SIDESCAN SONAR AS A TOOL FOR DETECTION OF DEMERSAL FISH HABITATS

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ABSTRACT

Sidescan sonar can be an effective tool for the determination of the habitat distribution of commercially important species. This technique has the advantage of rapidly mapping large areas of the seafloor. Sidescan images (sonographs) may also help to identify appropriate fishing gears for different types of seafloor or areas to be avoided with certain types of gears. During the early stages of exploration, verification of sidescan sonar sonographs is critical to successful identification of important habitat types. Tilefishes (*Lopholatilus* and *Caulolatilus*) are especially good target species because they construct large burrows in the seafloor or live around boulders, both of which are easily detectable on sonographs. In some special circumstances the estimates of tilefish burrow densities from sonographs can be used to estimate standing stock. In many localities the burrow and boulder habitats of tilefish are shared with other commercially important species such as American lobsters, *Homarus americanus*; cusk, *Brosme brosme*; and ocean pout, *Macrozoarces americanus*.

Acoustic techniques have become important tools in fishery research in the last 20 years. Of these, sonar has proven useful in a number of related efforts for pelagic fisheries (Forbes and Nakken 1972) including the detection of fishes in the water column (Harden-Jones and McCartney 1962; Anderson and Zahuranec 1977) and estimation of fish numbers and biomass (Smith 1970; Hewitt et al. 1976; Suomala and Lozow 1980; Barans and Holliday 1983; Nakken and Venema 1983). More recent studies have demonstrated how sidescan sonar, in combination with acoustically tagged fish, can be used to evaluate trawling gear (Harden-Jones 1980). Sidescan sonar has been used infrequently to assess critical habitat for demersal fishery resources with the exception of an early attempt to map a herring (*Clupea harengus*) spawning area (Stubbs and Lawrie 1962). Our research has focused on detection of tilefish burrows (Twichell et al. 1985; Grimes et al. 1986; Able et al. 1987), but an outgrowth has been the identification of the habitats of other species. Here we describe the use of sidescan sonar to map the extent and distribution of different habitat types and, in the case of tilefish, derive an estimate of standing stock and potential yield.

TECHNIQUE

Sidescan sonar is similar to low-angle, oblique, aerial photography except that the images (sonographs) are based on differences in the intensity of the reflected acoustic signal rather than the intensity of the reflected light (Belderson et al. 1972). The system consists of a towed vehicle (Fig. 1) in which is housed two sets of transducers that scan to each side, a conducting tow cable, a winch, and a dual-channel recorder for displaying the signals. The transducers are constructed so that their beams form a very narrow arc (1-2°) in the direction perpendicular to the ship's track, but a broad arc in the direction parallel to the ship's track (Fig. 1). As the ship moves, successive bands of seafloor are insonified, and in this way an acoustic areal map is recorded of the scanned area.

We used a 100 kHz Klein[5] sidescan sonar system. This system can resolve features as small as 0.5 m diameter (see Results) at a scanning range of 100 m to each side of the towed vehicle. The

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[5]Use of trade names in this report does not constitute endorsement by the U.S. Geological Survey or the National Marine Fisheries Service.

Manuscript accepted June 1987.
FISHERY BULLETIN: VOL. 85, NO. 4, 1987.

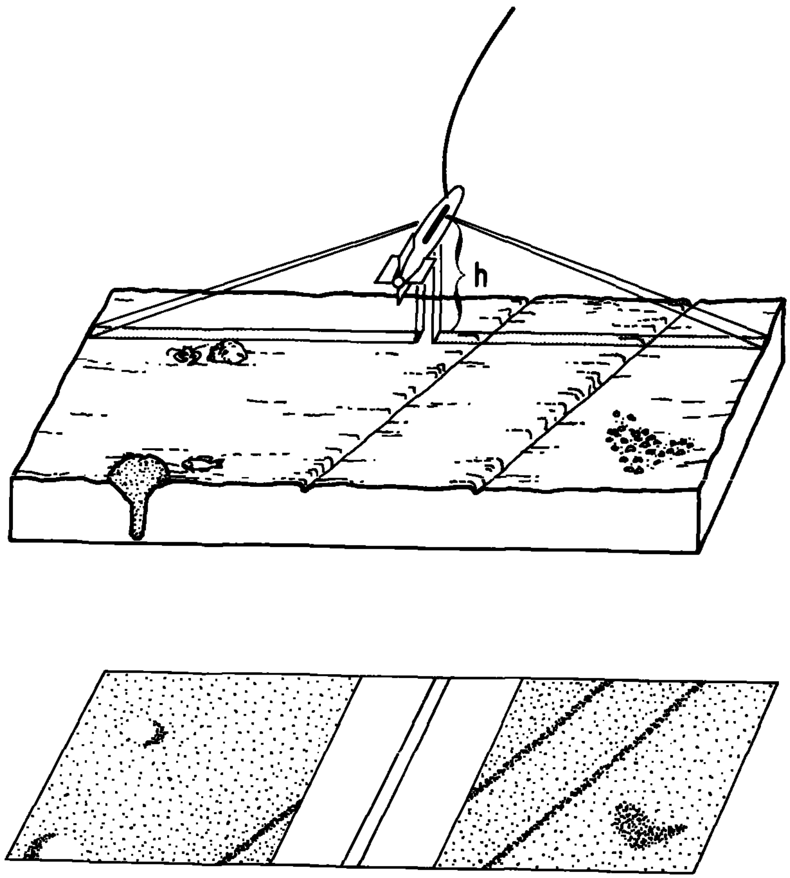

FIGURE 1.—Schematic diagram of a sidescan sonar vehicle being towed over the seafloor (upper) and resulting sonograph (lower) with images of trawl door tracks, tilefish burrow, gravel, and a boulder.

sidescan vehicle was towed 10-15 m above the seafloor at speeds of 3-7 km/hour and was set to scan 100 m or 150 m to each side of the towed vehicle. At these speeds and scanning range, 0.6-1.4 km^2 of seafloor could be mapped per hour.

The sidescan sonograph signatures that characterize different habitat types are largely determined by two conditions, topography and fine-scale roughness (in particular, differences in sediment texture). The signals received from tilefish burrows (Fig. 2) and boulders (Fig. 3) provide good examples of differences in strength of the recorded signal due to topographic effects. A strong signal (dark) is received from the side of the feature facing the transducer while a weak signal or shadow (light) is received from the side sloping away from the transducer. Thus, boulders have the strong return nearest the transducer followed by a shadow (Fig. 3), while burrows appear as a shadow preceding the strong return (Fig. 2). Gravel gives a much stronger signal than silt because of the many small facets facing the transducers. Textural differences usually can be distinguished from topographic differences because there is no shadow associated with them (Fig. 4).

Although the sonograph is a map view of the seafloor, there are two distortions that must be compensated for when interpreting these images. The first is the across-track, slant-range distortion which results from distances being measured from the sidescan vehicle that is positioned above the bottom and not the zero line on the seafloor below the towed vehicle (Fig. 1). For this reason, the point on the seafloor directly below the fish is plotted away from the actual zero line by the distance the fish is off the bottom (distance h on Figure 1). The second geometric distortion is in

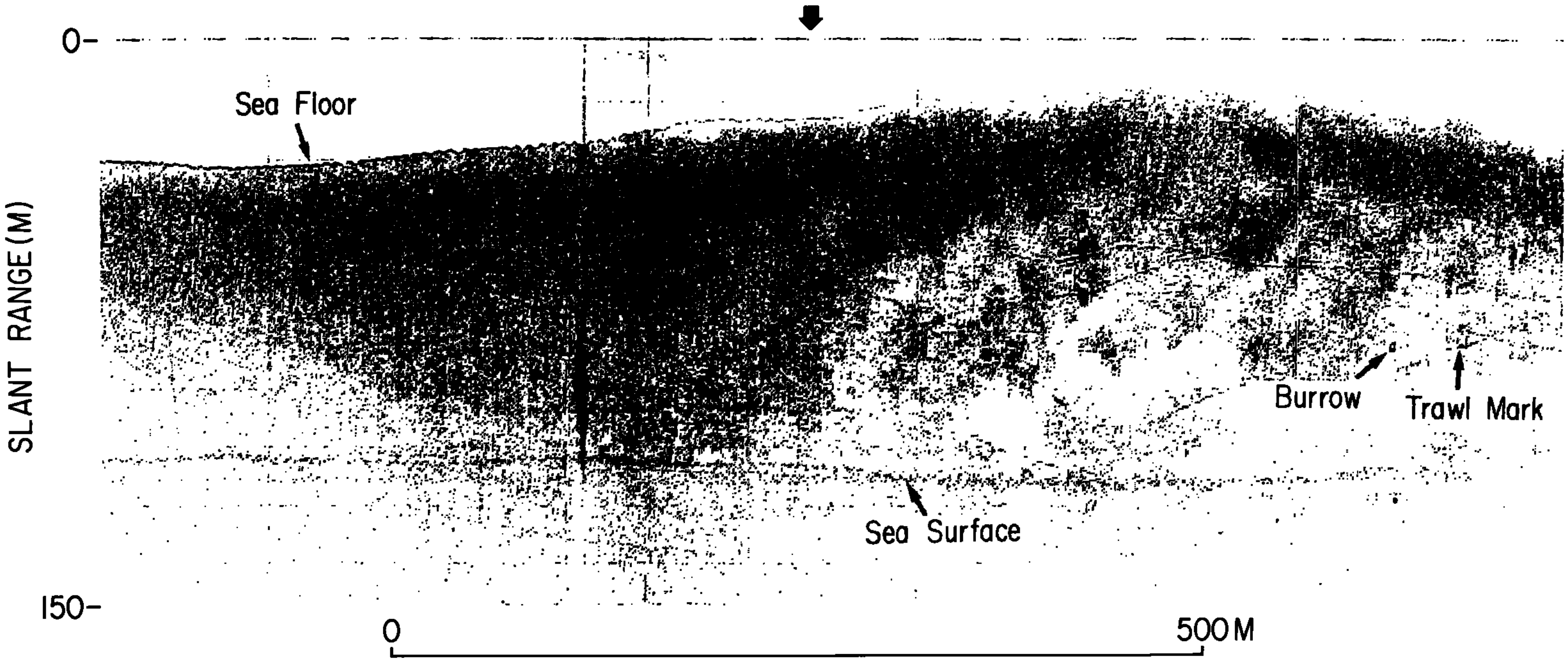

FIGURE 2.—Sidescan sonograph of seafloor with vertical burrows of tilefish, *Lopholatilus chamaeleonticeps*, and trawl door tracks in substrate. Heavy arrow denotes direction of incoming sound.

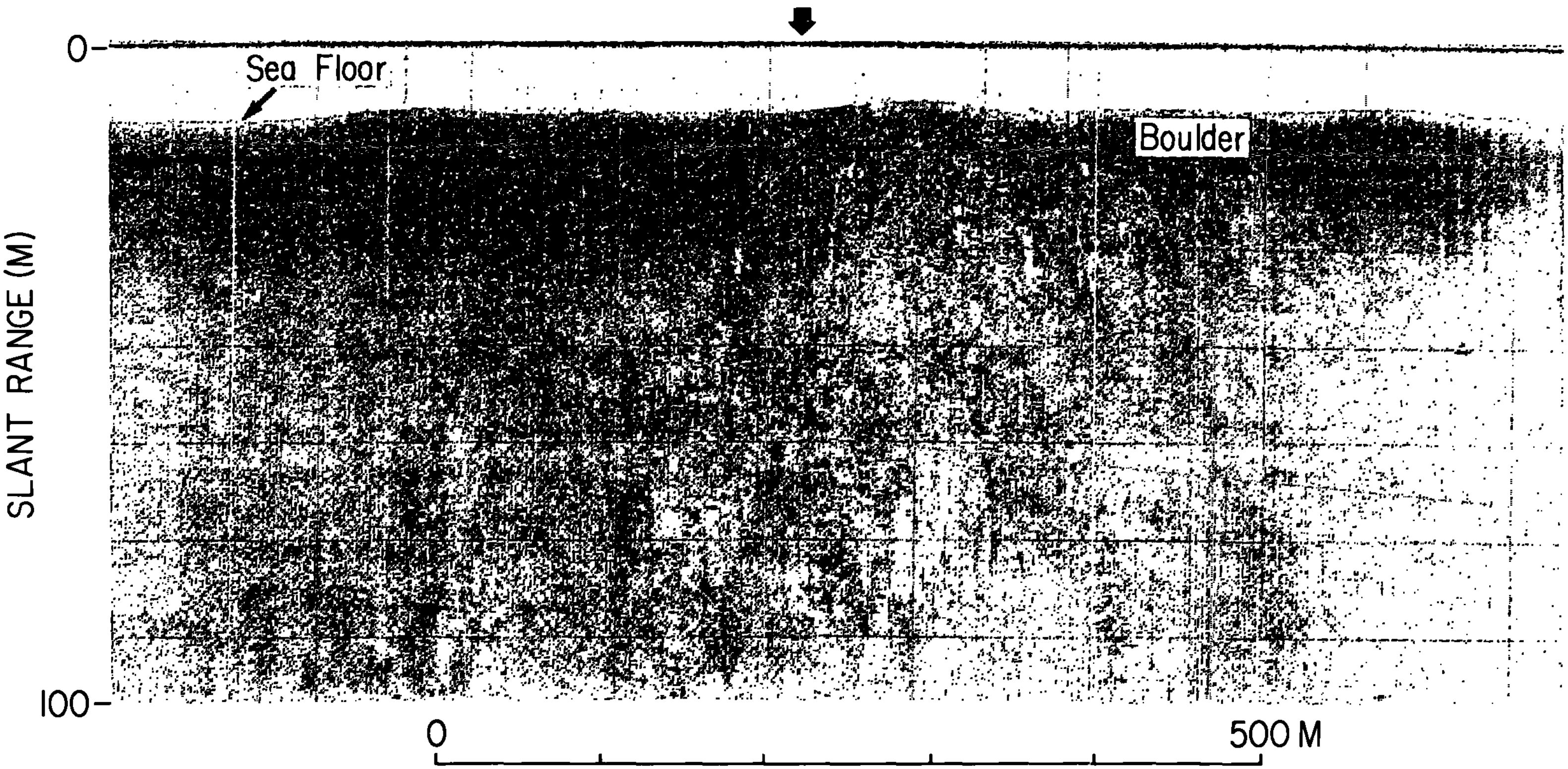

FIGURE 3.—Sidescan sonograph of seafloor in Vineyard Sound with boulders resting on the substrate. Heavy arrow denotes direction of incoming sound.

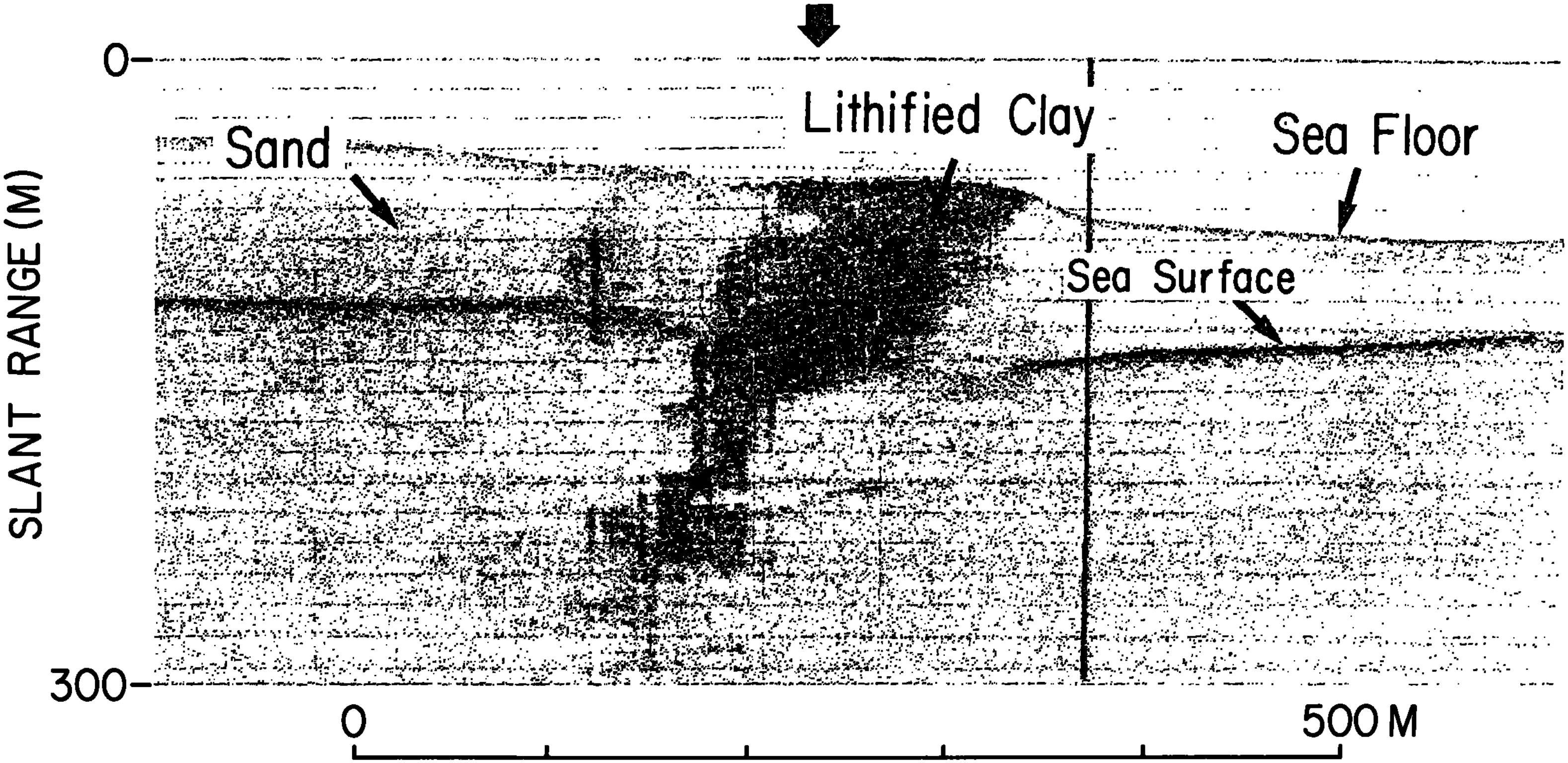

FIGURE 4.—Sidescan sonograph of Lydonia Submarine Canyon wall with outcrop of lithified, burrowed clay likely to be site of pueblo habitat of tilefish and American lobster. Heavy arrow denotes direction of incoming sound.

the along-track direction and is due to the ship's speed. Normally the records are compressed in the direction the ship travelled relative to the true geometry. A circular feature will look elliptical on the sonograph, with the long axis of the ellipse perpendicular to the ship's track, and a linear feature will look more perpendicular to the track than it really is.

RESULTS AND DISCUSSION

The Tilefish Example

Our initial discovery (Able et al. 1982) that tilefish, *Lopholatilus chamaeleonticeps*, construct large (up to 4-5 m diameter and 2-3 m deep), vertical burrows in the substrate (Fig. 5A) suggested that we might be able to detect these burrows with sidescan sonar. Since then we have successfully determined tilefish occurrence, distribution patterns, and relative abundance based on sidescan sonar observations at the edge of the continental shelf in the Mid-Atlantic Bight (Twichell et al. 1985; Grimes et al. 1986) and the upper slope off Florida (Able et al. 1987) (Table 1). Verification of sonograph images as tilefish burrows (Figs. 2, 5A) was accomplished by in situ observations from the *Johnson-Sea-Link* submersibles (Askew 1985) (Table 1).

As a result of these studies, we have demonstrated that sidescan sonar can consistently detect tilefish burrows both where the substrate consists of semilithified clay (Mid-Atlantic Bight: Twichell et al. 1985; Grimes et al. 1986) and softer carbonate muds (off east coast of Florida; Able 1987). During sidescan and submersible operations near Veatch Submarine Canyon, we determined that sidescan sonar could detect tilefish burrows as small as 0.5 m in diameter. Detection of small burrows on sidescan was confirmed when burrows in the area were measured in situ and found to be 35-65 cm in diameter (mean = 48 cm, sample number = 8).

TABLE 1.—Sidescan sonar observations of tilefish, *Lopholatilus* and *Caulolatilus*, burrows on the seafloor off the east coast of the United States.

Location	Date	Sidescan trackline distance (km)	Depth range (m)	No. of verification dives
Vicinity of Hudson Submarine Canyon, Mid-Atlantic Bight	July 1982; August 1983	100	90-200	6
Between Block and Veatch Submarine Canyons, Mid-Atlantic Bight	July-August 1984	129	100-350	2
Off Cape Canaveral, FL	May 1984	36	100-250	2

Under certain situations, tilefish abundance could be estimated directly from sonographs. Usually one tilefish is associated with each burrow (Able et al. 1982), therefore sidescan sonograms providing burrow counts could be used to estimate standing stocks in areas surveyed, with a modification of the area-density method (Everhardt and Youngs 1981). Frequency distributions of burrow density per unit area were log-normal, and there were considerable numbers of zero observations (i.e., about 14-24% zero observations). Therefore we $\log_e$ transformed the burrow density data, and calculated the sample mean and variance of the delta distribution according to Pennington (1983). We present sample estimates from our data for two different locations:

Case 1: Middle Atlantic Bight in the vicinity of Hudson Submarine Canyon (number of observations = 407, number of nonzero observations = 316, data from Twichell et al. 1985) based on the formula

$$N = \frac{B}{a} \cdot A$$

where N = total number of fish (burrows) in surveyed area, $\frac{B}{a}$ = delta-distribution mean number of burrows observed per unit area surveyed, A = total area surveyed, SD = standard deviation, and C.I. (confidence interval) = 95% (1.96 × SD) calculated from the delta-distribution variance, thus

$$N = \frac{2{,}558}{\text{km}^2} \cdot 0.407 \text{ km}^2 \text{ with SD} = 123 \text{ and } 95\%$$

$$\text{C.I.} = 241$$

$N = 1{,}041 \pm 98$ tilefish [in the surveyed area].

Case 2: South Atlantic Bight off Ft. Pierce, FL (number of observations = 46, number of nonzero observations = 40). The data was obtained with 167 kHz sidescan sonar from the research submersible NR-1 (Able et al. unpubl. data). In this instance

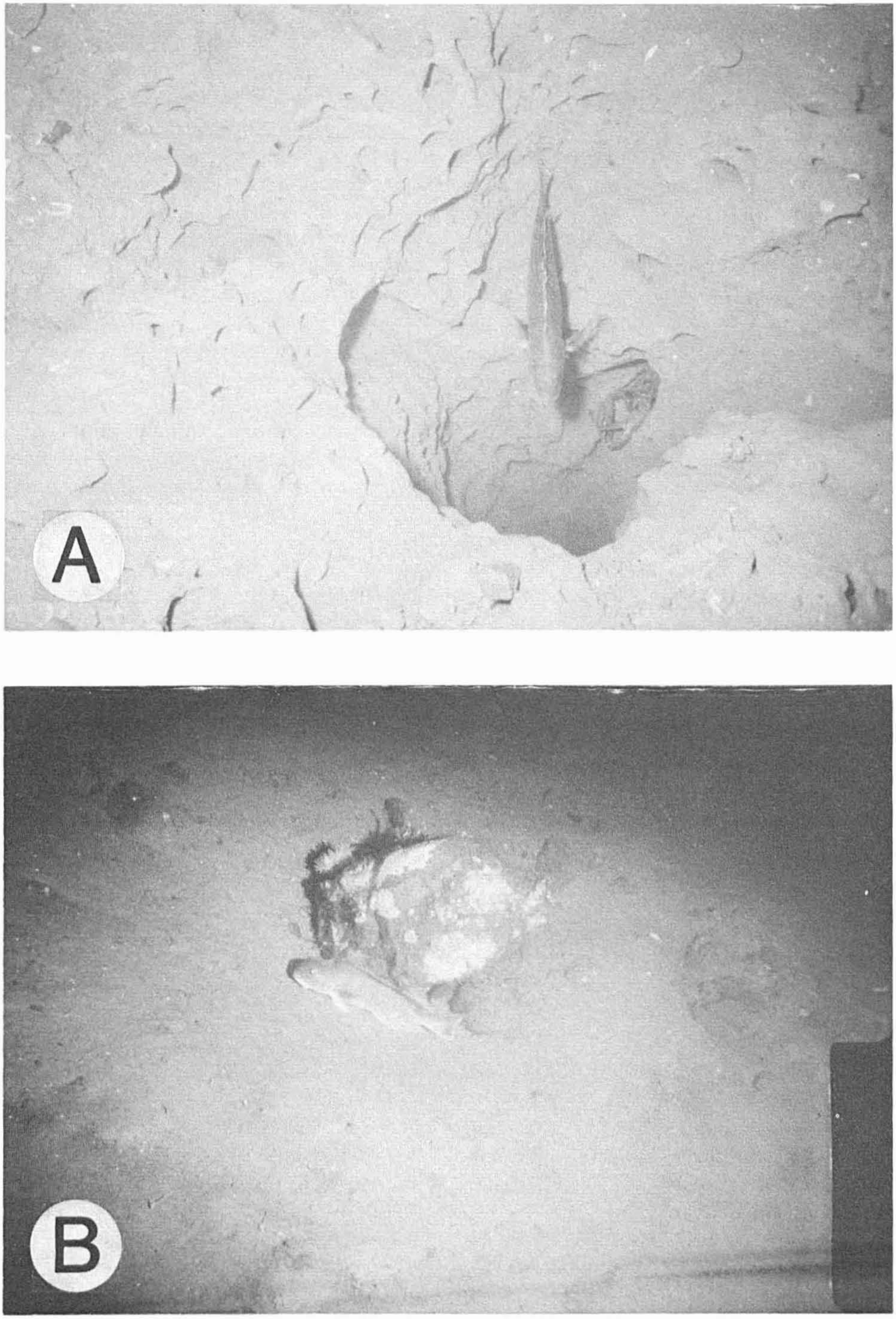

FIGURE 5.—Photographs of A) tilefish, *Lopholatilus chamaeleonticeps*, and American lobster, *Homarus americanus*, in a vertical burrow, and B) tilefish in boulder habitat. These are the same kind of habitats shown as sidescan sonographs in Figures 2 and 3 respectively.

$$N = \frac{369}{\text{km}^2} \cdot 0.42 \text{ km}^2 \text{ with SD} = 64 \text{ and } 95\% \text{ C.I.}$$

$$= 125$$

$$N = 154 \pm 53 \text{ tilefish [in the surveyed area].}$$

The estimates of N in cases 1 and 2 could be extrapolated to the entire fishing grounds using an estimate of the area of the entire grounds to provide an estimate of standing stock. However, we believe that extrapolation to areas where no density data is available is imprudent for several reasons. First, the density of burrows in different locations is quite variable as shown in the two above examples, and density on the Middle Atlantic-Southern New England ground (case 1) varies over the grounds at least tenfold (Grimes et al. 1986). Second, some burrows, at least in the Middle Atlantic-Southern New England area, may not be occupied during all seasons of the year (Grimes et al. 1986). Although we do not have as much background knowledge for case 2, we know that burrow density at different sites off the Florida east coast varied at least fivefold (Able et al. unpubl. data).

Another possible source of error in using burrow density to estimate tilefish stock size is that some burrows may be unoccupied. This should be of particular concern in exploited fishing areas. However, Twichell et al. (1985) and Able et al. (unpubl. data) have shown that abandoned burrows are filled by sedimentation relatively rapidly, i.e., less than one year, somewhat ameliorating the problem, at least over longer time periods.

Perhaps the most constructive aspect of cases 1 and 2 is the opportunity to examine the error associated with sidescan sonar estimates of N. These results show that the standard deviation varied from about 5 to 20% of the mean. Hennemuth (1976) found that the standard deviation in the numbers of different demersal species caught per tow within a stratum during stratified bottom trawl surveys approximately equalled the mean. Thus, this comparison suggests that area density estimates of abundance (calculated using the delta distribution) from sidescan sonar surveys will provide abundance estimates of much greater precision than trawl surveys. Reduced manpower needs and rapid application are additional factors that favor the sidescan sonar methodology. However, because the sidescan methodology is only useful for certain three dimensional habitats (e.g., reefs, rocks, and burrows) that would damage or make a trawl useless, application of the two techniques may usually be mutually exclusive.

Tilefish are known to occur in other habitats (Grimes et al. 1986) such as boulder fields, which can be detected on sidescan sonographs (Figs. 2, 5B). Another habitat type (pueblo habitats, Warme et al. 1977; Grimes et al. 1986) occurs in the clay outcrops along the walls of submarine canyons (Figs. 4, 6A). Neither of these habitat types lend themselves to quantification of fish abundance. Recently, we have been able to confirm that the burrows of other tilefish (*Caulolatilus* spp.) are also detectable with sidescan sonar (Able et al. 1987; Figs. 6B, 7). Subsequent observations from a submersible confirmed that these burrows were occupied by *C. microps* and *C. cyanops* with frequent multiple occupancy. Given that it has now been demonstrated that representatives of four of the five genera of tilefishes construct burrows (see Able et al. 1987), it is reasonable to suspect that all tilefish construct burrows. Thus, those larger species of commercial interest, such as red tilefish, *Branchiostegus japonicus japonicus* (Lim and Misu 1974), also may have burrows that are detectable by sidescan sonar.

Other Examples and Possibilities

As an outgrowth of our studies of *Lopholatilus* we have observed other species-specific habitats that can be detected with sidescan sonar. American lobster, *Homarus americanus,* typically occupy scour basins around large boulders (Cooper and Uzmann 1977; Valentine et al. 1980) as do cusk, *Brosme brosme*, and ocean pout, *Macrozoarces americanus* (Valentine et al. 1980; Grimes et al. 1986), and these habitats also are detectable with sidescan sonar. American lobster (Fig. 5) and conger eels, *Conger oceanicus,* (Able et al. 1982; Grimes et al. 1986) have been observed in tilefish vertical burrows as well. Similarly, it would not be surprising if the habitats of other clawed lobsters are detectable with sidescan sonar. For example, *H. gammarus* from the eastern North Atlantic is similar to *H. americanus* in that it is shelter seeking and occurs around boulders (Dybern 1973). In addition, recent in situ observations in the Gulf of Mexico have discovered that yellowedge grouper (*Epinephelus flavolimbatus*) also occupy burrows and elongate trenches (R. S. Jones, E. Gutherz, and W. R. Nelson, pers. obs.) that could easily be detected by sidescan sonar.

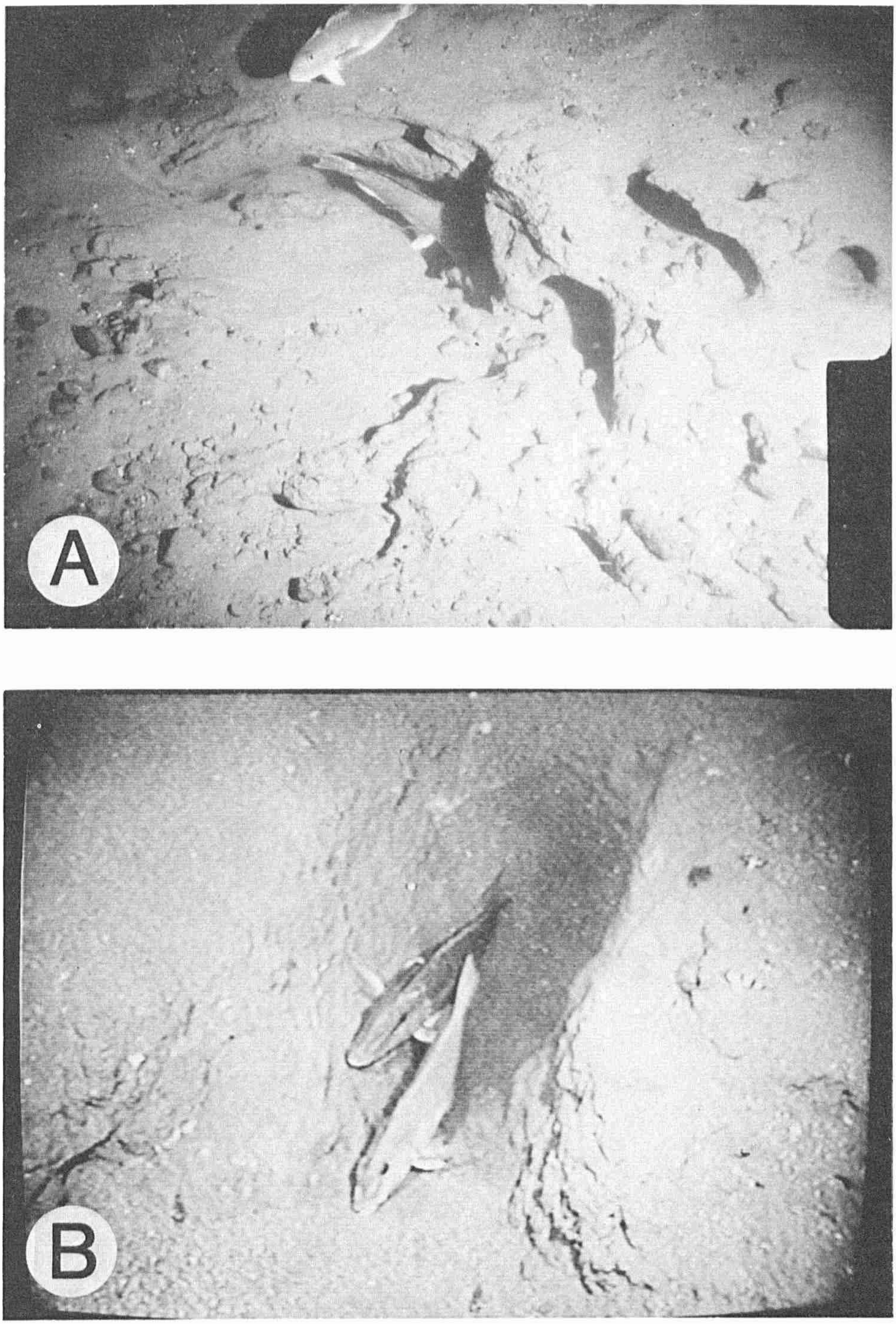

FIGURE 6.—Photograph of tilefish, *Lopholatilus chamaeleonticeps*, in A) pueblo habitat that is part of a clay outcrop and B) *Caulolatilus* tilefish in a burrow. These are the same kind of habitats as shown in Figures 4 and 7 respectively.

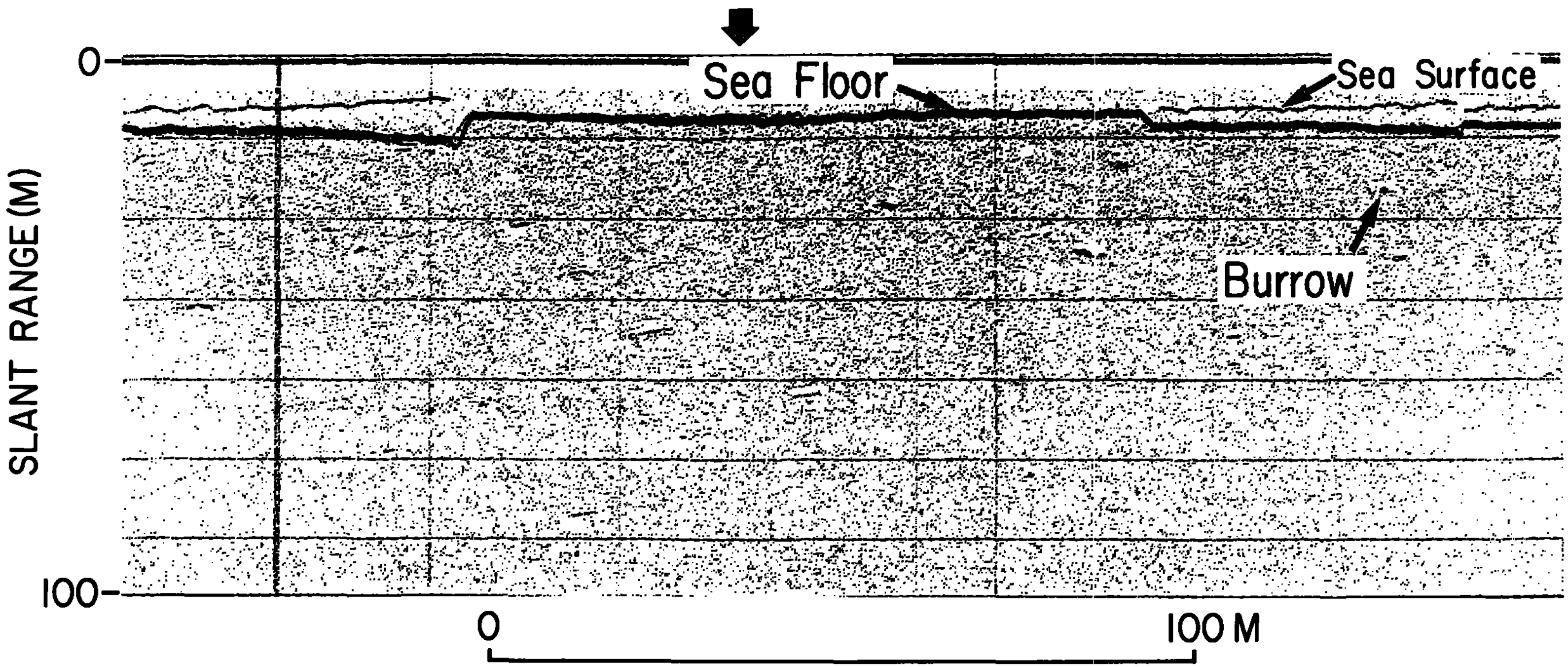

FIGURE 7.—Sidescan sonograph of seafloor with *Caulolatilus* tilefish burrows off Cape Canaveral, FL. The sharp steps in the seafloor trace are where the sidescan was raised or lowered. Heavy arrow denotes direction of incoming sound.

With sidescan sonar, detection and mapping of general habitat types such as rock outcroppings and wrecks, which support populations of commercially important species (e.g., Grimes et al. 1982; Sedberry and Van Dolah 1984), could be done efficiently. Sidescan sonar also could prove very effective (see Wong et al. 1970) in mapping the distribution and relief of a coral reef, and other outcroppings which are often the habitats of groupers, snappers, porgies, and grunts.

In addition to these specific examples, general characteristics of sidescan sonar are advantageous in detecting demersal fish habitats. The system has a wide effective search image (up to 150 m to each side for the 100 kHz Klein sidescan unit) that enables it to map large areas of the bottom during a single transect. With multiple transects a complete picture of the bottom can be obtained. Also, a sonograph could determine potentially appropriate habitats for several species simultaneously. For example, in our studies we have been able to detect boulders (potential lobster, tilefish, and cusk habitat) and vertical burrows (potential tilefish, lobster, and conger eel habitat) in the same transect of the sidescan sonar.

Verification of the various images that appear on the sonograph is critical to successful operation of sidescan sonar for fish habitat detection. We have been able to do this using observations from the *Johnson-Sea-Link* submersibles (Twichell et al. 1985; Grimes et al. 1986; Able et al. 1987). However, this is an expensive option and not generally available. Others have been able to verify sonograph targets from underwater photographs (Bouma and Rappeport 1984) or underwater television (Powles and Barans 1980). The simplest technique, and one that would offer the most information to a fishermen, is directed fishing at the location of sonograph targets of particular interest.

Even with these advantages, sidescan sonar operations are still expensive. However, a considerable body of sonograph data already exists that has not been utilized by fishermen or fishery biologists. A large number of sidescan sonar surveys have been conducted in North American waters in recent years, largely as a result of exploration for oil and related impact studies (Carpenter and Roberts 1979; Neurauter 1979; Carpenter et al. 1982). We have taken advantage of one of these surveys to identify possible tilefish burrows off the west coast of Florida, an area in which we had no prior experience. Individual burrows were clearly visible on sonographs (Neurauter 1979; target type No. 3, fig. 39) originally made to identify geologic bedforms.

ACKNOWLEDGMENTS

A number of individuals and institutions assisted in this effort. Greg Kennedy (Harbor Branch Foundation, Inc.) and Greg Miller (U.S. Geological Survey) helped to operate the sidescan sonar equipment and kept it functioning properly. The submersible and ships crews of the *Johnson-Sea-Link* submersibles and the RV *Johnson* and RV *Sea Diver* provided their usual professional operations. G. Scott (National Marine Fisheries Service, Miami) provided the delta distribution computer program. Helpful comments on an earlier draft of the manuscript were provided by Elizabeth Winget, Sally Needell, and Ron Circe (U.S. Geological Survey) and an anonymous reviewer. Denise Rucci and Patricia Eager prepared the manuscript. This work was supported by grants from the NOAA Office of Undersea Research, New Jersey Sea Grant, and Florida Sea Grant (No. NA80AA-D-00038) and logistical support was provided by Harbor Branch Foundation, U.S. Geological Survey and the Center for Coastal and Environmental Studies, Rutgers University.

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