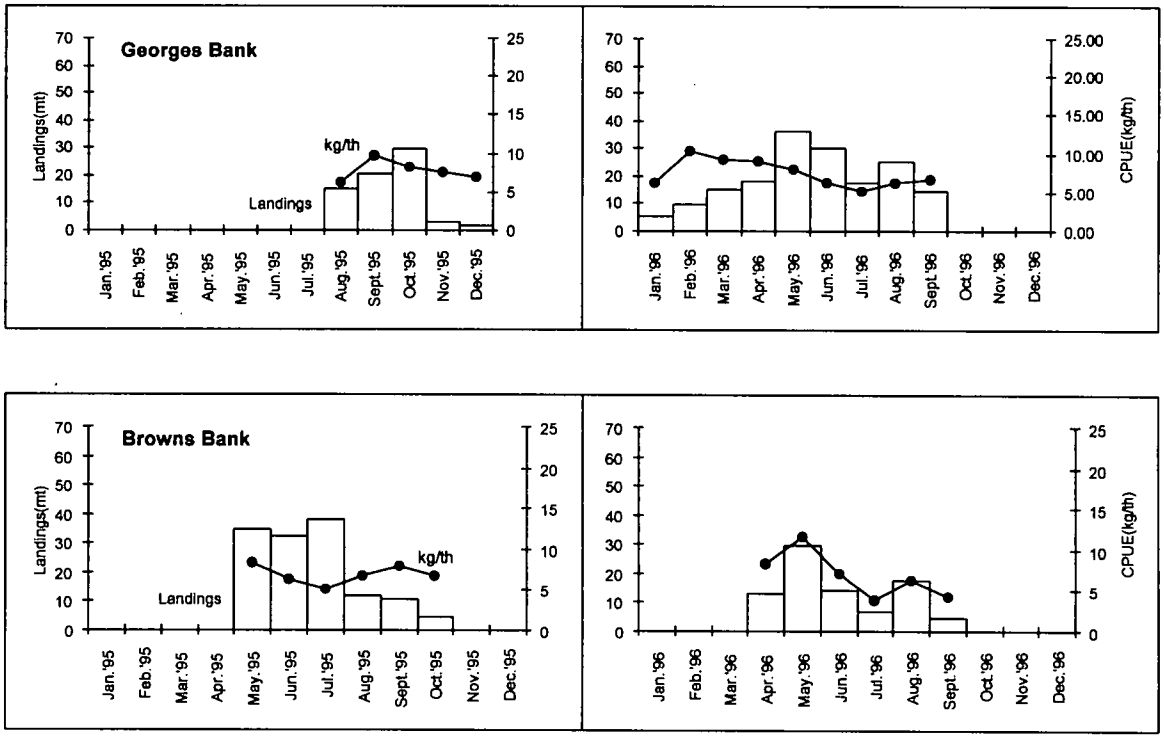

Figure 6. Evolution of monthly landings and catch per unit effort for Georges and Browns banks

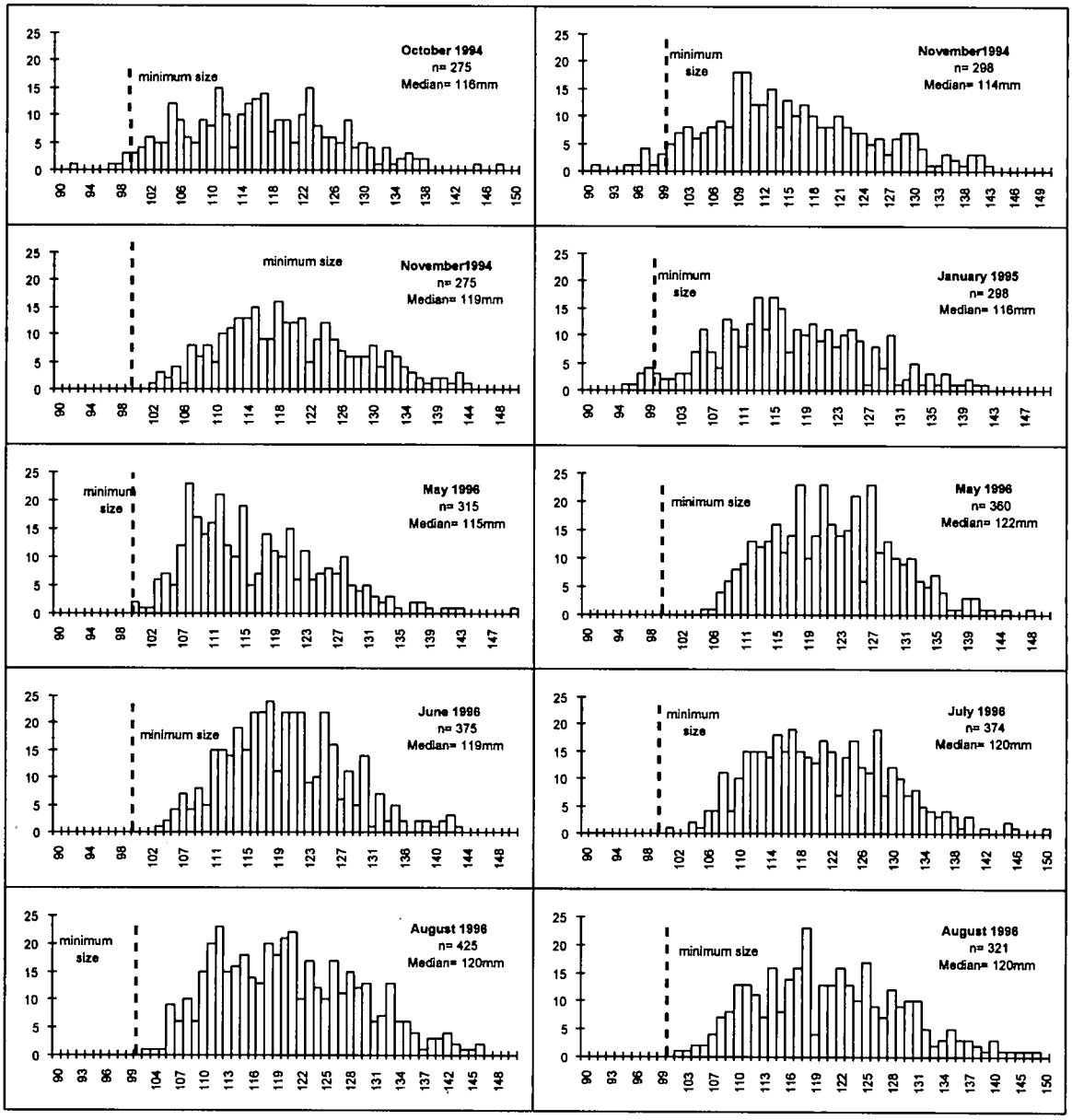

Figure 7. Emerald Bank size frequencies (1mm CW size classes) from port samples, October 1994 - August 1996.

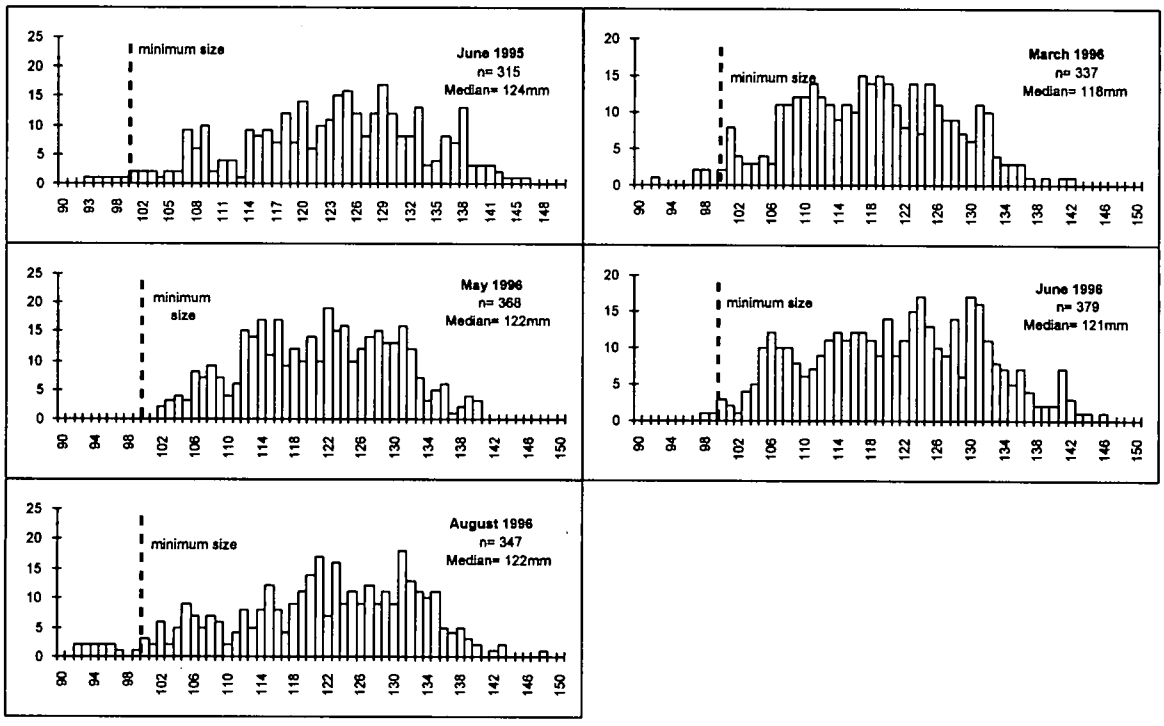

Figure 8: LaHave Bank size frequencies (1mm CW size classes) from port samples, June 1995 - August 1996.

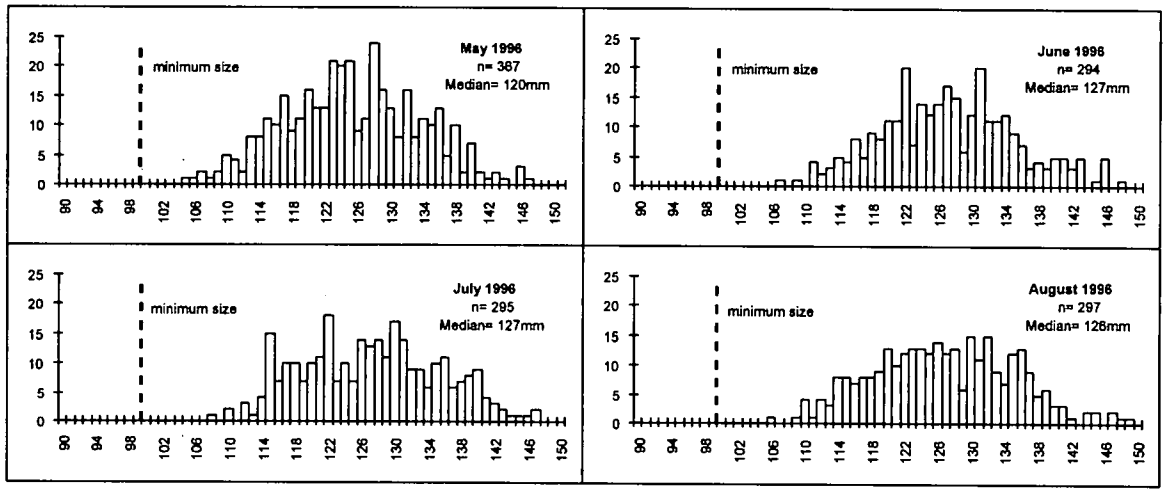

Figure 9. Browns Bank size frequencies (1mm CW size classes) from port samples, September 1995-July 1996.

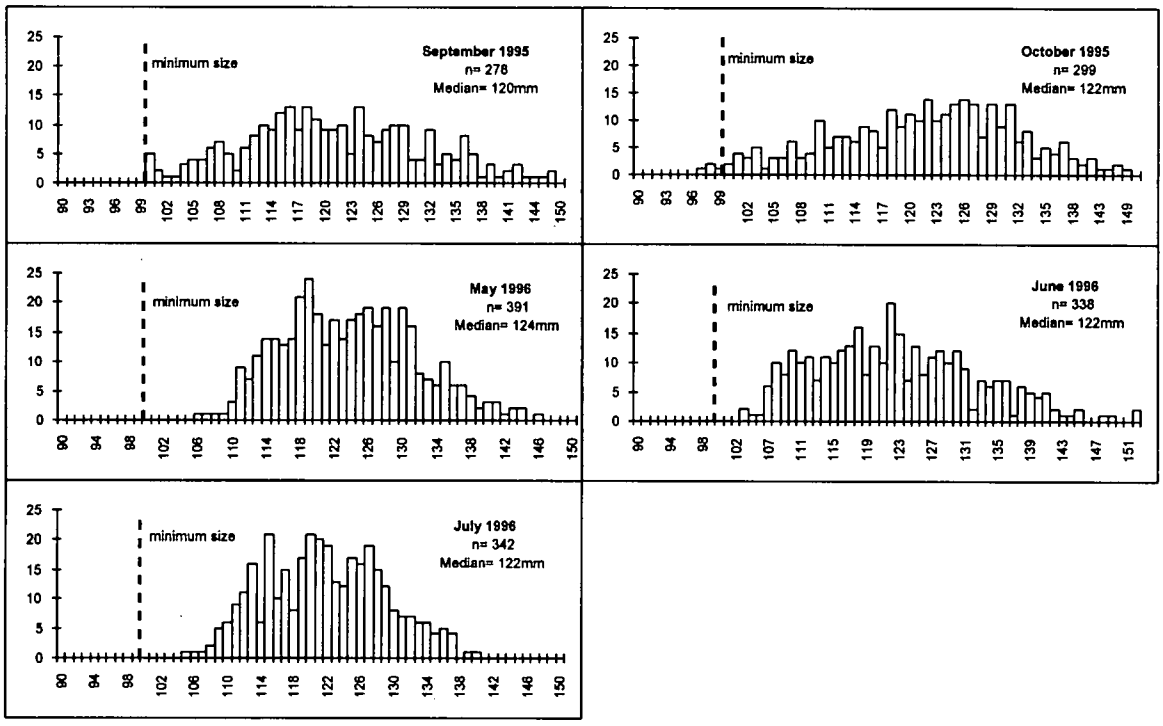

Figure 10. Georges Bank. size frequencies (1mm CW size classes) from port samples, September 1995 - July 1996.

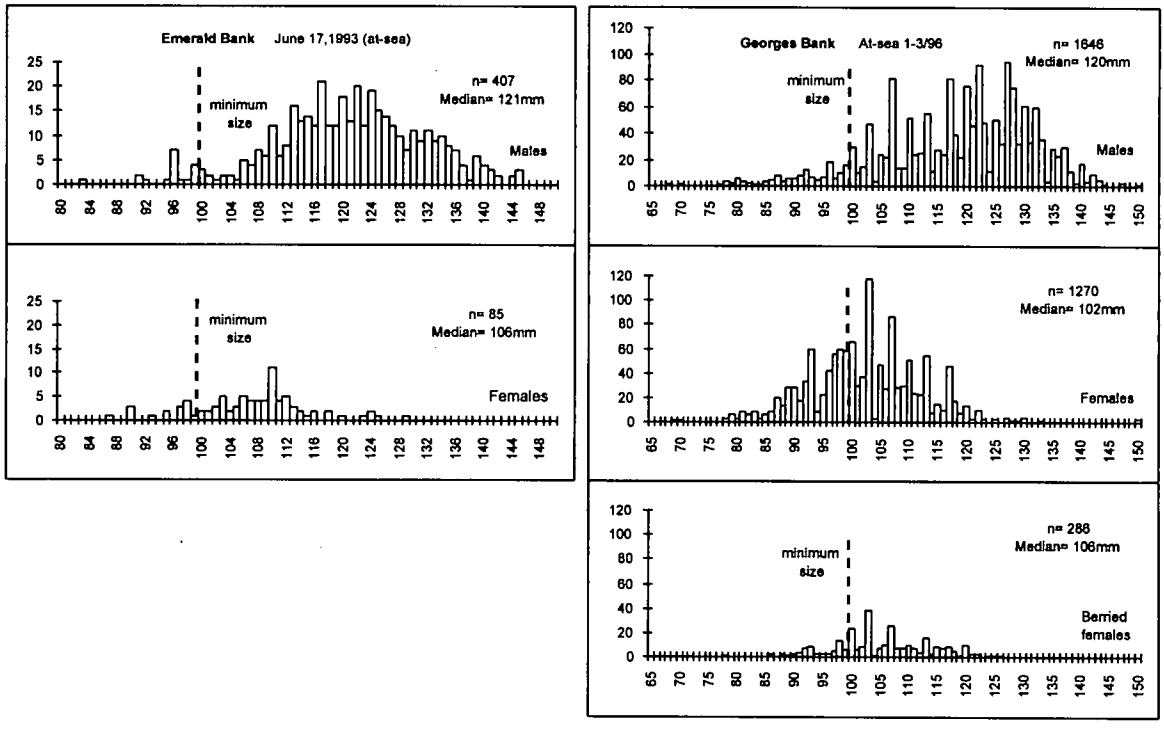

Figure 11. Size frequencies (1mm CW size classes) from at-sea samples taken on Emerald Bank (June, 1993) and Georges Bank (October 1996).