Overview of Biology for Deep-Sea Red Crab, Geryon quinquedens, in the Northwest Atlantic

By

Robert W. Elner
Invertebrates and Marine Plants Division
Fisheries Research Branch
Halifax Fisheries Research Laboratory
Department of Fisheries and Oceans
Scotia-Fundy Region
P.O. Box 550
Halifax, N.S.
B3J 2S7

ABSTRACT

There is a paucity of biological information relevant to management unit definition for deep-sea red crab, Geryon quinquedens. The species is distributed predominantly along the edge of the Scotian Shelf and continental slope to Argentina; concentrations are most dense from 300 to 900 m at temperatures of 5° to 8°C. Red crab constitutes a new developing Canadian fishery; however, management units have yet to be defined. Since 1984 the Canadian fishery (yet exploratory) has been prosecuted by two vessels trapping between Western and Emerald Banks. Catches were 118 t and 468 t in 1984 and 1985, respectively.

There are no restrictions on fishing season or trap numbers. The provisional TAC of 1,300 t is based on a 50% exploitation rate for the Scotian Shelf edge from the Fundian Channel to the Gully east of Sable Island.

Resource distribution, as assessed by research surveys and commercial fishing patterns, suggests that northeastern Georges Bank forms a broad natural boundary between U.S. and Canadian red crab grounds. Tagging studies have shown little along-slope movement by adult crab; however, development times for the planktonic larvae are such that long-distance recruitment relationships appear probable.

RESUME

Il y a rareté d'information biologique pertinente pour la définition d'unités de gestion pour le crabe rouge, Geryon quinquedens. On trouve principalement cette espèce le long du rebord de la plate-forme Scotian et du talus continental jusqu'en Argentine; les concentrations sont les plus élevées de 300 à 900 m à des températures de 5 à 8°C. La pêche au crabe rouge constitue toutefois une nouvelle pêche canadienne en voie de développement et les unités de gestion restent à définir. Depuis 1984 les pêches canadiennes (quoique exploratories) ont été effectuées par deux navires exploités entre les bancs Western et Emerald. Les captures se sont respectivement élevées à 118 et 468 t en 1984 et 1985.

Il n'y a aucune limite quant à la durée de la saison de pêche ou au nombre de cages. Le TPA provisoire de 1 300 t est basé sur un taux d'exploitation de 50 % pour le rebord de la plate-forme Scotian depuis le chenal Fundian jusqu'au Gully à l'est de l'île de Sable.

La répartition de la ressource, telle qu'évaluée à partir des relevés de recherche et des configurations de la pêche commerciale, suggère que la partie nord-est du banc Georges forme une large limite naturelle entre les zones canadienne et américaine de pêche au crabe rouge. Les études d'étiquettage n'ont révélé que peu de déplacements de crabes adultes le long du talus; cependant les durées de développment des larves planctoniques sont telles que des relations de recrutement à partir de stocks éloignés semblent probables.

INTRODUCTION

The deep-sea red crab, Geryon quinquedens (Fig. 1), is found in the western Atlantic from Nova Scotia to Argentina (Rathbun, 1937; Scelzo and Valentini, 1974). The species occurs between 40 m to over 2,000 m on mud, sand or hard bottom where the temperature range is 3.6°-12.7°C; however, populations are most dense from 300 to 900 m at temperatures of 5°-8°C.

Geryon quinquedens 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. The abdomen of the female changes shape and relative size at maturity; (Haefner, 1977); its broad bulk serving to shield the extruded eggs. Both sexes have similar sized chelipeds. Males attain a maximum carapace width (CW) of 178 mm and 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 G. quinquedens is an important constituent of the deep-water community on the Continental Shelf and slope of the western Atlantic, the ecology and behaviour of this crab are poorly understood. On the outer Continental Shelf and upper slope, G. quinquedens has been observed on a "mud-clay base with sea anemones (Cerianthus borealis)" habitat (Cooper and Uzmann, 1980). The fact that G. quinquedens has been observed digging in its natural environment suggests that burrowing animals may be incorporated into the diet. Mounds up to 1 m across, observed at depths of 1,300 m from a manned submersible, may have been made by this crab (Grassle et al., 1975). Geryon quinquedens were photographed in small craters in silt-clay sediment along the continental slope of the United States at densities of up to 0.382 crabs m^{-2} (Wigley et al., 1975). In comparison, densities of up to 0.022 crabs m^{-2} were estimated from trap surveys along the edge of the Scotian Shelf (Stone and Bailey, 1980; McElman and Elner, 1982). The American lobster (Homarus americanus) and Jonah Crab (Cancer borealis) may directly compete with G. quinquedens for space and food in the shallower depth ranges. Natural predators of G. quinquedens are unknown.

Laboratory mating behaviour of G. quinquedens has been observed (Elner et al., 1987), and appears similar to that reported for G. longipes (Mori and Relini, 1982). The male initiates protection of the female as many as 13 d before female moult. Copulation, with the newly-moulted female inverted under the male, may continue for 11.5 d. Guarding of the female by the male after copulation has not been documented. Information on the interval between copulation and egg extrusion is not available. 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 6-19.5°C and salinities from 29 to 33°/$_{\infty}$ (Roff et al; 1984; 1986). The duration of the larval stages is temperature dependent. Total planktonic development time for the larvae is estimated at a minimum of 125 d for temperatures of 6°-10°C and only 23 d for 25°C (Rowoski, 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). Immediate upslope migration to warmer water (>6°C) probably occurs to enhance growth rates. Laboratory studies suggest that G. quinquedens 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 size taken by the United States' fishery. However, some individuals appear to have a considerably slower growth rate; crabs were recovered up to 6 years after having been marked with tags that are not retained through the moult. (Gerrior, 1981; Lux et al., 1982).

Soft-shelled, newly moulted, crabs are found year-round (Gerrior, 1981). Egg-bearing females as small as 70 mm CW have been captured on the edge of the Scotian Shelf; however, sexual maturity generally occurs between 80-91 mm CW. Males are reputed to be mature "at a relatively small size" (Haefner, 1976; 1977).

Interest in G. quinquedens as a commercial species has been slowly increasing. Initial explorations were made by trawling along the outer Continental Shelf of the United States (Schroeder, 1955; 1959; McRae, 1961) and off the Scotian Shelf and Georges Bank (McKenzie, 1966; Perry, 1969; Cadegan, 1971, unpublished). Offshore stocks of lobsters were located in the same surveys, which led to the fishery, crab was ignored. However, promising economic and technological studies were conducted in the mid 1960's to early 1970's (Holmsen, 1968; 1973; Meade and Gray, 1973; Galus, 1973; Holmsen and McAllister, 1974). Subsequently, more intensive surveys were made in Canada and the United States to assess both commercial abundance and harvesting techniques (Gray, 1969; Silbajoris, 1975; Haefner and Musick, 1974; Wigley et al; 1975; Stone and Bailey, 1980; McElman and Elner, 1982). Attempts to establish a commercial fishery for G. quinquedens off eastern North America indicate the need for appropriate technology and economic conditions for the success of such an enterprise (Gerrior, 1981). The quality of meat is high but fishing expenses and risks are also high. Costs for an offshore fishery, compared to an inshore crab fishery, are greater because vessels must be larger, travel further, trap deeper and have additional equipment for catch preservation.

Commercial landings in the United States actually began in 1973 as by-catch to the offshore lobster fishery. Currently, two large vessels operate out of southern New England. Traps are set along the Continental Slope between Lydonia Canyon and Tom's Canyon with only minor eastward effort. Landings were approximately 1,200 t per annum in the late 1970's and reached approximately 3,000 t per annum by 1984. In 1975, a comprehensive U.S. survey using trawls and a sledge-mounted camera system indicated that there was a commercial biomass (>114 mm CW) of 27,000 t in Continental Slope waters from Maryland to Corsair Canyon. The United States is attempting to manage exploitation of their red crab resource by limiting annual landings to 10% (2,700 t) of the assessed commercial biomass (Anonymous, 1984).

Intermittent commercial trapping of G. quinquedens off Nova Scotia started in the late 1960's. Fishing ceased in the mid 1970's due to unfavourable economic conditions. Historical catch records are meagerand probably do not reflect actual landings. The fishery used two types of trap, a conical top entrance pot and a large square trap (Holmsen and McAllister, 1974). Processing was done by boiling, quick chilling and

shaking out the meat (Holmsen, 1974). Landings began again in 1984 as by-catch to the pilot fishery for Cancer borealis on the Scotian Shelf edge. Subsequently, two vessels directed exclusively onto G. quinquedens and catches were 118 t and 468 t in 1984 and 1985, respectively. Two additional vessels made brief attempts at the fishery in 1985. Gear used were an unrestricted number of modified side-entry offshore lobster traps set in strings of 80 traps at between 500-860 m (Elner and Robichaud, 1985). Crabs were kept live in holds filled with refrigerated seawater until landed onshore for processing.

The minimum legal size of 115 mm CW for Canadian G. quinquedens is designed to protect the reproductive integrity of the resource by ensuring that most crabs will have had a chance to produce offspring before being captured by the fishery. There are no season restrictions at present.

Management goals, strategy and regulations for the fledgling Canadian red crab fishery have yet to be ratified. The preemptive TAC of 1,300 MT is based on a 50% exploitation rate (as recommended by CAFSAC for snow crab, Chionoecetes opilio) of the commercial biomass, conservatively assessed along the Scotian Shelf edge from the Fundian Channel, south of Browns Bank, to the Gully, east of Sable Island, by Department of Fisheries and Oceans (DFO) trapping surveys in 1980 and 1981 (McElman and Elner, 1982, unpublished report). A previous red crab survey in 1979 (Stone and Bailey, 1980) was conducted along the Shelf edge between Sable Island Bank and NE Georges Bank. In all three surveys, red crab appeared patchily distributed with maximum abundances occurring on the slope between LaHave and Emerald Banks at 180-900 m (Stone and Bailey, 1980; McElman and Elner, 1982, unpublished report).

Recognizing that substainable-yield principles may not be applicable in red crab, management has limited new entrants. With the recently ratified U.S.:Canada boundary ICJ line on Georges Bank, it is possible that exploratory fishing for red crab by Canadian vessels will extend westwards to Corsair Canyon.

A. History of Management Unit Definition

Red crab constitutes a new and developing fishery on the Continental Slope, thus, management units have yet to be defined. The two vessels targeting red crab range along the Scotian Shelf edge from off Western Bank to Emerald Bank (Fig. 2). However, the fishery may eventually develop and incorporate red crab grounds down to Corsair Canyon on the ICJ line.

The revived Canadian red crab fishery developed from a pilot fishery for Jonah crab, Cancer borealis, that was instigated on the Scotian Shelf in 1983 (Elner and Robichaud, 1985). To avoid conflict with existing lobster fisheries, the area defined for trapping Jonah crab was as follows:

- Twelve or more miles off the coast; north and east of a line which commences 12 miles off at 65°63' west longitude, proceeds true south to 43° north latitude, then true east to 64°30' longitude, then true south to the "200-mile" limit.

Lucrative by-catches of red crab led to vessels re-directing their effort from Jonah crab onto red crab. The Jonah crab fishery failed in 1985.

Given that red crab traps are confined to the Scotian Slope at depths (500-860 m) beyond those exploited by the offshore lobster fishery (maximum 480 m) conflict between the two fisheries appears unlikely; hence, red crab vessels are permitted to range, beyond the Jonah crab area, to the ICJ line.

Commercial red crab concentrations are restricted, thus subdivision of the Scotian Slope and Georges Bank by biologically-based boundaries appears unnecessary. The patchy abundance pattern is typical of a species at the northern Unit of its distribution. Productivity may be low and sporadic because of this.

B. In-depth Review of Biological Basis for Definition of Unit Stocks[1]

Overall, there is a paucity of biological information relevant to stock definition for deep-sea red crab. Research surveys have indicated seasonal segregation by sex and depth, with females most abundant from 400-600 m (Haefner and Musick, 1974; Wigley et al., 1975; Haefner, 1978). A general inverse relationship between water depth and crab size has been described (Wigley et al., 1975; Haefner, 1978; Stone and Bailey, 1980; McElman and Elner, 1982). There is evidence for seasonal vertical migrations on the slope (Wigley et al., 1975). Mark recapture studies (using vinyl "spagetti" tags not retainable through the moult) have indicated little movement by adults along the Continental Slope of the United States (Gerrior, 1981; Lux et al., 1982). In contrast, given extended larval development times (that may exceed 80 d) larval behaviour and hydrography, red crab larvae have the potential to be transported for considerable distances (>900 km) (Kelly et al., 1982). The recruitment model proposed by Kelly et al., (1982) predicts a continuum of genetic communication amongst adults of the Mid-Atlantic Bight. Recruitment to Canadian grounds may depend on the northeast flow of the Gulf Stream and thus, on U.S. egg production. In a study of Scotian Shelf Brachyura larvae, Roff et al. (1986) found zoeas of G. quinquedens mainly between Georges Bank and southwestern Nova Scotia, and east to Sable Island. Megalopas have been reported from the same area (M.J. Dadswell, personal communication). Roff et al. (1986) suggested that the broodstock existed between Georges and Banquereau Banks; however, the authors ignored the apparently equal probability that the larvae may have originated south of Georges Bank.

Resource distribution of red crab, as assessed by research surveys and commercial fishing patterns, suggests that northeastern Georges Bank forms a broad natural boundary between U.S. and Canadian red crab grounds. Stone and Bailey (1980) estimated that the number of trappable red crab on the Canadian edge of Georges Bank was only 2% of those surveyed between Corsair Canyon and Sable Island Bank. For further comparison: maximum mean catch rate was less than 2.50 crabs per trap haul off Georges Bank compared to 51.50 crabs per

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[1]A 'Stock', for the purpose of this paper, is defined as a self-sustaining population of a species.

trap haul at the "best" survey site between LaHave and Emerald Banks. A comprehensive U.S. survey in 1974 (Wigley et al., 1975) estimated a commercial red crab biomass (>114 cm CW) of 27,000 t in Continental Slope waters from Maryland to Corsair Canyon. Greatest concentrations were off southern New England, with relatively few red crab being located off Georges Bank. No red crab were caught at the two trawling stations on the Canadian side of the ICJ Line. Currently the two American vessels direct most effort in Atlantis, Bloch and Hudson Canyons (5Ze-6A). Only minor effort has been directed into Corsair Canyon (Gerrior, 1981).

In summary, there are at present no biologically-defined stock divisions for deep-sea red crab. As there appears to be little movement of adults along the Continental Slope, fishing in one area should not directly affect short-term fishing prospects in adjacent areas. However, given the probability of larval recruitment across the ICJ Line and the fact that NW Atlantic red crab may be essentially a single stock, long-term interests may be best served by a cooperative Canada:U.S. approach to management.

C. Implications of Conclusions on Stock Structure to Definition of Optimal Boundaries for Statistical and Management Purposes

The best biologically based division for separating management units in the Gulf of Maine Area appears to be the northeastern Georges Bank/Fundian Channel region; this seems a natural discontinuity. Also, commercial potential of the resource in the area appears minimal compared to the exploited grounds to the southwest and northeast. As U.S. vessels have fished east to Corsair Canyon, the Canadian fleet will no doubt explore grounds down to the ICJ Line. The ICJ Line then would appear the optimal division for separating red crab management units in the Gulf of Maine. However, given the broad discontinuity in red crab distribution and commercial fishing patterns, the NAFO 4X/5Ze line on any new line bisecting the slope of northeast Georges Bank would also be applicable.

D. Recommendations for Future Research

The major questions regarding red crab stock structure in the Gulf of Maine Area pertain to resolving: 1) the lateral movements of benthic life history stages along the Continental Slope; and 2) the transport patterns of pelagic larvae. The first question could be addressed by long-term tagging and field surveys. Resolution of the second question demands developing and testing the hypothesis proposed by Kelly et al. (1982). Laboratory studies of red crab larval behaviour would have to be "married" to larval survey and hydrographic data. In general, the research questions posed are unanswered for most commercial invertebrates, althouth they appear fundamental to effective fisheries management.

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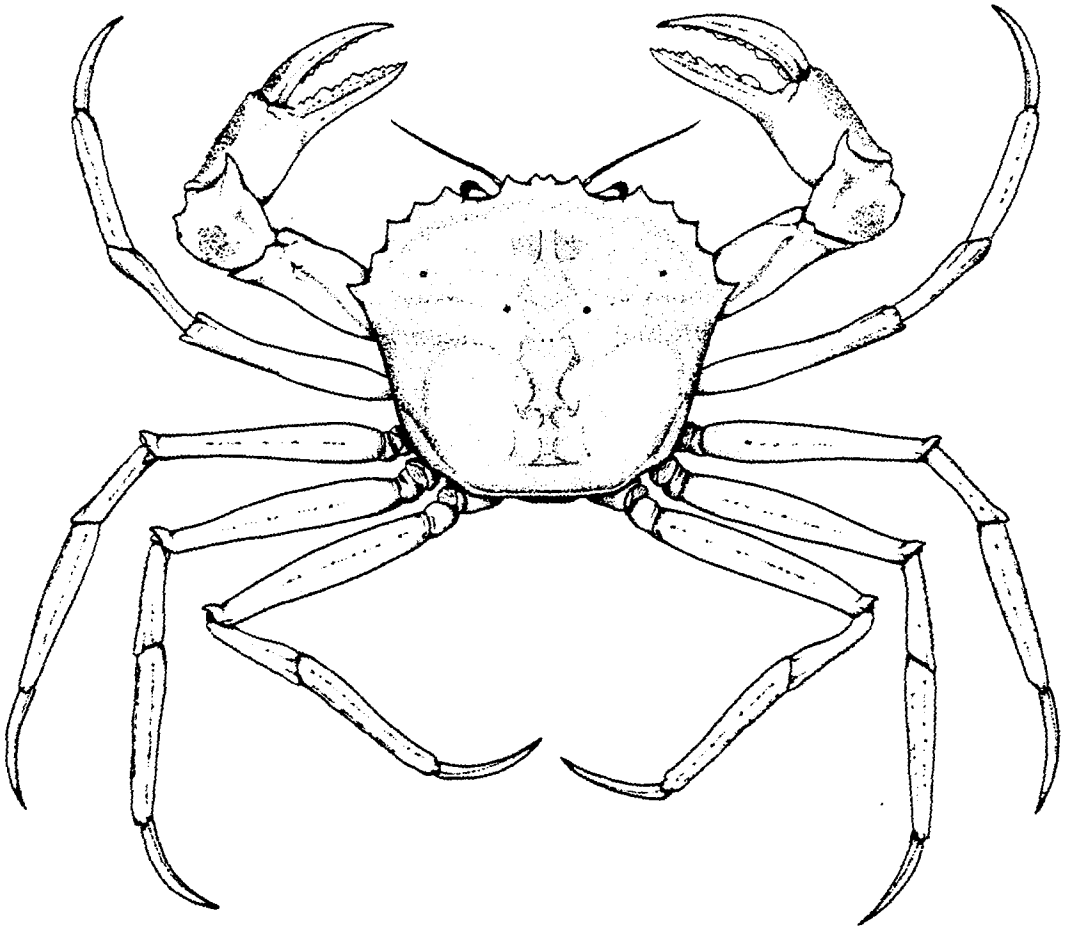

Figure 1. Male deep-sea red crab, Geryon quinquedens.

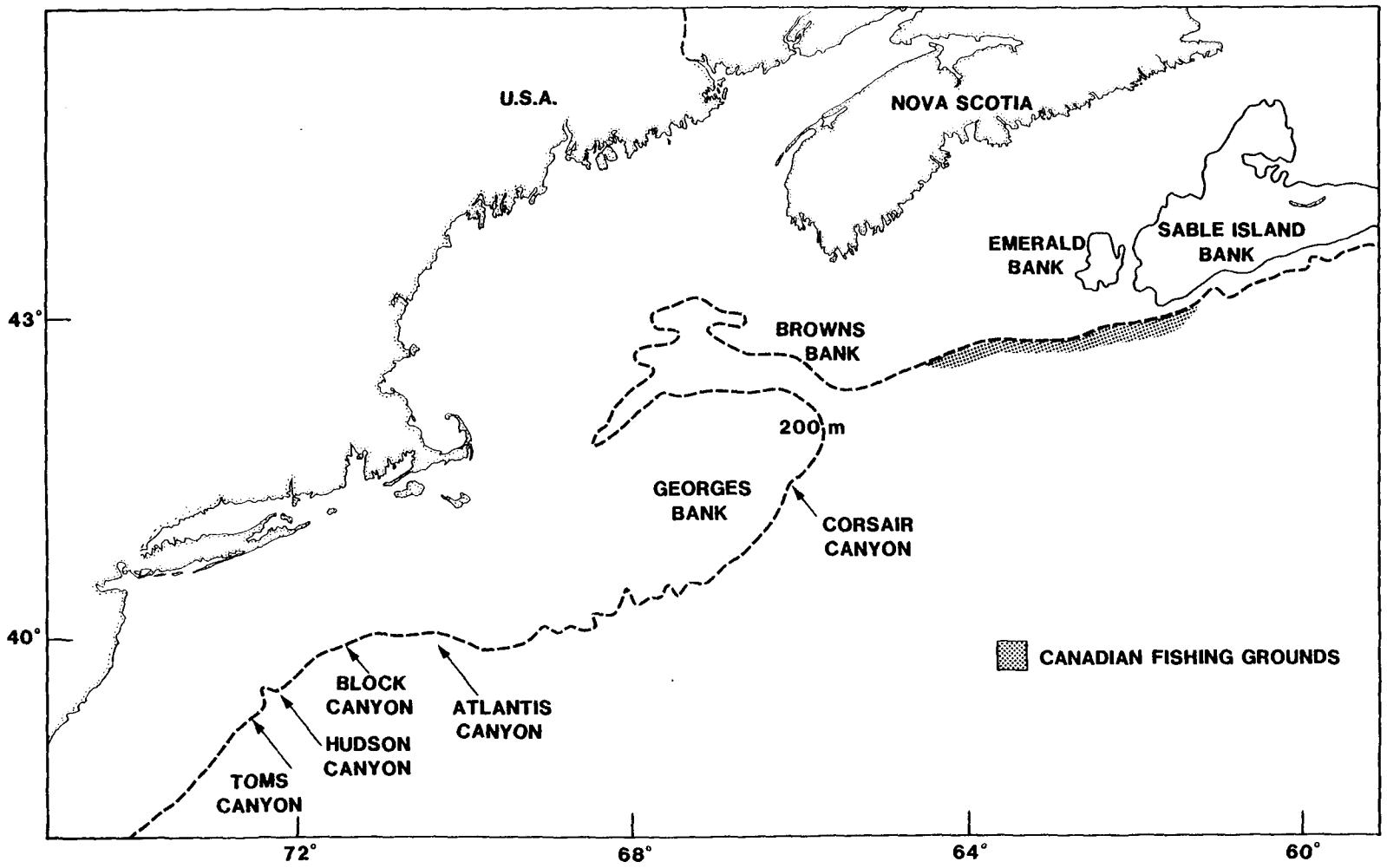

Figure 2. Known Canadian fishing grounds for deep-sea crab during 1985 (Elner, R.W., unpublished report).