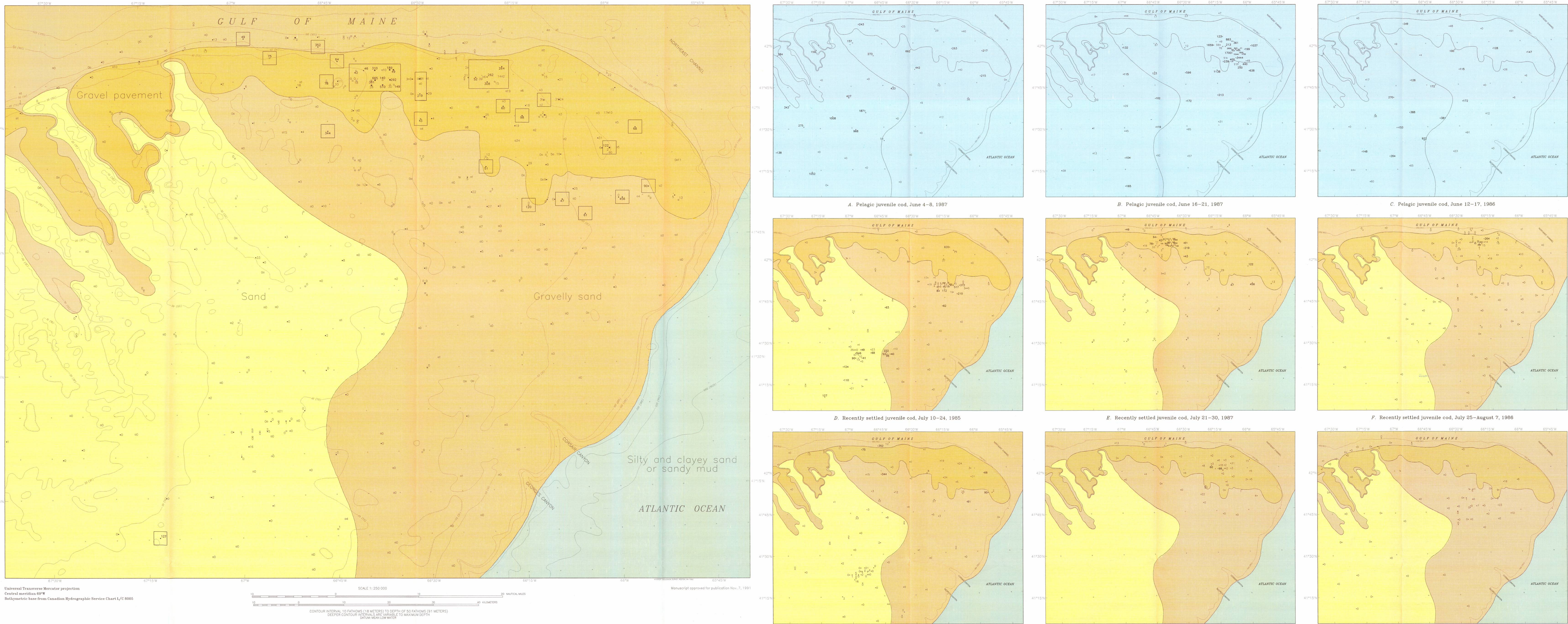




MAP SHOWING DISTRIBUTION AND ABUNDANCE OF RECENTLY SETTLED JUVENILE COD
DURING THE SEASONAL PERIOD JULY 21 - AUGUST 20, 1984-87, AND 1989

MAPS SHOWING THE DISTRIBUTION OF JUVENILE COD IN RELATION TO THE SEDIMENTARY ENVIRONMENT OF EASTERN GEORGES BANK

By

R. Gregory Lough¹, Page C. Valentine², Carol L. Brown³, and William L. Michaels⁴

1992

INTRODUCTION

These maps show the distribution and abundance of juvenile cod (*Gadus morhua* L.) during the transition period from pelagic to demersal life in relation to the sedimentary environment on eastern Georges Bank. A large-scale map shows the five-year composite distribution and abundance of recently settled juvenile cod during the seasonal period late July to late August (1984-87 and 1989) when they are restricted primarily to gravel habitat. In addition, three maps (figs. 1A-C) show the distribution of pelagic juvenile cod observed in individual surveys made during June of 1986 and 1987, and six maps (figs. 1D-I) show the distribution of the demersal, or recently settled, juvenile cod observed in individual surveys made during late July to late August of 1984-87 and 1989. The maps are designed to be used in conjunction with other maps in this series that depict the sedimentary environment and the sea floor topography of eastern Georges Bank (Plateau and others, in press; Valentine and others, in press b).

METHODS

Pelagic juvenile cod were sampled by means of two types of gear. The first, a "multiple opening and closing net environmental sensing system" (MOCHNESS) having a fixed mouth opening (15 square meters) and nets of 3-mm mesh size (White and others, 1985; Potter and others, 1990), was used on tow research vessel (RV) *Albatross IV* cruises (8802a, June 12-17, 1986; 8704a, June 4-8, 1987). Maximum depth of the MOCHNESS tow was less than two meters off the bottom. At each station a single net was towed from the sea surface to the sea bed and back to the surface (resulting in a double-slit profile of the water column) for a total of 30 min at 2 knots (37 km/h). The volume of water filtered was monitored electronically and averaged 19,000 cubic meters during a 30-min tow (Potter and others, 1990). MOCHNESS catches were standardized to individuals per thousand meters of sea surface. The second type of gear, an "International young geloid pelagic trawl" (TYPT) was used on the RV *Delaware*

in August 1985 and June 1987 documented the cod within 0.5 m of the bottom during the day, whereas at sunset part of the population rose 1-3 m off the bottom and drifted with the current. A comparison of standardized research bottom-trawl catches with counts made from the subsurface along the same tracks showed the extent of underestimating by the bottom trawl. For 4-m model-size cod (1987), daytime trawl abundance estimates were at least an order of magnitude lower than those based on subsurface counts; nighttime estimates did not differ significantly. With regard to larger juveniles of 7-m model length (1986) that are more demersally oriented, very few fish were caught during daytime trawls and abundance estimates based on nighttime trawls were at least an order of magnitude lower than those based on subsurface counts (Lough and others, 1989). The larger juveniles appear to stay closer to the bottom both day and night, and, consequently, they are less vulnerable to the bottom trawl that may pass over them. Preliminary results of Cohen and others (1985) show that more juveniles (4-5 cm in length) were caught by means of the bottom trawl where chain sweep was covered with "cookies" than with larger roller gear.

SEDIMENTARY ENVIRONMENT

Georges Bank is a shallow part of the continental margin that is separated from the mainland by deeper waters of the Gulf of Maine. At present, the bank receives no sediment from the continent. Sediment texture, current speed and direction, and bottom topography are the principal factors that interact to produce the sedimentary environment of eastern Georges Bank. The sea floor is covered by glacial sediment transported from source rocks in New England, New Brunswick, and Nova Scotia during late Pleistocene time (Schlee, 1973; Schlee and Pratt, 1975). This sediment originally ranged in texture from mud to gravel (including boulders), but it has been reworked and eroded to some extent since flooding by the rising sea, following the retreat of the glaciers.

DISTRIBUTION OF JUVENILE COD

Atlantic cod historically has been an important species in the New England fishery because of its abundance and wide distribution (Aarseth and Grossman, 1987). The cod found on Georges Bank are considered a separate stock from those in the Gulf of Maine and southern New England region (Brown, 1987). Cod spawn widely over Georges Bank throughout most of the year, but peak spawning occurs in February and March and is concentrated on the northeastern part of the bank (Sherman and others, 1984). Eggs spawned on eastern Georges Bank generally float south and west in the residual clockwise circulation and hatch in two to three weeks. By May, the planktonic larvae tend to be concentrated along the southern bank margin, geographically between the 55- and 61-m isobaths, but by June, they are spread across most of the bank (Lough and Bolt, 1989). The gradual transition from pelagic to demersal life occurs by the time the juvenile fish are 4 to 6 cm in length, or at about 3 months of age (Keefer and others, 1980; Bolt and Lough, 1988; Lough and Potter, 1991). By mid-July, they appear to be primarily demersal, and by late July they are abundant only on the large gravel patch on northeastern Georges Bank (Lough and others, 1989).

Recently settled juvenile cod are present on the bank in the middle of July. The maps showing their distribution and abundance in the July-to-August period are arranged from left to right chronologically by season, but with figure 1D-I as an exception in made for figure 1G, which is placed beneath figure 1D (rather than under 1F) so that data collected in July and August of the same year can be compared easily. Note that bottom trawl catches are not directly comparable because most are collected at night than during the day and because of variation in the type of roller gear used.

The earliest seasonal survey (fig. 1D) of recently settled juvenile cod was conducted from July 10-24, 1985 (Delaware II cruise 8502). A broad survey of eastern Georges Bank during the early part of the cruise (July 10-19) revealed a patchy distribution of cod. Benthic aggregations were present in a variety of sedimentary environments. In two areas (lat 43° 22' N, long 66° 55' W; 43° 49' N, 66° 15' W) these aggregations were dominated by sampling over a period of 6 to 8 hours. The gross distribution pattern for the month (July 1985) resembled an ellipse extending from southwest to northeast (somewhat elongated by latitude) with pelagic juvenile observed a month earlier in the 1986 and 1987 seasons (figs. 1A-C). During the latter part of the cruise (July 22-23), a trawl from the more southern area of concentration captured only 6 individuals, which suggests the number of individuals there had declined by late July; by contrast, a trawl from the more northern area of concentration captured 120 individuals and confirmed the continued presence of this aggregation. In the more northern area, a survey from August 7 to 20 (fig. 1G) recorded large aggregations of juvenile cod in or near the gravel patch (lat 43° 22' N, long 66° 55' W) in the early part of the cruise. The gross distribution pattern described above, which had supported a large aggregation of juveniles in the July 10-19 period, was replaced by a pattern in which large aggregations were present in the gravel patch and just to the south of it. In the gravel patch, sampling was intensive in a large

aggregation (located by trawling) where coordinated subsurface and trawler surveys were carried out. A second aggregation was present near the eastern end of the bank.

In 1989 (fig. 1F), sampling took place from July 25 to August 7 (Delaware II cruise 8905). As was the case in 1987, sampling was intensive in an area selected for subsurface and trawler surveys. The distribution of juvenile cod is similar to that encountered in 1987 (fig. 1E), but in 1989 sampling occurred somewhat later in the year, and only one aggregation of cod was identified.

In 1989 (fig. 1E), samples were collected from August 5 to 11 (Chapman cruise 8903), and a limited number of stations were visited. As in 1986 and 1987, trawling was conducted to locate aggregations of juvenile cod so that joint subsurface and trawler surveys could be made. On the basis of prior experience, the gravel patch was made the focus of sampling, and two aggregations were identified, one in the gravel patch and one on its southern margin. Juvenile cod were sparse in most of the area 10 to 15 km south of the gravel patch; the region even farther to the south where cod were not present or were poorly represented in the late July to late August period in 1984, 1985, 1986, and 1987 was not surveyed.

In 1984 (fig. 1C), sampling occurred from August 10 to 17 (Delaware II cruise 8407). Juvenile cod were absent in most of the region. The highest catches were in the eastern part of the gravel patch and just to the south of it. Cod were sparse or absent in the remainder of the area, although sampling was not uniform on the cruise and the gravel patch was not sampled adequately.

The large-scale map shows the composite distribution and abundance of recently settled juvenile cod on eastern Georges Bank for five years (1984-87 and 1989), during the seasonal period that extends from July 21 to August 20 (late July to late August). At this time of the year, juvenile cod are by far most heavily concentrated on the gravel patch and to some extent on a variably textured bottom of gravel, sandy gravel, and sand that lies within a 5- to 10-km-wide band along the southern margin of the gravel patch and just to the south of the gravel patch. Juvenile cod aggregations that occur earlier in the season (early to middle July) well to south of the gravel patch (lat 41° 25' N, fig. 1B) are not included in this compilation because they appear not to persist into late July and early August (excepting one station where 127 juveniles were sampled on July 22 at lat 41° 10' N, long 67° 13' W, fig. 1D).

SEDIMENTARY ENVIRONMENT AND SURVIVAL OF RECENTLY SETTLED JUVENILE COD

Pelagic juvenile cod are, by June, widespread in the water column over eastern Georges Bank by mid-July they become demersally oriented and are present on bottom types ranging in texture from sand to gravel. By contrast, in late July to early August the recently settled juveniles are abundant only on the large gravel patch on the northern edge of the bank and within a 5- to 10-km-wide band of highly variable texture to the south of the gravel. They are sparse or absent from the large areas of the gravel patch and the gravelly sand that cover most of eastern Georges Bank. Recently settled juvenile cod, during the daytime, tend to remain close to the bottom facing into and stemming the strong tidal current; they rise off the bottom during nighttime, presumably to feed, and drift with the current. As a result of their diel behavior, the flow of tidal currents, and the west-to-east residual current, cod on the northern edge will be transported from year to year due to variations in the time of peak spawning in water temperature, in current speed and direction, and in the occurrence of storms. However, the gross pattern of pelagic juvenile cod transport, settlement to bottom, and the presence or absence of demersal cod in certain regions of the bank is clear; it supports the hypothesis that the gravel patch on the northern edge of the bank is the primary settlement area for juvenile cod (Lough and others, 1989). The mottled appearance of the juveniles is remarkably similar to the appearance of the pelagic-gravel bottom. Observations from the subsurface and trawling surveys have documented that the cod are difficult to discern on the biologically rich gravel substrate, but are easily visible on the relatively barren sandy bottom. Two surveys of the juveniles on the gravel have been documented that the cod are difficult to predators, and by the availability of plentiful food. The maps presented here, based on data collected over five seasons, document a strong correlation between the sedimentary environment and the presence and absence of recently settled juvenile cod. Sediment type, current patterns, fish behavior, and food preference and availability all are important factors that determine the survival of juvenile cod on eastern Georges Bank.

REFERENCES CITED

- Aarseth, T. R. 1981. A brief historical review of the Woods Hole laboratory trawl survey time series. In *Shallow water cod and haddock*, W. G. and Brown, J. R., eds. Boston: Marine Fisheries Service, Canadian Special Publication of Fisheries and Aquatic Sciences, v. 56, p. 47-67.
- Atkinson, R. J., and Greenwood, M. P. 1987. Fishes and squids. In *Beckon, R. H., ed. Georges Bank: Cambridge Mass. Massachusetts Institute of Technology Press*, p. 313-346.
- Bolt, G. R., and Lough, R. G. 1988. Growth through the first six months of Atlantic cod *Gadus morhua*.

- and haddock, *Metamorphosis nelpytrius*, based on daily otolith increments. U. S. Department of Commerce Fisheries Bulletin, v. 86, p. 553-555.
- Brown, B. E. 1987. The fisheries resources. In *Beckon, R. H., ed. Georges Bank*. Cambridge, Mass.: Massachusetts Institute of Technology Press, p. 480-493.
- Butman, Bradford, and Beardsley, R. C. 1987. Physical oceanography. In *Beckon, R. H., ed. Georges Bank*. Cambridge, Mass.: Massachusetts Institute of Technology Press, p. 68-88.
- Butman, Bradford, Beardsley, R. C., Magaldi, B. P., D., Verneker, J. A., Schilt, R. Lineberger, R. Wright, W. B., and Bole, M. A. 1982. Recent observations of the mean circulation on Georges Bank. *Journal of Physical Oceanography*, v. 12, p. 568-591.
- Cohen, B. S., Green, J. R., Potter, D. C., and Haydon, B. P. 1985. Some preliminary results of juvenile cod and haddock studies on Georges Bank in 1984 and 1985. International Council for the Exploration of the Sea, Committee Meeting 1985/5/74, 23 p.
- Jordan, G. P. 1962. Large submarine sand waves. *Science*, v. 136, p. 839-848.
- Keefer, P. A., Hurley, P. C. P., Perley, P. C., Nelson, J. D. 1988. Juvenile fish surveys on the Scotian Shelf: implications for year-class assessments. *Journal of International Exploration de la Mer*, v. 43, p. 59-76.
- Lough, R. G., and Bolt, G. R. 1988. The movement of cod and haddock larvae onto the shoals of Georges Bank. *Journal of Fisheries Biology*, v. 35, p. 71-79.
- Lough, R. G., and Potter, D. C. 1991. Vertical distribution patterns and diel migrations of larval and juvenile haddock, *Metamorphosis nelpytrius*, and Atlantic cod, *Gadus morhua*, on Georges Bank. *Journal of International Exploration de la Mer*, v. 46, p. 131-158.
- Lough, R. G., Valentine, P. C., Potter, D. C., Audette, P. J., Bolt, G. R., Nelson, J. D., and Ferry, R. J. 1989. Ecology and distribution of juvenile cod and haddock in relation to sediment type and bottom currents on eastern Georges Bank. *Marine Ecology Progress Series*, v. 56, p. 1-12.
- Meady, J. A., Butman, B., Beardsley, R. C., Brown, W. S., Dufour, P., Joub, J. D., Mayer, D. A., McFady, H. O., Peirre, B., Rapp, S., Smith, P., and Wright, W. R. 1984. Atlas of tidal elevation and current observations of eastern Georges Bank. U. S. Geological Survey Miscellaneous Investigations Map I-250-A, scale 1:250,000.
- Potter, D. C., Lough, R. G., Perry, R. J., and Nelson, J. D. 1989. Comparison of the MOCHNESS and TYPT surveys for the capture of 0-group cod (*Gadus morhua*) on Georges Bank. *Journal of International Exploration de la Mer*, v. 46, p. 131-158.
- Schlee, John. 1973. Atlantic Continental Shelf and Slope of the United States - Sediment texture of the northeastern part. U. S. Geological Survey Map 529-I, 84 p.
- Schlee, John, and Pratt, B. M. Atlantic Continental Shelf and Slope of the United States - Gravel of the northeastern part. U. S. Geological Survey Professional Paper 529-II, 39 p.
- Sherman, Kenneth, Smith, W., Morse, W., Bernman, M. S., Green, J. R., and Emmott, L. 1984. Spawning strategies of fishes in relation to circulation, phytoplankton production, and pulses in zooplankton off the northeastern United States. *Marine Ecology Progress Series*, v. 18, p. 1-19.
- Valentine, P. C., Strom, C. W., and Brown, C. L., in press. A map showing the sea floor topography of eastern Georges Bank. U. S. Geological Survey Miscellaneous Investigations Series, v. 56, p. 1-12.
- Valentine, P. C., Brown, C. L., and Brown, C. L., in press. A map showing the sedimentary environment of eastern Georges Bank. U. S. Geological Survey Miscellaneous Investigations Series, v. 56, p. 1-12.
- Widde, P. H., Merion, A. W., Bradley, A. W., Beckon, R. H., Crockett, J. E., Barber, V., Cowles, T. J., and Miller, G. R. 1985. New developments in the MOCHNESS, an apparatus for sampling zooplankton and micronekton. *Marine Biology*, v. 87, p. 313-323.
- Wigley, R. J. 1968. Georges Bank bottom fauna. In *Graham, H. W., ed. Woods Hole Laboratory Annual Report*, U. S. Fish and Wildlife Service, p. 50-58.
- Wigley, R. J. 1969. Bottom sediments of Georges Bank. *Journal of Sedimentary Petrology*, v. 31, p. 165-168.
- Wigley, R. J. 1968. Benthic invertebrates of the New England fishing banks. *Underwater Naturalist*, v. 5, p. 47-52.

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

LOCATION MAP

Any use of trade names or products, or the names of individuals or organizations, is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

For more information, contact the U.S. Geological Survey, Map Distribution, Box 246, Reston, Virginia 20192.