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Anon. 1991. Project Summary: Exploration of deepwater resources off the Scotian Shelf. Atlantic Fish. Devel., Scotia-Fundy Region, Halifax, Nova Scotia. No. 32, Dec., 1991: 4pp.

This short report summarizes Canadian explorations using fixed gear on the continental slope of the Scotian shelf. The project used fixed gear because it was felt that this gear would be more effective in catching deepwater species than mobile gear. Reasons included the advantage of bait attraction, difficult towing terrain, and better product quality.

The work was performed by the R/V Alfred Needler between August 7 and 13, 1991. Fixed gear sets consisted of combinations of gill nets (5 1/2 - 7 inch mesh), crab traps (3-inch mesh), shrimp traps (1/2-inch bar spacing), and longlines (#10-#14 Mustad circle hooks). Eighteen successful sets were made in depths from 485-2800 meters.

Twenty-one species of fish were caught mostly by the gill nets. Red crab was the main crustacean taken; catches ranged in depths from 500-1300 m and in carapace width from 8-14 cm (about half of commercial size). No shrimp were caught in the traps, however, shrimp were caught previously in the area by trawl nets.

The largest fish catches were deepwater chimaera, black dogfish and other sharks; none of commercial interest. Commercially interesting species taken included Greenland halibut (turbot), roughhead grenadier and blue hake. The turbot were taken between 800-1800 m while the others were found to the deepest fished depth (2800 m).

Anon. 1992. The fisheries of the North Atlantic slope. Seafish Report No. 403 update, December 1992. 18pp.

This is a general report on the UK's effort to develop a deepwater fishery in the Northeast Atlantic; deepwater defined as 500-2000 m. The authors refer to the fishery as slope fishing to differentiate it from conventional bottom trawling. In this fishery (Rockall Trough)the greatest concentrations of fish are between 750 -1500 m with little marine life deeper than 1500 m. Water temperature is important in that in warmer Greenland waters the fishery is deeper (2000 m).

The deepwater species are slow growing and the fishery is now dependent on accumulated stock. Biological surveys have identified over 85 species of which 9 have commercial potential. These species include orange roughy (*Hoplostethus atlanticus*), roundnose grenadier (*Coryphaenoides rupestris*), black scabbard (*Aphanopus carbo*), rabbit fish (*Chimaera monstrosa*), and others. The report provides information on size, flesh quality and cooking characteristics for each of these species.

In a discussion of echo sounders, the authors conclude the best compromise, down to 1000 m, would be a high power output, narrow beam in the 30-40 Khz range. They also feel it essential to have an acoustic net link system on the gear. There is an extensive discussion of winch, engine power, and warp requirements. They report that there is evidence from German skippers that there are strong deep currents which are unpredictable in deep water fishing which will impact gear/vessel sizing. Regarding the net itself, there is little information available to design the optimum trawl. The preferred door however is a high aspect ratio cambered vee door.

The report discusses post harvest care of the catch and possible markets. The authors conclude care must be exercised in developing deepwater fisheries and the potential of longlining should be examined.

Anon. 1993. Project Summary: Deepwater trawling exploratory fisheries on west coast seamounts. Fishing Operations, Fishing industry Services, Ottawa, Canada, 4pp.

This brief project summary covers ten days of exploratory trawling begun in May, 1993 on three seamounts off British Columbia. The purpose was to develop a new fishery for larger trawlers since the traditional fishery was becoming increasingly restrictive. Recent catches of orange roughy from France, Iceland and Chile fueled the hope that this species was widely distributed.

Due to gear limitations the two vessels involved could not tow deeper than 475 fathoms. On Bowie Seamount nine tows were made between 150-200 fathoms with durations ranging from 17-21 minutes. Over 46,000 kg of harlequin and rougheye rockfish were caught. On Union Seamount tows were made in 160 fathoms with small catches of rougheye rockfish. On Cobb Seamount, one bottom trawl and four mid-water tows were made in depths ranging from 55-230 fathoms. The catch was 7000 kg of small immature widow rockfish. The mid-water trawls were not effective since the target fish were able to avoid the large slow maneuvering trawl.

The results indicate there is a potential resource but that much gear development needs to take place. This includes trawls, deck equipment, fish detection and trawl monitoring systems, and onboard processing facilities. A start was made towards technology transfer by inviting a successful fishing captain from New Zealand to speak at a series of meetings held with British Columbian fishermen. The project was considered a success because it gave an indication of species and quantities available as well as identifying requirements.

Anon. 1995. Deep-water fish stocks show potential. World Fishing (44)3:19-23.

This two part article reports on a study by Gordon and Hunter of the Scottish Association for Marine Science published in 1994. The study concluded that there is a potential deepwater fishery in 700-1000 m off the west coast of Scotland that was already being exploited by French and Spanish vessels. The UK fishery would focus on roundnose grenadier with a bycatch of scabbard fish, blue ling and deepwater sharks. The authors point out that the catch rates would eventually decrease once the accumulated biomass was fished down. They suggested that development support be linked to full utilization of the catch.

The study's authors suggested that high priority be given to basic research on age structure and stock identification. They expect difficulties in assessing the stocks and suggest accurate data on landings and effort be gathered. They also recognized that bottom trawling is not the most friendly method of exploiting deepwater resources but is what is most available. They suggest longline and trap studies but point out the catch composition would be different. The article mentions orange roughy stating that assumptions are being made that this species forms aggregations in the northeast Atlantic as it does in the South Pacific. The article points out that orange roughy would occur at greater depths and on steeper slopes than other potential commercial species.

The second part of the article reports on engineering trials using the 27 m F/V Maranatha III which was specifically designed for deepwater fishing. The trials were to determine power demands on winches and engines working at depths from 200-1000 m. Within this depth range, engine horsepower demands only increased by 15% (100 HP) and winch power requirements by 25% (from 4 to 5 tons pull). Winch drum capacity could be a problem on some vessels but warp diameter can be reduced; the trial suggests 18 mm wire would be suitable. One problem is slow haulback speeds from great depths when the winch spool is near empty. This could be resolved by larger hydraulics or two speed winch motors.

Anon. 1995. Major growth in toothfish longlining. World Fishing (44)7:26-29.

This article presents information about the toothfish fishery off South America. Toothfish are large deepwater fish that may stretch in a band around the world between 40-60 degrees south latitude. The fish are being caught by 50 m long state-of-the-art Mustad equipped longliners. These vessels have 30-50,000 hook systems but can only fish about 15,000 hooks due to the deep depths (1000-2000 m) and strong currents (up to 8 knots). It can take the gear two hours to settle. Some vessels fish six lines of 2,500 hooks (13/0) on 9 mm swivel lines while others set the hooks on one or two continuous lines. Catch rates and fish size are large. Gear loss was high in the beginning but is now coming down with experience.

Based on experience, one company plans to start fishing a 30,000 hook (15/0) Mustad system on a new vessel with a moon pool on the centerline. This would allow hauling the gear in rougher conditions with less fish dropping off the hooks.

Botta, J.R. and D.H. Shaw. 1975. Chemical and sensory analysis of roughhead grenadier (*Macrourus berglax*) stored in ice. J. of Food Science 40:1249-1252.

This paper reports on a study that examined the suitability of roughhead grenadier as a food. This species can be caught in Newfoundland waters between 180-730 m though most are found between 270-460 m. They can attain a length of 91 cm. Sensory and chemical analysis were performed on a sample of fish collected by trawl off Newfoundland and held on ice for up to 18 days.

The results of the chemical and sensory analysis indicate that this species was very suitable as food and fell between cod and haddock by preference even after 13 days of storage. The authors point out that due to lack of abundance and schooling behavior this species may only form an incidental catch.

Botta, J.R. and D.H. Shaw. 1976. Chemical and sensory analysis of roundnose grenadier (*Coryphaenoides rupestris*) stored in ice. J. of Food Science 41:1285-1288.

This paper reports on a study that examined the suitability of roundnose grenadier as a food. This species can be caught in the Northeastern and Northwestern Atlantic in depths of 180-2,200 m though most are found between 650-820 m. They can attain a length of 91 cm. This species is easily caught in large numbers. Sensory and chemical analysis were performed on a sample of fish collected by trawl at 549-640 m 260 km Northeast of Newfoundland, eviscerated, and held on ice for up to 18 days.

The results of the chemical and sensory analysis indicate that this species was very suitable as food. Unlike roughhead grenadier which has heavy scales that make cutting difficult, this species was thin skinned and easy to handle. Fish allowed to stand two days on ice before filleting and skinning were easier to handle and provided better looking fillets than fish cut within two days. British press reports indicated to the authors that there may be textural differences between fish within this species that are location dependent.

Botta, J.R., A.P. Downey, J.T. Lauder, and M. O'Neill. 1982. Chemical and sensory assessment of roundnose grenadier (*Macrourus rupestris*) subjected to long term frozen storage. J. of Food Science 47:1670-1673.

This paper presents a detailed sensory and chemical analysis of roundnose grenadier held for up to 24 months in frozen storage. Several treatments were used including pre-freeze holding on ice in gutted and non-gutted condition.

No significant change occurred in frozen samples stored for 12 months and the product was still acceptable after 24 months. It was found that the product was best when held on ice for eight days before being frozen. This indicates that intermediate iced storage of gutted fish followed by processing on land may provide a better product than if processed and frozen at sea.

Bullis, H.R. and R. Cummins. 1963. Another look at the royal red shrimp resource. Proc. Gulf and Carib. Fish. Inst. 15 th Session:9-12

This older paper presents the results of exploratory and commercial fishing 12 years after the first discovery of the royal red shrimp on the upper slope of the Gulf of Mexico. At the time of this report they knew that this species was distributed continuously along the upper slope from Cape Hatteras to Brazil in depth ranges from 150 to 500 fathoms.

The shrimp are found in a temperature range of 5 to 15 C; catch rates exceeding 25 lbs/hr in temperatures of 9 to 12 C. The shrimp seem to prefer mud bottom.

The report attempts to calculate shrimp densities based on catch rates during exploratory work and arrives at a figure of one shrimp (15 count head on) per 9.3 square meters. Three shrimp grounds are described; the Tortugas bed (50 sq m), Mississippi Delta bed (80 sq m), and the east coast bed (150 sq m). It was estimated that these beds contained about 2 million pounds of harvestable shrimp.

The early commercial attempts to fish royal red shrimp, starting in 1956, are described. Much gear was lost but the shrimp met with good consumer acceptance. The catch history continues through 1962. Landings per trip ranged from 900 to 14,000 pounds, about two thirds being 26/30 count.

Forster, G.R. 1968. Line-fishing on the continental slope. II. J. Mar. Biol. Ass. U. K. 48: 479-483.

This paper reports on the results from 1964 to 1967 of deepwater line fishing off the UK. Forty-seven hauls were made in depths from 600 to 3000 m; 28 hauls catching 168 deep-sea species.

The gear used consisted of groundlines between 165 and 240 fathoms long with 24 to 50 hooks. The snoods were attached to the groundline with stainless steel clips. A 400 lb spring balance was attached above the hauling block to indicate line tension. Squid was the main bait though herring and mackerel were tried with no noticeable variations in catch.

Eleven species were taken regularly; six elasmobranches and five teleosts. A table is presented listing the catch by species, number, main and absolute depth ranges and bottom temperature. The results from 1967 showed no catch differences between 3000 m and 1000 m.

It was found that the bait must be on the bottom to catch fish; a fact which has been observed elsewhere. It was also found that fishing was best in slack water

Forster, G.R. 1971. Line-fishing on the continental slope.. III. Mid-water fishing with vertical lines. J. Mar. Biol. Ass. U.K. 51: 73-77.

This report discusses the results of work with free drifting vertical lines set in deep water from 1967-1970. The catch, from 16 of 32 sets, consisted of 15 black scabbard fish (*Aphanopus carbo*) and 14 squaloids (13 *Centrophorus squamosus* and 1 *Etmopterus princeps*). The catch rate, fish caught to hooks set, was 4.5%.

In 1966, thin white lines were tried but were bitten through at 1100 m. In 1967 nylon-covered stainless steel wire was tried using No.2 treble hooks and scabbard fish were taken at that depth. The report covers various rigs tried. Eventually, due to hooks becoming twisted on the main line, booms or paternosters were rigged. Swivel conger hooks or Mustad 3/o beak hooks were used with a separate swivel. The main line was weighted with a 35 lb lead and supported on the surface by a spar type floatation system to minimize wave action. A 1300 m main line with 41 paternosters at 20 m intervals from 1300 to 500 m could be set in about 30 minutes.

Scabbard fish were mostly found in a very narrow depth range; 1000-1100 m. The shallowest record (860 m) was from a night haul but other night hauls were unsuccessful. Fish sizes ranged from 88-106 cm. The sharks were found from 720-1140 m and ranged in length from 108-130 cm.

The author references previous work which indicates that vertical longlines attached to vessels may not fish as well as drifting lines. He also points out that the Madeira scabbard fish fishery is conducted at night which is at odds with his results. The average catch rates off Madeira had been reported at 25%.

Forster, G.R. 1973. Line fishing on the continental slope: The selection of different hook patterns. J. Mar. Biol. Ass. U.K. 53: 749-751.

This report covers work performed in 1971 and 1972 using a 100 hook longline in depths from 800 to 3600 m. Two hook types were tested, incurving and normal, by alternating the hook types on the main line. The hooks were mounted on 1 m long wire snoods and spaced at 10 m intervals using clips.

One hundred and fifty deep sea fish of fourteen species were taken but only seven in numbers worth considering. The larger elasmobranchs, *Centrophorus squamosus* and *Centroscymnus coelolepis* were nearly equally divided between hook types (19 to 22). With smaller species of elasmobranchs a major part of the catch was with incurving hooks. Similarly, *Mora moro* and *Antimora rostrata*, were more frequently taken by incurving hooks.

Incurving hooks require slack in the snood in order to function properly. The fish most likely bite the hook and start moving away with it until the slack is taken up and hook set. In his discussion, the author feels that the incurving hook is more effective when the fish have delicate skin covering their jaws. He noted floating fish during haulback that apparently detached from the hooks due to the rolling motion of the vessel.

Gordon, J.D.M. 1994. Telling red from orange. World Fishing (43)1:14-16.

This article explains the anatomical differences between the various red colored fishes taken in deep water off the west coast of the UK. The work was stimulated by the catch of red fish of up to 4 kg which turned out to be orange roughy (*Hoplostethus atlanticus*); the same species found off New Zealand. The author points out that there is worldwide distribution of many deep water species.

Illustrations of five species of Scorpaenid fish and three species of Berycoid fish are shown and differences detailed. The author states that orange roughy were not found in his earlier explorations because they occur on steep slopes which are usually avoided in initial explorations.

Gordon, J.D.M. and J.E. Hunter. 1994. Orange roughy: a new resource? World Fishing (43)2:18-20.

This article presents biological and fishery information on the orange roughy. This species is distributed in the North Atlantic from the south of Iceland and along the continental slope of Europe to North Africa. It is also found on the Mid-Atlantic Ridge however there is only limited reports from the west such as the Gulf of Maine. It has not been found in the deeper colder waters of the North Atlantic such as the Norwegian Basin. The authors believe this species might prefer the relatively warmer waters of the deep Atlantic slope. In the Rockall Trough and Porcupine Sea Bight orange roughy is found in 1000 to 1800 m with peak abundance between 1200-1300 m. There have been popular press reports of large hauls (up to 20 tons) by German vessels. Little is known of the French fishery which landed 4500 tons from west of the UK in 1992.

The New Zealand fishery is conducted on dense concentrations requiring the gear to be hauled almost as soon as contact is made with the fish. The article contains a detailed discussion of fish size ranges between different locations. There are difficulties in aging this species but the belief is that they are slow growing and yield few eggs.

The fish yield good fillets that are white and meaty. They cook up well by all methods. This species has remarkable keeping qualities; up to 30 days on ice.

Gordon, J.D.M. and J.E. Hunter. 1994. The roundnose grenadier of the North Atlantic. World Fishing (43)7:7-9.

This article is a brief review of the biology of the roundnose grenadier (*Coryphaenoides rupestris*). It belongs to the family of fish known as macrourids which consists of more than 3000 species worldwide. They are benthopelagic which means they live close to the bottom. West of the UK there are at least 14 species in depths greater than 200 fathoms. At 1500 m, the probable limit for viable trawl fisheries, the roundnose grenadier is probably the only species large enough for exploitation. Another large macrourid in the North Atlantic is the roughhead grenadier (*Macrourus beglax*) which occurs in colder waters. It can be caught on hooks, the roundnose cannot.

The article presents some fisheries statistics of catches of roundnose grenadier from the North Atlantic grounds. In 1971, the Northwest Atlantic catch of all nations peaked at about 85,000 tons. There is a discussion of feeding and spawning of this species. The article ends with the fact that grenadier resembles cod in flavor and has good keeping qualities.

Greening, J. 1989. Deep water fishing in New Zealand. In: Proceedings World Symposium of Fishing Gear and Fishing Vessel Design 1988. Marine Institute, St. John's, Nfld. p. 264-271.

This paper describes the gear and operational strategies in the new Zealand orange roughy fishery. The fishery began in the late 1970's when Japanese and Soviet vessels discovered the large stocks of orange roughy, oreo dory and hoki in depths of 600-1000 m. The New Zealand vessels geared up by outfitting with more powerful winches, acoustic link net monitors, and powerful color sounders. They used their conventional trawl designs but reduced the gear size to compensate for longer warps and thicker twines.

Due to the fact that the orange roughy swim bladder is filled with oil instead of air, echo detection is difficult with units under 4kW. Most vessels use 10kW units with a frequency of 28kHz.

The paper discusses several different fishing conditions including spawning concentrations, pinnacle fishing and mixed fisheries. There are three main trawl designs depending on size class of vessel. The smaller 20 m vessels trawl to depths of 1000 m with a two seam trawl. Mesh size at the trawl mouth is 240 mm and tapers down to 120 mm. The footrope is either rope wrapped wire or rubber discs and chain. Forty meter bridles and groundcables from 25-100 m in length are used. The larger vessels, up to 80 m in length, use two and four seam trawls with 530 mm rubber and steel bobbins and additional steel wing weights. The trawl designs are illustrated.

The fishing operations are described. Warp ratios of 1.6:1 and 2:1 are used with towing speeds of 2.3 to 3.3 knots. The gear takes 20 minutes to settle. The paper explains how to calculate the time and distance that the trawl is astern. Most vessels are equipped with Furuno model FCV-140 echo sounders which are 10kW with dual frequencies of 28 and 50kHz. Furuno FNR-700 or Koden 860 acoustic link systems are used which have a depth rating of 1800 m and a range of 2800 m. Hull mounted transducers are preferred.

Haedrich, R.L. and G. Krefft. 1978. Distribution of bottom fishes in the Denmark Strait and Irminger Sea. Deep Sea Res. 25: 705-720.

This paper is based on the results of 27 bottom tows made by a German research vessel between Greenland and Scotland. Over 6000 individual fish representing 57 species were caught in depths from 240-2000 m. The tows were made with a 43 m commercial trawl with haul times of about 30 minutes.

Through a series of statistical analysis the authors group the catch into five species assemblages differing by species composition, diversity, evenness, catch rate, and the depth and temperature. Each grouping is described by these characteristics in tables.

Antimora rostrata which is found in greatest abundance at 1600 m off New England was found during this cruise in greatest numbers at 493-975 m. This is an example of submergence, the tendency of species that are zoned by depth to live in shallower strata at higher latitudes.

Haedrich, R.L. and N.R. Merrett. 1988. Summary atlas of deep-living demersal fishes in the North Atlantic basin. J. Nat. Hist. 22: 1325-1362.

This paper contains a series of maps/graphic representations that show the distribution of 67 deep living demersal fishes by location and depth in the North Atlantic. The data came from 9 major surveys conducted over a period of 16 years. The surveys represent data from 678 trawls which caught over 90,000 fish representing 338 species which are listed. The species are divided into three depth categories; slope depths (296 species; 200-2250 m), rise depths (99 species; 2250-4500 m), and abyssal depths (32 species; >4500 m). Some comparisons are made with other ocean basins.

Haedrich, R.L., G.T. Rowe, and P.T. Polloni. 1975. Zonation and faunal composition of epibenthic populations on the continental slope south of New England. J. Mar. Res. 33: 191-212.

This paper presents the results of a transit and cluster analysis conducted to examine zonation in epibenthic fauna living on the continental slope south of Cape Cod. The data was from the catch results of 26 tows with a small balloon trawl (16-foot) in depths from 140 to 1900 m. The trawl caught 4701 specimens weighing 88 kg representing 72 species, 26 of the species being fish. The results indicate faunal boundaries at 300-400 m and 1000-1100 m. These boundaries were related to changes in bottom characteristics and temperature regimes. The two boundaries create three fauna zones; shallow (141-285 m), middle (393-1095 m), and deep (1270-1928 m).

There is some discussion of the impact of trawl size on catch composition. Comparisons with submersible observations suggest the small trawl underestimates abundance by an order of magnitude or more. The number of fish in the catch declined with depth but the weight remained the same since the deeper fish were larger.

The paper contains a list of species caught by number and weight. A table presents dominant species by depth zone.

Haedrich, R.L., G.T. Rowe, and P.T. Polloni. 1980. The megabenthic fauna in the deep sea south of New England, USA. Mar. Biol. 57:165-179.

This paper is a rather technical discussion of zonation and diversity of deep water species. The data in the report is from 105 bottom trawl tows made from 1972-1976. Two trawls were used; a 16-foot balloon trawl and a 41-foot shrimp trawl. Specifications are given for the two trawl types. Tow times were from 30-60 minutes on bottom. Depths towed ranged from 40 to 5000 m at 100 m intervals.

The authors extensively discuss the literature on zonation and then review their catch results. Zonation is discussed in terms of catch rates, diversity, and species composition. Tables present the ten highest catches by species weight and number in each of four depth zones. The results indicate that canyon faunas do not differ from those found on the slopes at similar depths. There is some discussion on the impact of food availability on species zonation.

Haefner, P. A. 1978. Seasonal aspects of the biology, distribution and relative abundance of the deep-sea red crab *Geryon quinquedens* Smith, in the vicinity of the Norfolk Canyon, western North Atlantic. Proc. Natl. Shellf. Ass. Vol 68:49-61.

This is a detailed report of four red crab surveys conducted in the Norfolk Canyon area using a bottom trawl. The four surveys, one in each season, were conducted over a period of three years. The trawl used was a 15.1 m headrope semi-balloon four seam shrimp trawl equipped with mud rollers. The mesh size was 44 mm with a 12 mm liner. Tow times were 30 minutes in depths under 1000 m and 60 minutes at deeper depths.

The paper reports on the temperature, oxygen, and salinity regimes in the study area. The catch consisted of 2539 red crabs ranging in carapace length from 16 mm to 143 mm. Weight to length equations were derived for both males and females. Size-frequency distributions by season, sex, and depth are presented. There is also a discussion of sexual maturity and spawning.

Using 96 mm CL as a cull point, 70% of the males and 25% of the females would be of harvestable size. This is much higher than the 1974 NMFS survey and possibly related to sampling methods. The density of red crabs was estimated and compared to that of other researchers using trawls, camera sled, and submersible. There is some significant variations in estimates even between trawl methods.

Haefner, P.A. and J.A. Musick. 1974. Observations on distribution and abundance of red crabs in Norfolk Canyon and adjacent continental slope. Mar. Fish Rev. 36(1): 31-34.

This paper presents the results of trawl and trap sets made in the Norfolk Canyon area in June of 1973. Red crab were found in depths from 145 to 870 fathoms but were most abundant between 145 and 280 fathoms. The crabs were segregated by sex; females shallower than males.

Forty-seven trawl hauls were made; 27 in the canyon and 22 on the slope. The trawl was a 45 foot semi-balloon four-seam shrimp trawl with mud rollers. Two sizes of traps were fished and eleven trap hauls were analyzed. Two deepwater sharks and one hake were caught in the traps along with the crabs.

The largest trawl catch was 197 crabs weighing 319 lbs made while towing between 192-254 fathoms for 30 minutes. Detailed trawl and trap catch data is given.

The trap caught crabs were clean and active compared to the trawl caught which were inactive and muddy, however the trawl had a small 1/2-inch liner which may of added to the mud problem. Trawl and trap caught crabs had the same meat quality. Shipboard processing, in the opinion of the authors, would be the best method of handling for either a trap or trawl crab fishery.

Hopper, A.G. and H.R. English. 1992. Deepwater fishing along the continental slope. Seafish seminar held at Banff 15th November 1991. Seafish Report No. 403. Seafish Industry Authority Techn. Div. 19pp.

This is the original version of the report that is listed as Anon (1992) in this document. It is based on a Seafish seminar held at Banff in Scotland in November, 1991. The areas of interest are on the continental slope west and south of the UK. The slope fishery is considered to have a maximum depth of 1500 m. There are in excess of 80 species caught. The three most commercially interesting are orange roughy, grenadier, and black scabbard fish. A list of deepwater species is given with both English and Latin names.

There are many unknowns regarding slope fisheries. The species are slow growing and will require recovery times longer than on shelf fisheries such as cod. The deepwater fish are also delicate and easily bruised and little is known about post harvest care.

Winches and electronics will need to be designed for this fishery. Gear design will require more knowledge about fish behavior, discards, and vertical and horizontal distribution. Narrow beam echo sounders would be best.

The report contains a detailed discussion of winch requirements and presents several curves related to winch/warp operation.

Judd, W. 1989. New Zealand deep sea fishing industry. New Zealand Geographic No. 4. 21pp.

This popular style narrative contains much information on the New Zealand deepwater fisheries for orange roughy and hoki. The information is scattered through the article. Some examples follow:

At one point a school of orange roughy is located 30-100 m off the bottom(870 m)but can't be fished since the trawl only opens 7 m high.

There are four known spawning areas where fish aggregate starting in June/July. The fish move in mass and eventually break up by October.

There is a 43 m vessel length regulation; vessels larger than this size can not fish within 26 miles of the coast. Many large New Zealand fish companies don't own boats, they charter foreign vessels to fish their quota.

Chilled roughy can be held 13 days with of flake ice (salt and fresh water mixed) in a freezer hold at zero Celsius.

The 14 m wide trawl is towed at three knots. Tows can be several hours long. Many fish are off bottom above the trawl. One three hour tow had 30 tons. The bycatch was about 1% and include small rattails, deep water cod, and small sharks. The trip reported on caught 200 tons in 43 hours.

There is a discussion of the social make up and changes in the New Zealand fishery. What used to be small scale individual operations has been replaced by large corporate operations. The ITQ system is discussed in terms of benefits and problems.

There is a discussion of the hoki fishery, caught by mid-water trawls, and processed into fillets and surimi. The processing is covered in detail.

Leite, A.M. 1989. The deep-sea fishery of the black scabbard fish Aphanopus carbo Lowe, 1839 in Madeira Island waters. In: Proceedings World Symposium of Fishing Gear and Fishing Vessel Design 1988. Marine Institute, St. John's, Nfld. p. 240-243.

This paper starts off with an historical recounting of the black scabbard fish fishery of Madeira. The first known capture was in 1839 from a longline set for deep water sharks; the line was set further from the coast and at greater depth than normal. The fishery took hold because of the good eating qualities of the fish.

The report gives details of the vertical longline construction. The original gear was all hemp. The mainline would be constructed in 40 m sections. At 800 m, 2.8 m branch lines would come off at 4 m intervals and end with a swivel. To this a 0.3 m line with a #8 straight hook was attached. Bait was mackerel, sardine or squid. The oceanic squid, *Omnastrephes pteropus*, was the preferred bait. Each longline would have from 120 to 180 hooks.

Originally the gear was fished directly from small sail powered boats operating in sight of land and hauling by hand. The gear was set for 8-9 hours starting from nightfall. As vessels became equipped with engines and powered haulers the fishery expanded to offshore seamounts and fished the gear from buoys around the clock. The number of longlines per vessel increased from two to several dozen. Government sponsored research in the 1970's introduced new gear designs including a horizontal drifting longline which is now the most common gear type. Squid has been demonstrated to be the best bait with fishing efficiencies over 25%; other baits had efficiencies less than 10%. The best depths for capture of scabbard fish off Madeira are between 800-1300 m.

Biological studies indicate that black scabbard fish may be highly migratory. Only large males are caught off Madeira.
Black scabbard fish have been taken around Iceland, Greenland and the North Sea at depths from 100 m to 2000 m. Reports also indicate their capture in the Pacific and Indian Oceans. The fish found off Madeira are in a zone of low dissolved oxygen (6 mg/l) and temperatures between 8.5 and 10.5 degrees Celsius.

Lux, F.E., A.R. Ganz, and W.F. Rathjen. 1982. Marking studies of the red crab *Geryon quinquedens* Smith off southern New England. J. Shellfish Research. Vol 2, No.1:71-81.

This is a report on the results of red crab tagging studies conducted from 1974 through 1981. In 1974, 7,822 trap caught red crab were tagged with vinyl tubing tied around the carapace; a tag that is lost at molting. The crabs were caught and released in depths from 275 to 1100 m. The results were based on 593 recaptures (7.58%).

One of the limiting factors in this study was that the recaptures were dependent on a very small trap fishery, thus the fishing was not consistent throughout the project area and period. The vessels numbered from one to four during the project period.

Molt frequency was considered low in that crabs returned after 7 years had not molted. A lack of smaller sized crabs in the returns indicate that they might have molted. The authors present information supporting the hypothesis of low tag-induced mortality. The same data indicates low mortality in the discards of the trap fishery.

There is a discussion of crab movements; the maximum being 90 km in an easterly direction. There was some movement up the slope; 6 km or 500 m in depth. Most crabs however were caught within 20 km of their release point. No crabs moved passed Hudson Canyon to the south of the release points. There was no detectable seasonal migration. The reproduction cycle seems to involve spring hatching and summer/fall egg deposition. There is some discussion in the paper on this matter,

The paper ends with an estimate of fishing mortality rates. Based on the limited data the authors estimate 50 fishing trips of a trap vessel could catch 23% of the marketable crabs in an area. The authors acknowledge Ronald Smolowitz among others for his contributions to the tagging operations.

Markle, D.F. 1975. Young witch flounder, Glyptocephalus cynoglossus, on the slope off Virginia. J. Fish. Res. Bd. Can. 32:1447-1450.

This paper contains general information about the distribution of witch flounder, or greysole, in deepwater off the east coast. In the northern part of the range, off Canada, the greysole juveniles (<30 cm) are found in depths of 144-450 m. In the continental slope off Virginia the greysole juveniles are dominant at 900 m. Greysole can be found from 18-1565 m with the juveniles living deeper than the adults.

The report presents data from two cruises in the Norfolk Canyon area using a 45-ft semi-balloon trawl with a 12.5 mm cod end liner. Greysole were caught at every station between 256 m and 1080 m in depth; the shallowest capture at 166 m and the deepest at 1408 m. There seems to be a movement towards deeper water between June and November. In June, 90% of the catch were between 10-24 cm; in November, between 14-26 cm.

In his discussion, the author points out that there may be no significant spawning stocks of greysole west of Cape Cod; only a few adults up to 48 cm were captured in November. The Virginia slope may act as a nursery grounds for 1-4 year old greysole spawned by the Northern stocks. If this is the case, this unfished juvenile concentration may provide a conservation mechanism for the greysole fishery.

Markle, D.F., M.J. Dadswell, and R.G. Halliday. 1988. Demersal fish and decapod crustacean fauna of the upper continental slope off Nova Scotia from LeHave and St. Pierre banks. Can. J. Zool. 66:1952-1960.

Four areas were surveyed by trawl, each divided into four depth strata (400-1200 m in 200 m intervals), in order to characterize the fish and decapod crustacea. The trawl was a Western IIA with a 23-m headrope, 32-m footrope and a 19 mm cod end liner. Forty-five tows were made and 28 were considered problem free. Total catch for all tows was 12,820 specimens of 57 species of Demersal fish and 685 specimens of 23 Demersal decopod crustacean species.

The paper presents tables of the fish and crustacea by number of specimens and depth range. There is a description and discussion of the catch in each depth stratum covering dominant species and diversity. In summary, the upper slope fauna off Nova Scotia seems to be an extension of the fauna from the more southerly New England and the Mid-Atlantic Bight. There are some notable exceptions such as the major presence of red fish off Nova Scotia. There is also an indication of horizontal zonation but no obvious faunal discontinuity indicating depth zonation.

Markle, D.F., and J.A. Musick. 1974. Benthic-slope fishes found at 900 m depth along a transect in the western N. Atlantic Ocean. Mar. Biol. 26: 225-233.

This study describes the species composition of benthic fish fauna at a depth of 900 m along the Middle Atlantic Bight collected by bottom trawl in August, 1969. Eleven tows were made and 7 were considered successful. The tows were made by the R/V Albatross IV using a 12.2-m shrimp trawl with a 13-mm mesh liner. A total of 990 specimens were collected representing 29 species.

Two methods were used to describe faunal similarity between stations and the results presented. Species and catch numbers are presented in tabular form for each station. Species associations were seen to differ to the north and south of Wilmington Canyon (offshore of Delaware Bay).

There is difficulty in quantifying species diversity of slope fishes due to their mobility, tendency to form aggregations, and sampling gear selectivity. It is proposed that the diversity is high due to the stability of the environment which allows for narrower niches or niche specialization thus more species than an unstable environment. The large number of juvenile witch flounder (*Glyptocephalus cynoglossus*) may be present due to less feeding competition or less predation on the slope than on the shelf. Their numbers would be a function of spawning success of the adults on the shelf. The large number of cutthroat eel (*Synaphobranchus kaupi*) seen at certain stations may of been a spawning concentration as most females were full of eggs. This may explain their scarcity at other stations.

McRae, E.D., Jr. 1961. Red crab explorations off the Northeastern coast of the United States. Comm. Fish. Rev. 23:5-10.

This report covers data collected by the US Bureau of Commercial Fisheries during exploratory cruises conducted in a 12 month period starting in July,1959. A total of 121 tows were made from the Gulf of Maine to Cape Hatteras in depths from 50 to 1,040 fathoms. Red crabs were caught between 60 and 800 fathoms; best catches were made between 200 and 300 fathoms.

The author provides an historical review of the literature relative to explorations that caught red crab starting in the 1880's and through to the explorations described in this paper. The area covered in this survey included 38 tows in 200-299 fathoms and 19 tows deeper than 300 fathoms. The author states that it would be difficult to find an area more jagged and less conducive to trawling than that lying north of Cape May, New Jersey in depths greater than 150 fathoms.

Commercial Yankee 36 and 41 trawls were used as well as 40 and 100 foot shrimp trawls. Deep trawling was accomplished by using the 40-foot shrimp trawl with bridles to a single 3/4-inch warp created by shackling wire from both drums (total length of 2,200 fathoms).

Eighty-nine of the tows resulted in a catch of 3,279 red crabs weighing 4,049 pounds; catches ranged from 1 to 386 crabs. The record catch was 558 pounds from a 70 minute tow in 200-250 fathoms. The most productive area was east of Ocean City, Maryland in 200-300 fathoms. Weight data is presented giving the average male weight as 28 ounces; females as 11 ounces. There is some discussion of crab quality and yield; average yield being 36.5%. The author concludes that profitable red crab fishing would be feasible only if carried out in combination with some other commercially acceptable species found with the crabs or in the same general area.

Merrett, N.R., J.D.M. Gordon, M. Stehmann, and R.L. Haedrich. 1991. Deep demersal fish assembage structure in the Porcupine Seabight (Eastern North Atlantic): slope sampling by three different trawls compared. J. Mar. Biol. Ass. U.K. 71: 329-358.

This paper reports on the results of 144 tows taken by three different types of bottom trawls. Fifty-four thousand specimens of 118 species were taken from depths of 247 to 2172 m. The paper introduces the concept of species fidelity defined as "...the number of times each species occurred within its own sounding range as observed from the catches of a particular trawl, expressed as a percentage of the total number of samples taken within this range by the trawl." The concept was to improve the level of accuracy in assessing deep water distribution and abundance.

Tables include number of each species and percentage of total catch by each of the three trawls. The authors discuss the species frequency distributions and the influence of each gear on abundance estimates. The conclusion is that sampling just using one trawl can give an incomplete picture of species and size distribution present. Tentative comparisons are made with other deep water surveys regarding biomass and abundance.

Merrett, N.R., R.L Haedrich, J.D.M. Gordon, and M. Stehmann. 1991. Deep demersal fish assemblage structure in the Porcupine Seabight (Eastern North Atlantic): results of single warp trawling at lower slope to abyssal soundings. J. Mar. Biol. Ass. U.K. 71: 359-373.

This report represents the results of 34 tows of an 8.6 m semi-balloon trawl made in depths between 2230-4787 m. The report contains a number of tables and figures that present the species caught at depth. The report has a detailed discussion of the sampling artifact that comes from large specimens avoiding small and medium sized trawls. This may be reduced at greater depths due to the increased sluggishness of the animals thus resulting in higher sampling efficiency.

Musick, J.A., J.C. Desfosse, and E.D. Grogan. 1992. Fish assemblages at a deep-water sewage disposal site (DWD-106). A report submitted to NMFS by VIMS.: 43pp + tables.

Deep-water dumpsite 106 is located over the continental slope and rise about 106 miles east of New Jersey. This report compares trawl collections made during this study of the dumpsite with that of historical collections in the general area and concludes that no detectable changes had taken place in demersal fish biomass or abundance. The recent collections of this study were made with a 13.7 m headrope four-seam semi-balloon trawl with a 1.27 cm liner. The trawl was towed with a single warp at about 2 knots for 30 minutes (<1000 m depths) or 60 minutes (>1000 m). The trawl swept width was 6.7 m based on previous work.

The historical data set was collected from 1973 to 1978 by various researchers, vessels, and trawl gears. This report contains tables containing the station data and catches of the historical and current projects. The data analysis examines abundance, biomass and species richness but points out the difficulties in working with the different data sets. The trawl data collected in this study was from 1990 and 1991. In 1990, 17 successful tows caught 1193 specimens weighing 257.6 kg representing 68 species. In 1992, 19 successful tows caught 1858 specimens weighing 412.1 kg representing 66 species.

The authors discuss community structure and conclude that demersal fish communities were distributed with a gradual change in coencline with depth and had mosaics of species overlapping in distribution and relative abundance. Bathymetric faunal change was gradual and not rigidly zoned. Faunal change was steepest where environmental and topographical gradients were steepest (180 m to 2000 m). Benthic substrates were also more heterogeneous in this range. The paper also presents a discussion of species richness and dominance.

Abundance showed a marked decline with depth and decreased more rapidly with depth than biomass. There was a pattern of "smaller-shallower"possibly because larger fish traverse a wider depth range while smaller fish are restricted to shallower depths. The authors discuss that this may also be an artifact of gear selectivity in that larger fish are less vulnerable to small gear in the warmer shallow water.

Pinhorn, A.T.(ed.) 1976. Living marine resources of Newfoundland-Labrador: Status and potential. Bull. 194, Dept. of Environ., Fish. and Marine Svc., Ottawa. 65pp.

This report is organized on a species by species basis. While most of the species are on shelf there are a number of slope species covered. The report gives information on distribution, abundance, and general biology for each species covered relative to the Newfoundland area. Species of interest to New England slope fishermen covered in this report include redfish, Greenland halibut, black dogfish, grenadier, witch flounder, monkfish, and shrimp.

Pohle, G., T.J. Kenchington, and R.G. Halliday. 1992. Potentially exploitable deepwater resources of Atlantic Canada. Can. Tech. Rpt. Fish. Aqua. Sci. No. 1843. 79pp.

This report presents what is known about deep water species abundance and distribution in Canadian waters. The focus is on species that may have commercial potential and occur deeper than 300 m.

The section on shrimp identifies several species that are known to be present in sufficient numbers to warrant the development of a fishery including scarlet and crimson shrimp. Red crabs are also a possible candidate. Several species of squid are identified as potential resources.

The section on potential deepwater fish resources includes Atlantic saury, blue hake, black scabbardfish, black dogfish, orange roughy, and grenadiers. The report points out that up until now there is no evidence that commercial fish production (as opposed to standing biomass) from the continental slopes of the world would be anything but a small fraction of shelf production. Referenced material indicates that temperate shelf areas can produce about 1 ton per square kilometer per year of sustainable finfish harvest. The slope areas represent a very small area further indicating the limitations on overall production.

The study failed to find strong evidence of any major potential resource. One strategy the report identifies for developing deepwater fisheries is to promote the development of deep-shelf and shelf-break fisheries on redfish, turbot, silver hake, and witch flounder. The technology would then allow fishermen to move deeper if the resources are there.

The report contains an extensive reference list, an appendix for distinguishing characteristics of crustaceans, a listing of deepsea shrimp of the world with known interest to fisheries, a list of deepsea cephalopods, and a list of most Atlantic Canada deepwater finfish species containing common and scientific names.

Powles, P.M. and A.C. Kohler. 1970. Depth distribution of various stages of witch flounder (*Glyptocephalus cynoglossus*) off Nova Scotia and in the Gulf of St. Lawrence. J. Fish. Res. Bd. Can. 27 (11):2053-2062.

A number of different trawls were used to catch witch flounder, or greysole, at various life stages. The greatest number of adults were taken in 92-162 m in summer and 218-325 m in winter; fish concentration was higher in winter. Fish under 30 cm (2-5 years old) were taken in water primarily deeper than 180 m. Larvae were hard to find but flounders close to metamorphosis, about 6 cm, were found in mid-water above the thermocline 30-40 m from the surface.

A number of charts present the results showing the seasonal distribution and abundance. The discussion points out that greysole have an unusual and complicated life history occupying at least three different niches. The juveniles are discrete from the adult stock in that they are deeper except for possibly the winter period. This deeper distribution probably prevents direct food competition with more abundant cod and plaice up on the shelf. Since these juveniles are found deeper and on harder bottom they were immune to the commercial trawling operations of the day.

Schroeder, W.C. 1955. Report on the results of exploratory otter-trawling along the continental shelf and the slope between Nova Scotia and Virginia during the summers of 1952 and 1953. Papers in Marine Biology and Oceanography, supplement to vol. 3, Deep Sea Res.: 358-372.

The report begins with a summary of some of the early exploratory work of the US Fish Commission and the Woods Hole Oceanographic Institution along the New England continental slope up until this report. The report presents the results of a series of six cruise that used several trawls, 35-60 feet in footrope length, towed with a single wire for 30-60 minutes at 2.5 knots.

The area fished extended 600 miles (though only 2-20 miles wide) from Nova Scotia to Virginia. Depths to 730 fathoms were surveyed; the best catches were made in the 200-400 fathom zone. In the two years of the project 75 species of bottom fish and 30-40 species of bathypelagic species were taken. The only finfish species of commercial interest caught deeper than 200 fathoms in significant quantities were redfish, long-finned hake, gray sole, and the whitings. Significant lobster and red crab catches were also made.

The 193 hauls made yielded 21 species where the aggregate catch exceeded 100 individuals and most of these were in depths under 200 fathoms. The author points out that many large fish can avoid the small trawls he used. He compared his 50 foot trawl to his 60 foot trawl and found that the larger trawl caught more total fish as well as more larger fish. The same held true with red crabs.

The report calculates the catch of fish per acre and found that the easternmost part of the surveyed area was most productive. The report contains a good discussion of the catch by species and area.

US Dept Commerce. 1971. Shellfish Resource Assessment Cruise Report Delaware II Cruise 70-8. December 18,1970- February 26,1971. NOAA, NMFS, Woods Hole. 10pp.

This cruise report presents the results of a five part research cruise that tested a wide variety of trap/pot types along the continental slope south of New England. The main species targeted were lobster, red crab and jonah crab. Transects from 100-600 fathoms were fished with traps in Block, Hudson, and Baltimore Canyons. A total of 61 sets were made in depths from 85 to 823 fathoms with an average soak time of 21 hours.

The report describes the gear handling system and the setting/hauling methodology in some detail. A table presents a summary of fishing effort by pot type.

Red crabs represented 69% of the catch by weight with the highest concentrations between 250 and 500 fathoms. The record catch was 714 pounds in an 18-hour set of a king crab pot. Lobsters made up 13% of the catch with best concentrations between 150 and 200 fathoms. Jonah crabs were most plentiful in depths less than 150 fathoms. Fish catches were light; red and white hake in depths less than 500 fathoms; deep water sharks and blue hake beyond 500 fathoms. Detailed catch data by station is presented.

Uzmann, J.R., R.A. Cooper, R.B. Theroux, and R.L. Wigley. 1977. Synoptic comparison of three sampling techniques for estimating abundance and distribution of selected megafauna: submersible vs camera sled vs otter trawl. Mar. Fish. Rev. 39: 11-19.

A multi-vessel survey of the megafauna in the Veatch Canyon region south of Cape Cod was conducted in June of 1973 to gather information on the distribution and abundance of red crab, lobster, and jonah crab. In addition a comparison of sampling efficiency of three methods were made at 10 selected stations. A fourth method, lobster trapping, was conducted in the same area but could not be compared to the other three methods as it was not possible to estimate the seabed area a baited trap fished. Depths sampled ranged from 73 to 366 m (40-200 fms). The three primary sampling strategies/gear types are described in detail.

The work was undertaken because much of the sampling of offshore areas was by otter trawl yet sampling efficiency by trawl is poorly understood. The results of this project indicated that the submersible technique yielded the highest estimates followed by camera sled and trawl. The trawl however caught more squids, herring, mackerel, and butterfish than the other methods. Light avoidance as well as light attraction may of biased the results.

The report presents a table of standing crop estimates of many species observed.

Wenner, C.A. and J.A. Musick. 1977. Biology of the morid fish Antimora rostrata in the western North Atlantic. J. Fish. Res. Bd. Can. 34: 2362-2368.

The morid fish *Antimora rostrata* is commonly referred to as blue hake. In the Norfolk Canyon area it ranges in depth from 790 to at least 2930 m; maximum abundance found between 1300-2500 m. In Canadian waters this species may live about 500 m shallower. Data indicates higher abundance of blue hake on this side of the Atlantic when compared to the eastern North Atlantic.

This report describes the distributional pattern of blue hake and tries to estimate the abundance in the Middle Atlantic Bight. They found that depth distribution did not change with season and that blue hake may always stick to the bottom, ie, do not come off to feed in mid-water like other macrourids (for example, *Coryphaenoides Sp.*)

The report presents data from other studies on the depth distribution and catch rates of blue hake in other areas of the world. Data presented on the blue hake taken in this study includes length ranges, weights, and sex by depth. Smaller fish, mostly males, are found at the shallower depths. Many of the fish are in the 30-50 cm range.

There was an absence of smaller fishes and sexually mature adults in the catches. Based on this and other results of ovaries being analyzed, the authors feel the Middle Atlantic grounds are primarily for feeding; reproduction takes place in more northerly areas. The blue hake swims with the same power of a rainbow trout so they are capable of such large migrations.

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

This is a major report on the results of a quantitative survey for red crabs conducted by the NMFS in 1974 covering depths of 229-1646 m (125-900 fms) from offshore Maryland to eastern Georges Bank. The report reviews previous studies of red crab in good detail. There is a small section about the fishery which had landed as much as 45,000 kg per month.

The survey used two sampling systems; a towed camera sled and an otter trawl. The 4.9 m semi-balloon trawl was used to collect samples of red crab for determining size composition, sex ratios, and other biological parameters. The camera sled was used to get density estimates and is described in detail.

A number of tables present detailed catch and station data. Red crabs were found in all geographical areas surveyed from 274 to 1463 m. There were many observations made about the size and number of crabs found by depth. For example, there is evidence of an up-slope migration of crabs as they get older; larger crabs were found shallower.

Approximately 182 million crabs were estimated to be in the study area representing a standing crop of 43 million crabs of harvestable size (>114 mm CL; 24% of total). No large crabs (>114 mm) were obtained from depths greater than 914 m (500 fms). The biomass and size/sex distribution of crabs by geographic area and depth is presented in tabular form. Bottom sediments and topographical information is presented and discussed.

Williams, A.B., and R.L. Wigley. 1977. Distribution of decapod Crustacea off northeastern United States based on specimens at the Northeast Fisheries Center, Woods Hole, Massachusetts. NOAA Tech. Rep. NMFS Circular 407: 44pp.

This report gives distributional data for 131 species of decapod crustacean found between the Gulf of Maine and offshore Virginia. Most of the species are shelf inhabitants but there is also coverage from the upper slope. The distributional data for each species includes geographic, depth, and temperature ranges where known. Substrate type where specimens were collected is presented. Most of the report is a series of charts showing the geographic distribution of each species. There is a good literature cited section.

Coonamessett Farm