Areas, depths, and times of high discard rates of scup, *Stenotomus chrysops*, during demersal fish trawling off the northeastern United States

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In the waters off the northeastern United States, many stocks of commercial and recreational species have declined in recent years (Anthony, 1993; Sissenwine and Rosenberg, 1994; Collins, 1995; Matthiessen, 1995; NEFSC, 1995). Although much of the blame for these declines is ascribed to sustained overfishing, there also has been substantial concern over bycatch and discarding practices in key fisheries of the region, especially those involving demersal trawling (Murawski, 1994; Howell and Langan, 1987, 1992; Cadrin et al., 1995; Kennelly et al., 1997).

For many years scup (or porgy, *Stenotomus chrysops*) has been an important commercial species in the mid-Atlantic and southern New England regions, caught principally by otter trawling and to a lesser extent by pound nets, floating trap nets, and fish traps (Shepherd and Terceiro, 1994). Like many other key species in the region, annual commercial landings of this species have declined markedly in recent years from between 18,000 and 27,000 metric tons (t) in the 1950s and 60s to 6000 t in 1992 and 4400 t in 1993 (NEFSC, 1995). There is also an important recreational fishery for scup in this region, and recreational landings in recent years have accounted for 20 to 50% of the total annual catch. These have also declined from an estimated 3,100 t in the 1980s to 2100 t in 1992 and 1300 t in 1993 (NEFSC, 1995). Scientists at the 1995 Northeast Regional Stock Assessment Workshop for the scup stock in this region concluded that 1) it is currently overexploited; 2) it is at a low level of biomass; and 3) current high rates of exploitation of age 0–2 fish should be decreased as much as possible (NEFSC[1]).

As predicted by Wilk and Brown (1980) some time ago, one of the causes of mortality for young scup in this region is thought to be the incidental bycatch and subsequent discarding of this species from demersal trawlers that target other species, particularly squid (*Loligo* spp.). McKiernan and Pierce's[2] study of the inshore squid fishery in Nantucket and Vineyard Sounds, Massachusetts, showed significant discard of scup but, like Cadrin et al. (1995), they concluded that the inshore abundances of this species were more probably related to trawl effort throughout the region than to the relatively small effort of inshore squid trawlers. They concluded that significant numbers of small scup may be discarded by squid trawlers farther offshore where scup are known to migrate in the autumn (see also Finkelstein, 1971; Eklund and Targett, 1990) and recommended an examination of the discarding practices of these trawlers.

The most reliable way to quantify discards in commercial fisheries is for observers to record data during normal fishing operations (e.g. Jean, 1963; Powles, 1969; Young and Romero, 1979; Atkinson, 1984; Murawski et al., 1995). Information from such programs is a necessary prerequisite for the two main management alternatives used to reduce discards: 1) spatial and temporal closures to fishing in areas and times of high rates of discard of key species (i.e. discard "hotspots") (Murawski, 1992; Hendrickson and Griffin, 1993; Alverson et al., 1994, Kennelly, 1997); and 2) modifications to fishing gears and practices that improve selectivity (Robertson and Stewart, 1988; Isaksen et al., 1992; Hall, 1994; Broadhurst et al., 1996; Broadhurst and Kennelly, 1997).

Since 1989, the National Marine Fisheries Service's Northeast Fisheries Science Center (NEFSC) has operated a large-scale observer program in many of the fisheries off the northeastern United States from Maine to North Carolina (Murawski et al., 1995; Kennelly et al., 1997). The data collected from demersal trawlers in this program have provided an opportunity to examine the spatial and temporal occurrences of discarded scup in the offshore mid-Atlantic and southern New England trawl fishery.

[1] NEFSC (Northeast Fisheries Science Center). 1995. Report of the 19th northeast regional stock assessment workshop–the plenary. NOAA/NMFS/NEFSC, Woods Hole, MA. NEFSC Ref Doc. 95-09, 57 p.

[2] McKiernan, D. J., and D. E. Pierce. 1995. *Loligo* squid fishery in Nantucket and Vineyard Sounds. Massachusetts Div. Fish. Publ. 17648-75-200-1/95-3.47-CR, 62 p.

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Materials and methods

Field sampling

Each month between July 1990 and June 1994, Manomet Center for Conservation Sciences (under contract to the NEFSC) placed observers on board demersal trawlers working throughout the northeastern United States. The selection of vessels and trips undertaken did not adhere to any consistent survey design but was based on changing national, management and stock assessment priorities (Murawski et al., 1995) in addition to varying concentrations of fishing fleets in particular areas and times. As a consequence, the observer coverage of these trawlers was highly uneven throughout the period; some areas and times received high sampling and others received very little or no sampling. Of relevance to this paper are the observer data gathered in the southern New England and mid-Atlantic areas shown in Figure 1.

During observed trips, the contents of the codend from each tow were emptied onto the deck and sorted by the crew. If the entire catch could not be sampled, data were collected from a representative subsample. The data collected from each tow that were of relevance to this paper were the following: area, depth, date, time and tow duration, the weights of retained and discarded individuals of various species in the catch, the number of species caught, and the total weights of all species retained or discarded. Because of various operational and logistic reasons, not all tows from all trips were sampled for the weights of retained and discarded species; however, the data examined in this paper include only those tows that were completely sampled.

Analysis of data

Because of the lack of a consistent survey design in this observer program, the data generated could not be regarded as randomly collected, independent samples of the trawling effort of the region, and thus violated the basic assumptions required for conventional statistical analyses (see also Kennelly et al., 1997). Nevertheless, because of the size of the data set and its extensive spatial and temporal coverage, large subsets of data could be extracted for many areas and months and therefore permitted the identification of certain key areas, depths, and times of consistently high rates of scup discard (see "Results" section). The first and broadest examination of the data was to plot the discard rates for scup for all the areas sampled in the region to identify those areas that experienced consistently high rates. Next, discard rates for scup from each sampled tow in each of these identified areas was plotted against depth to

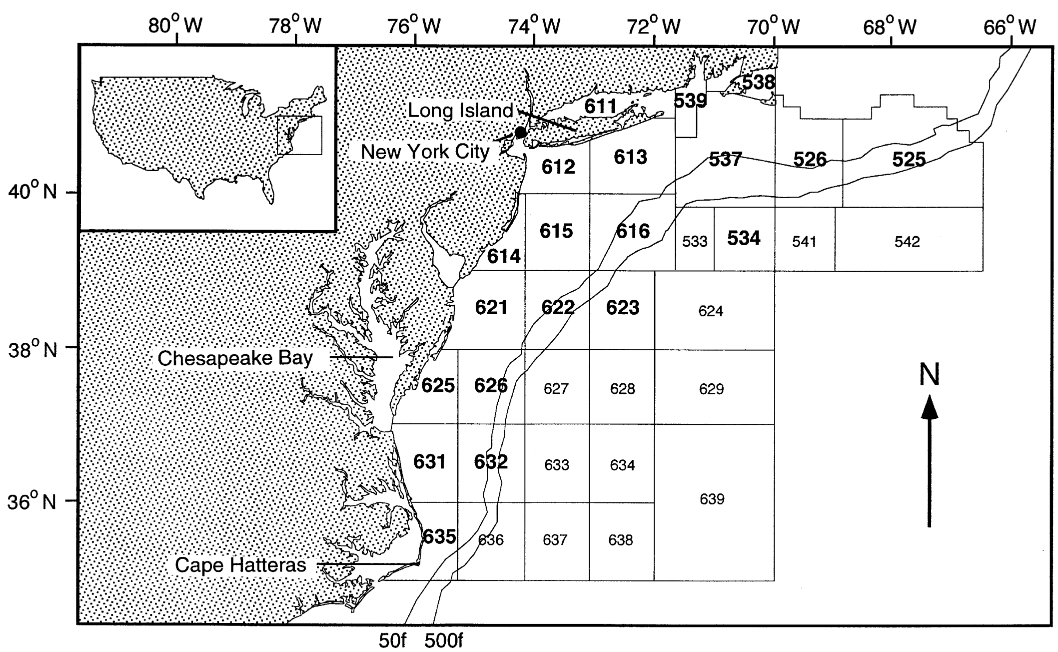

Figure 1

Map showing the various NMFS statistical areas examined in the present paper. Areas labelled in bold are those with sufficient observer coverage to be examined in Figure 2.

determine which depths yielded consistently high rates. Once these depths were identified, the discard rates of scup in these tows were plotted against time to determine the particular months when the high discards occurred. In this way, the large observer data set for the region was focussed to identify the particular areas, depths, and months that yielded high discard rates for scup. Finally, catches of other common species in these identified areas and times were examined by plotting their retention and discard rates.

Results

Figure 2 shows the average discard rates for scup (in pounds per hour towed) for the areas defined in Figure 1. All areas other than 526, 537, 539, 613, 615, 616, 621, 622, and 623 showed low discard rates for scup (defined as a maximum rate of less than 20 lb/h) or low levels of observer coverage (defined as less than 10 observed tows during the study), or both.

Figure 3 shows discard rates for scup against the depth of the tows sampled in each of the areas identified in Figure 2 above. Most areas recorded high discard rates across a range of depths, except areas 613 and 621 which showed marked concentrations from 30–40 fathoms (fm) and 6–17 fm respectively.

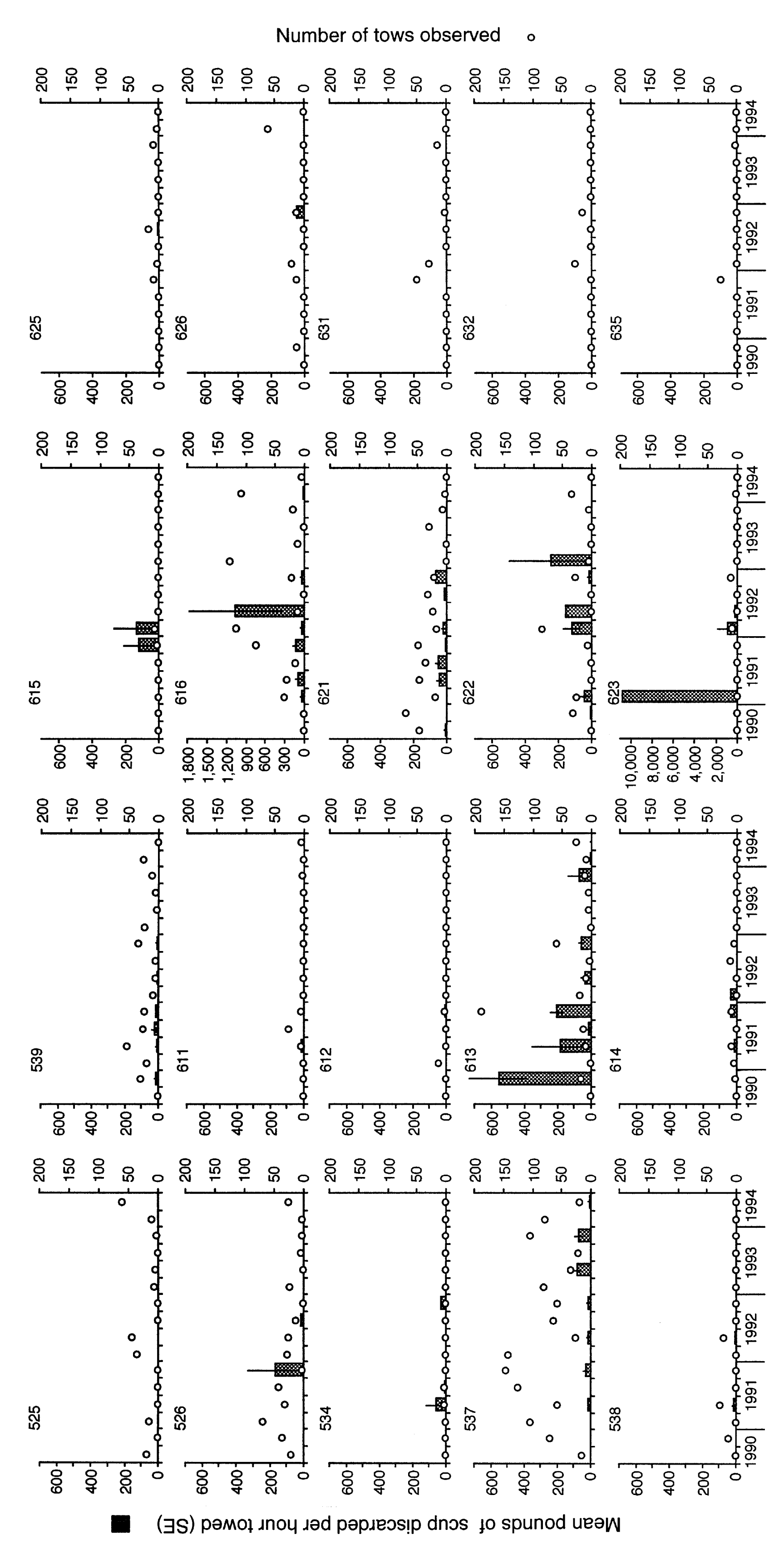

Figure 2

Average scup discard rates (per hour trawled) plotted against observer coverage for various statistical areas in the region.

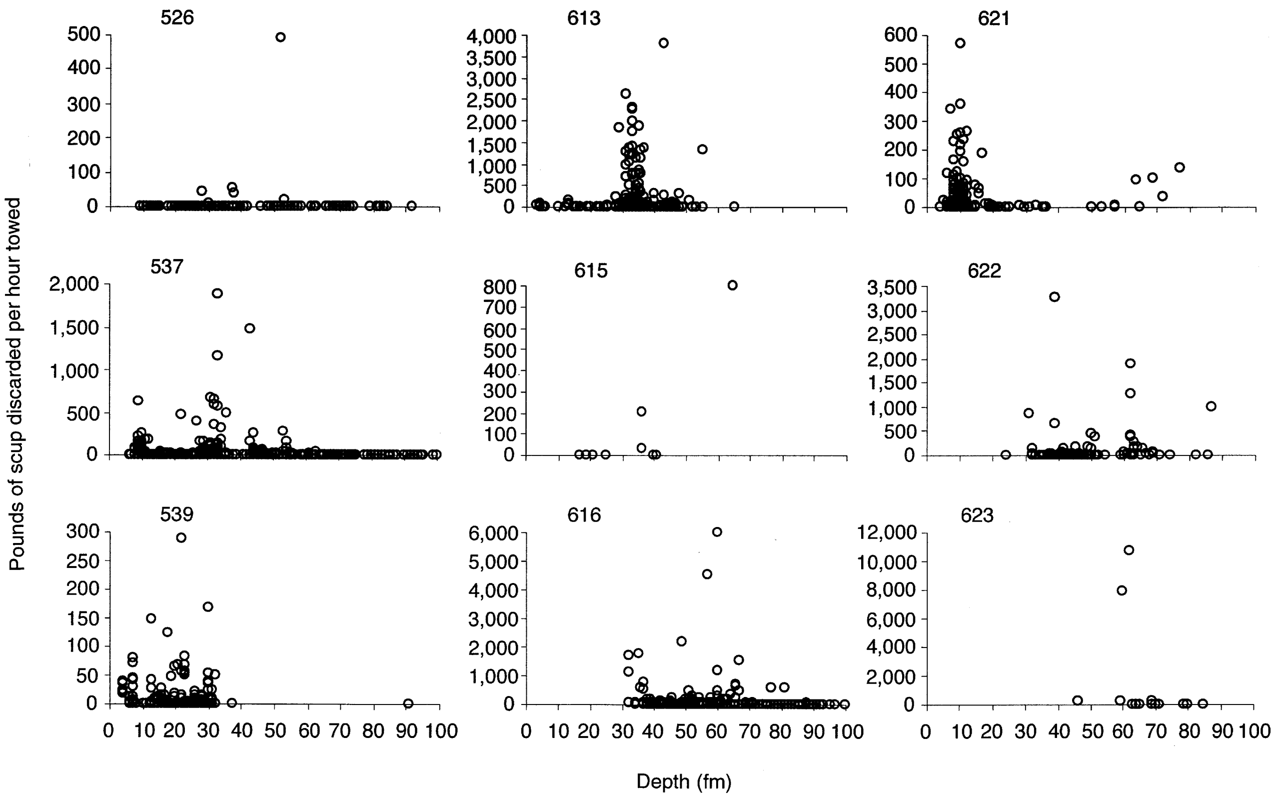

Figure 3

Scup discard rates (per hour trawled) plotted against depth for those areas in Figure 2 that showed consistently high rates of scup discard.

Figure 4 shows the timing of discard rates for scup in area 613 between 30 and 40 fm and in area 621 between 6 and 17 fm. For area 613, the highest rates at those depths occurred in November and December of each of the four years studied. Such a persistent trend for high scup discards was not evident for area 621, where highest rates occurred in May, August, and September 1991, and in September and October 1992.

Figure 5 shows the mean number of pounds retained and discarded for the most common species caught in all tows sampled in area 613, between 30 and 40 fm, in the months of November and December each year. Because of inconsistent identifications, data for squid and skates include data for all such species. Squid were by far the main retained species with an average of 507 lb/h. Scup and whiting, *Merluccius bilinearis,* were also retained in significant quantities at 227 and 223 lb/h respectively. The main discarded species was dogfish, *Squalus acanthias,* (672 lb/h), followed by scup (319 lb/h) and skates (236 lb/h), and lesser quantities of butterfish, *Peprilus triacanthus,* (96 lb/h), whiting (72 lb/h), and red hake, *Urophycis chuss,* (51 lb/h).

Discussion

The above treatment of a four-year subset of the NMFS sea sampling database indicated that trawling in a particular area (area 613), depth (30–40 fm), and time of year (November to December), consistently led to high discard rates for scup. Before discussing this result, however, it is necessary to consider the problems inherent in the data analyzed. In particular, the design of this observer program involved a nonrandom, nonindependent allocation of sampling effort that was uneven in space and time (see Fig. 2). These problems precluded 1) the use of conventional statistical analyses to detect trends and 2) the identification of patterns for all areas for all months. For example, the uneven observer coverage may have resulted in the identification of only 9 of the 20 statistical areas in the region as having high discard rates for scup (Fig. 2). Although adequate observer coverage seemed to occur across most of the depths in many of these nine areas (Fig. 3), not all areas had all depths sampled, precluding the conclusion that other depth-related areas of high scup

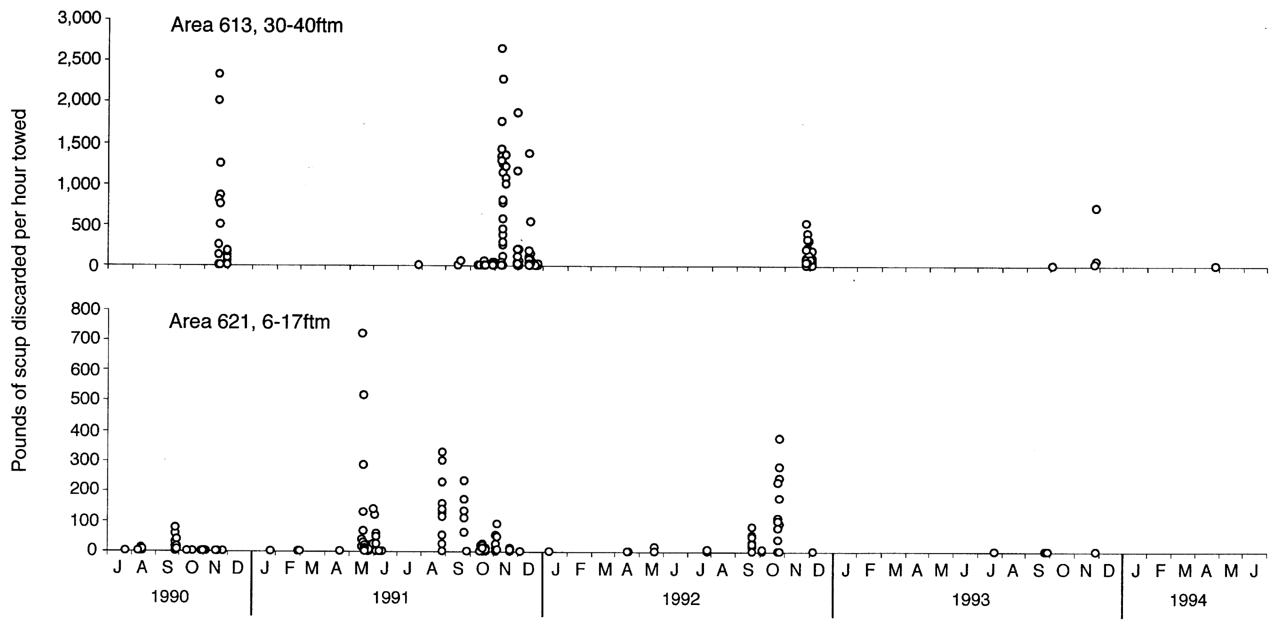

Figure 4

Scup discard rates (per hour trawled) plotted against time for those depths and areas in Figure 3 that showed consistently high rates for scup discard.

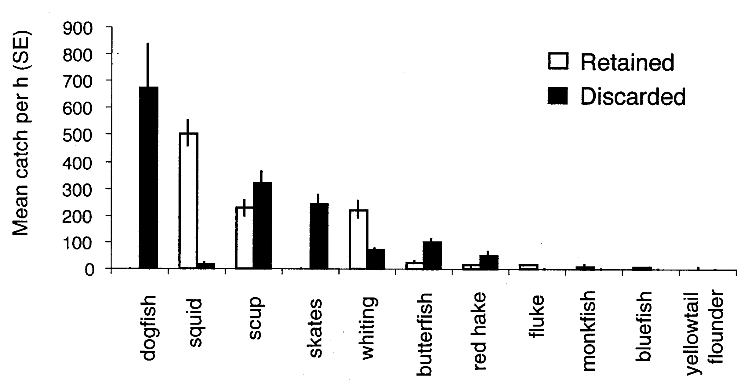

Figure 5

Retained and discard rates (per hour trawled) of the main species caught in those tows done in area 613, between 30 and 40 fm, in the months of November and December (the identified area and time of consistently high rates for scup discard).

discard did not exist in the region (i.e. in addition to the identified depths in areas 613 and 621). Figure 4 shows the temporal pattern of scup discard in those areas and depths identified from Figures 2 and 3 and reveals a consistent pattern of high discard for area 613 but not for area 621. However, more observer coverage throughout the year could have provided evidence of other consistent peaks of scup discard in one or more areas and depths, or could have defined better the small period of high scup discard in area 613. For example, the data indicated that November and December were key months, but more sampling in October and January could have widened this time frame.

A second problem with the data is that they were collected from many different boats, with different nets, horse powers, tow durations, etc. Although such problems are avoided in fishery-independent surveys by using standardized gears and sampling protocols, they are unavoidable when dealing with observer programs whose objective is to survey normal fishing operations across a variety of vessels, gear-types, etc. in order to detect fleet-wide patterns. Variation in observer data is inherent in all such programs, and it is only by doing properly designed and replicated, stratified, randomized observer surveys that such problems can be accounted for.

In most studies that have quantified bycatches, species-specific spatial, and temporal variabilities in discarding often preclude the identification of definite areas and times of persistently high discards of species (see also Robin, 1991; Martinez et al., 1993; Liggins and Kennelly, 1996; Kennelly et al., 1997). The present study shows that high discard rates for scup were rarely consistent in particular areas and times, although one area and time did show some persistence throughout the four years: the relatively small area (area 613) off Long Island, New York, between 30 and 40 fm in the months of November and December each year. It is well known that from May to August each year scup spawn in estuaries, bays, and inshore areas south of Cape Cod (e.g. see Wilk and Brown, 1980; Eklund and Targett, 1990), particularly around Long Island (Finkelstein, 1971). In autumn, after spawning, they migrate south at greater depths towards their wintering grounds from southern New Jersey to Cape Hatteras, returning back to their inshore spawning grounds in spring (see Neville and Talbot, 1964; Wilk and Brown, 1980; Jeffries and Terceiro, 1985; Eklund and Targett, 1990). It is apparent from this behavior, that the occurrence of large numbers of scup as trawl discards in area 613 off Long Island in the autumn of each year coincides with their migration from Long Island's inshore waters to their wintering grounds farther south.

When spatial and temporal patterns in observer data reveal persistent areas and times of high discard rates, they can be used by fisheries managers to identify where and when various management tools can be applied to reduce discards. These tools usually involve either spatial or temporal closures to fishing (or both) or modifications to fishing gears and practices that reduce discards.

If fisheries managers consider the area and time of high scup discard identified in this paper as a candidate for a closure, the data in Figure 5 provide some information on the consequences this may have on landings of squid and other species. In the identified area and time, an average of over 507 lb of squid were retained per hour towed, whereas an average 319 lb of scup were discarded per hour towed. The actual numbers of fish involved were not available but, because the discarded scup were those individuals considered too small to retain, discarded weights often represent more individual fish per pound than retained weights. One could expect, therefore, that closing this area at this time would protect significant numbers of small scup, thereby assisting the 1995 Northeast Regional Stock Assessment Workshop's recommendation to decrease their exploitation (NEFSC[1]). Larger quantities of dogfish and lesser quantities of skates, butterfish, and whiting would also be protected by such a closure. The "cost" of such a closure, however, would be significant reductions in the landings of squid from the area at that time and lesser reductions in the landings of scup and whiting. One way of estimating the potential effects that such a closure strategy might have for the region is to compare the overall squid retained and scup discard rates with rates adjusted by excluding all tows done in the identified area and time. Throughout the region, the overall discard rate for scup during the four years was 37.5 lb/h (standard error (SE)=4.7), but if the tows done in the identified area and time are excluded, the overall rate falls to 27.3 lb/h (SE=4.5): a decrease of 27%. This should be compared to the overall retained rate of squid in the region of 128.5 lb/h (SE=6.1) falling to 114.9 lb/h (SE=6.0) if the tows done in the identified area and time are excluded —a decrease of 10.6%. It is important to note, however, that closing the area at this time to trawling will not simply remove trawling effort from the region but merely redirect it to other areas that may yield lower scup discards. This means that the effects on landings and discards in the region will not simply be those protected inside the closure but will be tempered by increased landings and discards outside the closure by the redirected vessels.

The other suite of management tools available to reduce discards in areas and at times of high discarding involve modifying fishing gears and practices to improve selectivity. Such modifications as the Nordmore Grid and square-mesh panels have proven successful in reducing discards of small fish in trawl fisheries (e.g. Carr, 1989; Isaksen et al., 1992; Broadhurst et al., 1996; Broadhurst and Kennelly, 1997), and modifications like downward sorting grids and horizontal panels in nets have reduced the bycatches of unwanted sizes of species in groundfish trawls (see Larsen and Isaksen, 1993; Engas and West[3]). For the issue of scup discarding in the northeastern United States, gear modifications would be a better management alternative than the closure strategy outlined above if they could reduce greater quantities of scup discards (and concomitantly reduce landings of squid and other species by smaller amounts) than those under a closure strategy. Such a general, gear-based solution is also advantageous because its adoption throughout the region would not only lead to reductions in scup discard in identified "hotspots" but in all areas where scup discarding occurs. The information provided in the present study identifies the ideal locations and times for any gear-based research that aims to reduce scup discard by trawlers and where and when any gear modifications

[3] Engas, A., and C. W. West. 1995. Development of a species-selective trawl for demersal gadoid fisheries. Int. Coun. Explor. Sea Council Meeting (CM) 1995/B+G+H+J+K:1.

should be initially implemented. At the time of writing this paper, several such gear-based discard reduction programs are currently underway in the region.

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