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Potentially Exploitable Deepwater Resources off Atlantic Canada

by

G. Pohle, T.J. Kenchington, and R.G. Halliday

Marine Fish Division, Biological Sciences Branch
Department of Fisheries and Oceans
Bedford Institute of Oceanography
P.O. Box 1006, Dartmouth
Nova Scotia, Canada
B2Y 4A2

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G. Pohle[1], T.J. Kenchington[2], and R.G. Halliday

Marine Fish Division, Biological Sciences Branch
Department of Fisheries and Oceans
Bedford Institute of Oceanography
P.O. Box 1006, Dartmouth
Nova Scotia, Canada
B2Y 4A2

1. Atlantic Reference Centre, Huntsman Marine Science Centre, St. Andrews, N.B., Canada, E0G 2X0.

2. Gadus Associates, R.R. #1, Musquodoboit Harbour, N.S. Canada, B0J 2L0.

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ABSTRACT

Pohle, G., T.J. Kenchington, and R.G. Halliday. 1992. Potentially exploitable deepwater resources off Atlantic Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1843: 85p.

There has been little development of deepwater fisheries off Atlantic Canada by the domestic fishing industry and not much is known about the continental slope, and adjacent oceanic, fauna which might support such fisheries. The development of deepwater fisheries elsewhere in the world is reviewed to determine the species involved and whether they, or analogues to them, occur in Canadian waters. What is known about the distribution and abundance in Canadian waters, of species identified in this way, is summarized. A list of candidates, deserving of research and development efforts to establish whether they could support viable new fisheries, is drawn up. A variety of decapod crustaceans, particularly shrimp species, hold promise for development of continental slope fisheries, and there are several squid species which might form the basis of pelagic oceanic fisheries. However, almost all of the finfish identified by this method are species with fishery potentials which are already fairly well recognized.

RÉSUMÉ

Pohle, G., T.J. Kenchington, and R.G. Halliday. 1992. Potentially exploitable deepwater resources off Atlantic Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1843: 85p.

Il n'y a pas eu beaucoup de tentatives de développement de la pêche en haute mer au large du Canada atlantique de la part de l'industrie nationale de la pêche et l'on sait peu de chose sur la faune qui pourrait alimenter une telle pêche sur le talus continental et dans les zones océaniques avoisinantes. On examine le développement de la pêche en haute mer dans d'autres pays pour déterminer quelles sont les espèces pêchées et établir si les mêmes espèces ou des espèces analogues sont présentes dans les eaux canadiennes. On résume les données diponibles sur la distribution des espèces ainsi identifiées et leur abondance dans les eaux canadiennes. On dresse également une liste de celles qui méritent que l'on déploie des efforts de recherche et de développement pour déterminer si elles sont capables de soutenir une pêche viable. Une variété de crustacés décapodes, en particular de crevettes, forme une base d'exploitation prometteuse sur le talus continental. Par ailleurs, plusiers espèces d'encornet pourraient faire l'objet d'une pêche pélagique océanique. Cela dit, la plupart des poissons identifiés dans le cadre de cet exercice sont des espèces dont le potentiel d'exploitation est déjà assez bien connu.

PREFACE

This work was largely conducted under Department of Supply and Services contract FP142-0-7019/01-OSC, issued to the Huntsman Marine Science Centre, St. Andrews, N.B. The contract authority was C.G. Cooper, Fisheries Development and Fishermen's Services Division (FDFSD), Resource Management Branch, DFO, Halifax, N.S. We are most grateful to Mr. Cooper for this financial support. We are also indebted to W.M. Hickey (FDFSD), whose enthusiasm for exploration of deepwater resources provided the incentive to initiate this project.

INTRODUCTION

Diversification of fisheries increases total yield, and hence the economic and social benefits derived from regional fisheries. It also strengthens the foundations of the industry, making it more resistant to variations both in the abundance of particular stocks and in markets. In the last few years, the Department of Fisheries and Oceans (DFO) has increased efforts to promote diversification as one measure to counteract the adverse effects of declines in traditional groundfish resources. The species on which these efforts are concentrated are mainly ones for which yield potential has been clearly established for some time. This knowledge was obtained through conduct of research surveys and, in a number of important cases, through fisheries development by foreign nations prior to extended fisheries jurisdiction in 1977. Most of these species occur in shallow coastal waters or on offshore banks, but a few are either continental slope species, such as Greenland halibut[1] and roundnose (rock) grenadier, or oceanic forms, such as tunas.

The present report focuses on the deepwater resources of the continental slopes and adjacent oceanic areas off Atlantic Canada. Very little is known about the faunas of these areas. The small amount of research directed towards them has been largely restricted to faunal descriptions and there is not enough information, based on direct observations, to determine the potential for commercial exploitation of these species. The approach taken in this study, therefore, was to review developments in deepwater fisheries elsewhere in the world and to look for analogues in the Canadian zone which might be candidates for similar development. The purpose of the study was to derive a short-list of candidates deserving of research and development efforts that would directly establish resource potential and catching technology. It is not expected that this report will contribute to present DFO-industry diversification efforts; rather it will lay the groundwork for similar activities in the future.

In defining the scope of the report, it was decided not to consider in any detail those continental slope and oceanic resources which have already received considerable research attention and for which the fishery potential is well established, i.e. Greenland halibut, roundnose grenadier, and the large pelagic species. The primary systematic groups caught in research trawling are the crustaceans and fishes. Thus, these were the only groups reviewed in detail. Oceanic squids, despite their low catchability by research trawls, are also likely to have commercial potential, and a brief account of species occurring in the northwestern Atlantic is included in this report. While the same is no doubt true of some other invertebrate groups, such as bivalve molluscs, it was decided not to deal with these in the present study.

Common names of species are widely used in this report to make it more readable for non-scientists. The tables give cross-references between common and scientific names. A substantial proportion of the crustacean species short-listed as development candidates did not have common names. The authors have applied common names to these, as indicated in the tables of short-listed crustacean species.

Commercial catch weights given in the text are all in metric tons round fresh weight.

REVIEW OF PREVIOUSLY IDENTIFIED DEVELOPMENT CANDIDATES

A comprehensive list of species with fishery development potential was prepared in 1974 for review by a government-industry meeting on the utilization of Atlantic marine resources, sponsored by the Federal-Provincial Atlantic Fisheries Committee (May 1974). This list was as follows (asterisks indicate deepwater species, see below):

---

[1]Scientific names are given in the tables.

Fishes

Capelin (*Mallotus villosus*)
Roundnose grenadier (*Coryphaenoides rupestris*)*
Roughhead grenadier (*Macrourus berglax*)*
Common grenadier (*Nezumia bairdi*)*
Skates (various)*
Lumpfish (*Cyclopterus lumpus*)
Spiny dogfish (*Squalus acanthias*)
Black dogfish (*Centroscyllium fabricii*)*
Blue hake (*Antimora rostrata*)*
Arctic cod (*Boreogadus saida*)
Silver hake (*Merluccius bilinearis*)
Argentine (*Argentina silus*)
Sand lance (*Ammodytes spp.*)
Angler (*Lophius americanus*)
Mackerel (*Scomber scombrus*)
Sharks (various)*
Barracudina (*Paralepis brevis brevis*)*
Atlantic saury (*Scomberesox saurus*)*

Invertebrates

Northern shortfin squid (*Illex illecebrosus*)*
Longfin squid (*Loligo pealei*)
Green sea urchin (*Strongylocentrotus droebachiensis*)
Iceland scallop (*Chlamys islandica*)
Softshell clam (*Mya arenaria*)
Northern quahog (*Mercenaria mercenaria*)
Atlantic surfclam (*Spisula solidissima*)
Ocean quahog (*Arctica islandica*)
Blue mussel (*Mytilus edulis*)
Atlantic jacknife razor clam (*Ensis directus*)
Northern horsemussel (*Modiolus modiolus*)
Waved whelk (*Buccinum undatum*)
Common periwinkle (*Littorina littorea*)
Rock crab (*Cancer irroratus*)*
Jonah crab (*Cancer borealis*)*
Red deepsea crab (*Chaceon quinquedens*)*

In a more recent Scotia-Fundy regional meeting on underutilized species between DFO and the industry, a number of additional candidates were identified (DFO 1990):

Fishes

Tunas (other than bluefin)*
Hagfish (*Myxine glutinosa*)*

Invertebrates

Northern sea cucumber (*Cucumaria frondosa*)
Stimpson's surf clam (*Spisula polynyma*)
Northern shrimp (*Pandalus borealis*)*

These lists were, of course, developed in a Canadian context. Some of the species identified, although underutilized by the Canadian industry, are subject to exploitation by foreign nations.

To qualify for inclusion in the present report, a species was required to be distributed deeper than 300 m or to occur off the shelf over oceanic depths. Bottom species did not have to be distributed exclusively below 300 m for the species to be included, but some reason was required to believe that a significant proportion of individuals occurred below that depth. Similarly, pelagic species did not have to be exclusively oceanic to be included, but a significant part of their life cycle had to be oceanic. These criteria resulted in about 40% of the species in the above lists (those indicated by asterisks) being considered as deepwater resources. However, this does not imply that, for all of these, their greatest potential lies in deep water. For some it is clear that the bulk of the exploitable population is in coastal and shelf zones and that their potential in deep water is limited (see below).

CANADIAN DEEPWATER SPECIES WITH DEVELOPMENT POTENTIAL

PART I - CRUSTACEA

Most of the commercially valuable crustacean species are in the order Decapoda, which includes shrimps, lobsters and crabs. With about 8500 known species, this order represents almost one third of all described crustaceans. Shrimps and lobsters have elongated bodies with an extended abdomen bearing a tailfan and are capable of some swimming, in contrast to the primarily crawling crabs. The latter are short-tailed animals, characterized by a flat abdomen, permanently bent under the body (except when mating) and lacking a tailfan. All three groups are represented in the deepsea environment. Decapod crustaceans known from Canadian Atlantic waters have recently been described in detail by Squires (1990).

On a worldwide basis about 4 million tons of crustaceans are landed (FAO 1990). Crustacean fisheries are a most significant contributor to world fisheries, comprising about one third in terms of value (Lewis 1990). This report is restricted to those deepsea decapod Crustacea commonly found beyond the continental shelf break on the upper and middle continental slope, from 300 m to depths beyond 1000 m. Worldwide summary data are presented for those deepsea shrimps, crabs and other Crustacea with known commercial interest, and for which there are analogous Canadian species. In addition, all crustaceans known from Canadian Atlantic waters are considered for their commercial potential. Relevant species are reviewed by family. Information on size, habitat (depth, temperature, etc.), fishing methods (including gear used), and landed quantities is included whenever available, as well as other relevant data. Crustaceans presently exploited in the northwestern Atlantic are only briefly reviewed.

A) Shrimps

Shrimps include a diverse array of species which supports the most important invertebrate fisheries. There are two large subgroups comprising the penaeidean shrimps, which form the basis of valuable trawl fisheries in many tropical and subtropical countries, and the caridean shrimps, which are more widely distributed. Based on data summarized by Holthuis (1980), there are 343 species of shrimps worldwide which are of interest to fisheries. Among the deepsea fauna, i.e. in waters below 300 m, there are 76 species of known commercial interest, consisting of 29 penaeideans and 47 carideans (Table 1). Those occurring in the northwestern Atlantic are indicated by asterisks in this table. Additional deepsea species not listed in Table 1 but known to occur in the Canadian Atlantic (Pohle 1988) are also considered for potential commercial interest (Table 2). Species of small size (<25 mm carapace length (CL) or <100 mm total length (TL)) were either not considered as primary candidates for development, or were classed as unsuitable if known not to occur at high densities. The resulting available target species were divided into primary and secondary candidates (Table 3).

Aristeidae - gamba prawns, aristeid shrimps: Nine species among three genera are presently used, or being considered, for commercial exploitation (Table 1). The scarlet shrimp, *Plesiopenaeus edwardsianus*, is probably the most desirable among all deepsea shrimps, largely due to its great size, attractive appearance and relative scarcity. This is reflected in its cash value, which in the early 1980s, approached $10 per kg wholesale (Potter and Dredge 1985). It is found in the Atlantic, Indian and Pacific oceans, most frequently on muddy bottoms of the continental slope, between 400-900 m (Holthuis 1980) and prefers temperatures between 5 and 8°C (Lagardère 1981). Little is known about its biology. A life-span of 3-4 yr has been estimated, with sexual maturity occurring at 130-137 mm CL and spawning taking place in summer in the southeastern Atlantic (Burukovsky 1980). It is a predatory shrimp, living on other shrimps (*Pasiphea sivado, Plesionika martia, Nematocarcinus africanus*) and decapods (*Polycheles tylops*), fishes, and to a lesser extent on small crustaceans (euphausiids, amphipods), chaetognaths, polychaetes and cephalopods (Burukovsky *et al.* 1982; Lagardère 1981; Squires 1965). In western Australia, stomach contents are dominated by taxa of benthic origin (Rainer 1990) suggesting an absence of diurnal vertical migration. Off Newfoundland, Squires (1965) found another large shrimp, *Pasiphaea tarda* (the crimson pasiphaeid), in the same trawls with scarlet shrimp.

Until recently the scarlet shrimp was only fished commercially by Spanish trawlers (from Vigo, Huelva and Cadiz) in west African waters near Senegal, Guinea and especially off Congo and Angola (4-10°N) (Holthuis 1980). Off western Africa, north of Cap Blanc, scarlet shrimp is caught by bottom trawlers using 40 mm codends (Cervantes and Goni 1985), the annual harvest reaching a high of 2,234 tons in 1977, but decreasing to an estimated low of 33 tons in 1988 (FAO 1990 - and previous editions). Interest in this species has now developed in other parts of the world, such as Australia. Recently this shrimp has been taken as by-catch in northwestern Australia (Wadley and Morris 1990) in 500-530 m and commercial exploitation is also being considered on the eastern coast off Queensland and New South Wales, where specimens were caught in water depths of 530-740 m (Potter and Dredge 1985) and 550-900 m (Graham and Gorham 1985), respectively. In Australia a 40 mm mesh Siebenhausen prawn trawl with a single 27 m headrope was used, substituted by triple 27 m trawl gear to improve catches whenever possible (Potter and Dredge 1985). Graham and Gorman (1985) used a 45 mm mesh Kapala prawn trawl, increasing headrope lengths from 19.5 to 27 m. Shrimps are mostly frozen whole on board and sold in Spanish (e.g. Barcelona), French (Marseilles) and Japanese markets but some are also sold fresh (Holthuis 1980, 1981). In the northwestern Atlantic, scarlet shrimp were caught on the southwest slope of Grand Bank, Newfoundland, in 365-730 m at 4-8°C (Squires, 1965) and on the upper continental slope off Nova Scotia (Markle *et al.* 1988), with greatest abundance at depths of 401-600 m (1.2 specimens per 0.5 hr tow). At that depth interval, it represents the third most abundant decapod crustacean. The gear used by Markle *et al.* (1988) consisted of a 23 m (headrope) dual-warp Western IIA bottom trawl with 32 mm belly liner and 19 mm codend.

The giant red shrimp, *Aristaeomorpha foliacea*, has been fished commercially off western Australia since 1985, where it is the predominant species. It is morphologically similar to the scarlet shrimp but does not attain the latter's great size. In Australia, this is compensated for by its much greater abundance. Using the same gear as for scarlet shrimp, bottom trawlers catch most giant red shrimp in 400-450 m on the northwest coast (Wadley and Morris 1990), and at depths of 380-740 m (highest concentrations 530-700 m) on the east coast (Potter and Dredge 1985). In the northwest, the species occurs in a limited area in large daytime aggregations resulting in an annual catch totalling 420 tons in 1987/88, with catch rates between 25 and 75 kg per hr (Wadley and Morris

1990). A maximum of 35 kg per hr in 590 m was recorded off eastern Australia (Potter and Dredge 1985). Based on stomach contents and catch rates this species appears to migrate into midwater at night (Rainer 1990). The remaining Australian continental slope demersal trawl fishery is represented by two other penaeidean shrimps (*Aristeus virilis* and the solenocerid *Haliporoides sibogae*) and two other caridean prawns (*Heterocarpus sibogae* and *H. woodmasoni*), which are caught in the same vicinity but over a wider geographic area, for a total of 850 tons in 1987/88 (Wadley and Morris 1990).

Oplophoridae - deepsea shrimps: In the exhaustive worldwide survey of shrimps of interest to fisheries by Holthuis (1980), none of the deepsea shrimps were included (Table 1). In Atlantic Canada they are the most diverse group in deep waters, but most are too small or too rare for commercial purposes (Table 2). The fishery potential of two species of *Acanthephyra* may be worth investigating. *Acanthephyra pelagica,* the shortnose ridgeback, is an appealing shrimp both in terms of its deep-red colour and firm texture. Found in waters below 400 m, it is also the most abundant shrimp species in deep waters off Atlantic Canada (Markle *et al.* 1988), with twice the densities of any other decapod. It ranked first among shrimp species in both 801-1000 m and 1001-1200 m depth strata. The very similar but smaller *A. purpurea*, the longnose ridgeback, was ranked second most abundant among all species below 400 m and specifically within the 801-1000 m depth stratum. In terms of marketable size, this genus does not rank among the best, but otherwise it appears to be promising. Due to their great morphological similarity and similar depth distribution, both species could be caught and marketed as one entity.

Nematocarcinidae - spider shrimps: There is presently a developing fishery for only one species, *Nematocarcinus africanus* (Table 1), which has been caught off the western coast of Africa. Up to 85 kg per hr have been caught at 400 m (Lagardère 1981) with 12 m headline bottom trawls. This gear type may not be adequate for marketing purposes, however, since spider shrimps in general are rather fragile and require careful handling. Traps may be the gear of choice for these shrimps. In Canadian waters two species of *Nematocarcinus* are known to occur (Table 2), but *N. cursor* can be excluded from consideration as it reaches its northern limit in the southern part of the zone and is of low abundance. *Nematocarcinus rotundus*, the blunt spider shrimp, extends further north and represents a potential species for commercial exploitation along the edge of the Scotian Shelf (Table 3), where it is most abundant at depths over 1000 m (Markle *et al.* 1988). Off the Scotian Shelf it was found between 360-1115 m, with the highest abundance at the 400-600 m interval, where it also was the most abundant decapod crustacean (Markle *et al.* 1988).

Pasiphaeidae - glass shrimps: In this family of predatory shrimps (Lagardère 1981), three species are presently known to be of minor commercial significance and one of these, *Pasiphaea multidentata*, the pink glass shrimp, occurs in Canadian waters (Table 1). In Canada it was caught as by-catch of up to 24 kg per hr fished using midwater trawls during exploratory fishing for the northern shrimp, *Pandalus borealis*, in the Gulf of St. Lawrence (Tobey 1977). Largest among pasiphaeids is *Glyphus marsupialis*, caught by bottom trawls as a valuable by-catch of the penaeid shrimp fishery off western Africa (Lagardère 1981). Two other species are found in Canada, of which *Pasiphaea tarda*, the crimson pasiphaeid, is particularly worth investigating due to its very large size (Table 2). Larger specimens exist at greater depth, usually below 500 m (Squires 1965) in waters surrounding Newfoundland. It has been caught off Newfoundland from 200-640 m at 1-6°C and further north in 330-770 m at 1-4°C (Squires 1965). On the Scotian Shelf slope it occurred at its greatest density between 600-800 m, where it was the third most abundant shrimp species (Markle *et al.* 1988).

Pandalidae - pandalid shrimps: Among species of commercial interest, those belonging to the genera *Heterocarpus* (9 species), *Plesionika* (9 species) and *Pandalus* (7 species) form the majority among the seven genera from deep waters (Table 1). Species of the former two genera are restricted to tropical and subtropical areas, where most are in the early stages of commercial development (King 1986). The species which support major commercial fisheries are found in the genus *Pandalus*; *P. borealis* in the North Atlantic and North Pacific, and *P. jordani* in the North Pacific (Table 1). *Pandalus goniurus*, which is the most abundant shrimp in the northwestern Pacific (Zgurovsky and Alikin 1988), also has the potential to become of major commercial importance.

Only two of the pandalid species listed in Table 1 occur in Canadian waters. The northern shrimp, *P. borealis*, usually occurs in commercial quantities above 300 m but around Newfoundland and Labrador that is the mean depth of commercial concentrations (Squires 1965). Both the northern shrimp and *P. montagui*, the Aesop shrimp, are excluded from consideration here, since the former is already a major commercial species and the latter does not commonly occur in significant concentrations below 300 m (Squires 1965). However, there are three additional pandalids occurring in Canadian waters (Table 2), all of which extend well below 300 m. Among these *Stylopandalus richardi* can be eliminated from consideration due to its small size (Table 2), as can *Dichelopandalus leptocerus* because it is most common between 80-145 m (Wigley 1960). In contrast, *Pandalus propinquus*, the curvebeak pandalid, has the widest bathymetric range and commonly occurs in waters between 165-350+ m (Williams and Wigley 1977). The curvebeak pandalid is also worth investigating since Squires (1965) found it in 450-700 m in waters surrounding Newfoundland, a depth range similar to the crimson pasiphaeid, *Pasiphaea tarda*, which is another prime candidate with commercial potential (Table 3). Markle *et al.* (1988) recorded the curvebeak pandalid as the most abundant crustacean species between 400 and 600 m off Nova Scotia. This species has been found in waters ranging from 1 (Squires 1965) to 12.7°C (Wenner and Boesch 1979), but in northern waters Squires found 80% or more between 3.5 and 4.5°C. Although specimens up to 150 mm TL have been recorded off Norway, maximum sizes in the western Atlantic seem to be about 110 mm (Williams 1984).

Unlike northern and Aesop shrimps, Squires does not consider the curvebeak pandalid to be a hermaphrodite, probably largely due to the absence of distinct male and female size classes. Females are ovigerous in autumn with the majority of the population spawning annually in the spring (Squires 1965). Indications are that stomach contents consist mostly of phytobenthos and crustacean fragments (Squires 1965).

Crangonidae - crangonid shrimps: No deepwater crangonid species is presently commercially exploited to any significant degree and none of those which are fished occur in the northwestern Atlantic (Table 1). In this region, seven species among four genera are known to occur below 300 m but most are too small for commercial utilization (Table 2). *Sabinea hystrix*, the deepsea sabineid, and *Sclerocrangon ferox*, the back-spined shrimp, are both robust shrimps of appropriate size, and should be included as potential commercial species (Table 3). Information on their biology, particularly for the back-spined shrimp, is scarce. It is an arctic species (Pohle 1988; Zarenkov 1986) which, in the Atlantic, is restricted to areas extending north from Newfoundland. The deepsea sabineid extends further south. It was caught in the middle Atlantic Bight (Wenner 1978) on the continental slope and rise near Norfolk Canyon (approx. 36°50' to 37°10'N) by 13.7 m or 9.1 m (head-rope) semiballoon four-seam otter trawls. It has been caught between 452 and 2100 m at 7.3 to 3.8°C, but is most abundant between 800-1000 m in American (Wenner 1978) and Canadian Atlantic waters (Markle *et al.* 1988). At this depth range it is the third most abundant shrimp species on the Scotian Shelf slope. According to Wenner (1978), females are significantly larger and more numerous than males at all depths of capture. Reproduction is asynchronous and year-round. Ovigerous females were caught in every month, and ovarian growth was continuous, enabling multiple spawnings of small numbers of large eggs. Stomach contents were of benthic organisms, indicating that these shrimps do not migrate vertically into pelagic zones.

B) Crabs and Lobsters

The deepsea crustaceans other than shrimps, i.e. the crabs and lobsters, for which there is commercial fishery interest (Table 4), and additional deepsea species known from Atlantic Canadian waters (Table 5), were reviewed to provide a short-list of crabs and lobsters thought to be of potential commercial interest in Atlantic Canadian waters (Table 6). Deepsea fisheries among the clawed lobsters (Astacidea, Nephropidae) that are developing for species of *Metanephrops* (Table 4) are not considered here since they are restricted to tropical areas.

1) Palinura

Among this group are the well known members of the spiny lobster family from warmer southern waters. Much less known are the exclusively deepsea mud-dwelling polychelids with rudimentary eyes on immovable eyestalks. Unlike spiny lobsters which lack pincers, polychelids have them on all but the last pair of legs.

Polychelidae - blind lobsters, lobsterettes: A commercial fishery for these distinct lobsters presently does not exist. This group represents one of the least known crustaceans. Of the 35 species (among three genera), all are deepsea representatives, found in waters of the continental slope and beyond to abyssal depths (Firth and Pequegnat 1971). There are indications that some polychelids, like many other palinurids, migrate to shallower waters. Most polychelids, including the 12 or 13 Atlantic species, are found in 200-2000 m depth. In northern latitudes they tend to occur in shallower waters than further south. Polychelids are likely detritus scavengers which bury at least partially into bottom sediment. Four species have been reported from Canadian Atlantic waters (Table 5). Of these, *Polycheles validus* and *Stereomastis nana* can probably be discounted for commercial applications due to a limited Canadian distribution or relative rarity. In Canada, *Polychelis granulatus*, the unarmed blind lobster, has been found in 350-440 m in waters surrounding Newfoundland (Squires 1965) and further south on the Scotian Shelf in 640-1100 m (Markle *et al.* 1988). For commercial exploitation, this species is of marginal size (Table 5). In contrast, *Stereomastis sculpta*, the smooth-ridged blind lobster, is one of the largest polychelids (Table 5), with a carapace length of up to 70 mm. Firth and Pequegnat (1971) reported wet weights for adults at about 25 g but preserved specimens examined in the present study, ranging between 50 and 60 mm carapace length, weighed between 40 and 70 g. Weights of freshly caught adults would surely exceed 100 g. In Canadian Atlantic waters, it is the only polychelid worth considering for fishery purposes (Table 6). The unarmed blind lobster would perhaps be useful as a by-catch of smooth-ridged blind lobster. The latter species has a worldwide bathymetric range of 230-4000 m (Firth and Pequegnat 1971) at temperatures of 4-5°C, but the largest specimens are in 800-1300 m depth. Squires (1965) found specimens in 420-810 m at temperatures of close to 4°C, in the Newfoundland area, compared to 550-1110 m on the Scotian Shelf slope (Markle *et al.* 1988). In the latter area the smooth-ridged blind lobster was most abundant in the 600-800 m depth interval, where it represented the fifth most abundant decapod crustacean (Markle *et al.* 1988). Because of the burrowing tendency of polychelids, it is likely that abundance is underestimated by bottom trawling. Traps may yield very different results.

2) Anomura

Two rather dissimilar families, which both share the anomuran trait of reduced posterior legs, have been included here. Whereas the lobster-like galatheids have an extended abdomen with a terminal tailfan, lithodids have become very crab-like, with an abdomen, lacking a tailfan, that folds up under the body.

<u>Lithodidae - stone and king crabs</u>: While there is no commercial fishery for lithodid crabs in the North Atlantic, they are heavily fished in the Pacific Ocean. This can be partially attributed to the greater species diversity and greater size of some lithodid crabs in the Pacific. Best known is the Alaska king crab, *Paralithodes camtschatica*, which can attain carapace sizes just under 300 mm, making it the largest lithodid and one of the largest of all crustaceans. Sympatric species of secondary commercial importance are the closely related blue king crab, *P. platypus*, and, to an even lesser extent, the golden king crab, *Lithodes aequispina*. The commercial potential of *L. couesi*, a species with the deepest distribution (Table 4), has also recently been explored (Somerton 1981). At first, commercial species were caught with trawls (mainly U.S.A.) and bottom tangle nets (Japan), but gear is now restricted to traps or pots. Combined annual yields of the Pacific area have gone from 26,400 tons in 1969 to 48,000 tons in 1976, to over 54,000 tons in 1988 (FAO 1990, and earlier editions). Due to recent decreases in *P. camtschatica* in U.S.A. waters (Forrest-Blau 1986), a greater proportion of the catch now consists of *P. platypus* (Jensen and Armstrong 1989).

Other lithodids are also successfully exploited on a lesser scale in South America. Both the southern king crab, *Lithodes santolla (= L. antarctica)*, and the false king crab, *Paralomis granulosa*, have been fished in Chilean waters in recent years with combined yields of 2,000 to 3,000 tons annually (Anon. 1986). *Lithodes murrayi*, the subantarctic stone crab, has also been briefly fished commercially off southwestern Africa (Melville-Smith 1982) and has been considered for a fishery in the subantarctic Indian Ocean (Miquel *et al.* 1985). South American species were caught with trawl nets, gill nets and traps (Campodonico 1981) but since 1980 traps are the only permitted fishing method due to the heavy losses of sublegal sized crabs with tangle nets (Anon. 1986).

The North American king crab fishery underwent phenomenal increases followed by catastrophic declines despite regulations which included a size limit on male crabs and prohibition against landing females and soft-shelled crabs (Otto 1986). North American fishing gear is now also restricted to traps to reduce handling mortality of nonlegal size crabs. Trawls, which are now used only for annual surveys (Otto 1986), consisted of a "400 mesh eastern" otter trawl until 1980, to be replaced by a similar but larger trawl (designated 83-112) thereafter. To insure contact with the bottom, footropes were 30% longer than headropes and were weighted with chain. Despite the heavy fishing and the recent population decline which caused a temporary closure of the fishery in some areas in 1983 (Forrest-Blau 1986), it is suspected that fisheries and their management have played an insignificant role in the reduced population level (Otto 1986). Decreased stocks are more likely due to variable year-class strength (Incze *et al.* 1986) and high natural mortality (Otto 1986).

Although yields using traps are lower than for nets, trap efficiency has been gradually increased by modifying designs. There also seem to be advantages from a cost and ease of operation viewpoint. A conical trap of Japanese design was found to be superior to semi-spherical Chilean traps and traps built of polyethylene mesh and mesh made of a local plant ("coligue") were found to be most efficient and least expensive (Campodonico 1981). With recent advances it is likely that traps will gradually replace nets for most lithodid and some other crustacean fisheries. In general, traps for lithodid crabs are larger than those used for shrimps. In Alaska, crab traps are up to 200 x 200 x 80 cm in size (Miquel *et al.* 1985), with openings of 100 x 20 cm. In South America, conical traps with a base diameter of 160 cm and a height of about 60 cm (Anon. 1986) were most frequently used and deployed in sets of 10-20 traps for about two days. Traps and trawl gear may also select unequally among the population. Whereas the sex ratio among specimens caught by a 4.5 m beam trawl was more or less balanced, Miquel *et al.* (1985) found a strong selectivity of traps against females. The latter is attributed to dominant males preventing females from entering traps.

In general, the bathymetric distribution of each lithodid species is geographically variable and is probably largely dependent on environmental temperature. Annual migrations to shallower depth for reproductive purposes have also been observed but adults are generally found in deeper waters than juveniles (Sloan 1985; Somerton 1981).

The northern stone crab, *Lithodes maja*, which occurs in Canadian Atlantic waters, is similar in size to commercially fished southern king crab and subantarctic stone crab, and is therefore a potential species for exploitation. In the northwestern Atlantic it occurs from both coasts of Greenland south to New Jersey (Elner 1985). Northern stone crab are known in waters of 65-790 m depth at 1.0-9.7°C (Williams and Wigley 1977) but are rarely found in waters below 2.5°C (Williams 1984). In Canadian waters, from Davis Strait to the Flemish Cap (Squires 1965), they have been recorded from 100-790 m at 1-4.8°C, but the majority (80%) occurred in 160-460 m (mean = 325 m) at 3-4.5°C. Based on trawling on the Scotian Shelf slope, there are few specimens in waters deeper than 400 m (Markle *et al.* 1988). Further south, off the northeastern United States, northern stone crab have been recorded down to 400 m at temperatures of 2-9.7°C (Williams and Wigley 1977). The preferred substrate consists of gravel and glacial till, with fewer occurrences on smaller particles and none on shell substrate (Williams and Wigley 1977). Few data on relative abundance in Canadian waters are available, but significant densities of northern stone crabs were recently found in Sydney Bight, N.S., in about 180 m (R. Elner, DFO, Fish. Lab., Lower Water St., Halifax, N.S., pers. comm.), where boats equipped with Danish seines for catching flounder each collected about 200 lb per day of northern stone crabs as by-catch. These crabs were apparently being sold for a minimum of $1.40 per lb. There is, therefore, some indication of commercial quantities being available.

Size at maturity for northern stone crab and other lithodids differs with sex, and may also vary with locality. Squires (1965) found that, in waters near Newfoundland, female northern stone crab first mature at 37 mm CL (orbit to posterior carapace margin) whereas males grow to 76 mm CL before sexual maturity. Males of the closely related southern king crab from South America mature at about 90 mm CL. Based on this information, Campodonico (1981) considered that the minimum legal size, established at 120 mm CL, could be reduced to 110 mm. For northern stone crab, a tentative minimum legal size of 95 mm has been suggested (Elner, pers. comm.). In Alaska king crab, females and males mature at 90 (Otto 1986) and 100-105 mm CL respectively, but the latter do not enter the fishery until 135 mm CL to permit them to breed at least once or twice. For northern stone crab, in waters surrounding Newfoundland, the size range of crabs caught varied from 37-66 mm CL (mean = 53 mm) for females, and 33-92 mm (mean = 73 mm) for males but it was suspected that larger crabs may also have been collected (Squires 1965). Northern stone crabs obtained from lobster traps off Grand Manan Island and Cape Breton, Nova Scotia (Pohle 1989) were significantly larger, ranging from 36-149 mm CL (mean = 106 mm). Experience with other lithodid fisheries (see above), has shown that stocks are quickly depleted when non-trap fishing gear is used, and therefore the Danish seiners presently fishing for northern stone crab should be monitored carefully. Also, with the latter technique the majority of caught nonlegal size crabs will not survive when returned to the sea.

Neolithodes grimaldii, the porcupine stone crab, and the very similar *N. agassizii* (less likely to occur in Canadian waters) are the only lithodid species in Atlantic Canadian waters which are found in deeper waters than the northern stone crab. Both *Neolithodes* species are strictly deep water forms found below 300 m and usually at greater depths. In northern Atlantic waters, Squires (1965) found the porcupine stone crab in 720 m at 2°C. Further south, Wenner and Boesch (1979) recorded *N. agassizii* in waters of the Middle Atlantic Bight only below 1000 m at temperatures of 2.3-9.1°C. Judging by size both are potential commercial species (Table 6) but there is presently insufficient information to establish whether or not they occur in commercial quantities. Markle *et al.* (1988) did not report any *Neolithodes* during their survey of the Scotian Shelf. Nevertheless, characteristic fragments of these spiny crabs are often recognized in trawls from that area, indicating that specimens are present but too fragile for capture by trawling. Traps would be the most likely gear for successful sampling of *Neolithodes*.

Galatheidae - squat lobsters: Commercial interest for this group has only developed relatively recently. Presently the only major fishery is for *Pleuroncodes monodon* and *Cervimunda johni* off Chile, where the squat lobster fishery began in 1953 with *C. johni*. The latter is now of secondary importance to *P. monodon* (Bahamonde *et al.* 1986). Since the 1960s, landings from commercial trawling have usually been below 10,000 tons for *C. johni*, and between 20,000 and 40,000 tons for *P. monodon*. Both species occur in depths down to 400 m (Table 4), but seem to be more common above 300 m (Bahamonde *et al.* 1986). Mean carapace length of landed *P. monodon* was 39 mm in 1967 but has since decreased to 27 mm in 1978. The fishery for that species was temporarily closed in 1980-1982. Surveys with semiballoon trawls indicated that, whereas *C. johni* occurred over the entire known fishing area, *P. monodon* was distributed in discrete geographic areas, separated by areas where there were none. Surveys indicated that *P. monodon* appeared to migrate into deeper waters (250-300 m) during January and February (warmest months), with a tendency for larger individuals to occur at the lower extreme of the depth range.

In the Pacific, squat lobsters (*Pleuroncodes spp.*) are also being fished off El Salvador and Nicaragua (FAO 1990) and *Munida gregaria* is being considered for commercial exploitation in New Zealand (Zeldis 1989). In the northeastern Atlantic, *Munida rugosa* has only recently been targeted for a fishery (Howard 1981), with minor commercial catches being reported for Scotland, U.K., beginning in 1986 (FAO 1990). This species does not occur in the northwestern Atlantic. On the Pacific coast of Canada, *Munida quadrispina* is presently the only species being considered for a commercial fishery (Burd and Jamieson 1988). It has a wide bathymetric range, known to occur in waters beyond 1000 m (Table 4). In Atlantic Canada, four species of squat lobster are found: three species of *Munida (M. valida, M. iris* and *M. tenuimana)* and *Munidopsis curvirostra* (Pohle 1988). Both *M. tenuimana* and *M. curvirostra* are inappropriate for fishery purposes due to their small size (CL < 31 mm, incl. rostrum). *Munida iris* extends into Canadian Atlantic waters only in the Browns Bank area (42°N) near its northern range limit and therefore appears to have no commercial potential. *Munida valida*, the spinyhead lobsterette, is the largest species (CL to 83 mm incl. rostrum), and extends further north in deep waters off the Scotian Shelf. It is not found in areas north of Nova Scotia and its local population density is presently unknown. It is the only squat lobster worthy of consideration for potential commercial exploitation in Atlantic Canada.

3) Brachyura - true crabs

Fourteen species of crabs are known to occur in Canadian Atlantic waters (Pohle 1990), of which only six species have bathymetric distributions extending to waters below 300 m (Table 5). Among this latter group the following three species can be eliminated from consideration here: *Cancer irroratus* because it does not extend into deep waters off Canada (usually 5-50 m), as it does further south, where it has been found in up to 750 m (Bigford 1979); and *Hyas araneus* and *H. coarctatus* because they are scarce in waters below 200 m (Squires 1965).

Majidae - spider crabs: The snow crab, *Chionoecetes opilio*, which already is the most commercially valuable crab in Canada, is known to extend to depths beyond 2000 m (Pohle 1990), but in waters surrounding Newfoundland it was not found below 310 m, while 80% or more were located between 150-230 m (Squires 1965). Off the Scotian Shelf, Markle *et al.* (1988) found it in deeper waters (492-685 m). However, these were mostly juveniles at concentrations of less than 1 specimen per tow. In the Pacific, commercial fisheries exist for *Chionoecetes bairdii* and *C. japonicus*, in addition to *C. opilio*. Among these, only *C. japonicus* is strictly a deep water species. It is fished successfully with traps in the waters off Japan at depths of more than 800 m (Sinoda 1982). Annual catches of up to 35,000 tons have been recorded for *C. japonicus*.

Cancridae - rock crabs: The Jonah crab, *Cancer borealis*, the range of which does not extend north of Nova Scotia, has been mostly fished at intermediate depths on the outer continental shelf by means of bottom trawls and has also been caught as by-catch in lobster traps (Elner and Robichaud 1985; Williams 1978). Recently it has been shown that commercial patches exist in Canada on the upper Scotian Shelf slope, where crabs have been caught in standard offshore lobster traps at an average depth of 375 m (Elner and Robichaud 1985). To date, however, this pilot fishery has not proven to be cost effective (D.A. Robichaud, Biol. Stn., St. Andrews, N.B., pers. comm.).

Geryonidae - deepsea crabs: The red deepsea crab, *Chaceon quinquedens* (formerly *Geryon quinquedens*, c.f. Manning and Holthuis 1989), is the only true deep water crab in Canadian Atlantic waters. Investigations into its fishery potential date back to the 1950s in the United States (McRae 1961; Schroeder 1955, 1959) and the 1960s in Canada (McKenzie 1966; Perry 1969), but despite continued studies in both countries (e.g. Gerrior 1982; Lux *et al.* 1982; McElman and Elner 1982), exploitation has been increasing only slowly. Commercial landings started in 1973 in the United States and intermittent trapping occurred in Canada in the late 1960s (Elner 1986) but significant catches of 1,000-3,000 tons have only been recorded since the late 1970s in the United States. In Canada, the fishery has been less successful, with landings not exceeding 500 tons annually (Elner 1986). Based on trap catch rates (Stone and Bailey 1980) and abundance estimates (Elner 1986), there are indications that the red crab resource is much more limited in Canada than in the United States. This species, and perhaps other geryonids, tend to congregate near banks and seamounts (Zaferman and Sennikov 1988), which may explain why it seems to be patchily distributed in Canadian waters (Elner 1986).

As more geryonids are being discovered (Manning and Holthuis 1984, 1989), it is likely that fisheries will expand to other parts of the world, and the catch per unit effort will increase as more efficient capture techniques and processing technologies are being developed. Presently three other geryonids are being commercially exploited elsewhere. *Chaceon erythriae* is fished sporadically in a localized area off the African west coast (Macpherson 1984). *Chaceon fenneri* and *C. maritae*, which were only recently separated from *C. quinquedens* (Manning and Holthuis 1981, 1984), are fished in the Gulf of Mexico and off the African west coast (Melville-Smith 1988), respectively. The latter has developed into a major fishery with catches reaching 10,000 tons per yr. Crabs are caught by standard Japanese crab traps covered with 90mm mesh, attached to lines at 18 m intervals. Between 250 and 1,500 traps are attached to each line, which may extend as far as 30 km along the sea-bed. Trap soaking times are mostly between 20 and 120 hr. Until now this fishery has had no minimum size limit and crabs are fished throughout the year. Consequently current size at first entry into the fishery is below that at which females mature. Yield-per-recruit analyses have also shown that some fishery restrictions are necessary to prevent longterm overfishing (Melville-Smith 1988). Suggested control measures included increasing the age at first capture (by increasing mesh size), reducing fishing effort, and restricting fishing to waters below 500 m since females tend to be found at shallower depths.

C) Gears Used In Crustacean Fisheries

Deepsea shrimp fisheries of the world use trawl nets, e.g. off Spain, northwest Africa, Italy and southwest India, but also baited traps or pots, which originated in the tropical Pacific Islands (Wadley and Morris 1990). Trawling at present seems to be the most widely used fishing technique. Beam trawls and, to a greater extent, various types of otter trawls are the primary types of gear used for fishing in the deep sea (Garner 1988). In the U.S.A., semiballoon shrimp trawls predominate (Haedrich *et al.* 1975, 1980; Wenner 1978; Wenner and Boesch 1979).

Various modifications are used to reduce fish and other by-catch. These range from simple alterations, such as the addition of rollers or bobbins along the footrope to permit the escape of juvenile flatfish and to reduce the collection of rubbish. More complex modifications involve the addition of different separating panels that result in one or more codends or small mesh retainer bags, as well as trash chutes (Anon. 1973; Beardsley and High 1969; High *et al.* 1969; Jurkovich 1969). However, while successfully separating shrimp from unwanted organisms and rubbish, these devices often resulted in lower shrimp catches than for conventional trawls (High *et al.* 1969). Recently a more sophisticated shrimp trawling efficiency device has been developed (Watson *et al.* 1986). It is inserted between the body and the codend of the net, where it ejects unwanted by-catch by finfish deflector grids, as well as leading panels and exit openings which also act as trap doors for turtles, sharks, flatfishes, crabs and others. Average finfish separation rates of 53 to 73% were achieved without significantly altering shrimp catch rates. In order to maximize catches in deep waters, where little or no light penetrates, the addition of artificial lights has been tested. At 800 m, below the effective penetration of surface daylight, initial results seem to indicate that crustacean catches are hardly affected by lighted trawls (Hargreaves 1990). However, the attraction to, or evasion from light may vary with particular species, as has been shown in tests using bioluminescent bacteria (Makiguchi *et al.* 1980).

In recent years, more commercial use has been made of traps as an alternative to trawling techniques. In comparison to trawling, which requires large and relatively fast-moving boats with powerful engines, operating traps is simple, convenient and less costly (Miller 1990). Another major advantage over trawling is the superb condition of recovered specimens which yield an optimal market price. Traps can also be operated in terrain which is too irregular for trawls. For example, the spot shrimp, *Pandalus platyceros*, which occurs on rocky terrain in deep North Pacific waters, is fished almost exclusively by traps (Boutillier 1986a,b). In addition, traps, if properly designed, can be more size selective and less damaging than trawls which can cause high mortality of specimens of non-legal size. For example, in the British Columbia spot shrimp trap fishery, mesh-size variations allow for specimens of sublegal size to escape, while not decreasing catches of legal-sized animals (Boutillier and Sloan 1988).

Various traps have been tested for shrimps (King 1981, 1986) and crabs (Koike and Ogura 1977), desired species being targetted with different trap designs and bait. Factors known to affect the size of the catch include trap size, bait quantity and quality, time between setting and hauling, and loss of specimens escaping through an entrance (Miller 1990). Any design of traps must also take into account particular behavioural traits, as well as physical attributes, such as size, of the particular organism in question. Koike and Ishidoya (1978), in designing and testing different traps for northern shrimp, *Pandalus borealis*, found that the position of the trap entrance was important. Side entrances consistently yielded higher catches than top entrances. Also, more animals would enter the trap if the side entrance was lower, indicating that shrimps stay at or close to the bottom when entering traps. It is reasonable to assume that other benthic shrimps are likely to behave similarly. For other species, such as *Acanthephyra*, which are known to also occur in great numbers near and off the bottom, the side entrance design might not be optimal. For northern shrimp, more specimens were caught with smaller mesh sizes but for large specimens (CL > 24 mm) the differences between mesh sizes were minor. In traps with larger mesh (30 mm), smaller individuals (CL< 24 mm) escape through the mesh. Another critical factor is the diameter of entrances, optimal diameter being mostly dependent on shrimp size.

For spot shrimp, Boutillier and Sloan (1987, 1988) found that trap volume, type of entrance and soak time significantly influenced catches. Traps used were mostly of the conical nesting type and of three different sizes, varying in height from 24-30 cm, tops with a diameter of 45-81 cm, bottoms 45-97 cm; each trap had 2-4 tapering entrances of 8-18 cm length, depending on the trap size. Trap catches are also affected by gear saturation, at which point animals inside traps prevent those outside from entering (Miller 1990). Boutillier and Sloan (1987, 1988) found that, in contrast to smaller traps, which did not give an increased yield with increased soak time, larger traps not only caught more shrimps but yields also increased significantly with soak time from 48 to 96 hr. Therefore, it is suggested that larger traps with increased trap volume improve the trap saturation level. Entrances with medium lengths soaked for 24 hr gave the best results but the number of entrances, regardless of soak time, did not affect yields significantly. Tapered entrances with a wide external opening are considered more important than tunnel length in determining catch. Other modifications to prevent loss of shrimps through trap entrances include folding lips on the inner entrance of the cone (King 1986), to sealing of the entrances during hauling. Koike *et al.* (1981) increased trap efficiency for northern shrimp by 50% by the addition of a simple, but effective, closing trap-door design.

Traps can be successfully and efficiently used in deep waters, as shown by Ralston (1986) in an intensive fishing experiment for the tropical smooth nylon shrimp *Heterocarpus laevigatus*. These traps were half round in shape, measuring 91 x 66 x 46 cm with a frame made of 1.27 cm reinforcing steel, and were covered by 1.27 x 2.54 cm mesh hardware cloth. Catches of traps, set 40 m apart in 600-800 m, were so successful as to have depressed population size structure in the long term. Slow growth rates, high natural mortality and rapidly declining biomass at a relatively early age appear to be some of the biological factors which caused a low sustainable yield (King 1986). Some trapable deepsea shrimp species may therefore not be suitable for longterm commercial-scale fishing. In addition to trap design, the type of bait used can also have a significant effect on the catching rate (Krouse 1989; Zimmer-Faust and Case 1982).

Unlike shrimps, which have some swimming ability, crabs and lobsters from the deep sea are exclusively benthic, and are therefore even more prone to damage by bottom dragging trawls. Not surprisingly commercial crab fisheries use traps almost exclusively, with trawling now being restricted to exploratory and population census purposes. Traps are usually used in arrays, each array consisting of variable numbers of traps arranged along a single line anchored to the sea bottom (e.g. see Dawe 1989). Most commonly found types of traps include variations on a cone-shaped Japanese design. In the northwestern Atlantic they are made typically of quarter and half inch diameter (approximately 0.5 - 1.0 cm) iron rods welded together into a frame measuring 48 inches (1.2 m) in diameter at the base and tapering to a diameter of 28 inches (0.7 m) at the top (Dawe 1989). Polyethylene webbing with a 5.25 inch (13 cm) streached mesh size covers the frame. A funnel-shaped plastic cone tapering to a 14 inch (35 cm) entrance, located on top of the trap, allows crabs to enter while preventing their escape. Each trap weighs about 9 kg. The cone shape of the traps allows on-board stacking, which utilizes space efficiently. Other crab traps include large square or rectangular types used primarily for lithodids. In addition, semi-circular standard off-shore lobster traps have been used for geryonid crabs (see crab family sections for gear particulars). Methods for conducting trapping surveys, measuring catchability, and comparing fishing strategies have been critically reviewed by Miller (1990).

D) Conclusions - Crustacea

There is an obvious absence of relevant fishery data for many of the identified potential commercial species from the Canadian Atlantic. Selection of species has in large part been based on geographic distribution, depth range and maximum size. Other relevant fishery data have been considered whenever available. Based on this information a number of shrimps, crabs and lobsters of potential commercial importance have been identified (Tables 3 and 6). Illustrations of, and lists of characters which distinguish, these short-listed species are provided in Appendix 1 to aid in their identification. More information is provided by Pohle (1988, 1990).

Among primary shrimp candidates (Table 3), the scarlet shrimp, *Plesiopenaeus edwardsianus*, was selected due to its very large size and because there is a developing commercial fishery in place off western Africa and Australia. The crimson pasiphaeid, *Pasiphaea tarda*, is another very large shrimp which at present has not been exploited commercially anywhere. Smaller *Pasiphaea* species, however, are being fished elsewhere. Other species in this group (the deepsea sabineid, and shortnose and longnose ridgeback shrimps) are smaller but also have commercial potential. Specimens deposited at the Atlantic Reference Centre collection indicate that all of these species are caught regularly on the continental slope of the Scotian Shelf.

Species placed as secondary candidates (the pink glass, blunt-spider, and curvebeak pandalid, shrimps) appear to be less abundant or are smaller in size. An exception is the back-spined shrimp, a medium-sized arctic species which, however, does not extend south of Newfoundland. It has been placed in this group due to its restricted distribution.

Primary candidates among non-shrimp species include the large northern and porcupine stone crabs, as well as the spinyhead lobsterette and the unarmed and smoothridged blind lobsters (Table 6). The red deepsea crab, for which there already is a developing Canadian fishery, has also been included.

Often crucial data, such as abundance of the selected species, is unavailable or very limited, making it difficult to arrive at a satisfactory conclusion about potential commercial exploitability. Clearly, a significant amount of exploratory work, including the selection and testing of appropriate fishing gear (traps and trawls), as well as field surveys to establish patterns of distribution and abundance, will need to be conducted in order to narrow the field of short-listed candidates. In the case of shrimps, geographical and habitat overlap suggest a multiple species fishery strategy, rather than a selection for any single species.

PART II - FISHES

In this part, the deepwater finfish fisheries of the world are first listed, described and classified. The species of finfishes known to occur in deep water off Atlantic Canada are then listed and those which are thought to be particularly abundant are noted. A third list, of potential resources off the Canadian Atlantic coast, is derived from a comparison of the previous two. The probabilities that each of the species in this third list might support a fishery are then discussed and synopses of what is known about the most promising ones are provided.

A) Deepwater Finfish Fisheries of the World

Although the 300 m isobath represents a convenient marker for the outer limit of most Atlantic Canadian fishing, it has long since been passed by the fishermen of many other nations, by some in British Columbia and indeed by Nova Scotian halibut fishermen. All of these have gradually extended their continental shelf fishing operations into deeper water. Such fishing has been developed particularly in those areas with narrow continental shelves, where epipelagic resources over oceanic depths, and even deep-living demersal resources, can be exploited by artisanal or "inshore" fisheries. Deepwater fisheries have also been developed by distant water fishing nations which have turned to non-traditional resources as their access to more conventional ones has become limited. While the number of major fisheries for exclusively deep-dwelling resources remains small, there are, therefore, a great number of fisheries in many parts of the world that do exploit deep waters.

A summary is presented in Table 7, based largely on FAO sources, of those finfish fisheries that are currently being prosecuted in waters deeper than 300 m, arranged by fisheries area (or group of areas) and by broad functional and taxonomic groups of fishes. For present purposes, these various fisheries can be further classified into five partially-overlapping categories:

- extensions of outer continental shelf pelagic and demersal fisheries,
- fisheries for oceanic epipelagic species,
- fisheries for small mesopelagic fishes,
- fisheries for diadromous and primarily-inshore species at times or life phases when they can be found over deep water, and
- primarily demersal or semi-demersal fisheries confined to mid-slope depths.

This is not intended as either an ecological or a technological classification but rather as a convenient summary that may serve to illustrate the varied nature of deepwater finfish fisheries and to suggest the sorts of resources that might await development off Atlantic Canada. Each category is described below.

Extensions of Continental Shelf Fisheries: Of the five categories listed above, the first is of commonest occurrence. The 300 m isobath is neither a technological nor a biological barrier. Thus, many fisheries that are active in the 150 to 250 m depth range are also pursued out to the 350 or even the 500 m contour (some 50 species are fished in this manner in the East Central Atlantic alone: Fischer *et al.* 1981). Many of these species are demersal but this category also includes deepwater extensions of several neritic pelagic fisheries, such as those for Atlanto-Scandian herring and Peruvian anchoveta.

Since all of these fisheries use methods applicable to the nearby continental shelves and since they exploit species that are abundant on those particular shelves, neither their technological nor their biological characteristics are, in general, of marked importance for Atlantic Canada. The lesson that they do hold for this region is that the most promising immediate opportunities for deepwater fisheries probably involve resources that are already known to be commercially viable inshore of the 300 m contour or which might yet be developed inshore of that line. Indeed, such deep fishing as Atlantic Canadians already do (for Atlantic halibut, witch flounder, Greenland halibut and perhaps redfish) fits within this category. The silver hake fishery, if it should be successfully entered by Canadians, could also be extended beyond 300 m depth in this way. In addition, there is some possibility of pursuing neritic pelagics, such as capelin, and possibly benthopelagic shelf slope species, such as Atlantic argentine, out over deep water. However, since these species are already, or could be, exploited by Canadian fisheries at shelf depths, they are not reviewed further here.

Oceanic Epipelagic Fisheries: There are a number of highly valuable fisheries in the epipelagic category, particularly those for the tunas, billfishes, swordfish and pelagic sharks that are excluded from this study. Apart from those species, a number of sometimes-large, tropical or sub-tropical epipelagic species are taken commercially, either in directed fisheries or as bycatches of the tuna and similar fisheries. These include the flying fish, opah, dolphin fish (*Coryphaena* spp.) and others. With the important exception of the Atlantic saury and the less likely prospect of escolar, such oceanic epipelagics are rare in the cooler waters of the northwestern Atlantic north of the Gulf Stream and are unlikely to support a commercial fishery here. This is particularly so in view of the generally wide continental shelves and unfavourable weather in this region, which together impose high steaming and safety costs on vessels working beyond the shelf break. This is in marked contrast to many subtropical areas where oceanic epipelagics can be caught from small boats.

The important exception to this generally pessimistic outlook, Atlantic saury, is discussed in detail below. The possibility of a fishery for escolar (or oilfish) off Atlantic Canada must be considered slight, and even then they will probably only be taken as a bycatch in a deepwater tuna fishery. This species is not discussed further.

"Mesopelagic" Fisheries: Amidst the third category of deepwater fisheries, it is unlikely that any commercial fishing operations have exploited the true mesopelagic zone (200-1000 m depth in midwater) to any great extent but some have taken fishes of mesopelagic form (particularly myctophids and gonostomatids) when those occur closer to the surface at night. For many years, the South Africans carried on the only such "mesopelagic" fishery of notable size. They took, and to some extent still do take, the myctophid *Lampanyctodes hectoris* over continental shelf depths off their Atlantic coast, as a bycatch of, or alternative resource for, their reduction fishery for anchovy and other species. This fishery achieved a catch of 42,000 tons of *L. hectoris* in 1973 (Gjøsaeter and Kawaguchi 1980) but soon declined and has dwindled to a reported catch in 1988 of only 140 tons (FAO 1990). At its height and presumably thereafter, this fishery used surface-set, fine mesh purse seines capable of fishing down to 50 m depth (Gjøsaeter and Kawaguchi 1980).

None of the other "mesopelagic" fisheries have approached the scale of landings once achieved by the South Africans, though some have grown substantially in recent years and may expand further in the future. In particular, the USSR exploits the gonostomatid lightfish *Maurolicus muelleri* in the northwestern Pacific, with a reported catch of around 15 000 tons in 1987. They have taken around 1,000 tons per year of myctophids from the Southern Ocean (until 1988 when this fishery increased to 15 000 tons), and have reported some catches from the western Indian Ocean (FAO 1990). Other, minor "mesopelagic" fisheries for local consumption have existed off Japan, in the Mediterranean and probably elsewhere for many years.

A fishery for mesopelagic finfish (particularly for the myctophids *Benthosema glaciale, Ceratoscopelus maderensis* and *Notoscopelus elongatus*) is a possibility for Atlantic Canada but first indications suggest that it would not be economically attractive. In their review of world resources of such species, Gjøsaeter and Kawaguchi (1980) suggested, on the basis of scant data, that there might be 12 million tons of such fishes in this region, with the theoretical potential to support catches of 6 million tons per year. They further found, however, that mesopelagic fish biomass concentrations off Atlantic Canada were 0.5-10 g m^{-2} (i.e. 0.5-10 tons km^{-2}). In contrast, over substantial parts of the Arabian Sea equivalent concentrations exceed 200 g m^{-2} and yet no substantial fishery has developed there. Thus, it must be doubtful whether such a fishery could be viable in Canadian waters unless there are localized areas of high biomass density, not detected in the surveys cited by Gjøsaeter and Kawaguchi (1980), that are capable of supporting commercial operations. The USSR conducted an experimental fishery for mesopelagic fishes east of the Grand Banks during the 1980s, catching several hundred tons per yr (maximum catch reported in 1985 = 648 tons; NAFO Statistical Bulletins). The species caught was nominally *Notoscopelus elongatus* but other species were likely also taken. A continuing interest in fishery development for these species is reflected in a request in 1990 to the NAFO Scientific Council from the NAFO Fisheries Commission for a review of available data on mesopelagic species and advice on possible management measures (NAFO 1990).

The reasons that "mesopelagic" fisheries have not developed are doubtless various. Besides the presently depressed world market for fish meal (the only viable bulk product from such fisheries), there are obvious technical difficulties in efficiently harvesting small fish from considerable depths. These can only be overcome easily in special circumstances, such as the South African situation where the fish form dense schools near the surface at night. Once the fish have been caught, their small size (particularly their tendency to get trapped in the meshes of even the finest nets) and very high oil content make them difficult to handle. Furthermore, their composition tends to include high proportions of wax esters (Gjφsaeter and Kawaguchi 1980) and, at least in the case of *L. hectoris*, their oil is largely composed of saturated fats (Dr.S.Blaber, CSIRO Division of Fisheries Research, P.O. Box 120, Cleveland, Queensland 4163, Australia, pers.comm.), making the fish unattractive as a raw material for reduction.

This last factor alone was sufficient to prevent the promotion of an Australian myctophid fishery, despite the discovery of very dense concentrations (estimated to reach 400 tons km^{-2}: Kenchington, in May and Blaber 1989) off the Tasmanian coast.

In summary, the possibility of an Atlantic Canadian "mesopelagic" fishery presently appears remote. Canadian exploration and development work might best await more encouraging signs from USSR exploratory fishing activities that it is practical to utilize what is clearly a vast resource.

Fisheries for Diadromous and Inshore Species: The fourth category of deepwater fisheries can be roughly divided into two sub-groups, neither of which are of much local interest. Firstly, there are the highly migratory diadromous species, which in Atlantic Canada are represented by the Atlantic salmon and the American eel. Management concerns and economic factors respectively will prevent deepwater fisheries being developed for either of these, though the practicality of such a fishery is well established for both Atlantic salmon off Greenland and Faroe and for Pacific salmon in the North Pacific. The other sub-group comprises primarily inshore species that are occasionally swept out to beyond the 300 m isobath. In Atlantic Canada, with its wide continental shelves, this happens too rarely to be important but in some other areas, such as the Gulf of Guinea, inshore fishermen regularly pursue their quarry over great depths. This category of fisheries is, therefore, not relevant in the present context.

Deepwater Demersal Fisheries: The final group of deepwater fisheries, and the only one of major present interest, comprises the "true" deepwater demersal and near-bottom fisheries of mid-slope depths. Relatively few of these have yet been developed. They comprise:

- the small Korean and, to a lesser extent, Japanese fisheries for hagfishes,
- assorted fisheries for various rays and dogfishes, mostly in the North Atlantic,
- the major fisheries for blue whiting (*Micromesistius poutassou* and *M. australis*) in the northeastern Atlantic, east central Atlantic, southwestern Atlantic and the Mediterranean Sea, off New Zealand and in the Southern Ocean,
- fisheries for *Macruronus* spp. ("blue grenadier" or "hoki"; southern hemisphere relatives of the merluccid hakes and not to be confused with the macrurid grenadiers) in Australasia and around South America,
- minor fisheries for morid cods in a few areas,
- fisheries for the macrourid grenadiers, most notably the Soviet fishery for *Coryphaenoides rupestris* in the northwestern Atlantic,
- fisheries for cusk eels (*Genypterus* spp.) in the South Atlantic, northeastern and southeastern Pacific and off Australia,
- fisheries for trachipterid ribbonfish, particularly in the east central Atlantic and northwestern Pacific,
- the significant orange roughy fisheries of New Zealand and Australia (plus lesser fisheries for other roughies in the Atlantic and Mediterranean),
- the sablefish trap fishery in the northeastern Pacific,
- the various fisheries for centrolophids, particularly in the east central Atlantic and off Australia,
- fisheries for gempylids in various areas,

- fisheries for trichiurid cutlassfishes along the east side of the North and South Atlantic Oceans and in the northwestern Pacific, and
- fisheries for various deepwater flatfishes in the North Pacific.

Several of these fisheries do have Atlantic Canadian analogues. However, there are no *Macruronus* sp. in the northern hemisphere nor sablefish in the Atlantic. No trachipterids have been reported from Atlantic Canadian waters and neither of the northwestern Atlantic ophidiform cusk eels is large enough (in terms of individual body size) to be of commercial value. The only exclusively deepwater flatfish in this region, the Gulf Stream flounder, is also far too small to be of commercial interest. The fisheries for these groups are not, therefore, examined any further.

B) Deepwater Fish off Atlantic Canada

Information on the deepwater fish off Atlantic Canada has been gathered by a great number of research cruises and by incidental catches over many years, and most of it has recently been summarized by Scott and Scott (1988). Amongst all of this work, the only two intensive deepwater research fishing programs yet carried to completion in this region have been set respectively in the vicinity of Carson Canyon (on the eastern side of Grand Bank: Houston and Haedrich 1986; Snelgrove and Haedrich 1985) and along the continental slope off Nova Scotia (Markle *et al.* 1988). Each was confined to demersal fishing with trawl nets. Thus, the Atlantic Canadian deepwater ichthyofauna is well characterized for only these two areas, for only this one habitat and for only those species that are vulnerable to trawling. Other research programs south of Cape Cod (Haedrich *et al.* 1975, 1980; Haedrich and Merrett 1988; Markle and Musick 1974) and in the Denmark Strait-Irminger Sea area (Haedrich and Krefft 1978; Haedrich and Merrett 1988) may, however, serve to indicate the probable demersal faunas of the most southerly and northerly parts of the Canadian deepwater zone.

Unfortunately, most of this research fishing has been carried out with small, light and slowly-towed trawls (e.g. Snelgrove and Haedrich 1985) that cannot be expected to have taken quantitative samples of commercially-sized demersal fishes at great depths and which, judging from the species composition of the catches, may have touched bottom only intermittently. Thus, useful information on the relative abundances of potential deepwater demersal resource species off Atlantic Canada can only be drawn from Markle *et al.*'s (1988) work off Nova Scotia, which used a commercial-sized Western IIA bottom trawl, from the early Soviet resource exploration surveys (Pechenik and Troyanovskii 1970), from later German explorations [the only published report of which seems to be Karrer's (1973) compilation of ichthyological records] and, by extrapolation, from Haedrich and Krefft's (1978) Denmark Strait survey which also used a large trawl. Both the Soviet and the German explorations seem to have concentrated on the northern parts of the Canadian zone, from Grand Bank to the Davis Strait, thus serving to complement Markle *et al.*'s (1988) more southerly work.

In addition to these demersal studies, there have been some research cruises directed towards the smaller mesopelagic fishes off Atlantic Canada (Scott and Scott 1988) but there have not been any extensive acoustic surveys beyond the 300 m isobath in the northwestern Atlantic that might have revealed biomass concentrations well above the seabed. Thus, aside from the Soviet research on Atlantic saury (Dudnik *et al.* 1981) and such work as Templeman's (1967) longlining for redfish in the Labrador Sea, the only available data on potential deepwater epi- and mesopelagic resource species in the region comes from incidental observations and bycatches, particularly those from the bluefin tuna fishery. Scott and Scott's (1988) summary of this latter information can, therefore, be taken as an adequate reflection of what little is known of the occurrence of these pelagic fishes.

Combining all of these sources leads to the list of species and indications of relative abundance in Table 8. While this list is undoubtedly incomplete (too little fishing having yet been done for all rare species to be recorded), it is unlikely that many common, and hence potentially exploitable, fishes are missing. One potentially important exception is orange roughy which is known to occur in other parts of the world in small but very dense aggregations and which has recently been caught in small numbers in the Canadian zone by commercial vessels (see below), although missed during the deepwater surveys undertaken to date.

The more serious deficiency of Table 8 lies in its summary of abundances. Pechenik and Troyanovskii (1970) found that the redfishes, roundnose grenadier and Greenland halibut predominate at slope depths off Newfoundland. Commercial fisheries for these species have since developed, confirming their abundance. Pechenik and Troyanovskii (1970) also found black scabbardfish and smoothhead to be relatively common, though neither has yet been fished to any great extent. Pinhorn (1976) has suggested that the black dogfish *Centroscyllium fabricii*, the grenadiers *Macrourus berglax* and *Nezumia bairdi*, blue hake, Atlantic argentine and the barracudinas *Paralepis coregonoides* and *Notolepis rissoi* might be sufficiently abundant to support deepwater fisheries off Newfoundland. Further south, Markle *et al.* (1988) have shown that the redfishes predominate at continental slope depths off Nova Scotia, while appreciable quantities of *Centroscyllium fabricii*, the cutthroat eel *Synaphobranchus kaupi*, Atlantic argentine, longfin hake, silver hake, roundnose grenadier, *Nezumia bairdi* and witch flounder also occur there.

Among the less-quantitative studies, Snelgrove and Haedrich (1985) have supported the relative abundance of *Synaphobranchus kaupi*, blue hake, roundnose grenadier, *Macrourus berglax, Nezumia bairdi* and the redfishes off Newfoundland. South of Cape Cod, *Synaphobranchus kaupi*, longfin hake and witch flounder were particularly frequent in Markle and Musick's (1974) catches, while Haedrich *et al.* (1975, 1980) and Haedrich and Merrett (1988) reported particularly *Synaphobranchus kaupi, Halosauropsis macrochir, Alepocephalus agassizi*, blue hake, longfin hake, silver hake, *Nezumia bairdi, Helicolenus dactylopterus* and witch flounder as being abundant there. The Denmark Strait situation is more complex, with at least five recognizably different faunal groups (Haedrich and Krefft 1978). Atlantic argentine, *Alepocephalus agassizi, A. bairdii*, blue whiting, roundnose grenadier, *Macrourus berglax* and the redfishes were particularly frequent there.

The indications of relative frequency in Table 8 are based on these sources, with tuna and swordfish also being marked as abundant, since they are known to support major fisheries over deepwater. Clearly, the relevance and reliability of these indications are highly questionable. Indeed, the only deepwater species off this coast that are known for certain to be sufficiently abundant to support commercial fisheries are those already being fished: silver hake, roundnose grenadier, the redfishes, witch flounder, Atlantic halibut and Greenland halibut, plus the large pelagic bluefin tuna and swordfish.

C) Potential of Deepwater Fish Resources off Atlantic Canada

From the above considerations of deepwater fisheries around the world and of deepwater finfish species that occur off Atlantic Canada, it is possible to draw some conclusions as to the deepwater resources that might be developed in this region in the future. Firstly, it is clear that the world's major open ocean fisheries are those for the large pelagics, particularly the tunas, billfishes and swordfish. To the extent that these are not already developed off Atlantic Canada, they offer good prospects for future expansion. The next most important foreign deepwater fisheries, after those for the large pelagics, are extensions of continental shelf fisheries. These are mostly deep shelf demersal fisheries that extend down the upper slope but some are fisheries for primarily neritic epipelagics. Such outward expansions of continental shelf fisheries offer the best prospects for a future deepwater fishery off Atlantic Canada. However, some of the more promising resource species of this latter type in the northwestern Atlantic are currently either underexploited (e.g. the redfishes), unexploited by Canadians (e.g. silver hake) or simply ignored in Canadian continental shelf waters (e.g. the rajids). In each of these cases, the lack of exploitation seems to stem from a lack of markets or at least an insufficient market price for the fishery to be profitable with existing technology. Deepwater fishing for these species is, therefore, unlikely to be attractive to the industry, given its higher costs when compared to fishing on the shelf, unless much greater catch rates are possible at or over greater depths, or until processing and marketing changes allow the fisheries for these resources to expand to full exploitation. Regarding the exclusively deepwater fishes, the northwestern Atlantic already supports one of the few major demersal fisheries at continental slope depths: the foreign fishery for roundnose grenadier. There is a clear opportunity for increased Canadianization of this fishery, which opportunity may be one of the most promising in the deepwater area off Atlantic Canada.

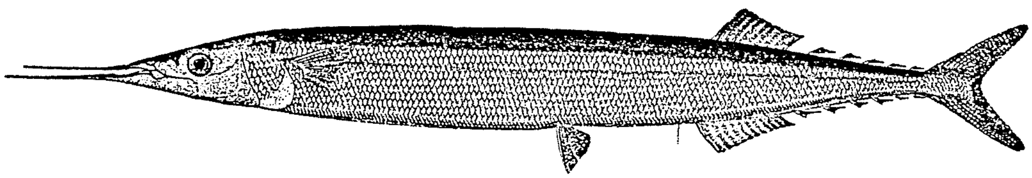
The focus of this report, however, excludes both large epipelagics and already-exploited resources. Hence, with the exception of the rajids (where the deepwater species are different from those on the shelf), the above possibilities will not be discussed further. Instead, comparing Tables 7 and 8 suggests that the following species might merit closer attention as future deepwater resources:

Hagfish	*Myxine glutinosa*
Black dogfish	*Centroscyllium fabricii*
Various rajids	
Blue hake	*Antimora rostrata*
Blue whiting	*Micromesistius poutassou*
Roughhead grenadier	*Macrourus berglax*
Marlin-spike	*Nezumia bairdi*
Other grenadiers	
Atlantic saury	*Scomberesox saurus*
Black scabbardfish	*Aphanopus carbo.*

In addition, even the slight possibility that orange roughy occur in commercial concentrations in Canadian waters cannot be ignored, given the importance of the fishery for this species off New Zealand (see below) and its interest as one of the most successful deepwater demersal fisheries yet developed. Each of these potential resources is discussed in the following sections. While this list includes all those resources of even minor promise, there is a possibility that, if an Atlantic deepwater demersal fishery is developed by Canadians, it will target on some fish that has yet to be exploited anywhere else; much as the New Zealand deepwater fishery now takes the previously almost unknown orange roughy. In the northwestern Atlantic, there are several species that might be commercially interesting, particularly the cutthroat eel *Synaphobranchus kaupi*. However, some of these fishes may have been ignored elsewhere for good reasons. The smoothheads (*Alepocephalus spp.*), for example, may appear promising in terms of their abundance off Atlantic Canada (Pechenik and Troyanovskii 1970) but studies of these species off Europe have shown them to be quite unsuitable as resources for any food product (Anon. 1974).

Synopses of biology, exploitation and resource potential for the primary species identified as possible candidates for future development follow.

1) Atlantic Saury : *Scomberesox saurus*



Biology: The sauries are oceanic epipelagic planktivores, with elongated but otherwise "mackerel-like" bodies and somewhat prolonged jaws. Of the four known species, only two are large enough to merit exploitation: the Pacific saury, *Cololabis saira*, and the Atlantic saury, *Scomberesox saurus*. The former supports a major fishery, with landings of about 300,000 tons per year from the northwestern Pacific, but the Atlantic species is not presently fished to any extent (FA0 1990).

Two subspecies of *S. saurus* are recognized. *S. saurus scombroides* is circumglobal in south temperate latitudes, being common in the South Atlantic but also known in the Pacific and Indian Oceans, including Australian and New Zealand waters. The nominate subspecies, on the other hand, is endemic to the temperate North Atlantic and the Mediterranean. In all areas, saury are primarily oceanic, though they certainly occur over continental shelf depths at times and on occasion are seen close inshore (e.g. Templeman and Fleming 1953).

The northern subspecies spawns in the waters of the Gulf Stream, North Atlantic Drift and Canary Current, well south of 40° N latitude and generally between the 16.5° and 23.5° C winter isotherms (Nesterov and Shiganova 1976). At least some of the adults migrate north for the summers, reaching the Barents Sea in the northeast and as far as Flemish Cap in the northwest. Despite repetitive accounts in the literature, the routes of these migrations are not well established. It does appear, however, that on the southward, autumnal, migration in the west, the fish delay crossing the Gulf Stream front and therefore become concentrated in the relatively narrow space between that front and the edge of the continental shelf. In doing so, Atlantic saury usually concentrate off the Scotian Shelf in October, moving gradually southwestwards but not leaving the southern parts of Georges Bank and the Nantucket Shoals until mid-December. At this time, they are in the Slope Water at temperatures that fall from 17° to 11.5°C as the season progresses, despite the fish's southward movement (Dudnik *et al.* 1981; Nesterov and Grudtsev 1980).

Some part of the northern migration evidently enters the Gulf of St. Lawrence as, in November and early December, aggregations of saury have been observed in the Strait of Canso, north of the causeway which blocks that exit to the Atlantic (M.J. Dadswell, Biology Dept., Acadia Univ., Wolfville, N.S., pers. comm.). They die there in large numbers, to be washed ashore along the northern face of the causeway. These saury are large specimens of about 45 cm total length, which is about the maximum for this species (Scott and Scott 1988).

Atlantic saury spend their lives at the ocean surface. As larvae, they are substantially more abundant in the top 0.1 m of the water column than 0.5 m down (Hartmann 1960) and even as adults they seem to be confined to the top 30 or 50 m. These maximal depths are only achieved by day and at night saury are all in the top 15 m of the ocean (Dudnik *et al.* 1981; Nesterov and Grudtsev 1980; Sauskan and Semenov 1969).

At certain life stages, Atlantic saury are strongly attracted by light. This property is vital to the commercial fishery since the fish must be concentrated if viable catch rates are to be achieved. The attraction is not strong when the fish are spawning or actively feeding but it does work well during the autumnal migration when Atlantic saury will fill the entire volume of illuminated water to a depth of 30m. This effect is noticeably decreased by December (Nesterov and Grudtsev 1980; Sauskan and Semenov 1969). As would be expected, the effect of artificial light is offset on naturally moonlit nights. Indeed, catch rates on full moon nights with clear skies and rough seas are only 10% of those with the reverse conditions (Dudnik *et al.* 1981; Zilanov 1970). This light attractant effect has allowed Soviet scientists to develop a visual counting survey technique based on "light stations". The battery of lights required is described by Zilanov and Bogdanov (1969) while Dudnik (1975) gives other details of the method.

Atlantic saury are exclusively planktivorous, adapting their diet to the types of plankton most abundant wherever they are (Nesterov 1981). They are probably the dominant temperate oceanic epipelagic planktivores of the North Atlantic. Their larvae and juveniles eat other appropriately-sized zooplankton (Hartmann 1960). Saury of all ages seem to feed very close to the surface. Even winged insects have been found in their stomachs (Nesterov 1981).

Atlantic saury are preyed upon by most of the larger epipelagic predators, including fishes, cetaceans, birds and squids. By their very abundance, Atlantic saury must be one of the principal food sources for these other species.

Atlantic saury mature at 26 to 34 cm length, with 50% being mature at 30.5 cm (males) or 32 cm (females). Histological maturity stage schemes for the females have been provided by Dudnik *et al.* (1981) and Korkosh and Timokhina (1983). They are serial spawners, each female spawning 5 to 23 batches of eggs in a single season, with an average of 1180 eggs per batch. The maximum annual fecundity of a single female is about 25,000 (Korkosh and Timokhina 1983). There seems to be some spawning activity all year but most occurs in winter months, particularly December and January (Dudnik *et al.* 1981; Korkosh and Timokhina 1983; Nesterov 1982; Nesterov and Shiganova 1976). The eggs and larvae of this species have been described in detail by Serebryakov (1982) and Fahay (1983). Extra details have been provided by Boehlert (1984) and Collette *et al.* (1984).

Nothing is known with any certainty about the stock structure of Atlantic saury, though there has been a general assumption that there are distinct stocks in the northeastern and northwestern Atlantic and Nesterov (1982) has suggested that there are no further divisions within the latter area. There may be more complexity than this simple two-stock model implies, however, since some adults must remain south of the Gulf Stream to continue spawning in the summer and Nesterov (1974) himself has suggested that spring and autumn spawned fish are recognizably distinct by their scale characters. It seems safe to conclude that the saury available to a fall fishery off the Canadian coast are all members of a single stock.

Atlantic saury reach lengths of 45 cm and weights in excess of 200 g but mean lengths in the exploited population are in the range 30 to 35 cm and individual weights are typically 70 to 140 g (Dudnik *et al.* 1981; Nesterov and Grudtsev 1980; Sauskan and Semenov 1969; Zilanov 1970). The observed lengths are often bimodal, with fish of 25-28 and 33-36 cm length (Zilanov 1970).

Nesterov (1974) has aged saury using scales and has concluded that they are fast growing and short lived, being around 23 cm long at 2 years of age and 31 cm at 3 years. These ages were not fully validated. Brownell (1983) has raised larval *S. saurus scombroides* in captivity and has found them to reach 13.5 cm in 236 days, with a projected length of 20 cm at 365 days. Conventional attempts to age Pacific saury have given conflicting answers but have been in rough agreement with Nesterov's (1974) and Brownell's (1983) results. Recently, however, diurnal otolith ring techniques have been applied to that species (Watanabe *et al.* 1988). If the otoliths were correctly interpreted in that study, Pacific saury reach 20 cm length in at most 250 days and achieve their maximum observed lengths (about 32 cm) in about a year. Thus, there seems no doubt that Atlantic saury are fast growing but it is less sure whether the bulk of the spawning adults are three, two or perhaps only one year old.

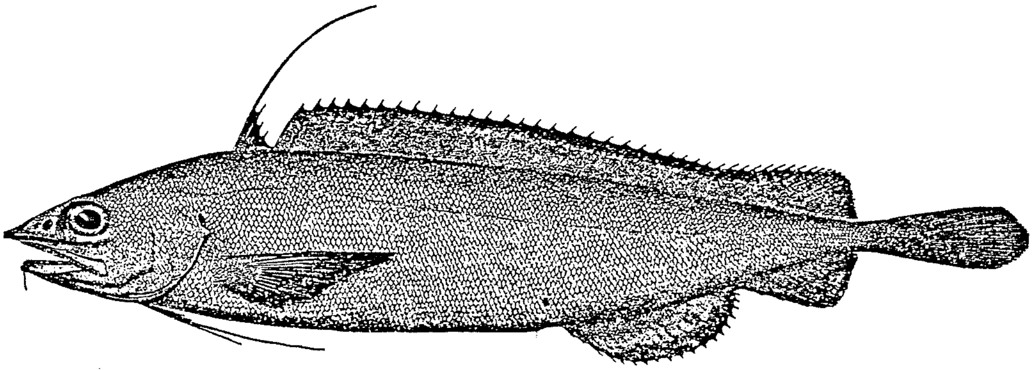
Using his scale ageing technique, Nesterov (1979) has estimated total mortality at $Z = 1.5$. Since fishing mortality is low, natural mortality (and hence also $F_{0.1}$) would then also be about 1.5 (Dudnik *et al.* 1981). From "light station" visual surveys, the biomass of saury in the northwestern Atlantic has been estimated at as much as 900,000 tons, leading to an annual yield estimate of 350,000 tons (Nesterov 1979) or about as much as in the northwestern Pacific saury fishery. Besides the questionable basis of the biomass estimate, however, this yield was based on yield-per-recruit reasoning, which is unsuitable to a short-lived species with low fecundity. Atlantic saury should be managed on a stock/recruitment basis, with appropriate attention to recruitment fluctuations, and to the species' role as prey for other commercial species. Nevertheless, it is clear that Atlantic saury could support very large catches in the northwestern Atlantic.

Exploitation: Nothing has been published in English on the modern fishery for Pacific saury. The Japanese exploited this species many years ago using drift gillnets. In the 1960s, they and the Soviets developed techniques using powerful lights to attract the fish followed by their capture with large dip nets or blanket nets. (The latter is a large rectangle of netting hung vertically from a boom held off the side of the boat. When fish have been attracted into the area between the net and the boat, the lower edge of the netting is hauled up to the boat's rail and the fish thus trapped are brought aboard; Radovich and Gibbs 1954). The Soviets seem also to have tried fish pumps with electrical fields to guide the fish to the pump orifice (Hughes 1970). Which of these gears is currently in use is unclear, though it is certain that the boats exploit Pacific saury concentrated against the complex fronts between the Kuroshio and Oyashio currents (Shinomiya and Tameishi 1988). They land some hundreds of thousands of tons of saury each year (347,000 tons in 1988: FAO 1990). The market supplied and the product made from these saury are unknown to the authors.

Soviet attempts to develop a northwestern Atlantic analogue to their Pacific fishery in 1969-74 showed that the only viable grounds were to the northwest of the Gulf Stream where Atlantic saury are concentrated in the autumn just as their Pacific relatives are to the northwest of the Kuroshio Current. The best months seem to be October (off the Scotian Shelf) and November (along the outer edge of Georges Bank). This fishery used the light fishing techniques developed in the Pacific but only achieved landings of some 3,400 tons per yr (Dudnik *et al.* 1981). Presumably the catch rates achieved were not adequate to support a commercial-scale fishery by distant water boats. However, the USSR appears to have a continuing interest in developing a fishery for this resource (NAFO 1990). Atlantic saury has also been caught occasionally in traps near Cape Cod (Bigelow and Schroeder 1953) and sold in the U.S. market as bait. [Sauskan and Semenov's (1969) account of this fishery does not correspond with that in the source they cite.] The apparently annual concentration of large quantities of Atlantic saury in the Strait of Canso has led Dadswell (pers. comm.) to suggest that a local fishery would be practical.

Potential: There is no doubt that Atlantic saury comprise a potentially exploitable, if seasonal, resource in the Canadian zone. Soviet research has shown where, when and how it can be caught. What remains is to find appropriate catching and processing technologies and a suitable market, such that a Canadian fishery for this species could be economically viable. Given the season at which these fish concentrate along the edge of the Scotian Shelf, this might be an appropriate fishery for relatively low-cost large "inshore" boats, perhaps 65 ft draggers, displaced or seasonally diverted from the groundfish fisheries. A coastal fishery in the Strait of Canso, if practical at all, would have a much lower yield potential than a shelf edge fishery but would present a low-cost opportunity to develop fishing methods, processing techniques, and markets.

2) Blue Hake : *Antimora rostrata*



Biology: Blue hake is a morid cod, one of a family of deep-dwelling, demersal gadiform fishes that closely resemble the more familiar cods and hakes. *Antimora* occurs in almost all of the world's oceans but is absent from such semi-enclosed seas as the Mediterranean and the Caribbean (Iwamoto 1975). The arrangement of species within the genus is still in dispute but most current authors accept Small's (1981) conclusion that all *Antimora* except those in the North Pacific (*A. microlepis*) are members of *A. rostrata.* The North Atlantic examples certainly belong to that species.

Blue hake are found along the continental slopes and rises of the North Atlantic basin from at least as far south as the Bahamas north to the waters off Baffin Island and, in the eastern Atlantic, from Denmark Strait to the west of the British Isles. They were not found, however, in two surveys off the northwest coast of Africa (Haedrich and Merrett 1988; Karrer 1973).

They have been caught over a very extensive range of depths. Their preferred depths, however, are more closely defined at any one geographic position, while showing noteable depression at lower latitudes. Thus, off the Bahamas they are found only on the continental rise (below 2250 m depth: Haedrich and Merrett 1988). Off southern New England, they are very abundant as shallow as 1400 m, though remaining the predominant fish to below 3000 m (Haedrich *et al.* 1980), and off Newfoundland they have been taken as shallow as 500 m although their depth of maximum abundance is probably below 1500 m (Snelgrove and Haedrich 1985). In the Irminger Sea, they are most common at 500 to 1000 m (Haedrich and Krefft 1978). In the Rockall Trough, they are common from about 1500 to 2000 m depth but much less so at 3000 m (Gordon and Duncan 1985a,b, 1987a). No evidence has yet been found for a diel or seasonal cycle in the depth distribution of *Antimora* (Wenner and Musick 1977) but there is a strong tendency for larger fish to live at greater depths (Wenner and Musick 1977; Snelgrove and Haedrich 1985), implying some ontogenetic movements.

Over its preferred depth range in the northwestern Atlantic, *Antimora* is the most abundant fish and accounts for the greatest proportion of the epibenthic biomass of any species, invertebrates included (Haedrich *et al.* 1975, 1980; Snelgrove & Haedrich 1985; Wenner and Musick 1977). Markle *et al.* (1988) did not find it to be so abundant off Nova Scotia but this may have been because they did not fish deep enough to find its major concentrations. Pinhorn's (1976) summary of the resources off Newfoundland may have undervalued *Antimora* for the same reason. It seems to be less dominant in European waters than off Atlantic Canada.

Blue hake appear to be exclusively demersal, a single reported midwater catch (Wenner and Musick 1977) notwithstanding. Confined in this way, their diet must be limited to benthic and benthopelagic species. It has proven difficult to confirm this because most of them suffer stomach eversion while being hauled to the surface. The few gut contents records that are available include fish, squid, octopus, euphausiids, amphipods, copepods, decapods, chaetognaths and polychaetes. In the Rockall Trough at the appropriate time of year they appear to scavenge blue whiting that have died after spawning and sunk to the seabed. Their prey are a mix of benthic and pelagic forms but it seems that *Antimora* feeds on only those pelagics that descend to its habitat and that it does not ascend into the water column to feed (Gordon and Duncan 1985b; Houston and Haedrich 1986; Mauchline and Gordon 1984b; Sedberry and Musick 1978). Although it has a "shovel-like" snout, this is not strongly reinforced (Iwamoto 1975) and it does not seem to be used to dig for infaunal food. *Antimora* is eaten in its turn by sharks (Mauchline and Gordon 1984b).

Very little is known of the eggs and larvae of any morid species and those of *Antimora* are entirely unknown (Fahay and Markle 1984). Although many adult fish have been examined, only very rarely have maturing gonads been seen (Gordon and Duncan 1985b, 1987a; Wenner and Musick 1977). The two maturing females noted to date were both taken off the U.S. east coast, one in January and the other in July (Wenner and Musick 1977). This lack of positive evidence of spawning has led to speculation on the spawning grounds of blue hake, including the possibility that all North Atlantic *Antimora* spawn in northwestern waters. It is, of course, possible that only the hake in that (or some other) area are able to mature, the remainder being expatriate populations, but alternatively there may be many small spawning grounds that have been missed by the rather limited sampling done to date. Another morid fish, *Lepidion eques,* has a distinct spawning season in the spring in the Rockall Trough (Gordon 1979). *Antimora* may have similarly confined spawning activity. Fecundity of the only two maturing females yet examined was about one million eggs (Wenner and Musick 1977).

Male blue hake tend to be smaller than the females and indeed rarely exceed 40 cm in length (Wenner and Musick 1977). This effect interacts with the tendency for larger fish to live deeper, causing the two sexes to be largely separately distributed (Iwamoto 1975; Wenner and Musick 1977).

There seems to have been no attempt made to age blue hake. From the limited length frequency information available, one might guess that the asymptotic length of the males is about 35 cm, while that of the females might be about 45 cm. Wenner and Musick (1977) have suggested that the length/weight relationship follows: $\log L = 1.831 + 0.279(\log W)$ for standard lengths in millimetres and weights in grams, suggesting an asymptotic weight for the females of about 0.9 kg. For comparison, mean individual weights in the catch from each tow below 1000 m depth off Newfoundland ranged from 0.4 to 1.1 kg (Snelgrove and Haedrich 1985).

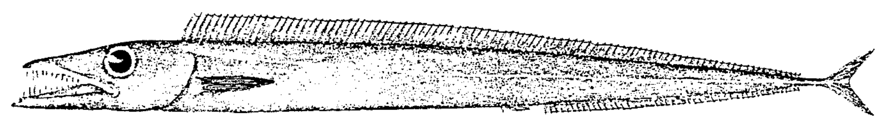
<u>Exploitation</u>: *Antimora rostrata* is not, and seemingly never has been, fished commercially, though it has been deliberately caught to provide specimens for physiological experiments. Other morid cods are exploited elsewhere in the world, notably in the east central Atlantic, in the waters around Australia and New Zealand and particularly in the northwestern Pacific, where the Soviet Union presently takes a large proportion of the world catch; some 17,000 tons in 1988 (FAO 1990). In no cases can these be regarded as major fisheries. Off Australia and New Zealand, for example, *Mora moro* is only taken as a bycatch (Last *et al.* 1983; Paul 1986). In research fishing, *Antimora* have generally been taken by otter trawls, and this certainly seems to be the most practical gear for them, but they will take baited hooks (Forster 1968, 1973; Pinhorn 1976).

Mora moro has been found to have a similar taste to haddock but its texture is much less firm (Anon. 1974). If this is also true of *Antimora,* its price might be expected to be correspondingly reduced, compared to those of the shallow water gadoids. Its relatively small size, suggesting increased processing costs, may also reduce wharf prices.

<u>Potential</u>: There is little doubt that large quantities of blue hake exist off Atlantic Canada although the apparent lack of food resources at the depths that this species inhabits suggests that their growth rates and sustainable yield may be low. It is also certain that this species could yield marketable products. The economic viability of an *Antimora* fishery remains to be tested, however. Their density on potential fishing grounds is

unknown, and hence future commercial catch rates cannot be predicted. Wharf prices may be expected to be lower than for the shallow-water gadoids. Moreover, a blue hake fishery would be the deepest commercial fishery yet developed anywhere and this would inevitably increase catching costs. Despite these problems, blue hake might be a useful adjunct to other deepwater resources for the Canadian offshore trawler fleet. It is unlikely that any other sector of the industry could exploit this resource.

3) Black Scabbardfish : *Aphanopus carbo*



Biology: The black scabbardfish is one of the cutlassfishes, a family of medium-sized deepwater predatory fishes that are distinguished by their elongated and laterally compressed bodies. Some species are silvery in colour and may be truly mesopelagic. *A. carbo*, however, is black and seems to remain near the bottom as a benthopelagic fish. Only one species of *Aphanopus* is known (Nelson 1984). It has been found in the North Atlantic, North Pacific and Indian Oceans and may indeed be more widespread than present records suggest. It is not very vulnerable to any fishing gear other than baited hooks set at great depths and its absence can therefore only be demonstrated where such gear is frequently employed.

Scabbardfish were first reported from the northwestern Atlantic by Templeman and Squires (1963) on the basis of two specimens caught northeast of Newfoundland in research trawls and a third taken on a halibut longline southwest of Sable Island Bank. Three more specimens were taken, two off Labrador and one off Baffin Island, by German exploratory trawling (Karrer 1973). There have been no other formal records (Scott and Scott 1988) and none were taken by Markle *et al.*'s (1988) trawling off Nova Scotia, nor by the various other deepwater research surveys in the western North Atlantic (Haedrich and Merrett 1988; Snelgrove and Haedrich 1985). The species may, however, be much more abundant than this lack of records suggests. Pechenik and Troyanovskii (1970) found scabbardfish in sufficient abundance from off west Greenland to Flemish Cap to suggest the species as a potential commercial resource, albeit not one that the Soviet fleet developed. This apparent anomaly probably relates to the gear used in the various studies. Scabbardfish are not very vulnerable to small bottom trawls (Gordon and Duncan 1985a) such as those used in the Carson Canyon surveys (Haedrich and Merrett 1988; Snelgrove and Haedrich 1985). Scabbardfish are much more common in the northeastern Atlantic, particularly around Madeira, where they have been commercially-exploited for more than a century (Leite 1989), and in the Rockall Trough area west of Scotland.

Black scabbardfish mostly live at depths between 500 and 1800 m (Bridger 1978; Ehrich 1983; Gordon and Duncan 1987b; Martins *et al.* 1989; Mauchline and Gordon 1984a; Zilanov and Shepel 1975) and within 100 m of the bottom (Leite 1989). In the Madeiran fishery, they are taken on the slopes around the islands and over surrounding seamounts, mostly between 800 and 1200 m, but not in midwater (Leite 1989). Off Brittany, they seem to be common at around 1100 m (Forster 1971), while in the Rockall Trough they are concentrated at 600 or 750 m in the spring but are deeper and more dispersed later in the year (Ehrich 1983; Gordon and Duncan 1987b; Zilanov and Shepel 1975).

At these depths, they experience temperatures anywhere between 3.5° and 8.5° or even 9°C (Ehrich 1983; Forster 1971; Leite 1989; Templeman and Squires 1963; Zilanov and Shepel 1975). The Madeiran concentrations are found mostly above 5°C, however, and this temperature might be the lower limit of occurrence in high densities. Otherwise, their distribution seems to be controlled more by depth, perhaps in its effect on light levels, than by temperature.

Bone (1971) has suggested that scabbardfish are able to detect their prey at ranges as great as 32 m, using their acoustico-lateralis systems, but that they must rely on visual cues for the final attack. This may have implications for selection of baits and lures and may relate to the light levels at which scabbardfish can survive.

Scabbardfish have the usual adaptations required by deepwater fish for holding gas at high pressures in their swimbladders (Bone 1971). In addition, those bladders are encased in a "rib cage" formed by incurving ventral ribs. This may allow the bladder to tolerate internal pressures higher than ambient, giving the fish some ability to ascend faster than they are able to out-gas (Howe *et al.* 1980). This would be of obvious benefit to a mid-water predator.

Black scabbardfish are almost entirely piscivorous but do eat a few cephalopods. Their fish prey in the Rockall Trough area includes blue whiting, argentine and mackerel (Du Buit 1978; Mauchline and Gordon 1984a; Zilanov and Shepel 1975). Further west, they have been noted as a predator of roundnose grenadier (Gushchin and Podrazhanskaya 1984).

Scabbardfish mature at a length of 78 cm in the case of males and 96 cm in the case of females off Portugal (Martins *et al.* 1989), at about 80 to 85 cm further north (Zilanov and Shepel 1975) and at rather smaller sizes off Madeira (Leite 1989). They are known to spawn off Madeira and there is some evidence for another spawning ground in the Rockall Trough area but only immature fish have been caught off Portugal (Ehrich 1983; Leite 1989; Martins *et al.* 1989; Pechenik and Troyanovskii 1970; Zilanov and Shepel 1975). Presumably spawning is more extensive than this since it seems unlikely that scabbardfish in the northwestern Atlantic would undertake regular trans-oceanic migrations. In the north, they seem to be winter spawners (Zilanov and Shepel 1975) and this may cause their tendency to aggregate in relatively shallow water in the spring (see above). The eggs and larvae of this species do not seem to have been described.

In most areas, the length frequency distribution of scabbardfish catches is tightly grouped around a mode at about 100 cm (Bridger 1978; Ehrich 1983; Martins *et al.* 1989; Mauchline and Gordon 1984a; Pechenik and Troyanovskii 1970) with nearly all of the fish being of adult size. There has been no published study of age and growth, though Geistdoerfer (1982) has presented some size-at-age values that he incorrectly ascribed to Bridger (1978). If those values are correctly drawn from some other source, then scabbardfish are slow growing, taking 20 or more years to reach maturity and well over 40 years to achieve average commercial size. Such ages are, of course, highly questionable in the absence of any evidence but, if correct, imply low natural mortality and a concomitantly low optimal exploitation rate (probably below $F = 0.1$). Martins *et al.* (1989) have provided a length/weight relationship for this species. No other population dynamic information is available.

Exploitation: There are only two significant fisheries for *Aphanopus carbo*, off Madeira and off mainland Portugal, and even these are small, accounting between them for some 4,500 tons of the world catch of only 5,600 tons (FAO 1990). There is a much more substantial fishery for the related cutlassfish *Trichiurus lepturus*. Annual landings are reported as about 750,000 tons (FAO 1990), primarily from the northwestern Pacific, although it is also taken in the central and southern Atlantic and Indian oceans. *Trichiurus lepturus* has a shallower depth distribution than does *A. carbo*, occurring on shelf and even in estuarine waters as well as on the continental slope. It is taken with a variety of conventional gears including bottom trawls.

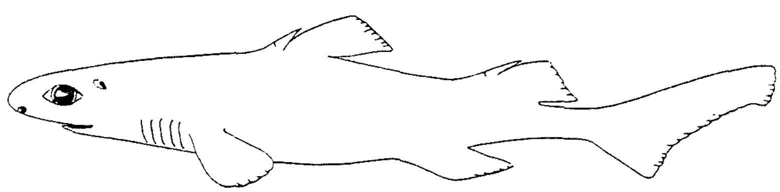
Scabbardfish have been caught commercially off Madeira since 1839 when a drifting longline, intended for deepwater sharks, chanced to be set a little too deep and too far offshore. As a directed fishery for scabbardfish grew, the fishermen abandoned conventional longlines and developed a hooked gear known as "Aparelho da Espada" but better described in English as a "drifting vertical longline" or "dropline". This comprised a backline (500 m long off Madeira) with baited hooks attached to it at intervals by snoods, in the manner familiar from normal groundfish longlines. Instead of being set along the bottom, however, one end of the backline was attached to a weight while the other was bent to several hundred metres of line leading to the boat. The early wooden sailing boats (about 8 m long) worked two such lines, one each over the bow and the stern. More recently, pairs of lines were suspended under large buoys and 10 to 15 m motor boats were used to tend 13 buoys. In the 1980s, there has been some return to horizontal longlines set in midwater at 900 to 1000 m depth (Leite 1989). This fishery grew to some 1,200 tons per yr by 1960 but technological improvements and an extension to new grounds in the 1980s have recently raised catches to 1,800 tons per yr (Leite 1989). The catch seems to be locally consumed and is reported to have good taste and quality.

The scabbardfish fishery off the Portuguese mainland is much more recent, having started only in 1983. After initial exploration with vertical longlines of the Madeiran pattern, this fishery has adopted conventional bottom-set horizontal longlines. Small boats of 15 to 20 gross registered tons set about 4,000 hooks each to take 200 to 550 kg of fish per boat day (25 to 100 tons per boat yr). The grounds are 10 to 20 miles off the Sesimbra shore in 800 to 1800 m depth. In 1987 and 1988, this fishery took about 2,600 tons per yr. Scabbardfish achieved similar prices per kg as did horse mackerel (Martins *et al.* 1989).

Scabbardfish have acceptable texture and taste properties and they will keep on ice for about as long as cod (Anon. 1974). Provided that consumers can be persuaded to accept a previously unknown deepwater fish, they should be fully marketable.

Potential: On the strength of Pechenik and Troyanovskii's (1970) observations, black scabbardfish must be regarded as a potential deepwater resource species, at least off Labrador and northern Newfoundland. The scarcity of other records, however, cannot be encouraging, particularly to the southward of Flemish Cap and the Nose of the Grand Bank. Markle *et al.*'s (1988) commercial-sized trawls should have taken at least a few individuals in the latter area if exploitable quantities were present and commercial deepwater halibut fishermen might be expected to have reported them. If scabbardfish can indeed be taken in sufficient quantities, it will probably be by drop lines, in which case the fishery might be developed by relatively small (45-65 ft) boats, though larger (65-99 ft) longliners might be more appropriate off Labrador.

4) Black Dogfish : *Centroscyllium fabricii*

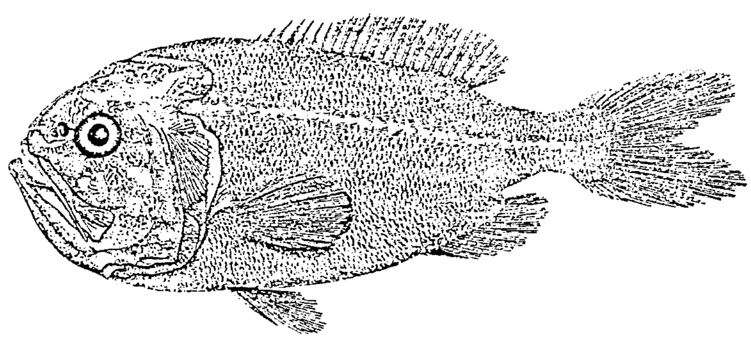


A number of sharks and dogfish are known from the deep waters off Atlantic Canada (Scott and Scott 1988) but of these only one, the black dogfish *Centroscyllium fabricii*, is sufficiently abundant to be of even minor interest to the commercial fisheries. Since the common dogfish of shallow waters (*Squalus acanthias*) is almost unexploited, despite its much greater abundance and availability, it is highly unlikely that *C. fabricii* will be exploited for its flesh in the foreseeable future. Unlike *Squalus*, however, many of the deepwater sharks have high concentrations of the hydrocarbon squalene in their liver oil. Squalene occurs in small quantities in many species, including humans where it serves in part as a precursor in cholesterol synthesis (Heller *et al.* 1957). In those sharks which have large quantities of it, the squalene is synthesized by the fish and probably provides buoyancy. There is a small, but not insignificant, world market for this chemical for use as a lubricant, a cosmetic base and a raw material for the pharmaceutical and similar industries (Deprez *et al.* 1990; Wu *et al.* 1980). Reported world landings of squalid dogfishes other than *S. acanthias* are about 7,000 tons per yr (FAO 1990), some but not all of which are landed for their squalene.

The squalene content of some deepwater sharks can reach 90% of the total liver oil, equivalent to about 20% of the total body weight of the animal, but is highly variable between species, even within genera (e.g. Blumer 1967; Deprez *et al.* 1990 and references therein; Hayashi and Takagi 1981; Heller *et al.* 1957; Wu *et al.* 1980). Moreover, there is some evidence that the squalene content of particular species varies substantially among regions (Deprez *et al.* 1990). Thus, the potential of Atlantic Canadian *C. fabricii* as a commercially viable source of squalene will remain unknown until appropriate assays are made on locally-caught specimens. Even if its squalene content proves to be high, the resource potential of this species will be limited by its relatively small body size in the northwestern Atlantic (usually 60 to 75 cm total length: Templeman 1963) when compared either to other squalene-bearing species (often 80 to 100 cm long) or even to *C. fabricii* in the northeastern Atlantic (Bridger 1978). This small size would clearly increase the handling costs per unit liver weight obtained. Moreover, although one 1,400 kg catch has been recorded (from a 90 minute tow on the edge of St. Pierre Bank: Templeman 1963), past catch rates of this species off Atlantic Canada have been low.

Very little is known of the biology of this species, except for distributional information. It is widespread around the margins of the North Atlantic basin (Haedrich and Merrett 1988; Scott and Scott 1988) at depths of 250 to 1,500 m (Gordon and Duncan 1987b; Haedrich and Krefft 1978; Haedrich and Merrett 1988; Kotthaus and Krefft 1967; Markle *et al.* 1988; Markle and Musick 1974; Pinhorn 1976; Sedberry and Musick 1978; Snelgrove and Haedrich 1985; Templeman 1963). It is particularly common off the Canadian coast, where it occurs in some abundance from 600 to 1200 m depth off Nova Scotia and perhaps rather shallower further north. The *C. fabricii* off Labrador and northeastern Newfoundland are considerably larger, on average, than those in the southern parts of the Canadian zone (Pinhorn 1976). They would be correspondingly more attractive to a fishery. What little is known of their diet suggests that they are active nektonic predators that feed in the water column (Baba *et al.* 1987; Sedberry and Musick 1978).

5) Orange Roughy : *Hoplostethus atlanticus*



There are no published records of orange roughy from Canadian waters (Scott and Scott 1988) and their larvae have not been taken, or at least have not been recognized, during the extensive ichthyoplankton surveys on the Scotian Shelf (Markle *et al.* 1980). However, orange roughy have been reported by fisheries observers in trawler catches off Labrador (D. Kulka, Northwest Atlantic Fisheries Centre, St. John's, Newfoundland, pers. comm.), and one specimen was recently taken off the Scotian Shelf (D. Themelis, Biology Dept., Dalhousie Univ., Halifax, N.S., pers. comm.). Pechenik and Troyanovskii (1970) took a few off western Greenland, some have been taken from waters seaward of the Gulf of Maine, and others from points further south (Woods and Sonoda 1973). Thus, the species occurs in the northwestern Atlantic from Greenland to USA waters, but none of these records suggest that it is abundant. In both Australasian and European waters, however, roughy occur in spatially small but very dense aggregations. This aggregatory behaviour makes them hard to detect during research and exploration surveys, even when they are sufficiently abundant to support significant fisheries. Roughy were not recorded off New Zealand, even as a taxonomic curiosity, until 1972 (McKnight 1972), yet within a decade over 20,000 tons per yr were being landed in that country. Thus, the rarity of catches of orange roughy in Canadian waters cannot be considered proof of the absence of commercially exploitable aggregations.

Overseas knowledge of orange roughy is summarized here not only because there is some small chance of a viable Canadian roughy fishery but also because the New Zealand roughy fishery represents the most successful attempt to date, by any nation with an economic system resembling that of Canada, to develop a demersal fishery at mid-slope depths.

Biology: The orange roughy is a medium-sized member of a deepwater fish family variously known as the "roughies", "bigheads" or "slimeheads", the latter refering to the large quantities of lipid present in cavities in their skulls. Anatomically, they are superficially similar to the sebastinid redfishes of the North Atlantic and they may yet prove to be ecologically similar to that much better known group. Many species of *Hoplostethus* have been described and Kotlyar (1984) has recently accepted 19 of them as being valid. Some of these have, however, been described on the basis of very few specimens and seem likely to be reduced to synonymy as the extent of intraspecific variation in the group becomes better known. It is at least certain that the exploited *Hoplostethus atlanticus* off New Zealand and off Europe are genetically indistinguishable from each other (Smith 1986), while they are clearly distinct from the rather smaller *H. mediterraneus* which also occurs in both North Atlantic and Australasian waters.

Hoplostethus spp. are circumglobal at continental slope depths, having been found in most, though certainly not in all, areas where suitable fishing gear has been deployed at appropriate depths. *H. atlanticus* occurs in considerable abundance off New Zealand between depths of 700 and about 1300 m (Robertson *et al.* 1984). Lesser, but still commercially attractive, concentrations are known off the southern parts of Australia, while very occasional but very large catches have been taken from the Rockall Trough, west of Scotland (Ehrich 1983; Freytag 1979). [The orange roughy off Scotland were originally misidentified as *Gephroberyx.* Merrett and Wheeler (1983) corrected this identification but not before the erroneous name had been used in several publications.]

Little is yet known of the preferred habitat of orange roughy. Even their depth range is less than clear, though they seem to live consistently below 500 m depth and they are usually caught commercially above 1000 m. In the northeastern Atlantic, they have been found at 5 to 7.5 or even 10° C (Bridger 1978; Ehrich 1983), while off New Zealand and Australia they are abundant at 4.4 to 7.6° C (Newton *et al.* 1990; Robertson *et al.* 1984). In some areas they are noticeably associated with bottom features such as canyons or pinnacles (e.g. Pankhurst 1988) but elsewhere they are found in abundance on relatively flat bottom.

No ethological research has yet been carried out on orange roughy but it is clear, from the catches obtained in both research and commercial fishing, that adult roughy characteristically live in exceedingly dense aggregations (but see Smith and Koslow 1990 for a somewhat contrary view). These aggregations can yield catches of tens of tons in a few minutes of aimed trawling (e.g. Tracey *et al.* 1986). As seen on echo sounders, the tops of these aggregations can be anything from a few to more than one hundred metres off bottom, while their bases reach to the seabed (Do and Coombs 1989; Lyle *et al.* 1989). Various attempts have been made to fish the upper parts of these sound-detected aggregations. While conclusive proof is not yet available, it does appear that the sound scatterers off New Zealand are indeed roughy, or at least that the distribution of the roughy corresponds to that of the scatterers. Off Australia, however, recent observations suggest that much of the observed off-bottom mass of sound scatters may be composed of other species (Smith and Koslow 1990). Thus, orange roughy should be seen as a bottom-associated, rather than a strictly demersal, fish. The aggregations are not all specifically for feeding or spawning (Elliot and Bulman 1989) though some may have one or the other function.

Roughy seem to be opportunistic bentho-pelagic feeders, adapting their diet to whichever types of prey (decapods, fish, squid etc.) are most abundant in the particular area (Elliot and Bulman 1989; Gordon and Duncan 1987b,c; Kotlyar and Lipskaya 1980; Macpherson and Roel 1987; Mauchline and Gordon 1984a, 1985; Newton 1988; Rosecchi *et al.* 1988;). A high proportion of them have empty stomachs, however, and studies published to date leave a general impression that roughy do not eat very much.

Roughy mature at about 30 cm fork length for males and 33 cm for females (Elliot and Bulman 1989; Evans and Wilson 1987; Liwoch and Linkowski 1986). A maturation scale has been prepared by Pankhurst *et al.* (1987). They are synchronous spawners and in Australasian waters spawn in the middle of the austral winter (Evans and Wilson 1987; Newton *et al.* 1990; Pankhurst *et al.* 1987). Pankhurst (1988) noted that the mean spawning dates on the three principal New Zealand grounds are the dates on which day length reaches 9 h 28 min, following the winter solstice. This rule does not seem to be strictly correct for the one major spawning site found in Australia. Roughy seem to have complex within-aggregation behaviour during the spawning season (Lyle *et al.* 1989; Pankhurst 1988).

Gonosomatic indices of ripe female roughy reach only 17 to 19% (Lyle *et al.* 1989; Newton *et al.* 1990) and their fecundities are in the range of 20,000 to 90,000 eggs per female (Evans and Wilson 1987; Pankhurst 1988) both of which are rather low for an oviparous, pelagic spawning fish of this size. Their eggs are large for a pelagic spawner (2 to 2.5 mm diameter: Pankhurst and Conroy 1987) and may rise to the surface immediately after spawning, though this has recently been disputed (Smith and Koslow 1990). Little is known of their subsequent development, nor of the ecology of pre-recruit juveniles. No useful information is yet available on the variability of recruitment.

Length frequencies of orange roughy from commercial fishing grounds characteristically show a very marked single mode at adult lengths. In the northeastern Atlantic, this mode is at 55 to 65 cm total length (Bridger 1978; Freytag 1979). Off Australia and New Zealand it is centred around 35 to 45 cm fork length, or rather smaller than off Europe (Elliot and Bulman 1989; Evans and Wilson 1987; Liwoch and Linkowski 1986; Lyle *et al.* 1989; Robertson *et al.* 1984). More recently, research fishing outside commercial aggregations has found the fish there to be typically smaller than those within the aggregations (Elliot and Bulman 1989), suggesting that the distinctive unimodal frequencies from commercial fishing are caused by a behavioural change at maturity combined with limited adult growth and not by any lack of juvenile fish.

There have been several attempts to age orange roughy, along with a number of associated studies of their otoliths. Unfortunately, these otoliths are complex and very difficult to read (Gauldie 1987, 1988, 1990; Linkowski and Liwoch 1986). Recently Mace *et al.* (1990), working with unvalidated ages, concluded that the growth of New Zealand roughy follows a von Bertalanffy model with an asymptotic length of nearly 42 cm and a growth coefficient, K, of 0.064. The maximum ages found were in excess of 50 years. Fenton *et al.* (1991)

applied radiometric methods to Australian samples and confirmed that the maximum ages must exceed 100 yr, while their best estimates of age reach 150 yr and lead to an asymptotic length of 40 cm and a value of K of 0.044. These values place orange roughy among the longest lived and slowest growing commercial species. Their production to biomass (P/B) ratio, natural mortality rate and optimum exploitation rate are likely to be very low. Mace *et al.* (1990) have suggested that F_{OPT} must be much less than 0.1. If Fenton *et al.'s* (1991) ages are correct, it must be very much less than this.

Very little is known about the structure of roughy populations. Smith (1986) was unable to find a detectable genetic difference between fish off New Zealand and those off Europe, suggesting extensive interchange of individuals. Ovenden *et al.* (1989) have examined mtDNA polymorphisms from Australian roughy and concluded that more local genetic differentiation does occur, though their data do not appear to support that conclusion. Lester *et al.* (1988), on the other hand, found marked differences in parasite loads between the fish from aggregations only a few hundred kilometres apart off Australia, suggesting very limited movements of the adults; a conclusion consistent with the existence of multiple spawning sites around New Zealand. These contrasting views can be reconciled if it is supposed that most post-settlement roughy are relatively sedentary while the limited amount of interchange (of larvae or occasional larger fish) between semi-isolated populations is sufficient to prevent the genetic divergence even of opposite poles of a circumglobal continuum of such populations. Roughy are not, however, entirely sedentary. In some areas off New Zealand they have recognizable seasonal migrations (Robertson *et al.* 1984).

<u>Exploitation</u>: A few orange roughy were landed by German trawlers working the Rockall Trough for blue ling in the 1970s (Ehrich 1983; Freytag, 1979) and Soviet boats fishing off New Zealand may have taken some at about that time. A large scale roughy fishery did not appear, however, until New Zealand extended its economic zone to 200 miles and set about developing its newly acquired resources. New Zealand now has a large and successful roughy fishery. The only other directed fisheries for this species are the relatively new Australian one, which has been exploiting waters off Tasmania since the mid-1980s, and an international fishery in parts of the Tasman Sea outside any national zone, which began in 1988 (Clark 1990).

New Zealand recognizes eight discrete roughy fisheries in its waters, the largest being for spawning fish on the Chatham Rise, an extensive ridge running (at mid-slope depths) for hundreds of kilometres eastwards from that country's main islands. The Chatham Rise Total Allowable Catch (TAC) for 1986-87 was 38,000 tons. There was another 12,000 ton TAC spawning fishery on the Challenger Plateau, west of New Zealand, while the remaining six fishing areas provided yields of several hundred to a few thousand tons each. Some of these are winter (spawning) fisheries while others take fish in the summer (Robertson 1986). The Australian situation is less stable, in as much as each roughy "hot spot" found to date has been exploited for only a few weeks before the fish disappeared, though whether through natural migration, forced dispersal or simply by being fished up is unclear. Only one "hot spot" has been reported as having recovered after such a disappearance, that being the proven spawning ground off St. Helens, Tasmania (Anon. 1989, 1990; Lyle *et al.* 1989, 1990; Madden 1987; Newton 1988; Newton and Burnell 1989; Ross 1990).

Orange roughy are taken exclusively by otter trawls and almost, if not entirely, by bottom gear. The sizes of boats used range from less than 15 m in length for some relatively sheltered grounds, to the very large factory freezer trawlers employed on the Chatham Rise. Details of the nets and other gear used in New Zealand have recently been summarized by Greening (1989). The Australian gear is essentially identical.

Roughy fishing differs in degree from normal bottom trawling in as much as the net is "targeted" onto aggregations previously located by sounders, the aggregation being only fished for a few minutes although the complete operation, from shooting away to recovering the net, may take some hours due to the great amount of warp that must be paid out and hauled. There is, therefore, a great stress in this fishery on the use of powerful sounders, on headline monitors and on maintaining precise knowledge of the relative positions of boat, net and fish (Greening 1989).

When the roughy fishery was first being developed, there was some interest in the wax esters which make up a high proportion of the lipids of these fish. Those esters can provide oils with similar lubricant properties to those of sperm whale oil (Body 1985; Body *et al.* 1985; Buisson *et al.* 1982; Grigor *et al.* 1983, 1990; Hayashi and Takagi 1980; James and Treloar 1984; Mori et al. 1978; Phleger and Grigor 1990; Sargent *et al.* 1983; Takagi *et al.* 1985). The New Zealand industry has not developed a market for these lipid products, however. Indeed, the marked laxative effect of the esters led to a decision to allow the export only of skin-off fillets of very high quality. These fillets have a bland flavour and a stable, firm texture, making them ideal for the North American restaurant market. There has been considerable research into the best methods of handling the fish for human consumption in this form (e.g. Fletcher *et al.* 1988a,b; Scott *et al.* 1984, 1986; Thrower and Bremner 1987; van den Broek and Tracey 1981).

The New Zealand marketing strategy worked well and roughy enjoyed very high prices on the U.S. market in the mid-1980s. As late as 1989, Australian fishermen received $3 per kg live weight on the wharf (Newton and Burnell 1989), for a fish that provides fillet yields of only 30% or so (Graham 1987).

Potential: There is little evidence that orange roughy occur in Canadian waters in commercial concentrations. Water temperatures at appropriate depths off Atlantic Canada (ca. 4°C) are at the low end of the preferred temperature range of 4-7.5°C (Ehrich 1983; Robertson *et al.* 1984). Nevertheless, there is a possibility that dense aggregations do occur here.

Orange roughy (*H. atlanticus*) were originally considered for exploitation because they contain rare wax esters that are not found in the other roughies, such as *H. mediterraneus*. These other species may, however, be as desirable as *H. atlanticus* for fillet production, except perhaps in terms of their much smaller maximum sizes. A fishery for *H. mediterraneus*, one specimen of which has been reported from Canadian waters (Scott and Scott 1988), is therefore a possibility, though no more likely at this point than is a fishery for *H. atlanticus*.

6) Other Potential Resources

Other Grenadiers - *Macrourus berglax* and *Nezumia bairdi*: A considerable number of grenadier species occur in the northwestern Atlantic. Off Newfoundland, they comprise a high proportion of the total fish biomass at slope depths (Snelgrove and Haedrich 1985). Pechenik and Troyanovskii (1970) identified three grenadiers, *Coryphaenoides rupestris*, *Macrourus berglax* and *Nezumia bairdi*, as potential resource species. The USSR proceeded to develop a substantial fishery off Atlantic Canada for the first of these. Over 20,000 tons of *C. rupestris* were landed from the North Atlantic in 1987, 8,000 tons of those (nearly equally divided between German and Soviet fishing) being taken from the northwestern Atlantic. Over 30,000 tons of grenadiers are taken elsewhere in the world, mostly in the Soviet fishery for *Macrourus* in the southwestern Atlantic (FAO 1990).

Besides the possibility of Canadianizing the existing roundnose grenadier fishery in the northwestern Atlantic, there is a possibility of developing fisheries for *M. berglax* and *N. bairdi* off Atlantic Canada. The latter species is, however, a rather small grenadier (maximum length 40 cm, whereas roundnose grenadier reach 70 cm: Scott and Scott 1988), while the former seems to be markedly less abundant than is roundnose grenadier (Markle *et al.* 1988; Snelgrove and Haedrich 1985). Moreover, it is unlikely that Canadian boats could economically exploit these fishes without first gaining experience in the fishery for roundnose grenadier, given that the USSR has not found them attractive despite considerable experience with that species.

<u>Hagfish - *Myxine glutinosa*</u>: The hagfishes of the world support a number of minor fisheries, either for human food (e.g. in Japan: Gorbman *et al.* 1990) or for biomedical research specimens (Scott and Scott 1988). The only hagfish fishery of greater consequence supplies raw material to a Korean industry that, for 30 years, has produced a specialty luxury leather marketed as "eelskin". This fishery has expanded into the waters off Japan and Japanese fishermen now supply hagfish to the Korean processors. Recently, the Koreans have begun to develop additional fisheries for the hagfish off British Columbia and the U.S. west coast, and there have been attempts to exploit the inshore hagfish off Nova Scotia.

In Japan, the bulk of the fishery is carried out in continental shelf depths. However, some Japanese boats, and presumably most of the Koreans fishing off Japan, fish down to 500 m depth, where they take *Eptatretus okinoseanus* and *Myxine garmani* (Gorbman *et al.* 1990). In Canadian Pacific waters, the species of interest will presumably be *E. stouti* or perhaps the less abundant *E. deani* (Hart 1973). All of these fisheries use small baited traps set on longlines. For the "eelskin" processors, it is important that the fish reach them alive and with their skins undamaged (Gorbman *et al.* 1990).

The Atlantic hagfish, *Myxine glutinosa*, is of similar size and form to the North Pacific species and might well provide a suitable raw material for the "eelskin" industry. They can be readily caught in traps in Canadian inshore waters (Scott and Scott 1988). A successful, deep-water fishery for this species off Atlantic Canada is, however, unlikely. "Eelskin" is a specialty fashion product and consequently has a small and volatile market. Only the Korean processors have been able to achieve acceptable product quality at a viable price; Japanese attempts to compete having failed (Gorbman *et al.* 1990). Since the processors require live fish, this would necessitate expensive air freight to Korea, raising costs relative to those of foreign competitors. Thus, even if the demand for raw material exceeds the North Pacific supply, it seems unlikely that a significant market for Atlantic Canadian hagfish would develop.

Even if local processors were to develop a Canadian "eelskin" industry, their initial needs could easily be filled by inshore fishing, without requiring the development of a deep-water fishery. Thus, no deepwater hagfish fishery off Atlantic Canada seems likely in the foreseeable future.

<u>Deepwater rajids</u>: Much of the demersal fish biomass at continental slope depths in all parts of the world may well comprise large skates and rays. If so, their lack of greater prominence in exploratory catches would be ascribed to their known low catchability in otter trawls worked with bobbin gear (Edwards 1968). Eleven species of rajids are known from Atlantic Canadian slope waters (Table 8), some of which may well be abundant.

Unfortunately, the continental slopes tend to have hard, steep and uneven bottoms, which require the use of large bobbins on bottom trawls. The rajids would, therefore, be no more abundant in commercial trawl catches than in exploratory ones. This problem might be overcome by using hooked gear, to which rays are vulnerable, but no such fishery seems yet to have developed elsewhere in the world. Furthermore, rays caught at continental shelf depths in Canadian waters are generally treated as trash fish and not landed. It is unlikely that a deepwater rajid fishery will develop in this region until essentially the same fish from shallow water become commercially acceptable. Thus, the rays might provide a useful bycatch to some other deepwater fishery but it is unlikely that any fishery will be directed onto them in the foreseeable future.

<u>Blue Whiting - *Micromesistius poutassou*</u>: Following initial resource explorations in the mid-1970s, the blue whiting fishery in the eastern Atlantic has expanded into a major industry that landed about 700,000 tons annually in the late 1980s, making it one of the world's largest deepwater fisheries. In addition, the southern poutassou, *Micromestius australis*, is being extensively fished off South America and New Zealand, with landings

of over 100,000 tons per yr (FAO 1990). The northern species has, however, only rarely been reported from the northwestern Atlantic and then only from Sable Island southwards (Miller 1966; Scott 1963; Scott and Scott 1988). It was not taken in Markle *et al.*'s (1988) catches and Haedrich and Merrett (1988) did not report it from west of Cape Farewell in their summary of research trawling studies. Since blue whiting mostly live above 500 m depth and have no particular cryptic behaviour that would cause them to be missed during research fishing, it seems unlikely that significant quantities of them can exist off Atlantic Canada when they are so rarely captured.

D) Conclusions - Fishes

It has repeatedly been pointed out that, with the exception of the large oceanic epipelagics and certain fisheries in upwelling systems, the world's major fisheries are all for continental shelf species (e.g. Cushing 1975). It has been further suggested that this is no accident. Rather, the continental shelves are thought to be the only areas with sufficient fish production to support great fisheries. Recent developments of fisheries at upper and mid-slope depths, particularly off New Zealand, have led some to question Cushing's suggestion but, to date, there is no evidence that the commercial fish production (as distinct from the standing biomass) per unit area on the slopes is more than a small fraction of that on the shelves.

Since the surplus production of optimally-managed finfish stocks on productive continental shelves in temperate latitudes is of the order of one ton per square kilometre (i.e. 1 g m^{-2}) per yr (assuming F_{opt} is about 0.20 and that the average biomass density of commercial species is about 10 tons per square kilometre, e.g. Edwards 1968; Kenchington 1980; May and Blaber 1989; Oviatt and Nixon 1973; Scott 1971), this may be taken as an approximate upper limit to the yield per unit area expected on the continental slopes. Moreover, most exploitable species have a relatively narrow preferred depth range which, for deep dwelling demersal species, is set on a steeply-sloping seabed. In relatively few cases, therefore, will a particular slope species' exploitable range be wider than a few kilometres. This is particularly true in the southern part of the Canadian zone off Nova Scotia, while in more northern areas off eastern Newfoundland, the slope zone is relatively broad.

There may, of course, be more than one species suitable for exploitation, each stratified by depth on the slope; there may be particular slope areas where production is above average; and some resource species caught demersally may exploit the mesopelagic zone seaward of the slope, allowing much higher sustainable yields than suggested by the bottom area over which the species is taken in demersal trawling. Furthermore, even a resource yielding a few thousand tons per year could be a useful addition to the Canadian fishing industry. Nevertheless, demersal fishing on the continental slope seems unlikely to provide sustained yields equivalent to those of Canada's principal continental shelf finfish resources.

This review of presently unexploited, deepwater finfish off Atlantic Canada has failed to find strong evidence for the presence of any significant resource with immediate development potential. There are at least encouraging indications that Atlantic saury, blue hake and black scabbardfish might all be able to support fisheries. The first can certainly be caught in quantity off Nova Scotia in the autumn but it is not certain whether a fishery for them would be economically viable. Given the location, season and type of gear required for this fishery, it might ideally be developed by boats of about 65 ft in length, such as the large "inshore" draggers, diverting these from the presently overcapitalized groundfish fishery. Blue hake are certainly known to be present off this coast in large quantities and could be caught by large stern trawlers. It is not yet clear, however, whether they could provide adequate catch rates to outweigh the high costs of fishing in such deep waters and the expected low wharf prices. Scabbardfish are even more problematical. If they occur in commercial concentrations in Canadian waters, it is probably off Labrador and northern Newfoundland, where they may best be caught by droplining from "midshore" or large "inshore" boats.

Other less promising deepwater opportunities include black dogfish and orange roughy. Hagfish, the deepwater rajids, grenadiers other than the roundnose and even blue whiting are all present but a fishery for any of them seems unlikely at this time. Still other fishes, particularly the synaphobranchid eels, might support a commercial fishery but they are not presently being landed elsewhere in the world.

There seem to be two strategies available for the continued development of deepwater fishing off Atlantic Canada. One is to promote the commercial exploitation of deep-shelf and shelf-break resources (e.g. Greenland halibut, witch flounder, the redfishes and silver hake) and the extension of those fisheries to upper slope depths. Building on the infrastructure of a deepwater fishery thus created and using capital either generated or attracted by that fishery, Canadianization of the roundnose grenadier fishery and commercial exploration for other mid-slope species would follow. The second strategy would be to begin a determined government-driven search for mid-slope resources. This might initially be targeted on blue hake and scabbardfish but should use as wide a variety of gear as possible so as to identify any fish species that is sufficiently abundant to support a fishery. Certainly bottom and midwater trawls, bottom-set longlines, droplines and traps should all be tried, along with epipelagic gear and, particularly, powerful acoustic equipment suited to great depths. A combination of both strategies is, of course, possible. Their relative virtues in an Australian deepwater setting have recently been discussed by Ross (1990). Atlantic saury, as the only species considered here whose potential has already been established and as the only pelagic, may be amenable to more rapid development. The present efforts to develop a Canadian fishery for silver hake may provide a suitable model for the establishment of an Atlantic saury fishery.

PART III - CEPHALOPODA

The class Cephalopoda is thought to contain fewer than 1000 living species arranged in four groups - squids, cuttlefishes, octopuses, and chambered nautiluses. However, many, particularly deepwater, species may remain to be described. Less than 200 of the known species are likely to be of interest to fisheries (Roper *et al.* 1984). Current (1988) world landings of 2.2 million tons (FAO 1990) are considered to be a small proportion of potential cephalopod yields (Caddy 1983). Much of this potential, and most of the current fisheries production, is formed by the squids (order Teuthoidea), particularly of the suborder Oegopsida which is comprised of oceanic species.

In their catalogue of cephalopod species of interest to fisheries, Roper *et al.* (1984) illustrated 16 deepsea species as occurring in, or adjacent to, the Canadian zone (Table 9). Half of these species appear to be marginal candidates for exploitation because of small body size or deep distribution (Table 9 - Group B). Eight of the oceanic squid species (oegopsids) meet several criteria which make them development prospects (Table 9 - Group A). These eight have a large body size (mantle length > 15 cm), occur in surface or near surface waters at least part of the time, and are either subject to some fishing already, or the flesh is known to be of good quality for human consumption.

The most obvious prospect for fishery development in the Canadian zone is, of course, the northern shortfin squid, *Illex illecebrosus*. Its habit of spending summer months in shelf and coastal waters makes it readily accessible, and it has already been extensively fished, by foreign fishermen in particular. Distribution, fishing methods and many aspects of biology are well documented (e.g. Black *et al.* 1987).

Other members of the family Ommastrephidae, to which *Illex* belongs, also offer good potential for development. The flying squid, *Ommastrephes bartrami*, which occurs in the southern part of the Canadian zone, is already subject to intensive fishing in the northwestern Pacific. Resource distribution and the Japanese fishery for this species are described in detail by Murata (1990). The webbed squid, *O. caroli*, although recorded from the northwestern Atlantic, appears to have its centre of distribution in the northeastern Atlantic, but may in fact be conspecific with *O. bartrami* (Murata 1990). The orangeback squid, *O. pteropus*, is believed to be very abundant. It is more of a warm-water species than *O. bartrami*, the 22°C surface isotherm being suggested as its northern limit.

There are two species of the genus *Gonatus*, which occur in temperate to arctic waters of the North Atlantic, with fishery potential. The boreal armhook squid, *G. fabricii*, occurs in arctic and subarctic waters adjacent to Baffin Island, Labrador, eastern Newfoundland and the Grand Banks. The Atlantic gonate squid, *G. steenstrupi*, has a more southern distribution, occurring in subarctic and temperate waters, including those east of Newfoundland and the Grand Banks.

Not much is known about the other two development prospects identified - the common clubhook squid, *Onychoteuthis banksi*, and the diamondback squid, *Thysanoteuthis rhombus*. Both have widespread distributions in the warm parts of the world's oceans. However, *O. banksi* occurs as far north as east of Newfoundland and *T. rhombus* to the Grand Banks.

In summary, in addition to the previously recognized potential of *Illex illecebrosus*, there are two genera with species which may have substantial potential in the Canadian zone and which are worthy of some directed investigation. In the southern part of the zone *Ommastrephes* spp. merit research, particularly *O. bartrami*, as the practicality of fishing this species has been established in the Pacific Ocean. In more northern waters, the *Gonatus* species also deserve attention.

GENERAL CONCLUSIONS

This review identifies a number of species, the commercial potential of which in Canadian waters has not previously been recognized. Almost all of these are invertebrates, particularly decapod crustaceans.

The scarlet shrimp (*Plesiopenaeus edwardsianus*), presents the best immediate prospect among the shrimps for fishery development. It has a bright-coloured, attractive, appearance and a large size (up to 33 cm TL), and is already fished commercially elsewhere. The crimson pasiphaeid (*Pasiphaea tarda*) also achieves a large size (up to 22 cm TL). Although it is not presently fished, smaller species of the same genus do support fisheries elsewhere in the world. The deepsea sabineid (*Sabinea hystrix*), although smaller (maximum length 13 cm), is fairly abundant, and may have some potential. The abundant *Acanthephyra* species, the shortnose and longnose ridgebacks, are quite small (maximum length 10-11 cm) but these animals have good market prospects due to their deep-red colour and firm texture. Several other species may also prove to have some commercial value.

The scarlet shrimp is benthic in habit. The other species have various degrees of association with the bottom, though in some cases their habits are not well known. Nonetheless, all have been caught in some numbers along the continental slope with bottom gear. A multispecies demersal shrimp fishery would perhaps have the best prospects for success.

Among non-shrimp decapod crustaceans, the northern stone crab (*Lithodes maja*) has some potential for exploitation. Similar-sized species of the same genus are fished in southern oceans and, indeed, commercial landings of *L. maja*, taken as by-catch in the Danish seine fishery for flatfish in Sydney Bight, N.S., have recently been made. The porcupine stone crab (*Neolithodes grimaldii*) occurs in deeper water than northern stone crab and may also prove to have some potential, given its large size. The spinyhead lobsterette (*Munida valida*) and the smooth-ridged blind lobster *(Stereomastis sculpta)* may also prove to have some commercial value. The red deepsea crab (*Chaceon quinquedens*) has already been the subject of various development efforts which, however, have suggested that its potential in Canadian waters is not large, most fishing success being achieved in U.S.A. waters.

Among the finfishes, only three species which have not appeared on previous lists of development candidates are recognized here: black scabbardfish (*Aphanopus carbo*), blue whiting (*Micromesistius poutassou*) and orange roughy (*Hoplostethus atlanticus*). Occurrence of these species in commercial abundance in the northwestern Atlantic has not been established and, for the latter two, high abundance in the Canadian zone seems most unlikely. The best development prospects, as long recognized, lie with the grenadiers, particularly the roundnose (*Coryphaenoides rupestris*). A grenadier fishery could perhaps be extended into water of sufficient depth to include blue hake (*Antimora rostrata*). In the southern part of the Canadian zone it has been established that there is an adequate resource of Atlantic saury (*Scomberesox saurus*) to support a substantial epipelagic fishery.

Among the cephalopods there are two species of the genus *Gonatus*, the boreal armhook (*G. fabricii*) and Atlantic gonate (*G. steenstrupi*), which occur in northern waters, as far south as the Grand Banks, with possible commercial potential. In the southern part of the Canadian zone, species of the genus *Ommastrephes* also hold some promise. As the flying squid (*O. bartrami*) already supports a large fishery in the Pacific Ocean, it would be a logical species to receive first consideration in an Atlantic context. It could be argued that development of new fisheries for squid species is not worthwhile until the potential of the northern shortfin squid (*Illex illecebrosus*) in shelf waters is fully utilized. However, the abundance of shortfin squid is highly variable and diversification of squid fisheries might provide the stability of supply necessary to develop a viable enterprise.

Most deepwater research surveys in the northwestern Atlantic have been conducted using trawl nets but commercial fishing experience elsewhere indicates that other types of gear may be more effective in catching some of the species identified here as possibly having commercial potential. Although it has been established that bottom trawl fishing is effective for grenadiers, and this probably also applies to blue hake, for black scabbardfish, vertical longline has been the most successful gear. For Atlantic saury, light fishing with dipnets is the established fishing method. Oceanic squids have been fished effectively in the Pacific with both jigs and drift gillnets[2]. Bottom-set traps have proved effective in both shrimp and crab fisheries and for some types of deepwater finfish. If it was decided to conduct exploratory fishing for any of the species identified here, trials using some of these non-trawl gears would likely enhance prospects for success.

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[2] The use of pelagic driftnets has, however, become an international conservation issue, as reflected by resolution 44/225 adopted by the fortyfourth session of the United Nations General Assembly on 22 December 1989 which calls for restrictions on driftnet fishing.

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APPENDIX 1.

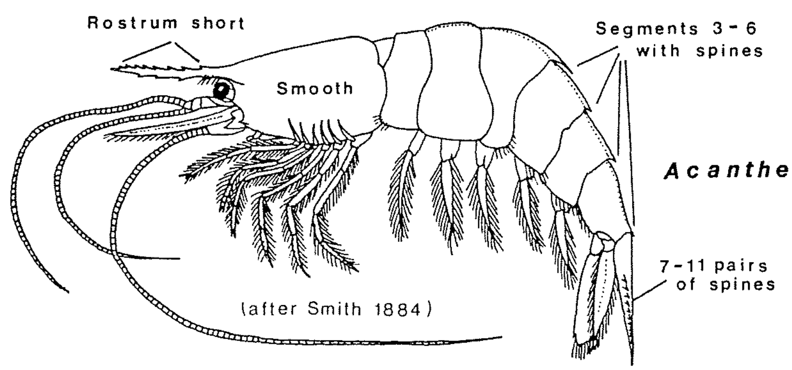
DISTINGUISHING CHARACTERS OF SHRIMPS, LOBSTERS AND CRABS WITH COMMERCIAL POTENTIAL FROM DEEP WATERS OFF ATLANTIC CANADA.

Described below are distinguishing characters together with illustrations of shrimps, lobsters and crabs which are short-listed in Tables 3 and 6. Species within these groups are listed alphabetically. This information is based on Pohle (1988, 1990), which can be referred to for further details. Asteriks after common names indicate that these names are applied by the present authors.

A) Shrimps

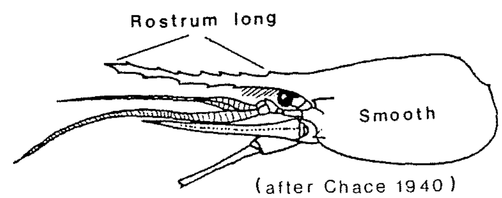
1) ***Acanthephyra pelagica*** (Risso, 1816) - shortnose ridgeback shrimp*
- brilliant scarlet-red
- carapace appears smooth, with 2 lateral spines on anterior margin
- rostrum about as long as carapace (shorter in adults, longer in juveniles), usually with 8 dorsal and 5 ventral spines
- scale of antenna about as long as carapace
- abdominal segments 3-6 each with a middorsal spine posteriorly
- telson with 7-11 pairs of dorsolateral spines
- carapace length to 24 mm males, 31 mm females
- depth range 200-1650 m (commonly below 900 m), 3-12°C
- Latitude 64° (Davis Strait) to 13°N.

2) ***Acanthephyra purpurea*** A. Milne-Edwards, 1881 - longnose ridgeback shrimp*
- brilliant scarlet-red
- carapace appears smooth, with 2 lateral spines on anterior margin
- rostrum always longer than carapace, with 8 dorsal and 5 ventral spines
- scale of antenna longer than carapace
- abdominal segments 3, 5 and 6 with middorsal posterior spine; small or no spine on segment 4
- telson with only 4 pairs of dorsolateral spines
- carapace length to 23 mm in males and females
- depth range 100-1500 m (commonly above 600 m), 4-18°C
- Latitude 53° to 23°N.



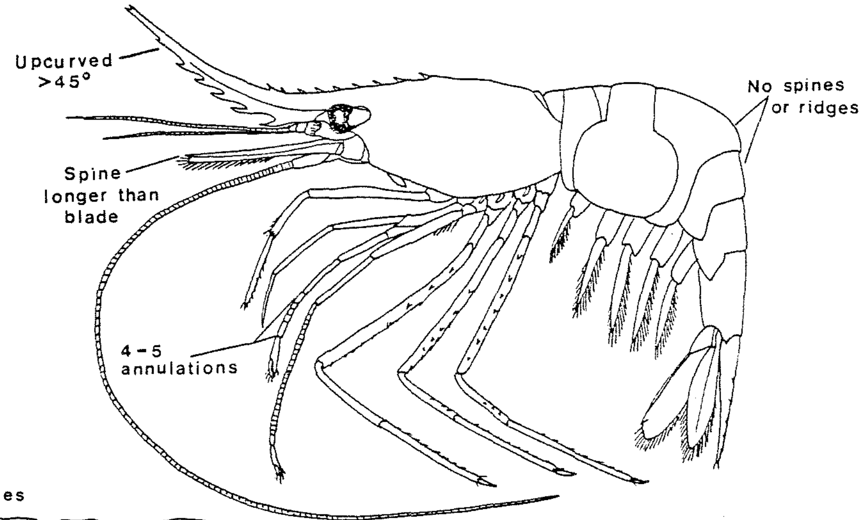
Acanthephyra pelagica

Acanthephyra purpurea



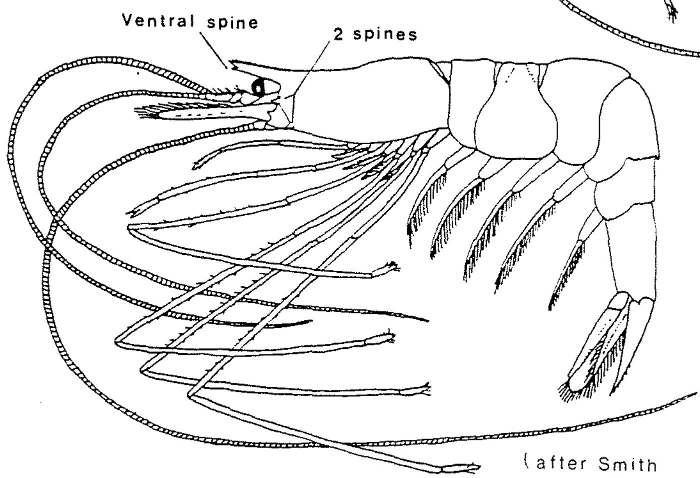
3) *Nematocarcinus rotundus* Crosnier and Forest, 1973 - blunt spider shrimp*
- crimson-red
- carapace smooth, 2 spines laterally on anterior margin
- short flattened rostrum about 1/4 length of carapace, with 12-17 dorsal spines and 1 ventral spine near tip
- lateral plate of abdominal segment 5 posteriorly culminating in a blunt tip or microscopic spine
- telson without dorsolateral spines on proximal half
- carapace length to 27 mm
- usually benthic, depth range 300-1580 m
- Latitude 44° to 16°N.

4) *Pandalus propinquus* G.O. Sars, 1869 - curvebeak pandalid*
- carapace often uniform red, rostrum often yellowish toward tip; abdominal segments 1-4 with transverse red bands, segment 5 pale red with darker spots, segment 6 and tail fan darker red; legs pale red except colorless second pair
- carapace smooth, without ridges
- rostrum slightly longer than carapace, not arched above eyes but distally strongly upcurved at an angle of about 45°; tip with 2 spines; 8-10 movable spines dorsally, proximally first 3 spines on carapace posterior to base of eye and extending anteriorly about 1/3; 5-7 fixed ventral spines
- wrist of right leg 2 with 4-5 annulations
- abdomen rounded, without median ridge or spine
- total length to 150 mm, but usually less than 110 mm
- benthic, 20-2000 m but usually 165-350+m, 3-10°C
- Davis Strait to Delaware.



(after Smith 1887)

Pandalus propinquus

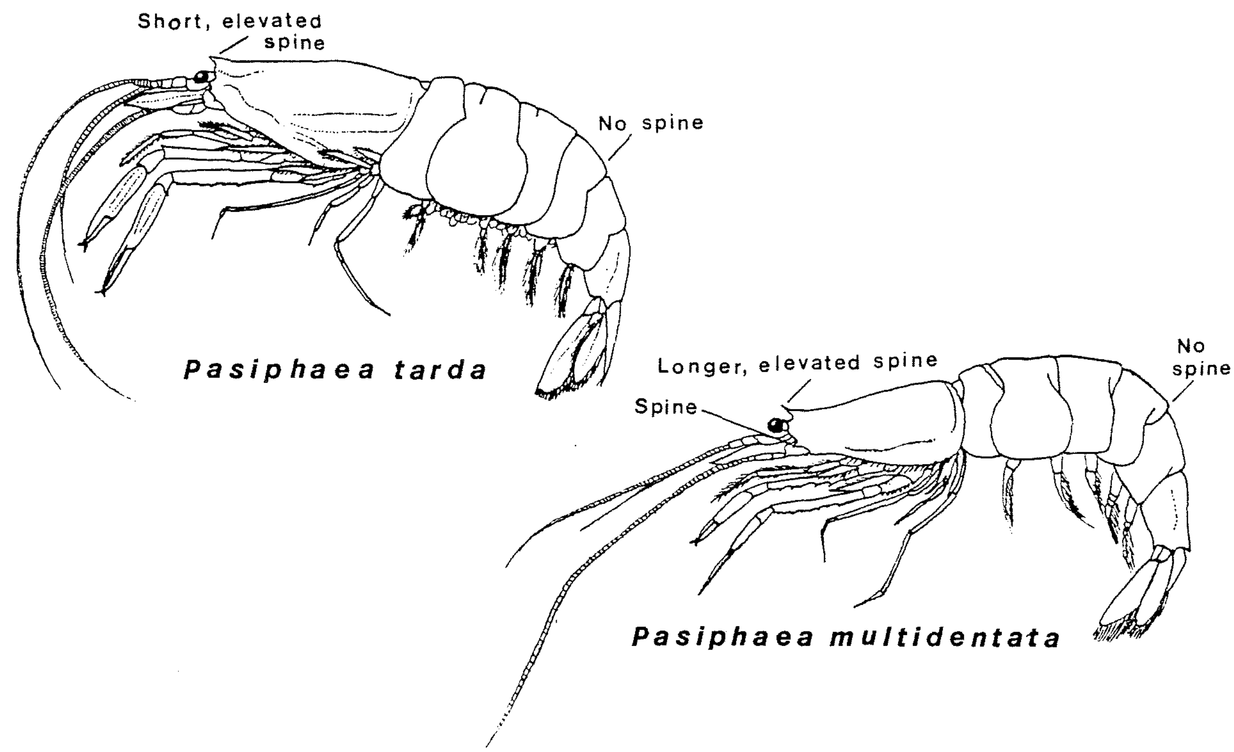


(after Smith 1887)

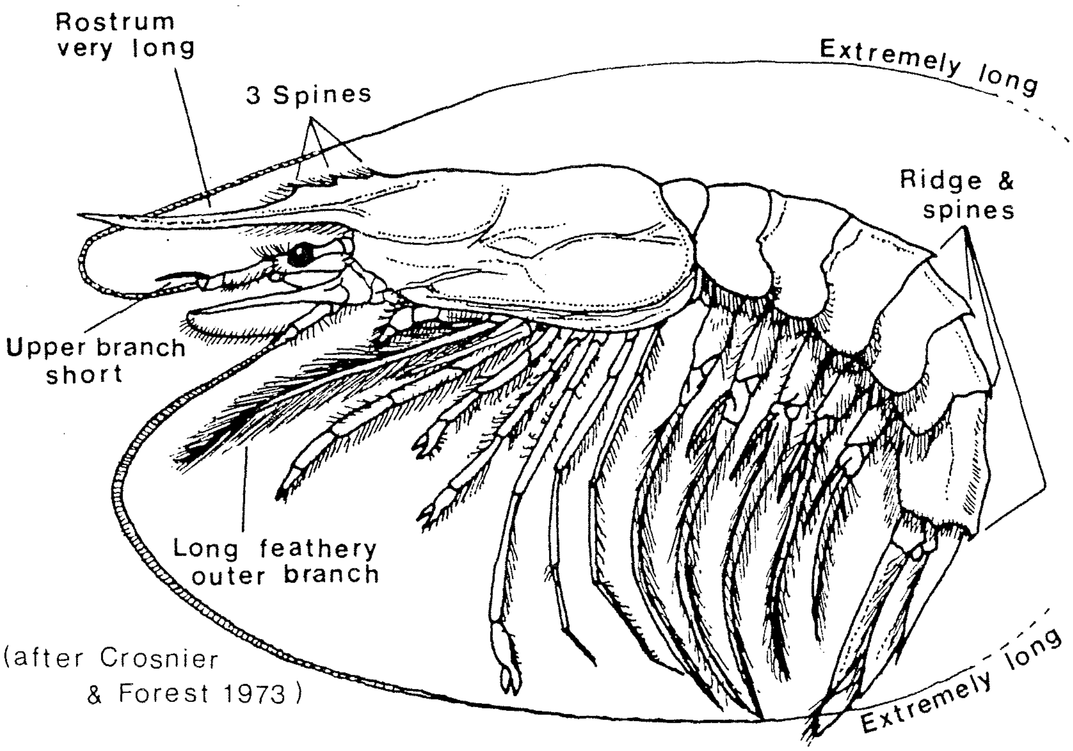
Nematocarcinus rotundus

5) ***Pasiphaea tarda*** Kroyer, 1845 - crimson pasiphaeid
- carapace, most of abdomen and appendages uniform vermilion-red; antenna and antennal scale milky-white with red tint; abdomen dorsally with white patches; eyes black
- carapace more than 1/2 length of abdomen (excluding telson); with lateral spine
- rostrum shorter than in *P. multidentata*, directed forward but not upward; rostrum in form of an erect spine
- antennal scale less than 1/2 length of carapace; distal third strongly convex, *with small,short spine at tip*
- segment 2 of second leg with 0-5 spines
- abdomen unarmed
- telson with broader tip and shallower bifurcation than in *P. multidentata*
- carapace length to 75 mm, total length to 215 mm
- usually near bottom but also in midwater, depth range 250-2400 m, 1-6°C
- Latitude 65°N (Davis Strait) to off South Carolina.

6) ***Pasiphaea multidentata*** Esmark, 1866 - pink glass shrimp
- color variable from mostly translucent and milky-white to reddish-brown; eyes black
- carapace about 1/2 length of abdomen (excluding telson); with lateral spine
- rostrum longer and directed more upward and forward than *P. tarda;* rostrum in form of an erect spine rising from dorsal ridge
- antennal scale more than 1/2 length of carapace; evenly convex along entire length, *with long stout spine at tip*
- segment 2 of second leg with 7-12 spines
- abdomen unarmed
- telson narrow at tip, with deep bifurcation
- carapace length to 20 mm, total length to 105 mm
- usually in midwater but also found on bottom, depth range 10-2000 m, 3.5-8.0°C
- Greenland to Massachusetts (Latitude 41°N).



7) ***Plesiopenaeus edwardsianus*** (Johnson, 1867) scarlet shrimp, gambon écarlat
- brilliant crimson red, more intense on carapace and dorsally on abdomen; fringes of setae gold coloured
- several lateral ridges on carapace, one with single anterior spine
- long sharply-pointed rostrum equal to at least 1/2 carapace length; 3 dorsal spines
- upper antennular flagellum very short, other flagellum very long, up to 3 times total body length; antennal flagellum also very long
- maxilliped 2 and 3 with exopod, that on maxilliped 2 very long (twice as long as endopod) and feathery
- abdomial segments 3-6 dorsally with ridge, forming short spine at end of each segment
- a very large species, carapace length to 55 mm males, 104 mm females; total length to 193 mm males, 334 mm females
- benthic, inhabiting muddy bottoms on continental slopes
- 274 to 1850 m (mostly 400-900 m), 4-8°C
- Latitude 47°N (Gulf of St. Lawrence) to Gulf of Mexico.

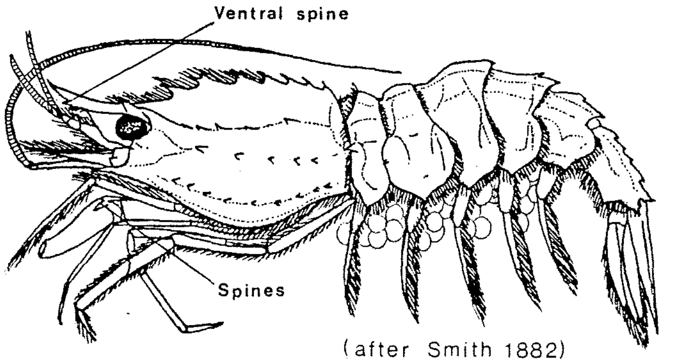


(after Crosnier & Forest 1973)

Plesiopenaeus edwardsianus

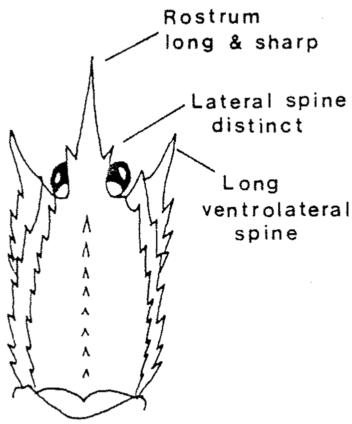
8) ***Sabinea hystrix*** (A. Milne-Edwards, 1881) - deepsea sabineid*
- pale grayish-brown
- carapace with long ventrolateral spine at anterior margin
- rostrum sharp, more than 1/2 carapace length, reaching far beyond eyes; with ventral spine near sharp tip and flanked by pair of dorsal spines at base
- first leg segments 4 and 5 (next to pincer) each with distinct spine
- telson ending in unarmed sharp tip
- carapace length to 30 mm, total length to 130 mm
- benthic, depth range 500-3957 m, 0-5.5°C
- Latitude 65°N (Davis Strait) to Caribbean.

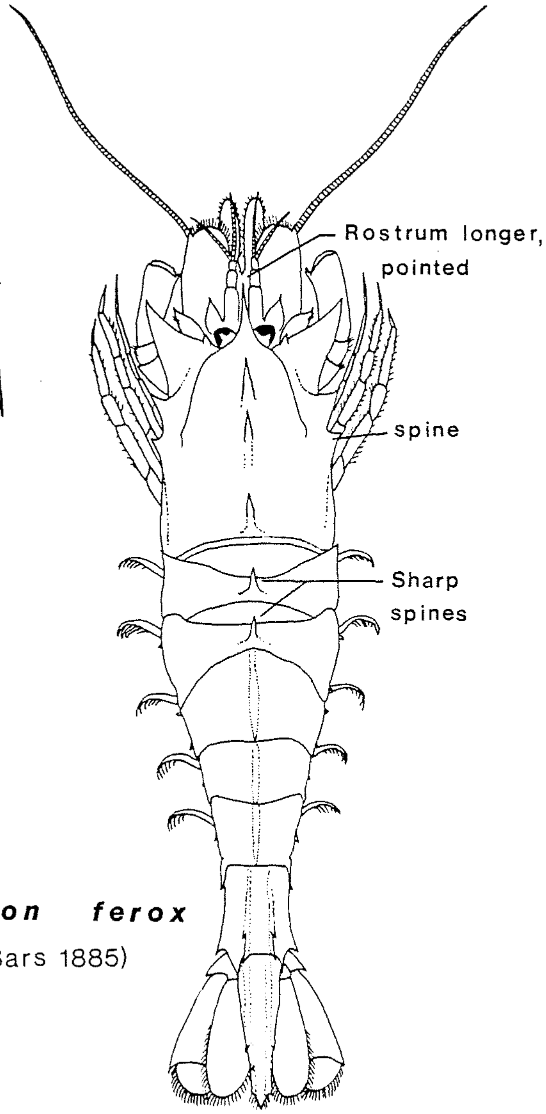
9) ***Sclerocrangon ferox*** (G.O. Sars, 1877) - back-spined shrimp*
- reddish-brown, often mottled with ivory
- carapace with 2 larger and 1 smaller spine on middorsal ridge, lateral ridge armed with 2 more spines
- rostrum sharply pointed, directed forward and upward, extending beyond eyes
- abdomen with distinct median ridge, especially on segments 1-3
- carapace length to 31+ mm, total length to 130 mm
- benthic, depth range 90-1000 m, commonly below 200 m, -0.5-3.6°C
- Latitude 82° to 57°N (Grand Banks).



(after Smith 1882)

Sabinea hystrix



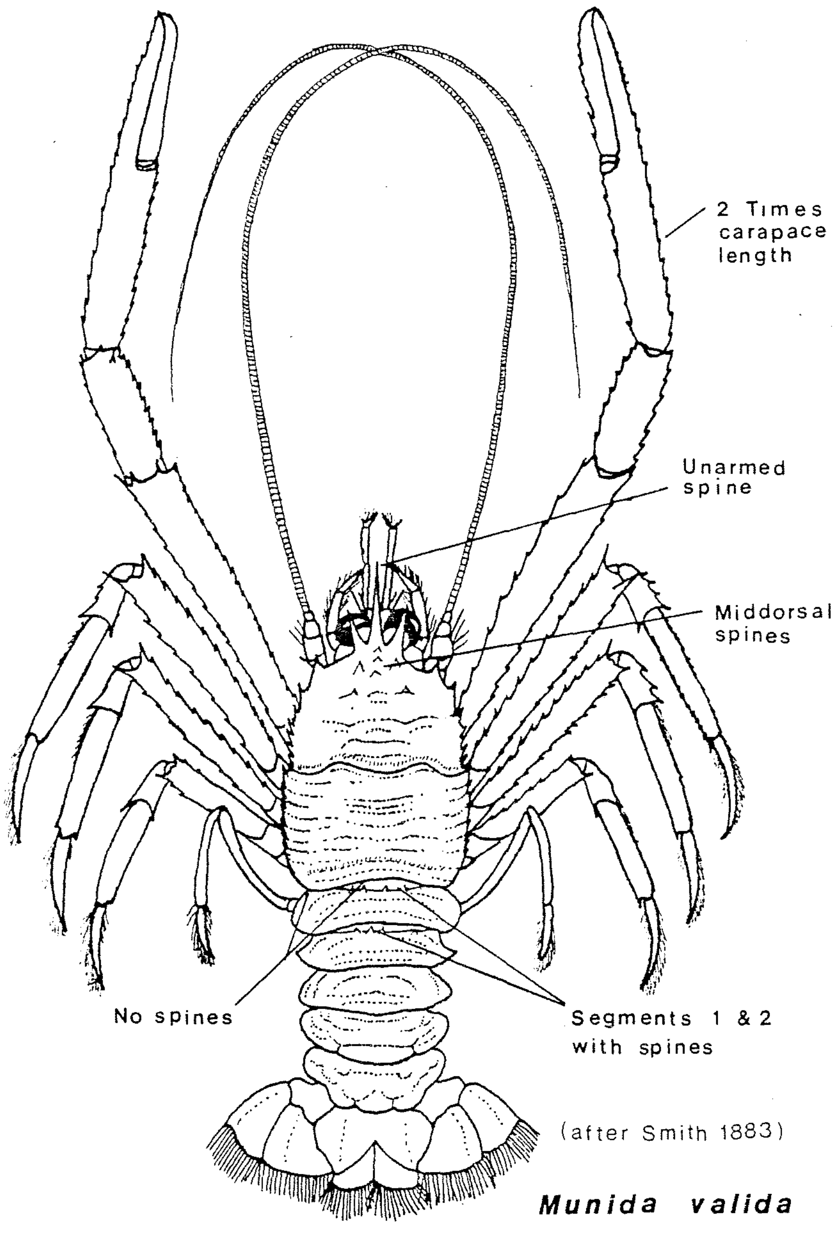


Sclerocrangon ferox

(after Sars 1885)

B) Squat lobsters and lobsterettes

1) ***Munida valida*** Smith, 1883 - spinyhead lobsterette*
- eyes pigmented and with facets
- carapace lightly calcified, armed with about 7 spines on lateral margin; several smaller spines further dorsally, including on midline behind rostrum, largest pair behind lateral prongs of rostrum; posterior margin without spines
- rostrum a 3-spined prong; middle spine straight, smooth and about twice length of lateral spines; rostrum shorter than antennules
- antennae much longer than carapace (incl. rostrum), reaching far beyond extended first legs with pincers
- first legs about twice carapace length (incl. rostrum)
- abdomen dorsally armed with series of small spines on anterior margin of segments 1 and 2
- carapace length (incl. rostrum) to 83 mm
- benthic, depth range 441-1150 m, 5.0°C
- Latitude 43°N to Caribbean Sea.

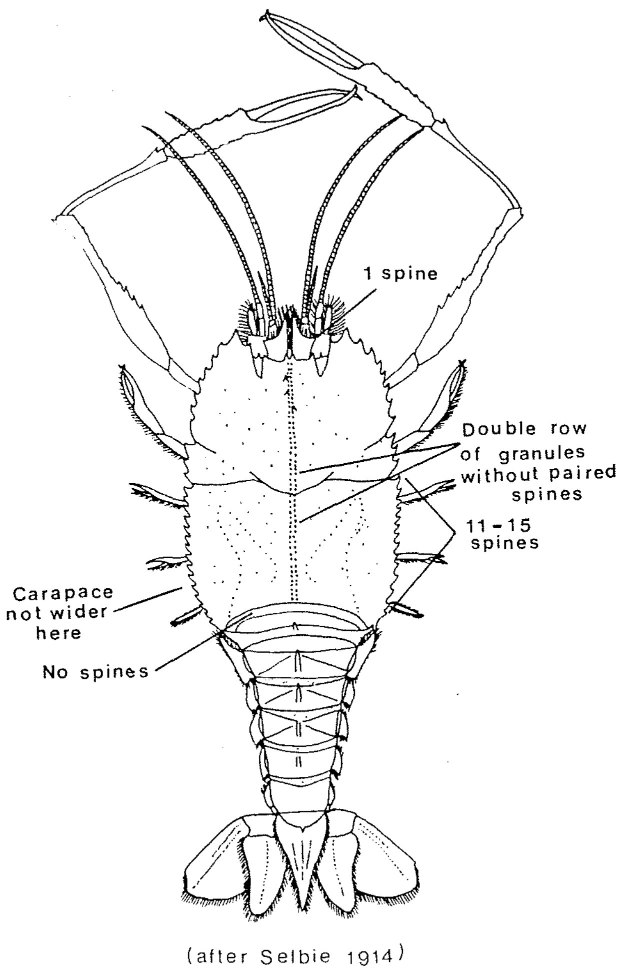


(after Smith 1883)

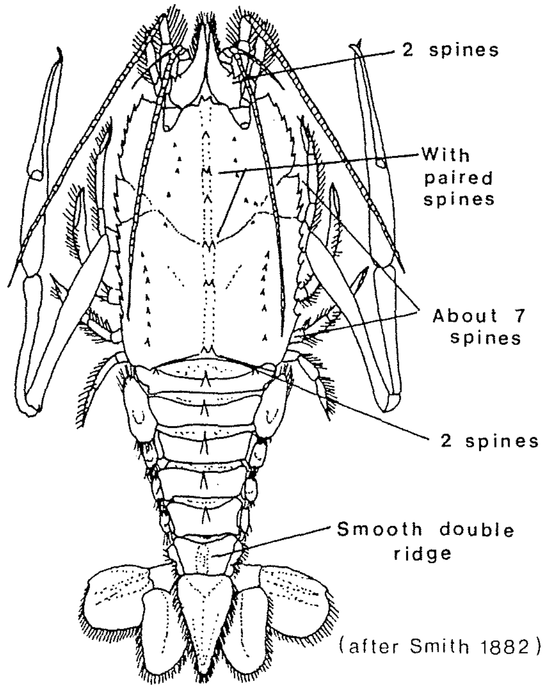
Munida valida

2) ***Polycheles granulatus*** Faxon, 1893 - unarmed blind lobster*
- first segment of antennule with single lateral spine
- carapace wide, with lateral margin bearing less than 38 spines not decreasing in size posteriorly; lateral spines in 3 groups varying from 6 + 3 + 11 to 10 + 3 + 15 (usually 7 + 3 + 14); with faint median ridge marked anteriorly by small spines in no definite order and posteriorly by a double row of granules; posterior margin unarmed
- abdominal segments 1-5 each with median ridge, ridges of segments 1-3 extended into anteriorly directed spine; segment 6 smooth, without dorsal double ridge
- carapace length to 50 mm; total length to about 110 mm
- benthic, depth range 347-2505 m, 3.4-4.4°C
- south from Latitude 49°N (Newfoundland).

3) ***Stereomastis sculpta*** (Smith, 1880) - smooth-ridged blind lobster*
- mostly milky-white with pink; appendages pinkish-red
- first segment of antennule with 2 lateral spines
- lateral margin of carapace not expanded posteriorly, spines in 3 groups (6 + 3 + 7 spines from front to back); posterior margin of carapace unarmed other than a pair of spines on midline
- abdominal segments 1 to 5 each with a single forwardly directed middorsal spine; segment 6 with double ridge; edges of ridges smooth
- carapace length to 70 mm
- benthic, depth range 230-4000 m, 4.3-5.0°C
- Latitude 57°N (Davis Strait) to Caribbean Sea.



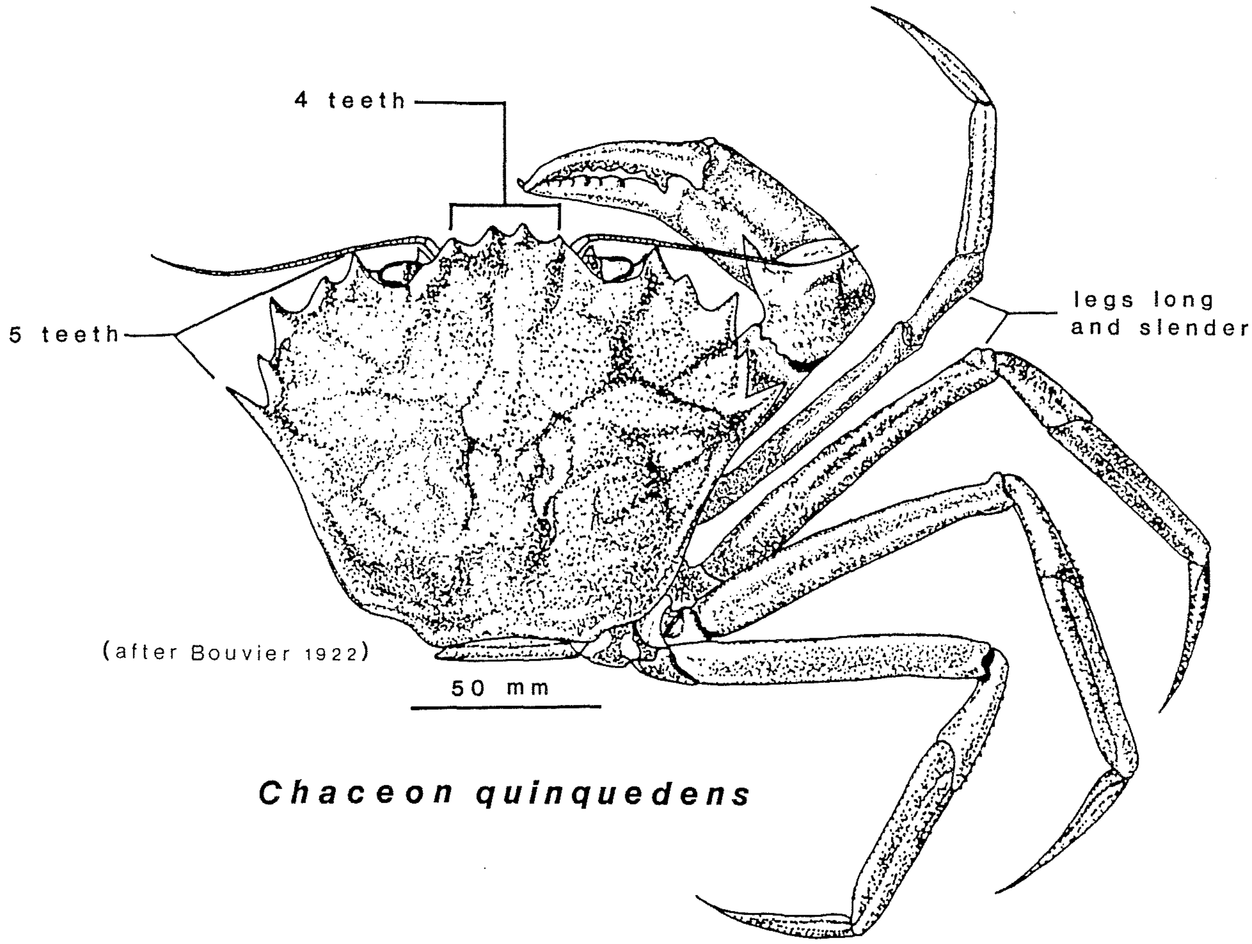
Polycheles granulatus



Stereomastis sculpta

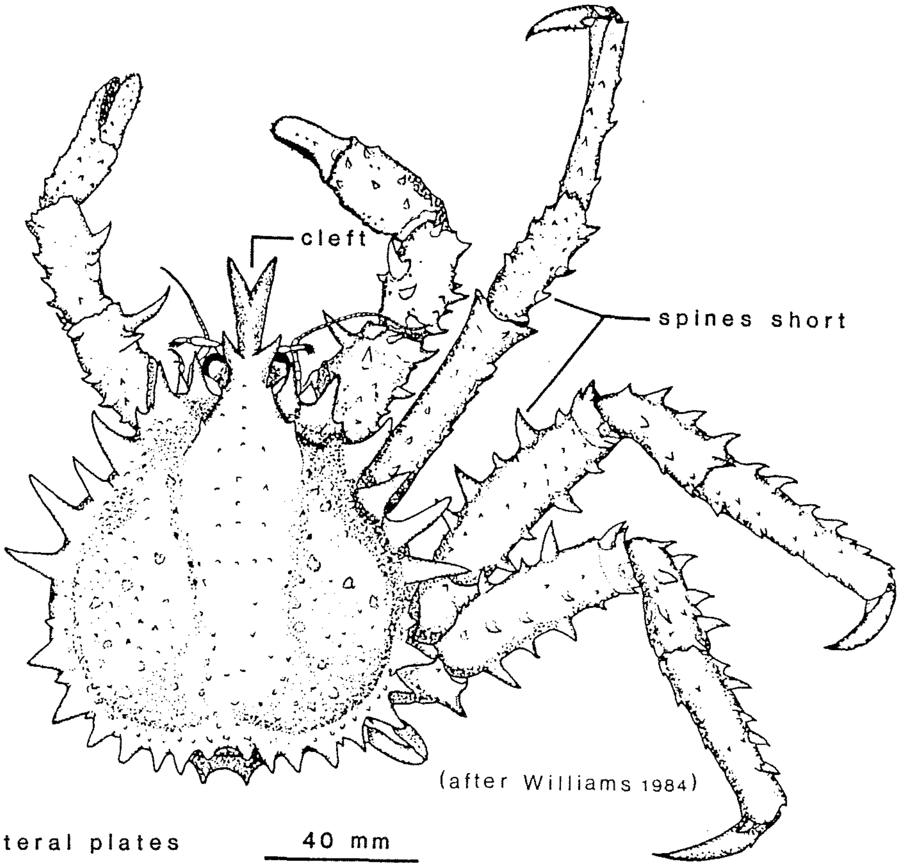
C) Crabs

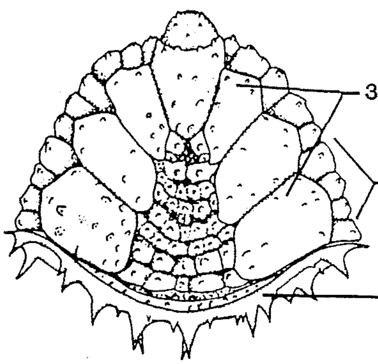
1) ***Chaceon*** (previously ***Geryon***) ***quinquedens*** (Smith, 1879) - red deepsea crab
- usually dark red, but also pink and reddish brown
- carapace longitudinally convex, hexagonal and wider than long in outline; blunt transverse ridge at widest part and deep grooves just lateral to midline; with 4 teeth between eye sockets and usually 5 anterolateral teeth, last lateral tooth most produced and pointing forward (in adults anterolateral teeth are less prominent than shown)
- first leg bearing elongate pincer and 1 spine on each of the next two segments
- walking legs very long and slender
- to 180 mm CW
- 66-2160 m, mostly between 300-900 m; 180-550 m on Scotian Shelf slope; in soft mud-clay based habitat; 4-13°C
- Nova Scotia (43°N) to South Carolina.



Chaceon quinquedens

2) ***Lithodes maja*** (Linnaeus, 1758) - northern stone crab
- light brown, purplish to yellowish red, spines darker, paler below
- carapace pear-shaped, ornamented with many spines (longest along margin); about as long as broad exclusive of rostrum and marginal spines; rostrum long, cleft at tip, with lateral spines and ventral spine between eyestalks
- all legs with spines, first legs with pincers shorter than other walking legs
- abdomen with short spines on first visible (actual second) segment, tubercles on other segments; second segment entire, not subdivided into plates; remaining segments adorned with 3 pairs of lateral, 1 pair of large distal plates and smaller marginal plates (in female larger plates enlarged and smaller marginal plates absent on left side)
- to ~150 mm CW, 175 mm CL (incl. spines), leg span up to 600 mm;
- 65-790 m, 1-10°C (rare below 2.5°C)
- Davis Strait to New Jersey.



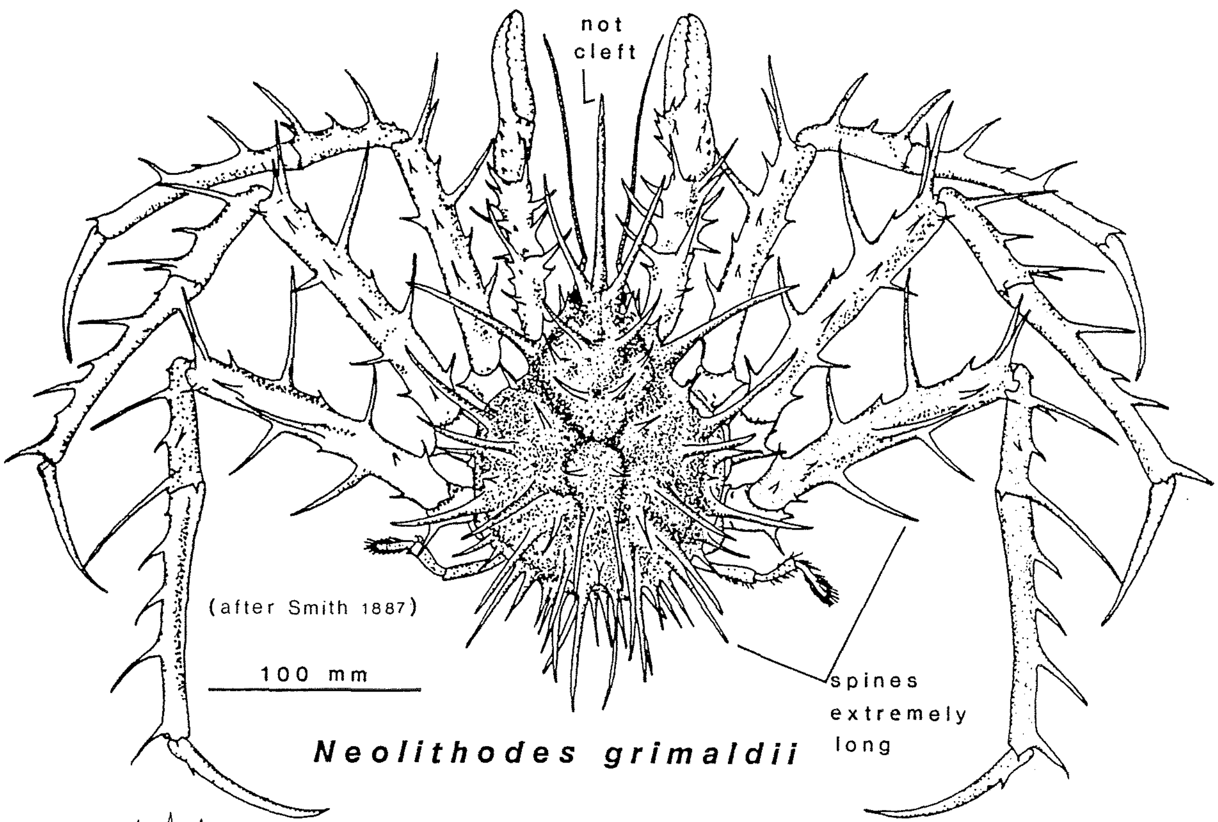


male abdomen

Lithodes maja

3) *Neolithodes grimaldii* (A. Milne-Edwards and Bouvier, 1894) - porcupine stone crab
- brilliant crimson red
- carapace pear-shaped, adorned with many, extremely long (to 60 mm) and sharp spines (marginal spines only little longer); rostrum consisting of 3 very long spines (1 central, 2 lateral)
- all legs with many long spines, legs with pincers shorter than walking legs
- abdomen with very long spines on first visible (actual second) segment which is subdivided into single central and 2 lateral plates; shorter spines on remaining segments; with 2 serially arranged plates distally
- male to 155 mm CW, 239 mm CL (incl. rostrum); leg span 760 mm
- 330-2000 m, ca. 2°C
- Arctic to off Nantucket; not in Gulf of St. Lawrence or Bay of Fundy.

Note: another species, *Neolithodes agassizii*, is very similar except for shorter spines on the carapace, abdomen and appendages.



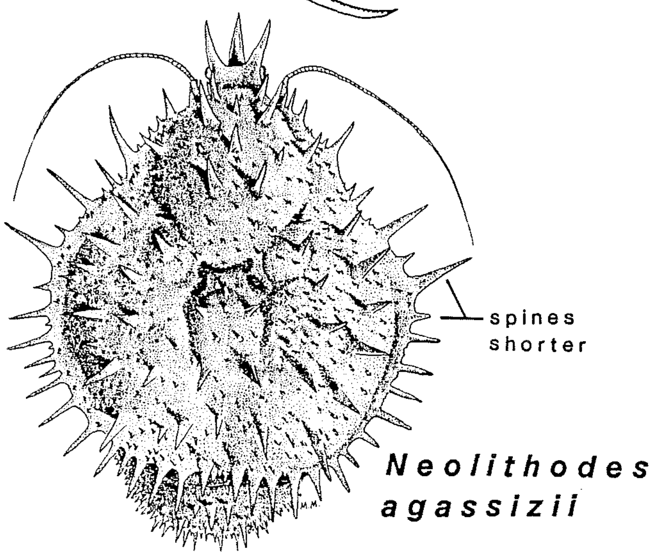


Table 1. Deepsea shrimps of the world with known interest to fisheries. Those occurring in the northwestern Atlantic are indicated by asterisks. (Depth ranges in parentheses are depths of common occurrence; CL = carapace length - mm; TL = Total length - mm; EP = Eastern Pacific; EA = Eastern Atlantic; IWP = Indo-West Pacific; NA = North Atlantic; NP = North Pacific; NWA = Northwestern Atlantic; WA = Western Atlantic; mt = metric tons.)

Scientific name	Common name[1]	Depth Range (m)	Max.Size CL ; TL	Distribution	Fishery Importance & Information	Reference
Infraorder Penaeidea						
Family Solenoceridae	Solenocerid shrimps					
Hadropenaeus lucasii	Trident shrimp	180-500	26;100	IWP	potential	Crosnier & Jouannic 1973
Haliporoides diomedeae	Chilean knife shrimp	240-1866	101;215	EP	potential	Holthuis 1980; Perez-Farfante 1988
Haliporoides sibogae	Jack-knife shrimp	100-1460	200	IWP	minor, developing; Australia; 500mt	Graham & Gorman 1985; Rainer 1990
Haliporoides triarthus	Knife shrimp	290-550	50;150	IWP	major; S.Af., Mozambique; 700mt (DDR)	FAO 1990; Holthuis 1980
Hymenopenaeus aequalis	Veiled shrimp	200-1362	15;90	IWP	potential?	Kurian & Sebastian 1976
*Pleoticus robustus**	Royal red shrimp	180-730 (250-475)	62;225	WA	declined; 50mt(USA); trawl; in NWA occurs mainly south of 35°N.	FAO 1990; Holthuis 1980
Solenocera africana	African mud shrimp	50-450	138	EA	minor	Holthuis 1980
Solenocera agassizii	Kolibri shrimp	86-384	54;149	EP	minor; Costa Rica, Panama	Vidal & Rosetti 1971
Solenocera hextii	Deepsea mud shrimp	115-505	20+;138	IWP	potential	Kurian & Sebastian 1976
Solenocera membranacea	Atlantic mud shrimp	20-700	112	EA	minor; Medit., W.Africa	Holthuis 1980
Family Aristeidae	Gamba prawns, aristeid shrimps					
*Aristaeomorpha foliacea**	Giant red shrimp	120-1300 (250-700)	225	EA,WA,IWP?	moderate; Australia; trawl; in NWA occurs mainly south of 39°N.	Holthuis 1980, Wadley & Morris 1990
Aristaeomorpha woodmasoni	Indian red shrimp	330-500	153	IWP	minor	Kurian & Sebastian 1976
Aristeus alcocki	Arabian red shrimp	270-1086	150	IWP	developing; Spain; 2000+mt	Kurian & Sebastian 1976; FAO 1990
Aristeus antennatus	Blue and red shrimp	80-1440	220	EA	major; NW Africa, Medit.; 900mt; trawl	FAO 1990; Holthuis 1980
Aristeus antillensis	Purple-headed gamba prawn	200-1100	193	WA	?	Perez-Farfante 1988
Aristeus semidentatus	Smooth red shrimp	180-1100	178	IWP	potential	Kurian & Sebastian 1976
Aristeus varidens	Striped red shrimp	300-1134	200	EA	minor; Angola	Crosnier & Forest 1969
Aristeus virilis	Stout red shrimp	344-800	52;190	IWP	minor, developing; Australia	Crosnier & Jouannic 1973; Rainer 1990
*Plesiopenaeus edwardsianus**	Scarlet gamba shrimp (prawn)	274-1850 (400-960)	334	EA,WA,IWP	developing; 33mt (2000+mt in 1977); Spain, Australia; in NWA occurs south from Nfld.	FAO yearbooks; Holthuis 1980
Family Penaeidae	Penaeid shrimps					
Metapenaeopsis lata	Broad velvet shrimp	150-350	15;59	IWP(Japan)	potential?	Yasuda 1957
Metapenaeopsis philippi	Philip velvet shrimp	80-894	130	IWP	potential	Kurin & Sebastian 1976
Parapenaeus investigatoris	Explorer rose shrimp	220-1240	18;82	IWP	minor	Kurin & Sebastian 1976
Parapenaeus lanceolatus	Lancer rose shrimp	300-350	20;75	IWP	moderate	Yasuda 1957
*Parapenaeus longirostris**	Deepwater rose shrimp	18-700 (200-300)	190	EA,WA	major; Medit., NW Africa; 13100mt; trawl; in NWA occurs south of 40°N.	FAO 1990; Holthuis 1980
Parapenaeus sextuberculatus	Domino shrimp	50-350	140	IWP	potential	Crosnier & Jouannic 1973
Penaeopsis balsii	Sythe shrimp	280-980	150	IWP	minor, off E. Africa	Miquel 1984

[1] Based on Williams *et al.* (1988) and/or FAO vernacular names.

Table 1. Continued.

Scientific name	Common name	Depth Range (m)	Max.Size CL ; TL	Distribution	Fishery Importance & Information	Reference
Penaeopsis rectacuta	Needle shrimp	180-750	34;131	IWP	potential	Crosnier & Jouannic 1973
Penaeopsis serrata	Megalops shrimp	100-640	54;140	EA,WA	minor, bycatch of *P. longirostris*	Longhurst 1970
Family Sicyoniidae	Rock shrimps					
Sicyonia cristata	Ridgeback rock shrimp	46-350	18;57	IWP	minor	Holthuis 1980
Sicyonia stimpsoni	Eyespot rock shrimp	20-585	12	WA	minor	Ewald 1969
Infraorder Caridea						
Family Nematocarcinidae	Spider shrimps					
Nematocarcinus africanus	African spider shrimp	75-850	104	EA	potential	Holthuis 1980
Family Pasiphaeidae	Glass shrimps					
Glyphus marsupialis	Kangaroo shrimp	500-1000	61;162	EA	minor; bottom trawls	Longhurst 1970; Holthuis 1981
*Pasiphaea multidentata**	Pink glass shrimp	10-2000 (400-700)	105	NA	minor; occurs from Greenland to Mass.,USA	Holthuis 1980
Pasiphaea sivado	White glass shrimp	0-700	22;80	EA	minor	Holthuis 1980
Family Rhynchocinetidae						
Lipkius holthuisi	Wellington shrimp	360-470	17	IWP	potential	Anon. 1964
Family Campylonotidae						
Campylonotus rathbunae	Sabre prawn	280-810	28	IWP	potential	Anon. 1964
Family Ogyrididae	Longeye shrimps					
Ogyrides orientalis	Telescope shrimp	9-535	6;18	IWP	minor	Liu 1955
Family Hippolytidae	Cock shrimps					
*Eualus macilentus**	Greenland shrimp	27-540 (35-90)	16;68	NWA	potential;occurs from Arctic to Nova Scotia	Couture 1971
*Spirontocaris lilljeborgii**	Friendly spine shrimp	20-1200	74	NA	incidental;occurs from Greenland to Delaware Bay, USA	Longhurst 1970
*Spirontocaris spinus**	Parrot shrimp	5-465	60	NA	incidental; occurs from Arctic to Mass.,USA	Longhurst 1970
Family Processidae	Night shrimps					
Processa canaliculata	Processa shrimp	70-600	75	EA	minor	Holthuis 1980
Family Pandalidae	Pandalid shrimps					
Chlorotocus crassicornis	Green shrimp	3-600	78	EA	minor	Longhurst 1970; Holthuis 1980
Dichelopandalus bonneri	Whip shrimp	60-1200	120	EA	potential	Longhurst 1970; Holthuis 1980
Heterocarpus dorsalis	Madagascar nylon shrimp	185-1325	37;165	IWP	potential	Crosnier & Jouannic 1973
Heterocarpus ensifer	Armed nylon shrimp	146-885	35;142	WA,EA,IWP?	minor	Guézé 1976; Crosnier & Forest 1973

Table 1. Concluded.

Scientific name	Common name	Depth Range (m)	Max.Size CL ; TL	Distribution	Fishery Importance & Information	Reference
Heterocarpus gibbosus	Humpback nylon shrimp	265-1280	40;140	IWP	potential	Kurian & Sebastian 1976
Heterocarpus laevigatus	Smooth nylon shrimp	302-1156	49;180	EA,IWP	potential	Guézé 1976; Crosnier & Forest 1973
Heterocarpus reedi	Chilean nylon shrimp	155-550	39	EP	major; 4500 mt (Chile)	Hancock & Henriquez 1968; Bahamonde & Henriquez 1970
Heterocarpus sibogae	Mino nylon shrimp	238-560	140	IWP	minor, developing; Australia	Yasuda 1957; Rainer 1990
Heterocarpus tricarinatus	Scarred nylon shrimp	500-2000	119	IWP	potential	Crosnier & Jouannic 1973
Heterocarpus vicarius	Northern nylon shrimp	73-550	29;110	EP	minor	Vidal & Rosetti 1971
Heterocarpus woodmasoni	Indian nylon shrimp	290-640	32;149	IWP	minor, developing; Australia	Crosnier & Jouannic 1973; Kurian & Sebastian 1976; Rainer 1990
Pandalopsis dispar	Sidestriped shrimp	38-649	39;200	EP	minor	Longhurst 1970
Pandalopsis japonica	Morotoge shrimp	64-650	150	IWP	minor	Yoshida 1941
*Pandalus borealis**	Northern shrimp	16-1380 (54-90)	165	NA,NP	major; 163000 mt (10 nations); trawls; in NWA occurs from Greenland to Mass.,USA	FAO 1990; Longhurst 1970
Pandalus goniurus	Humpy shrimp	5-450	70;142	NP	minor	Longhurst 1970
Pandalus hypsinotus	Coonstriped shrimp	5-460	43;209	NP	moderate	Longhurst 1970; Butler 1964
Pandalus jordani	Ocean shrimp	36-457	30;161	EP	major; 15000+mt (USA,Canada)	Longhurst 1970; Butler 1964,1980; Dahlstrom 1970
*Pandalus montagui**	Aesop shrimp	4-790 (20-100)	160	NA	incidental; occurs from Greenland to Rhode Island, USA.	Longhurst 1970; Couture 1971; Simpson et al. 1970
Pandalus nipponensis	Botan shrimp	19-583	85	IWP	moderate?	Yasuda 1957
Pandalus platyceros	Spot shrimp	4-487	61;253	NP	moderate;40+mt(USA,Canada);mostly traps	Butler 1970; Longhurst 1970
Parapandalus narval	Narwal shrimp	10-910	145	EA,IWP	minor	Holthuis 1980
Parapandalus spinipes	Oriental narwal shrimp	50-805	130	IWP	potential	Kurian & Sebastian 1976
Plesionika acanthonotus	Lesser striped shrimp	190-1350	84	EA,WA	minor	Holthuis 1980
Plesionika alcocki	Gondwana striped shrimp	500-1170	22	IWP	potential	Crosnier & Jouannic 1973
Plesionika antigai	Catalonian striped shrimp	120-400	18	EA	minor, incidental	Holthuis 1980
Plesionika edwardsii	Striped soldier shrimp	50-680	166	EA,WA	minor, incidental	Holthuis 1980
Plesionika ensis	Gladiator striped shrimp	100-1251	128	Circumtropic	incidental	Kurian & Sebastian 1976
Plesionika gigliolii	Italian deepsea shrimp	118-800	62	EA	v. minor	Zariquiey Alvarez 1946
Plesionika heterocarpus	Arrow shrimp	35-850	106	EA	minor, incidental	Holthuis 1980
Plesionika martia	Golden shrimp	165-2195	169	Circumtropic	potential	Holthuis 1980
Plesionika williamsi	Guinea striped shrimp	300-455	166	EA	potential	Forest 1963
Family Crangonidae	Crangonid shrimps					
Argis lar	Kuro shrimp	10-400	109	NP	moderate?	Yoshida 1941
Crangon communis	Gray shrimp, two spine crangon	16-1537	73	NP	minor	Holthuis 1980
Pontocaris lacazei	Hardshell shrimp	30-684	49	EA,IWP?	v. minor, incidental	Zariquiey Alvarez 1946
Pontocaris pennata	Feather shrimp	20-900	43	IWP	minor	Yasuda 1957
Pontophilus spinosus	Spiny shrimp	20-1550	52	EA	v. minor, incidental	Zariquiey Alvarez 1946

Table 2. Deepsea shrimps known from Canadian Atlantic waters additional to those listed in Table 1 (CL = carapace length - mm; TL = total length - mm), from Pohle (1988).

Scientific name	Common name	Depth range (m)	Max.Size CL ; TL	Criteria against fishery selection
Infraorder Penaeoidea				
Family Benthesicymidae	Benthesicymid shrimps			
Benthesicymus bartletti		609-5777	219	rare in Canadian waters, usually south of 35°N
Gennadas elegans		200-700	10;43	small size
Gennadas valens		100-1500	48	small size
Family Sergestidae				
Sergestes arcticus		175-4500	20;65	small size, planktonic
Sergia robusta		150-4600	27;90	small size, planktonic
Infraorder Caridea				
Family Oplophoridae	Deepsea shrimps			
Acanthephyra pelagica		200-1650	31;~110	
Acanthephyra purpurea		100-1500	23	
Acanthephyra eximia		200-3700	41;140	rare in Canadian waters, usually south of 44°N
Hymenodora glacialis	Northern ambereye	0-3900	19	small size, rare in Canadian waters
Hymenodora gracilis		750-5400	19	small size, rare in Canadian waters
Notostomus elegans		450-5400	45;110	rare in Canadian waters, usually south of 45°N
Notostomus robustus		850-3000	51	rare in Canadian waters, usually south of 44°N
Oplophorus spinosus		0-1800	17	small size, extends north to Latitude 44°N only
Systellaspis debilis		25-3000	14;85	small size, not very abundant
Family Nematocarcinidae	Spider shrimps			
Nematocarcinus rotundus		300-1580	27	
Nematocarcinus cursor		670-1240	27	rare in Canadian waters, usually below 43°N
Family Pasiphaeidae	Glass shrimps			
Parapasiphaea sulcatifrons		500-5400	26;83	small size, often pelagic
Pasiphaea tarda		250-2400	75;215	
Family Hippolytidae	Cock shrimps			
Bythocaris gracilis		550-1900	8;39	small size, not abundant
Bythocaris payeri		180-1000	12;50	small size, not abundant
Family Pandalidae	Pandalid shrimps			
Dichelopandalus leptocerus	Bristled longbeak	0-790	100	
Pandalus propinquus		20-2000	~19;150	
Stylopandalus richardi		12-1800	9;70	small size, often off bottom
Family Crangonidae	Crangonid shrimps			
Metacrangon jacqueti		481-1754	17;60	small size
Pontophilus brevirostris		13-426	6;37	small size, rare in Canadian waters
Pontophilus norvegicus	Norwegian shrimp	50-1450	19;80	small size
Sabinea hystrix		500-3957	30;130	
Sabinea sarsii	Sars shrimp	48-710	20;72	small size, rare in deeper waters
Sabinea septemcarinata	Seven-line shrimp	0-406	20;90	small size, uncommon below 200 m
Sclerocrangon ferox		90-1000	31;130	

Table 3. Short-list of Canadian Atlantic deepsea shrimps of potential commercial interest. (CL = carapace length - mm; TL = total length - mm.)

Scientific name	Common name	Depth range (m)	Common depth range (m)	Max.Size CL ; TL
Primary candidates:				
Plesiopenaeus edwardsianus	Scarlet shrimp	274-1850	400-960	334
Pasiphaea tarda	Crimson pasiphaeid	250-2400		75;215
Sabinea hystrix	Deepsea sabineid*	500-3957		30;130
Acanthephyra pelagica	Shortnose ridgeback*	200-1650		31;~110
Acanthephyra purpurea	Longnose ridgeback*	100-1500		24;~100
Secondary candidates:				
Pasiphaea multidentata	Pink glass shrimp	10-2000	400-700	105
Nematocarcinus rotundus	Blunt spider shrimp*	300-1580		28;105
Sclerocrangon ferox	Back-spined shrimp*	90-1000		31;130
Pandalus propinquus	Curveback pandalid*	20-2000		~19;150

* Name applied by authors of present study.

Table 4. Lobsterettes, deepsea crabs and squat lobsters of the world with known commercial interest to fisheries. (Sizes are in mm, CW = carapace width; EA = Eastern Atlantic; NEA = Northeastern Atlantic; NEP = Northeastern Pacific; NP = North Pacific; NWA = Northwestern Alantic; SEA = Southeastern Atlantic; SEP = Southeastern Pacific; SP = South Pacific; WA = Western Atlantic.)

Scientific name	Common name	Depth range (m)	Common depth range (m)	Max.Size CL ; CW	Distribution	Fishery importance	Reference
Astacidea							
Nephropidae	Clawed lobsters						
Metanephrops spp.	Lobsterette (USA), scampi (Australia)	100-900		to TL 200	WA, Indo-Pacific	developing	Williams & Dore 1988; Davis & Ward 1984
Anomura							
Lithodidae	Stone and king crabs						
Lithodes couesi	Deepsea king crab	384-1125		136	NEP	potential	Somerton 1981
Lithodes aequispina	Golden king crab	51-900		187	NP,Bering Sea	minor;Canada.	Hart 1982; Sloan 1985
Lithodes santolla	Southern king crab	0-600	<200		SEP	good;Chile,Argentina	Anon. 1986
Lithodes murrayi	Subantarctic stone crab	0-1015		192	subantarctic	experimental; Af,NZ	Arnaud 1985
Paralithodes camtschatica	Alaska or red king crab	14-384	<200	227	NP	major;USA,USSR,Japan.	Hart 1982
Paralithodes platypus	Blue king crab				NEP	bycatch of *P. camtschatica*	
Paralomis aculeata	Red stone crab	180-1000+		118	subantarctic	bycatch	Arnaud 1985
Paralomis granulosa	Softshell red crab or false king crab				SP,S.America	minor; Chile,Falkland Is.	
Galatheidae	Squat lobsters						
Cervimunida johni	Blue squat lobster	125-400	125-200	TL 62	SEP	minor;bycatch of *P. monodon*	Bahamonde *et al.* 1986; Williams & Dore 1988
Munida quadrispina		22-1463			NEP	potential?	Burd & Jamieson 1988
Munida rugosa		0-1255	45-546	TL 80	NEA	developing;UK	Howard 1981
Pleuroncodes monodon	Carrot squat lobster	125-400	125-200	TL 25	SEP	major; Chile;to 50000mt/yr	Bahamonde *et al.*1986
Brachyura							
Majidae	Spider crabs						
Chionoecetes bairdi	Tanner crab	6-474		121;139	NEP,Bering Sea		Hart 1982
Chionoecetes japonicus	Pink crab	411-2103	>800		NP	major; Japan	Sinoda 1982
Chionoecetes opilio	Snow crab	13-2222		128;126	NWA,Arctic,NP	major; traps,seining	Elner 1982; Sinoda 1982

Table 4 Concluded.

Scientific name	Common name	Depth range (m)	Common depth range (m)	Max.Size CL ; CW	Distribution	Fishery importance	Reference
Cancridae	Rock crabs						
Cancer bellianus	Toothed rock crab	37-620		130;200	EA	minor bycatch; trawls	Holthuis 1981
Cancer borealis	Jonah crab	0-800		175	NWA	good;trawls,traps	Williams 1978
Cancer irroratus	Atlantic rock crab	0-751		135	NWA	good;trawls,traps	Williams 1978
Geryonidae	Deepsea crabs						
Chaceon (Geryon) erythiae					SEA	localized	Macpherson 1984
Chaceon (Geryon) fenneri	Golden deepsea crab				NWA	developing	Manning & Holthuis 1984
Chaceon (Geryon) maritae	West African geryon			172	SEA	good;7000-10000mt/yr	Manning & Holthuis 1981;Melville-Smith 1988
Chaceon (Geryon)quinquedens	Red deepsea crab	66-2160	300-900	178	NWA	good;USA,Canada	Lux *et al.* 1982

Table 5. Deepsea blind lobsters, squat lobsters and crabs known from Canadian Atlantic waters. (Depth ranges in parentheses are depths of common occurrence; CL = carapace length - mm; CW = carapace width - mm.) From Pohle (1988, 1990).

Scientific name	Common name	Depth range (m)	Max.Size CL ; CW	Criteria against fishery selection
Palinura				
Polychelidae	Blind lobsters			
Polycheles granulatus		347-2505	50	marginal size
Polycheles validus		1698-3365	80	rare in Canadian waters, usually south of 43°N
Stereomastis nana		457-3506	45	rare, marginal size
Stereomastis sculpta		230-4000	70	
Anomura				
Lithodidae	Stone and king crabs			
Lithodes maja	Northern stone crab	65-790	175	
Neolithodes agassizii		-3083		rare, mostly south of Canadian waters
Neolithodes grimaldii	Porcupine stone crab	330-2000	239	rare?
Galatheidae	Squat lobsters			
Munida iris		43-613	47	limited distribution in Canadian waters
Munida tenuimana		440-650	31	small size
Munida valida		441-1150	83	
Munidopsis curvirostra		135-2325	25	small size
Brachyura				
Majidae	Spider crabs			
Hyas araneus	Atlantic lyre or toad crab	1-360 (1-52)	95;75	rare in deep waters
Hyas coarctatus	Arctic lyre or toad crab	1-1650 (1-50)	80;65	rare in deep waters
Chionoecetes opilio	Snow crab	13-2222	128;126	
Cancridae	Rock crabs			
Cancer borealis	Jonah crab	0-800	160;102	probably rare in deep waters off Canada
Cancer irroratus	Atlantic rock crab	0-751	89+;141	rare in deep waters off Canada
Geryonidae	Deepsea crabs			
Chaceon (Geryon) quinquedens	Red deepsea crab	66-2160 (300-900)	178	

Table 6. Short-list of Canadian Atlantic deepsea non-shrimp decapods of potential commercial interest. (CL = Carapace length - mm; CW = Carapace width - mm.)

Scientific name	Common name	Depth range (m)	Max.Size CL ; CW
Palinura			
Polychelidae	Blind lobsters		
Polycheles granulatus	Unarmed blind lobster*	347-2505	50
Stereomastis sculpta	Smooth-ridged blind lobster*	230-4000	70
Anomura			
Lithodidae	Stone and king crabs		
Lithodes maja	Northern stone crab	65-790	175
Neolithodes grimaldii	Porcupine stone crab	330-2000	239
Galatheidae	Squat lobsters		
Munida valida	Spinyhead lobsterette*	441-1150	83
Brachyura			
Geryonidae	Deepsea crabs		
Chaceon quinquedens	Red deepsea crab	66-2160	178

* Name applied by authors of present study.

Table 7. Finfish fisheries of the world prosecuted in deep water (>300 m) by major fishing area and by functional and taxonomic groups. (Principal sources: Anon. 1981; FAO 1990; Fischer 1973; Fischer *et al.* 1981. Major fishing areas: AA = Australasia; ECA = East Central Atlantic; ECP = East Central Pacific; IO = Indian Ocean; MED = Mediterranean Sea; NEA = Northeastern Atlantic; NEP = Northeastern Pacific; NWA = Northwestern Atlantic; NWP = Northwestern Pacific; OC = Oceania; SEA = Southeastern Atlantic; SEP = Southeastern Pacific; SO = Southern Ocean; SWA = Southwestern Atlantic; WCA = West Central Atlantic; WCP = West Central Pacific).

MAJOR FISHING AREAS

	NWA	NEA	WCA	ECA	SWA	SEA	MED	IO	NWP	NEP	WCP	OC	ECP	AA	SEP	SO
SPECIES GROUPS																
LARGE EPIPELAGICS (TUNA, BILLFISH ETC.)	X	X	X	X			X	X			X	X	X	X	X	
SMALL EPIPELAGICS:																
HERRINGS		X														
ANCHOVIES AND SARDINES			X		X	X			X				X	X	X	
MACKERELS				X		X			X				X		X	
JACK MACKERELS				X		X	X	X					X		X	
CAPELIN	X	X														
ARGENTINES		X					X		X							
SAURIES									X							
DIADROMOUS FISHES	X								X							
ESTUARINE AND INSHORE FISHES							X									
MESOPELAGICS						X		X	X							X
DEMERSALS AND SEMI-DEMERSALS:																
HAGFISHES									X							
RAJIDS	X	X		X			X									
DEEPWATER DOGFISHES	X	X														
CONGER EELS				X												X
GADID CODS		X							X	X						
BLUE WHITINGS		X		X	X		X							X		
LOTINID HAKES AND LINGS		X														
MERLUCCID HAKES	X	X	X	X	X	X	X		X	X			X		X	
MACRURONID "GRENADIERS"					X									X	X	
MORID CODS				X					X					X		
MACRURID GRENADIERS	X	X		X	X		?		X	X				X		
CUSK EELS					X	X				X					X	
LOPHIID ANGLERFISHES		X		X			X									
TRACHIPTERID RIBBONFISHES				X					X							
ROUGHIES				X										X		
BERYCID ALFONSINOS	X			X					?							
SEBASTINID ROCKFISHES	X	X			X		X		X	X						
SABLEFISH									X	X						
CENTROLOPHIDS				X										X		
PENTACEROTIDS										X		X				
ZOARCID EELPOUTS					X											
ANARHICHADID WOLFFISHES		X														
BRAMID POMFRETS		X														
NOTOTHENOIDS																X
GURNARDS							X		X							
GEMPYLID SNAKE MACKERELS														X		
TRICHIURID CUTLASSFISHES		X		X		X			X							
OTHER PERCIFORMS				X		X	X		X							
HALIBUTS	X	X								X						
OTHER FLATFISHES	X						X		X	X						

Table 8: Finfishes known to occur in waters deeper than 300 m off Atlantic Canada, excluding species known from that area only as expatriate larvae or juveniles. Nomenclature and sequence follow Scott and Scott (1988). Species believed to be relatively abundant are listed in bold face. (Sources: Haedrich and Merrett 1988; Karrer 1973; Markle *et al.* 1988; Pechenik and Troyanovskii 1970; Pinhorn 1976; Scott and Scott 1988; Snelgrove and Haedrich 1985.)

Order	Common name	Scientific name
Petromyzontiformes	Sea lamprey	*Petromyzon marinus*
Myxiniformes	Hagfish	*Myxine glutinosa*
Squaliformes	Various pelagic sharks	
	Deepsea cat shark	*Apristurus profundorum*
	Black dogfish	***Centroscyllium fabricii***
	Portuguese shark	*Centroscymnus coelolepis*
	Rough sagre	*Etmopterus princeps*
	Greenland shark	*Somniosus microcephalus*
Rajiformes	Deepwater skate	*Bathyraja richardsoni*
	Skate	*Breviraja marklei*
	Skate	*Raja bigelowi*
	Round skate	*Raja fyllae*
	Arctic skate	*Raja hyperborea*
	Shorttail skate	*Raja jenseni*
	Barndoor skate	*Raja laevis*
	White skate	*Raja lintea*
	Soft skate	*Raja mollis*
	Thorny skate	*Raja radiata*
	Smooth skate	*Raja senta*
Chimaeriformes	Longnose chimera	*Harriotta raleighana*
	Deepwater chimera	*Hydrolagus affinis*
	Knifenose chimera	*Rhinochimera atlantica*
Anguilliformes	American eel	*Anguilla rostrata*
	Slatjaw cutthroat eel	***Synaphobranchus kaupi***
	Snubnose eel	*Simenchelys parasiticus*
	Neckeel	*Derichthys serpentinus*
	Duckbill oceanic eel	*Nessorhamphus ingolfianus*
	Stout sawpalate	*Serrivomer beani*
	Slender snipe eel	*Nemichthys scolopaceus*
	Pelican gulper	*Eurypharynx pelecanoides*
Notacanthiformes	Halosaur	*Aldrovandia phalacra*
	Halosaur	***Halosauropsis macrochir***
	Blackfin tapirfish	*Lipogenys gilli*
	Spiny eel	*Notacanthus chemnitzi*
	Shortspine tapirfish	*Polyacanthonotus rissoanus*
Clupeiformes	Atlantic herring	*Clupea harengus*

Salmoniformes	Atlantic salmon	*Salmo salar*
	Capelin	*Mallotus villosus*
	Atlantic argentine	***Argentina silus***
	Striated argentine	*Argentina striata*
	Large-eyed argentine	*Nansenia groenlandica*
	Various bathylagid deepsea smelts	
	Spookfish	*Dolichopteryx binocularis*
	Müller's pearlsides	*Maurolicus muelleri*
	Various other gonostomatid lightfishes	
	Various sternoptychid hatchetfishes	
	Various astronesthid snaggletooths	
	Various melanostomiid dragonfishes	
	Various malacosteid loosejaws	
	Dana viperfish	*Chauliodus danae*
	Sloane's viperfish	*Chauliodus sloani*
	Boa dragonfish	*Stomias boa*
	Shortbarbel dragonfish	*Stomias brevibarbatus*
	Ribbon sawtailfish	*Idiacanthus fasciola*
	Agassiz' smoothhead	*Alepocephalus agassizii*
	Baird's smoothhead	***Alepocephalus bairdii***
	Bigeye smoothhead	*Bajacalifornia megalops*
	Bluntsnout smoothhead	*Xenodermichthys copei*
	Various searsids	
	Lizardfish	*Bathysaurus agassizi*
Myctophiformes	Spiderfish	*Bathypterois dubius*
	Spiderfish	*Bathypterois quadrifilis*
	Longnose greeneye	*Parasudis truculenta*
	White barracudina	***Notolepis rissoi***
	Duckbill barracudina	*Paralepis atlantica*
	Barracudina	***Paralepis coregonoides***
	Halterfish	*Omosudis lowei*
	Shortnose lancetfish	*Alepisaurus brevirostris*
	Longnose lancetfish	*Alepisaurus ferox*
	Daggertooth	*Anotopterus pharao*
	Pink sabertooth	*Evermannella balbo*
	Paperbone fish	*Scopelosaurus lepidus*
	Glacier lanternfish	*Benthosema glaciale*
	Horned lanternfish	*Ceratoscopelus maderensis*
	Various other myctophid lanternfishes	
Lophiiformes	Monkfish	*Lophius americanus*
	Redeye gaper	*Chaunax stigmaeus*
	Atlantic batfish	*Dibranchus atlanticus*
	Various ceratioid anglerfishes	
Gadiformes	**Blue hake**	***Antimora rostrata***
	Dainty mora	*Halargyreus johnsoni*
	Smallscale mora	*Laemonema barbatula*
	Largeye lepidion	*Lepidion eques*

	Cusk	*Brosme brosme*
	Fourbeard rockling	*Enchelyopus cimbrius*
	Atlantic cod	*Gadus morhua*
	Silver rockling	*Gaidropsarus argentatus*
	Threebeard rockling	*Gaidropsarus ensis*
	Winged hake	*Lyconus brachycolus*
	Offshore hake	*Merluccius albidus*
	Silver hake	***Merluccius bilinearis***
	Blue whiting	*Micromesistius poutassou*
	Blue ling	*Molva dypterygia*
	Pollock	*Pollachius virens*
	Longfin hake	***Urophycis chesteri***
	White hake	*Urophycis tenuis*
	Grenadier	*Chalinura brevibarbis*
	Roundnose grenadier	***Coryphaenoides rupestris***
	Grenadier	*Lionurus carapinus*
	Roughhead grenadier	***Macrourus berglax***
	Marlin-spike	***Nezumia bairdi***
	Grenadier	*Nematonurus armatus*
	Various other macrourid grenadiers	
Ophidiiformes	Cusk-eel	*Dicrolene intronigra*
	Cusk-eel	*Monomitopus agassizii*
Atheriniformes	**Atlantic saury**	***Scomberesox saurus***
Beryciformes	Various melamphaeid ridgeheads	
	Spinyfin	*Diretmus argenteus*
	Rosy soldierfish	*Hoplostethus mediterraneus*
	Ogrefish	*Anoplogaster cornuta*
	Slender alfonsino	*Beryx splendens*
	Redmouth whalefish	*Rondeletia loricata*
	Whalefish	*Barbourisia rufa*
Zeiformes	Buckler dory	*Zenopsis conchifera*
	Zeniontid dory	*Zenion hololepis*
	Tinselfish	*Xenolepidichthys dalgleshi*
Lampriformes	Opah	*Lampris guttatus*
Gasterosteiformes	Longspine snipefish	*Macrorhamphosus scolopax*
Perciformes	Percichthyid bass	*Howella sherborni*
	Tilefish	*Lopholatilus chamaeleonticeps*
	Greenland manefish	*Caristius groenlandicus*
	Bathyclupeid	*Bathyclupea argentea*
	Black swallower	*Chiasmodon niger*
	Various zoarcid eelpouts	
	Northern wolffish	*Anarhichas denticulatus*
	Atlantic wolffish	*Anarhichas lupus*
	Spotted wolffish	*Anarhichas minor*

	Wrymouth	*Cryptacanthodes maculatus*
	Escolar	*Lepidocybium flavobrunneum*
	Black snake mackerel	*Nealotus tripes*
	Oilfish	*Ruvettus pretiosus*
	Black scabbardfish	***Aphanopus carbo***
	Frostfish	*Benthodesmus elongatus*
	Smalleye frostfish	*Benthodesmus tenuis*
	Bluefin tuna	***Thunnus thynnus***
	Swordfish	***Xiphias gladius***
	Various other tunas and billfishes	
	Brown ruff	*Centrolophus medusophagus*
	Black ruff	*Centrolophus niger*
	Stromateid butterfish	*Cubiceps capensis*
	Barrelfish	*Hyperoglyphe perciformis*
	Man-of-war fish	*Nomeus gronovii*
	Scaly hedgehogfish	*Ectreposebastes imus*
	Blackbelly rosefish	*Helicolenus dactylopterus*
	Acadian redfish	***Sebastes fasciatus***
	Golden redfish	***Sebastes marinus***
	Deepwater redfish	***Sebastes mentella***
	Armored searobin	*Peristedion miniatum*
	Various cottid sculpins and agonid poachers	
	Various cyclopterid lumpfishes and snailfishes	
Pleuronectiformes	Gulf stream flounder	*Citharichthyes arctifrons*
	Windowpane	*Scophthalmus aquosus*
	Witch flounder	***Glyptocephaluscynoglossus***
	American plaice	*Hippoglossoides platessoides*
	Atlantic halibut	***Hippoglossoides hippoglossus***
	Greenland halibut	***Reinhardtius hippoglossoides***
Tetraodontiformes	Ocean sunfish	*Mola mola*

Table 9. Deepsea cephalopods of possible commercial interest known to occur in the northwestern Atlantic. Group A - primary candidates, Group B - secondary candidates. (ML = mantle length, A = Atlantic, EA = eastern Atlantic, WA = western Atlantic, NA = north Atlantic, P = Pacific.)

Scientific name	Common name	Depth range (m)	Max Size ML (cm)	Distribution	Fishery Importance & Information
GROUP A					
Family Ommastrephidae					
Illex illecebrosus	Northern shortfin squid	0-1000	31	NA, temperate, oceanic and neritic	Max. catch in Canadian zone - 160,000 mt (1979).
Ommastrephes bartrami	Flying squid	0-1500	50	All oceans, sub-tropical and temperate	Fished in Pacific, Max. catches > 200,000 mt (1982-83) (Murata 1990).
Ommastrephes caroli	Webbed squid	0-1500	70	WA, EA, P, sub-tropical and temperate	Local fishery at Madeira. May be same species as *O. bartrami* (Murata 1990).
Ommastrephes pteropus	Orangeback squid	0-1500	40	A, tropical and warm temperate	Local fishery at Madeira. Flesh excellent quality.
Family Gonatidae					
Gonatus fabricii	Boreal armhook squid	0-500	30	NA, arctic and subarctic	Local fishery by Greenland eskimos.
Gonatus steenstrupi	Atlantic gonate squid	0-1000	15	NA, subarctic and temperate	No fishery at present. Flesh good quality.
Family Onychoteuthidae					
Onychoteuthis banksi	Common clubhook squid	0-150	30	All oceans, tropical - temperate	No fishery at present. Flesh good quality.
Family Thysanoteuthidae					
Thysanoteuthis rhombus	Diamondback squid	epipelagic	100	All oceans, tropical - warm temperate	Local fishery in Japan Sea.
GROUP B					
Family Enoploteuthidae					
Pterygioteuthis giardi	Roundear enope squid	0-500	4	All oceans, tropical - warm temperate	No fishery at present.
Family Architeuthidae					
Architeuthis spp.	Giant squid	200-400	600	All oceans, tropical - arctic	No fishery at present. Flesh contains ammonium ions.
Family Histioteuthidae					
Histioteuthis bonnellii	Umbrella squid	500-1500	33	A, tropical - temperate	No fishery at present.
Histioteuthis elongata	Elongate jewel squid	500-1000	20	NA, boundaries unknown	No fishery at present.
Family Bathyteuthidae					
Bathyteuthis abyssicola	Deepsea squid	700-2000	7	All oceans, poorly known	No fishery at present.
Family Brachioteuthidae					
Brachioteuthis riisei	Common arm squid	0-3000	4	NA, P, boundaries unknown	No fishery at present.
Family Octopodidae					
Bathypolypus arcticus	Spoonarm octopus	15-1000	10	NA, temperate - arctic, benthic	No fishery at present.
Family Argonautidae					
Argonauta argo	Greater argonaut	epipelagic	12	All oceans, tropical - warm temperate	Probably no directed fisheries. Marketed in India and Japan.