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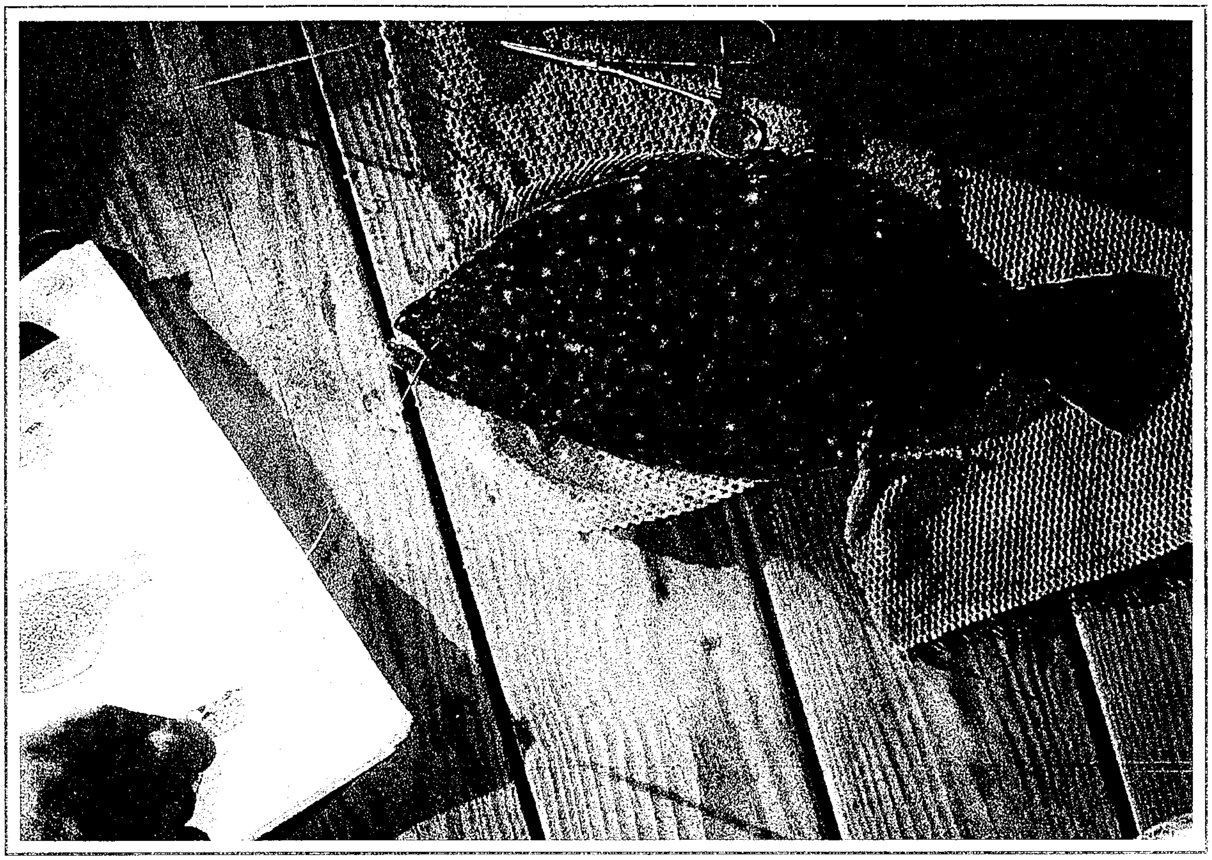

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Summary

The recreational fishery for summer flounder consistently ranks among the top fisheries in the mid-Atlantic region. Under the Fishery Management Plan (FMP) for the Summer Flounder Fishery, recreational fishery quotas, minimum size limits, and trip bag limits are being utilized to reduce fishing mortality to sustainable target levels. Estimated hook-release mortality is incorporated into annual recreational catch estimates as well as models used to establish size and bag limits. Beginning in 1993, the FMP has employed a hook-release mortality rate of 25% for the recreational fishery.

This study was undertaken to determine levels of release mortality under recreational fishing conditions and, through tank experiments, to determine what factors might significantly contribute to such mortality. The project involved use of a large-scale, outside, flow-through tank system to conduct hooking experiments as well as field fishing trials involving catching flounder from private boats (drift fishing using live-fresh bait). In addition, a survey was made of anglers at various recreational fishing shows and fishery meetings concerning flounder fishing practices, perceptions of release mortality levels, and major factors contributing to such mortalities. The study was carried out principally at the Virginia Institute of Marine Science Wachapreague Laboratory on the seaside of Virginia's Eastern Shore. Fish were collected in the Wachapreague Inlet area for tank experiments, while field fishing trials were conducted in the same area as well as inside Chesapeake Bay off the town of Cape Charles.

Tank experiments evaluated the effects of hook wound location, degree of bleeding, and fish size on release mortality. Additionally, angling practices such as crimping hook barbs, cutting leaders in deeply hooked fish, and using different shape hooks were examined to determine whether such practices could be demonstrated to reduce mortalities in released flounder. Fish used for the tank trials were caught by a small trawl net, transported in aerated live wells to flow-through, laboratory tanks, acclimated to the tank, and fed regularly. Tank-held fish were then systematically caught on hook and line using live bait, the hooking data recorded, and the fish were released back into the tank. To increase sample sizes to make comparisons among hooking treatments, extended hook setting delay periods were used whereby fish were given slack line for 30-45 seconds after taking a baited hook. Post-release observation periods for four tank experiments ranged from 7-21 days, and experimental water temperatures ranged from 15-24°C (59-75°F).

The only factor consistently observed to impact release mortality in the tank experiments was deep hooking of fish (hooks lodging in the esophagus, gills, or deep mouth-tongue area). Deep-hooked flounder accounted for 95% of the mortalities in the tank experiments. Of the dying fish, 76% were hooked in the esophagus, 16% in the gills, and 8% in the deep mouth-tongue area. Mortality rates for fish hooked in the referenced wound areas were 42%, 29%, and 12%, respectively. Hook wound location was the only variable which significantly affected mortality in all tank experiments. Factors such as water temperature, fish size, crimping hook barbs, and using wide gap hooks were

not demonstrated to significantly affect mortality. While also not statistically proven to reduce mortality, cutting leaders and leaving the hooks in deep-hooked fish, especially those hooked in the esophagus, showed potential for lowering release mortality.

Proportions of deep-hooked fish in the tank experiments were artificially high, as well as significantly different among experiments. Therefore, mortality rates were weighted by the percentage of hooked fish which were deep-hooked. The resulting weighted mortality rates ranged from 7-23% over the four experiments, the mean mortality being 11% (95% CI=3-24%).

Three field fishing trials (N=65, 45, and 80 fish) were completed at water temperatures of 23-26°C (73-79°F), producing rates of deep-hooked flounder of 20%, 13%, and 10%, respectively. Held in aerated live wells for up to 3-5 hours after capture, the fish were transported to live cages to observe release mortality rates. Unfortunately, inconsistencies in cage holding conditions made the cage mortality data unreliable. Although representing short observation periods, live well mortality rates ranged from 6-9%, levels similar to weighted mortality rates in three of four tank experiments. The mean mortality rate in live wells for the three field trials was 8% (95% CI=4-9%), with 93% of the total mortality occurring in deep-hooked fish.

Knowing the number of deep-hooked fish in each field trial, a projected mortality rate for each trial was estimated using mortality rates of deep-hooked fish in the tank experiments. This estimate was considered to be relatively conservative, since tank-held fish were likely subjected to more stress than fish caught under natural conditions. The projected mortality was weighted to account for the fact that 7% of the fish dying in the live wells were not deep-hooked. The projected-weighted mean mortality values for the field trials ranged from 5-16%, with the overall projected mean mortality for the trials equal to 6% (N=12, 95% CI=4-9%).

Therefore, mean release mortality estimates in this study ranged from 6% (field trials) to 11% (tank experiments). This level of mortality is supported by additional work conducted on flounder during the summer of 1997 in New York. Flounder caught aboard a party boat, maintained in aerated containers, then held for 72 hours in submerged cages, exhibited a release mortality rate of 12% (N=124 fish).

Estimated mortality rates observed in tank and field trials were considerably lower than the 25% release mortality rate currently used in the Fishery Management Plan for Summer Flounder. If the intent of the plan is to use a release mortality rate that reflects actual mortality under natural fishing conditions, the current rate seems conservative. It would be of interest for the MAFMC and ASMFC to evaluate effects, if any, of lower release mortality rates on annual recreational flounder catch estimates as well as size and bag limits established for achieving targeted levels of fishing mortality.

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Introduction

This project was initiated to examine hook-release mortality in the recreational fishery for summer flounder. Given that angling practices most often involve fishing for flounder with fresh bait, flounder typically strike hooks fairly aggressively, resulting in some portion of captured fish being deeply hooked. Deep hooking of fish, especially in the esophagus, has been demonstrated in other coastal species to contribute to higher levels of hook-release mortality, i.e., black sea bass (Bugley and Shepherd 1991), red drum (Jordan and Woodward 1994), spotted seatrout (Murphey *et al.* 1995,) and striped bass (Diodati and Richards 1996). The Fishery Management Plan (FMP) for Summer Flounder (Amendment 2), administered by the Mid-Atlantic Fishery Management Council (MAFMC), utilizes an estimated release mortality rate of 25% for the recreational flounder fishery (MAFMC 1991). This rate is applied in models used to calculate minimum fish size and bag limits aimed at achieving desired fishing mortality reductions in the recreational fishery. In concert with regulated fishing mortality reductions in the commercial flounder fishery, the plan's overall objective is to accomplish a gradual rebuilding of the overfished flounder stock.

Flounder shape and feeding behavior is somewhat different from other species studied to date, and no specific research has been done to examine factors contributing to release mortality in the fishery. This project utilized hooking experiments in a large tank and field fishing trials to gain insight into levels of release mortality which may occur during fishing. Tank experiments provided the opportunity to examine certain hooking and fish-releasing factors which might be associated with release mortality.

Summer flounder (*Paralichthys dentatus*) is one of the most important recreational and commercial species of the mid-Atlantic region (MAFMC 1990; 1991; 1995). Recreational landings account for a large portion of total landings of summer flounder, sometimes exceeding commercial landings. Historically, recreational landings have comprised approximately 40% of total landings of summer flounder (NMFS 1993). For 1995 and 1996, the National Marine Fisheries Service's (NMFS) Marine Recreational Fishery Statistical Survey (MRFSS) indicated that in the mid-Atlantic region, summer flounder ranked highest in number of estimated fish landed by anglers, accounting for 17% and 21%, respectively of the region's total estimated recreational catch (NMFS 1996; 1997a).

Since 1980, total east coast landings by weight for summer flounder have declined. As of 1990, commercial landings of summer flounder along the Atlantic coast dropped to their lowest level in 15 years, while the estimated recreational catch was also at a record low (MAFMC 1990). Although landings have improved slightly in recent years, they still are well below the average for past years (NMFS 1995). Assessments continue to indicate that summer flounder stocks along the entire Atlantic coast are experiencing growth and recruitment over-fishing (CBP 1991; MAFMC 1991; NMFS 1995). While the commercial-recreational flounder fishing effort declined slightly from 1995 to 1996, it remained far above the level to stop overfishing, and quotas in both fisheries were estimated to have been significantly exceeded in 1996 (NMFS 1997b). The FMP for summer flounder states that fishing mortality of flounder must be reduced significantly and that research is required to improve estimates of catch-related mortality attributed to use of certain gear, e.g., hook and line, and trawls (MAFMC 1990; 1991; 1995).

To accomplish fisheries management objectives, size limits often are implemented in an attempt to control fishing mortality and increase the spawning stock (CBP 1991). In accordance with the FMP and coordinated efforts of the Atlantic States Marine Fisheries Commission (ASMFC), the Virginia Marine Resource Commission (VMRC) in 1995 established a summer flounder recreational fishery minimum size limit of 14 inches (356 mm) total length (TL) and a creel limit of 8 fish per person per day. Hook and line fishermen were to release all under-sized flounder, as well as all fish over the creel limit. In 1997 the VMRC, in cooperation with ASMFC, had to continue making adjustments in recreational flounder fishing catch limits, increasing the size limit to 14.5 inches (368 mm) TL and the daily creel limit to 10 fish per day.

Mortalities associated with catch-and-release fishing reduce potential effectiveness of minimum size limits as the probability decreases that undersized, released fish will survive (Waters and Huntsman 1986). As the probability of survival decreases, minimum size limits become less effective as management tools. Therefore, it is important to determine the magnitude of mortality of sub-legal size fish associated with hook-and-release practices as well as larger fish released by anglers in compliance with bag limits.

As previously mentioned, the flounder FMP, in coordination with recommendations from the ASMFC Summer Flounder Board and S&S Committee (ASMFC 1991), currently uses a 25% release mortality rate in the process for estimating total annual fishing mortality in the recreational fishery. The nature of the fishery, particularly that anglers in general use live or fresh cut bait to capture the fish, warranted consideration be given to release mortality, and the rate chosen was felt to be prudently conservative and in line with limited research on coastal species (Jack Musick, VIMS, personal communication).

Research on freshwater and marine species demonstrates that release mortality rates vary widely among species under various fishing conditions (Muoneke and Childress 1994). Higher water temperatures have been correlated with higher release mortality rates in black drum and spotted seatrout in Texas (Martin *et al.* 1987). Studies on black sea bass (Bugley and Shepherd 1991) indicate release mortality rates can be higher in larger than smaller size fish; however, similar findings were not observed for red snapper (Gitschlag and Renaud 1994).

The most consistent factor contributing to release mortality appears to be hook wound location (Muoneke and Childress 1994), i.e., fish deeply hooked in the oral cavity, esophagus or gills, demonstrate higher release mortalities than those hooked in the jaw or anterior mouth area. Hook wound location is largely determined by the type and size of hook in conjunction with using fresh or live bait (as opposed to artificial lures). Correlations between higher release mortality and deeply hooked fish have been demonstrated for black sea bass (Bugley and Shepherd 1991), red drum (Jordan and Woodward 1992), and striped bass (Diodati and Richards 1996). Use of certain hook types (single versus treble) or varying hook size have demonstrated mixed results relative to impacts on release mortality in various fisheries, i.e., smallmouth bass (Weidlein 1989), red drum and spotted seatrout (Matlock *et al.* 1993), chinook salmon in the troll fishery (Orsi *et al.* 1993), and striped bass (Diodati and Richards 1996).

Methods

The primary objectives of this study were to determine flounder release mortality rates through field fishing trials and, using a large flow-through tank, examine impacts of certain practical factors on hook release mortality under controlled conditions. Tank experiments were designed to examine effects of hook wound location and fish size on release mortality along with certain popular angler conservation practices aimed at reducing release mortality in fish, i.e., removing versus not removing deeply taken hooks in "gut-hooked" fish, using wide gap versus straight shank hooks, and crimping barbs on hooks.

A non-random, angler survey was conducted at various recreational fishing shows and meetings during 1994-1995 to gain insight into flounder angling practices, i.e., bait-tackle preferences, frequency of flounder trips, preferred fishing locations, and fish handling practices, including those which anglers use to try reducing mortality in released fish. The one page questionnaire was passed out at meetings and placed on exhibit tables at fishing shows, and anglers making flounder trips during the previous fishing season were encouraged to complete it. In 1995 several questions were added to the questionnaire for 1994 fishing trips regarding: (1) whether any released flounder looked as if they might not have survived, and (2) if responding "yes" to the former question, the approximate proportion of released flounder which appeared significantly stressed or injured when released (Appendix A).

Hooking experiments were conducted in a large flow-through holding tank where possible impacts of various hooking options and fish size were tested. Field fishing trials using volunteer anglers and researchers were also completed to provide data on rates of release mortality under actual fishing situations. Tank experiments were conducted during 1994 at VIMS Eastern Shore Laboratory at Wachapreaque, Virginia (on the seaside of the Eastern Shore). Field fishing trials were completed during 1995 in the area of Wachapreaque Inlet, and off the town of Cape Charles, inside lower Chesapeake Bay (Fig. 1).

Hook types and bait combinations for the tank experiments were chosen after checking with tackle shops, charter boat captains, and recreational fishermen through the angler survey regarding preferred fishing tackle and techniques used when targeting summer flounder. With flounder, anglers often slightly delay setting the hook after first feeling the fish pick up the bait. This improves chances that the baited hook gets deeper into the fish's mouth, thereby producing higher catch rates. Coupled with the use of fresh bait, this practice also potentially increases the likelihood of flounder taking hooks deep in the mouth, especially into the esophagus.

Flounder collection and holding methods were field tested beginning in 1993 at the VIMS Gloucester Point campus. Tank experiments and field fishing trials were performed at the VIMS Wachapreague Laboratory where a tank built by the New

England Aquarium was available for use. Equally as important, flounder abundance was known to be relatively good in protected waters inside Wachapreague Inlet, the area historically supporting some of Virginia's best recreational flounder fishing.

Experimental facilities consisted of a large circular fiberglass tank (6 m/20 ft. in diameter, 1.5 m/4.5 ft. deep) with an approximate volume of 40,000 l (10,568 gal.). Since flounder are benthic fish, the level of the water in the tank was maintained at approximately 0.46-0.75 m (1.5-2.5 ft.) to allow for more rapid turnover of the tank water. The tank was set up in a flow-through mode (approximately 3 l/sec or 48 gal./min.) with raw water (salinity ranged from 29-31 ppt) pumped directly from the channel bordering the lab. The water passed through two large sand filters to reduce the organic load and improve water clarity before entering the tank. Coarse sand was added to the tank as a substrate in which the flounder could bury themselves, behavior observed in flounder held in captivity (Olla *et al.* 1972). Shade cloth was suspended over the tank to reduce exposure of the flounder to direct sunlight.

Prior to the collection of flounder, the experimental tank was divided into three sections using a modified beach seine. Half of the tank was designated as the "release" portion of the tank in which fish were placed after being hooked, thereby avoiding re-hooking fish. Initial hooking trials in the tank demonstrated that hooked and released flounder frequently took baited hooks again if not following this practice. The other half of the tank was equally divided with netting to allow separation of collected flounder into groups of "small" and "large" fish.

Summer flounder were collected using an otter trawl (10 m/ 32.8 ft. with a mesh size of 2.5 cm/ 1 in.) in the vicinity of Wachapreague, Virginia. Tows were limited to 7-10 minutes to reduce trauma and injury to fish caught in the net. The trawl net was brought on board and emptied into a plastic fish box to sort the catch. Any summer flounder showing signs of injury (abrasions, continued lethargy and/or rapid gilling), and all other non-target species were released. Those flounder that appeared to be in good condition were placed in large, aerated coolers (113.5 l /120 qt.) for transport back to the VIMS lab.

After transport to the lab, flounder were placed immediately into the experimental tank, being separated into "large" fish (> 330 mm/13 in.) or "small" fish ($\leq$ 330 mm/13 in.). Fish then were allowed several days to acclimate to holding conditions during which time they were fed live minnows on a daily basis. Fish appearance and response to the live prey were used as indicators of acclimation to the holding facilities. A smaller circular tank with continuously flowing seawater was also occasionally used to hold small catches of flounder before placing them into the experimental tank.

All fish in the experiments were marked individually using a cold or freeze brand, a method causing minimal injury and stress to the fish (Wydowski and Emery 1983). This method has been used to mark other flatfish species with no negative effects on growth, behavior, and survival (Dando and Ling 1980; Berge 1990). The branding apparatus consisted of a slotted holder with 2 cm (0.8 in.) interchangeable, metal characters. Characters were arranged and secured in the holder, then placed against dry ice for cooling. The super-cooled branding iron was then held against the flounder (upper dorsal area above the lateral line) for a few seconds to produce the brand. Brands (letter-number combinations) were visible on the flounder throughout the duration of the experiment, making it possible to identify individual fish regarding their condition and behavior.

Tank Experiments

After determination was made that fish were suitably acclimated, summer flounder were fished out of their respective areas of the tank using medium action spinning rods (4.5 kg/10 lb. test line), live bait (*Fundulus heteroclitis*), and standard hooks available in tackle shops. Once taking the bait, the fish were momentarily given slack line, a technique often used by flounder anglers. Delay times before setting hooks in fish were approximately 10 seconds in Experiment 1, a preliminary trial, then increased to 30-45 seconds in Experiments 2-5. Once setting the hook, fish were quickly reeled in and generally netted, being placed on a wooden deck level with the top of the tank (typical fighting-landing time was 30 seconds). After removed from the tank, fish were measured, cold branded, and sometimes photographed. A determination of the placement of the hook was made and any bleeding or damage from the hook noted. Hooks were then carefully removed from the fish, either by hand or with needle-nosed pliers for deeply hooked fish, the fish placed in a rectangular container of seawater for several minutes of observation, then the container and fish gently lowered into the "release" portion of the tank whereby the fish was allowed to swim out of the container.

For each small and large flounder fished out of the tank, one of the same size class was netted and removed from the tank to serve as a control for that replicate. Control fish were measured, cold branded, and placed in the release portion of the tank. After finishing the hooking process, any remaining flounder in the "catch" areas of the tank were removed and released, and the modified seine net dividing the tank removed to allow the flounder free range of the entire tank. During the observation period, flounder were generally fed live prey (*F. heteroclitus)* or freshly frozen Atlantic silversides (*Menidia menidia*). The tank was checked regularly after the hooking of fish to evaluate the immediate (within 24 hours) and longer term mortality. Dead fish were removed and necropsied to determine the probable cause of death (trauma to vital organs, significant bleeding, etc.). Temperature and dissolved oxygen in the tank were monitored daily. Sand filters were back-washed twice daily to ensure good clarity and water quality. Other water quality parameters (salinity, ammonia, nitrate, nitrite) were also monitored during the experiments.

Mortality rates for each size class and treatment group were calculated and compared statistically. Although we realized that the mortality rate data were censored data, i.e., not normally distributed, our statistical tests did not explicitly use procedures for testing limited, independent variables. Instead, we used the G-test or log-likelihood ratio method to compare mortality rates between various treatment options (Sokal and Rohlf 1981; Zar 1996) as calculated by SPSS statistical analysis software for Windows (Release 6) with Yates correction for continuity applied to all 2 X 2 tables (Norusis/ SPSS Inc. 1993).

Tank Experiments 1 and 2 were completed from late April through mid-June 1994. Experiment 1 was a preliminary trial to work out logistical problems and determine general patterns of release mortality. In Experiment 2, fish hooked in either the lip or cheek were considered control fish to increase treatment sample sizes. Efforts to continue tank experiments during the summer were frustrated by high mortalities in captured fish which began within 24 hours after the fish were placed in the tank. Mortalities appeared to be related to trawling and handling stress occurring at water temperatures greater than 25°C (77°F). In spite of reduced tow times and more gentle handling of fish in live wells during trawling operations, tank-held fish regularly experienced high mortalities throughout July and August. Tank experiments subsequently were postponed until mid-September when ambient water temperatures dropped back to approximately 25°C. Experiments 3-5 were conducted from mid-September through mid-November 1994.

Field Fishing Trials

Field fishing trials were organized using researchers and volunteer anglers with each participating boat required to record detailed catch information. Generally 2-4 boats fished most days with a mix of researchers and volunteer anglers catching fish. Researchers participated in all trials and some volunteer anglers participated in two of three trials, providing continuity in fishing experience and technique among the trials. Three trials were held, two in the Wachapreaque Inlet area (mid June and early August; salinity 30-32 ppt) and one in waters off the town of Cape Charles inside Chesapeake Bay (late September; salinity 25-28 ppt). Wachapreague trials were assisted by anglers from the Eastern Shore Chapter of the Coastal Conservation Association of Virginia. The Cape Charles trial was assisted by anglers from the Southern Gentlemen's Fishing Club at Cherrystone Campground.

Trials were organized so that participating boats fished in proximity to one another. Each boat was provided with a portable live well (120 qt./ 113.5 l) cooler outfitted with a recirculating aeration device) for holding captured flounder. In addition to aeration of the water, boat captains were instructed to regularly replace significant portions of the water about every 30 minutes to reduce stress on held fish. Efforts were made to have anglers fish with similar terminal tackle, but data forms revealed some resistance to this practice. As a result, fish in Trials 1 and 3 were primarily captured on 2/0 wide gap and 2/0 straight shank hooks, while catches in Trial 2 were largely made on #2 straight shank hooks. Hooks, fresh bait (live minnows and squid strips), and fuel were provided each boat.

Anglers were required to complete a standardized catch data form for each flounder landed. The most critical data recorded for each fish were time of catch, hook wound location, observed tissue damage or trauma to the fish from the hook, degree of bleeding, how the hook was removed, and time of death (if fish died in the live well). Captured fish were generally held in live wells approximately one to two hours before being transported to floating live cages, but fishing conditions and distances to live cages sometimes required holding fish as long as four to five hours in live wells. Fish were held in live cages a minimum of three days beyond the last day of fishing, then released. Mortalities were recorded as occurring either in live wells or in cages, the latter mortality being 24-72 hours after capture. Fish were not tagged to reduce additional stress beyond that associated with holding and transporting the fish.

Live cages for the Wachapreague trials were 1.2 m X 2.4 m X 0.6 m (4 ft. X 8 ft. X 2 ft.), having wooden framing, a plywood floor, and sides/tops made of 2.5cm/1 in. mesh galvanized wire. Cages were tethered in a protected creek, floating with their tops just at the water surface. Numerous narrow slits were cut in the plywood floors with a table saw to enhance water movement and, hopefully, retard silt accumulation (silt still accumulated on the cage floors). For Trial 1 (mid June) flounder were captured inside Wachapreague Inlet, resulting in transport distances to the live cages of about 2.4-4.8 km/1.5-3 miles (boat running time approximately 10-20 min., depending upon sea conditions). Trial 2 fish (early August) were primarily available outside the Inlet, resulting in transport distances of 4.8-9.7 km/ 3-6 miles (running time approximately 20-40 min., depending upon sea conditions).

Different cages without solid bottoms had to be used for the Cape Charles trial to accommodate an existing mooring area at Kiptopeke State Park, being loaned to the flounder project by the U. S. Fish and Wildlife Service's Office of Fishery Assistance at Gloucester. No suitable arrangements could be made in the Cape Charles harbor area for mooring the cages used in the previous trials, largely due to the volume of commercial and recreational boat traffic in the harbor. The different cages were circular (diameter=1.8 m/6 ft.; depth=1.2 m/ 4 ft.) with plywood tops. The walls and bottoms consisted of 1.3 cm/0.5 in. square mesh, plastic aquaculture netting. The cages were tethered in somewhat protected water at an old ferry boat landing at the park, approximately 8 km (5 miles) from the primary flounder fishing area.

Results

Angler Survey

Although limited in scope and sample size, the angler survey provided useful background information on flounder fishing practices, equipment preferences, and practical observations concerning hook-release mortality in the local flounder fishery. Information for the 1993 fishing season, (from 64 completed surveys), addressed fishing frequency, primary fishing location, bait-tackle preferences, and anglers' possible use of practices to reduce flounder release mortality. Information for the 1994 fishing season (78 completed surveys) also included anglers' observations which might provide some indication of possible levels of, and factors contributing to, flounder release mortality in the fishery. Responses (sample sizes) varied due to unanswered questions as well as occasional multiple responses to questions.

Survey respondees represented a broad mix of flounder fishing activity regarding both fishing frequency and areas fished. Trip frequency patterns for the 1993-94 seasons were similar. Slightly better than one third of the respondees made 1-10 flounder trips per year, just under one third made 11-20 trips per year, and 28%-29% made greater than 20 trips each year (Fig. 2). While sample size for each year was small, the responses represented considerable flounder fishing experience, an estimated 806 trips in 1993 and 934 trips in 1994. Yearly total trip estimates were derived by multiplying a conservative estimate for each trips-per-year category, e.g., 5 trips for (1-10 trips), 10 trips for (11-20 trips), and 20 trips for (>20 trips), by the number of angler responses tallied in the respective category, then summing the three products for each year.

The most frequently mentioned flounder fishing area was the Chesapeake Bay Bridge Tunnel (47% in 1993 and 26% in 1994; N=64 and 92 responses, respectively). In no particular order, other favorite fishing areas specified were either general areas (the lower or middle Bay) or specific areas, e.g. Lynnhaven, Hampton Roads, Cape Charles, the Cell, bayside Eastern Shore creeks, and seaside Eastern Shore inlets (especially Wachapreague and Chincoteague).

Bait and tackle preferences, like fishing frequency, also demonstrated similar patterns in both fishing seasons. Live bait ("minnows") and cut bait (squid or fish strips) were the most popular baits used, each accounting for more than one third of the responses for each season (Table 1; Fig. 3). Both bait types were indicated as the "bait most often used" on 17% (N=75) of surveys for the 1994 season. Strip baits dressed with a "skirt" and artificial lures/jigs represented relatively small numbers of responses in each season. Combining live and cut bait responses, fresh bait accounted for 86% and 83% of preferred bait options in the respective 1993 and 1994 seasons. If adding "strip bait with skirts" to the fresh bait category, such baits were used most often by 95% of respondees in each season.

Preferred hook types for flounder were the wide gap (or "kahle") hook (55% and 43%), followed by standard straight shank hooks (35% and 39%), and offset hooks (10% and 14%) for 1993 and 1994 (Table 1; Fig. 4). Mention of circle hooks (known for reducing deep-hooking in fish) only occurred in 1994 (4% of responses).

Many hooks are available in both long and short shank styles. Anglers' responses indicated that long shank hooks were highly preferred for flounder fishing during both fishing seasons (Table 1; Fig. 4). The most commonly mentioned hook size used for flounder was 2/0 (34% and 41% for 1993 and 1994). Smaller hooks (1/0) were used by 23% and 19% of respondees, with 25-26% using larger 3/0 hooks during the two seasons. Relatively few anglers used hooks smaller than 1/0 or as large as 4/0 (Fig. 5).

With respect to fish release practices, 31% of respondees (N=64) used no special practice; however, a significant proportion of anglers indicated using a variety of practical techniques during the 1994 season to minimize release mortality with flounder. The most popular practice was to employ some sort of dehooking device when removing the hook in fish to be released (36%). Other practices included crimping barbs on hooks (14%), careful handling of the fish (9%), and cutting the leader in deep-hooked fish (6%).

To obtain some perspective on anglers' experiences with possible release mortality during 1994 flounder fishing trips, a series of three questions asked anglers to recall occurrences of significantly stressed or injured fish being released. Regarding whether they ever experienced any fishing trips on which some proportion of released flounder "looked like they might not survive due to major dehooking damage or blood loss," anglers provided a 74% affirmative response (N= 78).

Of those anglers making an affirmative response, major factors considered contributing to possible poor survival of such released flounder were difficulty in removing a "gut" hook (72%), gill damage (24%), and warm water (4%), these being the three factors listed for consideration. Although anglers were also requested to describe "other contributing situations" which could have affected poor survival of released flounder, none were indicated (N= 71 responses with some responses containing multiple answers, e.g., removing a gut hook and gill damage). Size distribution of released flounder showing signs of stress-injury problems were as follows: <254 mm/10 in. (43%), 254-356 mm/10-14 in. (50%), and >356 mm/14 in. (7%) (N=46; 12 anglers did not respond).

Finally, if reporting that some released flounder may not have survived, anglers were requested to check off the approximate percentage of released fish which showed serious stress-injury problems. Response range options were provided because of the difficulty anglers might have responding to the question, i.e., 1-2%. 3-5%, 5-10%, 10-15%, 15-20%, 20-30%, 30-40%, 40-50%, etc., with options then increasing by 10% intervals to "all." No such problems were indicated by 26% of the anglers, while 3-5% and 5-10% of released fish were considered seriously stressed or injured by 22% and 18% of the anglers, respectively (Fig. 6).

An estimate of flounder release mortality was derived from the data in Figure 6. Assuming that all significantly stressed/injured released flounder actually died, one can take the upper limit of each response option (2%, 5%, 10%, etc., with the highest response option [>30%] being counted as 35%) and multiply it by the corresponding response rate (.02 x .11, .05 x .22, .10 x .18, etc.). Adding together the respective "weighted" response options provides a cumulative estimated flounder release mortality rate of approximately 7.5%.

Tank Experiments

Tank Experiment 1 (Preliminary Trial)

This hooking experiment was conducted to examine general release mortality patterns and significant impacts, if any, of handling and marking the fish. A total of 44 fish were hooked using rod and reel with 1/0 wide gap hooks (J. J. Scotchman-Mustad Hooks, Stock No. 1008-12). Another 44 fish were treated as control fish (not hooked but otherwise handled and marked like hooked fish). After being acclimated to the tank and readily taking live food, fish were hooked over a four day period (April 29-May 2) during which tank water temperatures ranged from 19-21°C (66-70°F). To simulate anglers' practice of momentarily delaying setting of the hook when they first sense flounder taking the bait into its mouth, line was kept slack or allowed to pull off the reel for approximately 10 seconds after a fish took the baited hook, then the hook was set.

Only eight (8) of 44 hooked fish were deeply hooked (hooked deep in the mouth-tongue, esophagus, or gills), with all release mortality occurring in these fish, i.e., no mortality occurred in lip-cheek hooked fish (N=36) or in controls (N=44). Overall mortality for the trial equaled 13.6% (6 of 44 hooked fish) with mortality in deep-hooked fish being 75.0% (Table 2). Three small fish (mean TL = 300 mm/11.8 in.) and three large fish (mean TL= 374 mm/14.7 in.) accounted for the observed deep-hooked fish mortalities, with mortality rates for the two size groups being 10.3% and 20.0%, respectively. Fish were observed for 21 days with no mortality associated with the handling or marking of fish.

During the period of hooking fish and the observation period, water temperatures averaged 17°C (63°F), ranging from 13-21°C (55-70°F).

While all mortalities in the preliminary experiment occurred in deep-hooked fish, the 10 second hook setting delay period resulted in only a small number of such fish. For tank experiments to explore effects of various hooking-releasing scenarios on release mortality, larger sample sizes of deep-hooked fish were needed. Therefore, subsequent experiments incorporated a hooking protocol using a 30-45 second delay period before setting the hook, thereby increasing the proportion of deep-hooked flounder in Experiments 2-5 (Fig. 7). Therefore, only in Experiments 2-5 were various hooking treatments and other factors such as fish size examined for effects on release mortality.

Experiment 2
Effect on Mortality of Removing and Not Removing Hooks (2/0 Hook)

Since no mortality occurred in Experiment 1 in either lip-cheek hooked fish or in non-hooked control fish, and since only 76 flounder were available for this experiment, no control fish were used. This increased sample sizes for deep-hooked and hook treatment fish groups. The primary objective of the experiment was to determine if cutting leaders to leave hooks embedded in deep-hooked fish produced different mortality rates compared to removing the hooks. The null hypothesis was that mortality rates were equal for the two hooking treatments as well as for the other variable options examined (deep versus lip-cheek hooked fish, hook wound locations, degree of bleeding, and two fish size groups).

Using a delayed hook setting period of approximately 30 seconds increased the proportion of deep-hooked fish to 45% (N= 76 fish; 34 deep-hooked), as compared to only 18% in Experiment 1. Tank water temperatures were 23-25°C (73-77°F), higher than in Experiment 1, and fish were observed for 14 days after hooking. Fish were hooked over a three day period using 2/0 long, straight shank hooks (Eagle Claw No. 231-X) and live minnows. Mortality rates, mean lengths, and sizes of the respective fish groups are shown in Table 3. A total of 12 fish died following release back into the tank, of which 10 (83.3%) were deep-hooked fish. Therefore, release mortality was 29.4% in deep-hooked fish versus 4.8% in lip-cheek hooked fish; overall mortality for all hooked fish was 15.8%. Mortalities were equally divided between those occurring within 24 hours and those occurring within 48-72 hours after release of the fish. Mortalities were primarily associated with hook damage (bleeding-clotted blood) in the pericardial cavity or gill arches.

Because mortalities were not limited to only deep-hooked fish, the analysis of factors affecting mortality included "all hooked fish" (N=76) as well as "deep-hooked fish" (N=34) (Table 4). The hooking treatment, deep-hooked or lip-cheek hooked, and hook wound location were the only variables demonstrated to significantly affect mortality rates in all hooked fish, the latter variable not being significant in deep-hooked fish. The mortality rate in deep-hooked fish was significantly greater than in lip-cheek hooked fish (Table 4). In the latter group, mortality occurred in one (1) lip-hooked fish and in one (1) fish with its eye penetrated by the hook as it exited the cheek wall. The specific cause of death of these two fish was not obvious, i.e., no significant bleeding or clotted blood was observed.

Hook wound location (categories defined in Table 4, footnote d) significantly affected release mortality (Table 4). Fish hooked in the esophagus, gills, and deep mouth area accounted for 25.0-33.3%, respectively, of all mortalities, the cumulative total for the three wound locations being 83.3% of observed mortalities. In comparison, mortalities in fish hooked either in the lip-cheek or eye accounted for 16.7% of observed mortalities.

The hooking treatment of removing or not removing hooks, i.e., trying to reduce trauma and tissue damage by cutting the leader and leaving the hook in place rather than trying to remove the hook, was examined only in deep-hooked fish (N=34). Fish in which hooks were not removed (leaders cut off close to the lip) experienced 33.3% mortality compared to 25.0% mortality in fish with hooks removed. The apparent differences, however, were not statistically significant (Table 4). Concerning the six fish dying 48-72 hours following release, they were equally divided between the two hook removal options. One hook was found on the tank bottom when the experiment was terminated, indicating a 5.6% rate of hook rejection from the 18 fish in which hooks were not removed.

Fish size did not significantly affect mortality. For all hooked fish, mortality in small and large fish was 20.0% and 9.7%, respectively; in deep-hooked fish, the size categories exhibited 38.9% and 18.8% mortality, respectively. In neither case were the rates shown to be significantly different between small and large fish (Table 4). Similarly, degree of bleeding (ranked as none, slight, moderate, or heavy) was not demonstrated to be a significant factor associated with mortality (Table 4).

Experiment 3 Effect on Mortality of Removing and Not Removing Hooks (#2 Hook)

This second experiment to examine effects of removing or not removing hooks in deep-hooked fish was conducted using #2 long, straight shank hooks (Eagle Claw No. 231-X), smaller hooks than the 2/0 hooks used in the previous experiment. Some charter captains and private boat anglers indicated using the smaller #2 hooks. Using the smaller hook and an average hook setting delay period of 45 seconds resulted in a larger percentage of deep-hooked fish than in Experiment 2 (45% versus 69%, respectively, see Fig. 7). Conducted in early November, the mean water temperature for Experiment 3 was 15°C (59°F), ranging from 11-16°C (52-61°F).

The null hypothesis was the same as in Experiment 2: that mortality rates were equal between examined variable options and hooking treatments. The hooking protocol was changed to include a control fish group, smaller hooks, and a longer hook setting delay period. In comparison to Experiment 2, more fish were available for testing (N=101), there was a seven day hooking period, and fish were observed for 12 days. A total of 74 fish were hooked of which 50 were deep-hooked, 24 lip-cheek hooked, and 27 used as controls (handled and marked, but not hooked). Mortality rates, fish sizes, and sample sizes for fish groups appear in Table 5.

Overall mortality was 13.5% in hooked fish (N=74), with all mortalities occurring in deep-hooked fish, i.e., no mortality observed in either non-deep-hooked fish nor in control fish (Table 5). The mortality rate in deep-hooked fish was 20.0% (N=10) with 80.0% of the mortalities occurring within a few hours of hooking and release. Two fish, both with hooks removed, survived for five days (120 hours) before dying. Variables significantly affecting mortality were the deep versus lip-cheek hooked condition, hook wound location and hook point orientation (point up versus down) (Table 6).

With all release mortality (10 fish) occurring in deep-hooked fish, fish hooked in the esophagus or gills accounted for 90.0% and 10.0% of the mortality, respectively. Of the deep-hooked fish, 34% (17 fish) were hooked in the deep mouth-tongue area, but none of these fish died.

Although not examined in Experiment 2, hook point orientation was noted in deep-hooked fish in this experiment. The majority of mortality in Experiment 2 resulted from hook damage in the pericardial cavity, located immediately ventral to the opening of the esophagus. Hooks with their points turned down have a greater likelihood of causing damage in this area. The mortality rate in fish with hook points down was 33.3% versus 4.3% in fish with hook points up, significantly different rates (Table 6). Of the 10 deep-hooked fish which died, 90% had hook points turned down.

As in the previous experiment, the hook treatment of removing or not removing hooks in deep-hooked fish was not shown to significantly affect mortality rate. In Experiment 3, mortality in fish for which hooks were removed was 23.3% compared to 15.0% for fish in which hooks were not removed (Table 5). This was a reversal of the trend observed in Experiment 2 in which mortality was 25.0% and 33.3% for the respective hook removal treatments. Examining only "esophagus-hooked" fish (N=29) in Experiment 3, there was 54.5% mortality in fish with hooks removed compared to 16.7% with hooks not removed, however, the rates were not significantly different (Table 6). In addition, neither degree of bleeding nor fish size were shown to significantly affect mortality rates in deep-hooked flounder (Table 6).

Five hooks were found on the bottom of the tank at termination of the experiment. Hooks were not removed from 20 deep-hooked flounder; therefore a 25% hook rejection rate occurred in such fish.

Experiments 2 and 3 Combined Data

Although carried out in June and November at different water temperatures (23-24°C/73-77°F versus 15-16°C/59-61°F, respectively) and with different size hooks (2/0 versus #2 long shank hooks), Experiments 2 and 3 tested the same hooking treatment, i.e., hooks removed-hooks not removed. Therefore, mortality rates in the separate experiments were compared by hooking treatment to determine whether the two data sets might be combined to obtain larger sample sizes (Table 7). Within each hooking treatment, comparisons were analyzed for two fish groups, those representing all deep-hooked fish (hook location esophagus, gills, deep mouth, or deep tongue) and a subset of the group, fish hooked in the esophagus-gills. The latter group accounted for 70% of deep-hooked fish mortality in Experiment 2 and 100% in Experiment 3.

Comparing the data sets for fish groups in which hooks were removed demonstrated the greatest apparent disparity in mortality rates for fish hooked in the esophagus-gills (22.2% and 50.0%), but the differences were not significant between the two experiments. Likewise, no significant differences in mortality rates between the experiments were demonstrated for the other hook treatment options compared, i.e., hooks removed (all deep-hooked fish) and hooks not removed (all deep-hooked fish, and esophagus-gill hooked fish) (Table 7). The lack of significant mortality differences between the two experiments also indicated that water temperature (23-24°C/73-75°F and 15-16°C/59-61°F, respectively) did not affect mortality rates, a factor examined in more detail across Experiments 2-5 (see Overview—Tank Experiments 2-5).

Given these results, the two data sets were combined for further analysis of hook treatment effects on release mortality rates. Comparisons between hook treatments (hooks removed-hooks not removed) were made for all deep-hooked fish (N=85) and subgroups of these fish. Mortalities among deep-hooked fish only occurred in fish with hooks lodged in the esophagus, gills, and deep tongue areas. The all deep-hooked fish group includes these subgroups as well as fish hooked in the less specific deep mouth area. In spite of the larger sample sizes provided by the combined data sets, no significant differences in mortality rates could be demonstrated between deep-hooked fish groups in which hooks were removed versus not removed (Table 8).

While the referenced mortality rates were not significantly different in the combined data sets, plotting the rates for fish in which hooks were removed versus not removed across a spectrum of increasingly specific hooking wound locations in deep-hooked fish demonstrated a clear pattern of divergence between the hook removal treatments (Fig. 8). To determine whether the two trend lines were truly different, dummy variables (1-4) were substituted for the four deep-hooked fish wound groups, respectively, and linear regressions calculated. Using the Chow Test (Maddala 1977) , the respective slopes proved to be significantly different (F= 24.26, df=2,4, p>0.01).

Experiment 4-Effect of Hook Shape on Mortality (#2 Straight Shank and Wide Gap Hooks)

This experiment was conducted in late September 1994 when tank water temperatures were 21.8-23.5°C (71-74°F). The hook treatment compared long, straight shank #2 Eagle Claw hooks No. 231-X) and wide gap #2 J. T. Scotchman Mustad hooks (Stock No. 1008-12). Only 36 flounder were available for the experiment, resulting in 12 fish in each hook treatment group and 12 control fish. Hooking of fish occurred over a period of four days and a hook setting delay time of approximately 30 seconds was used. Within each hook treatment group, fish were equally divided between small fish and large fish, and fish were held for 14 days. The null hypothesis was that mortality rates were equal for the two hook shapes as well as among hook wound locations, bleeding categories, and fish size groups. Mean lengths, sample sizes, and resulting mortality rates are indicated for various fish groups in Table 9.

The mortality pattern was generally consistent with other experiments, but the mortality rate was the highest observed among Experiments 2-5. Mortalities occurred within 24 hours of hooking and releasing of fish and only in deep-hooked fish (hooked in the esophagus or gills). Deep-hooked fish exhibited a mortality rate of 76.9% (10 of 13 fish), equivalent to an overall mortality rate of 41.7% (10 of 24 fish) for all hooked fish (Table 9). Mortality rates were significantly different between all hooked fish versus control fish as well as deep-hooked versus lip-cheek hooked fish (Table 10).

Effects of variables on mortality were primarily examined in all hooked fish rather than deep-hooked fish, since the latter group only included 13 individuals. Hook wound location (lip-cheek, eye, esophagus, and gills) and degree of bleeding significantly affected mortality rates in all hooked fish (Table 10). Of eleven fish hooked in the esophagus, ten died, accounting for all observed mortality. Fish exhibiting moderate or heavy bleeding experienced 80-83% mortality compared to 0-33% in fish exhibiting no or slight bleeding.

No significant differences in mortality could be demonstrated between hook treatments (straight shank or wide gap hooks) for all hooked fish (N=24), each treatment exhibiting a 41.7% mortality rate. In the small sample of deep-hooked fish, straight shank and wide gap hooks produced mortality rates of 83.3% and 71.4%, respectively, non-distinguishable rates given the small sample size. Similarly, no significant difference in mortality rates was observed in small fish compared to large fish, each group exhibiting 33.3% and 50.0% mortality, respectively (Tables 9 and 10). Examination of fish experiencing mortality indicated that hemoraging associated with hooks penetrating into the pericardial cavity or damaging gill arches accounted for the majority of mortalities.

Because hook wound location and degree of bleeding significantly affected mortality rates in all hooked fish (Table 10), researchers examined whether the hook treatments (different hook shapes) might produce different patterns either in the location of hook wounds or degree of bleeding. However, in light of the small sample sizes for each hook treatment (N=12), no significant differences could be demonstrated in hook wound patterns between straight shank and wide gap hook treatments (G=4.25, df=3, p>.05) nor in patterns of bleeding (G=4.76, df=3, p>.05).

Similarly, for all hooked fish no differences in hook wound location patterns were demonstrated between small (N=12) and large fish (N=12) (G=1.48, df=3, p>.05).

Experiment 5 Effect of #2 Straight Shank Barbed and Non-Barbed Hooks on Mortality

This experiment was carried out in mid-October with tank water temperatures ranging from 15.3-16.8°C (59.5-64.2°F). The hooking treatment involved using barbed #2 straight shank hooks and and non-barbed hooks, the latter produced by crimping the hook barbs flat with pliers. Hooking protocol was the same as in previous experiments with fish hooked over a period of four days. The available flounder (N=57) were equally divided among the two hooking treatment groups and a control group (N=19 for each group). Since all mortality in the previous experiment occurred within 24 hours of hooking and releasing the fish, the observation period was reduced to seven days for determining short term and delayed mortality. The null hypothesis was that mortality was equal between barbed and non-barbed hook groups as well as among hook wound locations, bleeding categories, and fish size groups.

All release mortality occurred in deep-hooked fish with no mortality observed beyond 24 hours of hooking and releasing fish. Deep-hooked fish exhibited a mortality rate of 50.0%, resulting in an overall mortality rate of 18.4% in all hooked fish. Morality rates, mean fish lengths, and sample sizes for fish groups are presented in Table 11. Mortality rates in hooked fish and control fish were significantly different (Table 12).

As in Experiment 4, because of relatively small numbers of deep-hooked fish (N=14), the effects of variables on mortality were examined primarily in all hooked fish (Table 12). For the hook treatments of non-barbed versus barbed hooks, mortality rates were not significantly different in all hooked fish (26.3% and 10.5%, respectively). Neither were mortality rates different between small fish (13.6%) and large fish (25.0%). Both hook wound location and degree of bleeding in all hooked fish affected release mortality (Table 12). As previously noted, there were no mortalities in fish hooked in lip-cheek or eye areas, but deep-hooked fish (hooked in the esophagus or gills) experienced 100% mortality. Fish demonstrating either no bleeding or slight bleeding when released experienced a 3.7% mortality rate compared to 54.5% in fish having moderate to heavy bleeding. Hemorrhaging associated with hooks penetrating the esophagus wall into the pericardial cavity and damage to gill arches accounted for the majority of deaths. On several occasions hooks were taken so deeply into the esophagus that, upon removal, stomach tissue was pulled out of the esophagus into the oral cavity.

Examination of the relative distribution of hook wound locations among fish hooked with barbed versus non-barbed hooks (N=19 fish in each group) indicated distinctive patterns between the two groups (G=8.73, df=3, p<.05). For fish hooked with barbed hooks, 84.2% were hooked in either the lip-cheek or eye areas compared to 42.1% of fish hooked with non-barbed hooks. Conversely, only 15.8% of barbed-hooked fish were deep-hooked (hooked in the esophagus or gill areas) while 57.9% of non-barbed-hooked fish were deeply hooked.

Bleeding patterns were also significantly different between fish hooking treatments (G=13.08, df=3, p<.01). In fish hooked with barbed hooks, 94.7% of the fish exhibited no bleeding or only slight bleeding upon release while only 5.3% of the fish showed moderate to heavy bleeding. A more balanced pattern was observed in non-barb-hooked fish with 47.3% and 52.7% of fish, respectively, falling into the none-slight versus moderate-heavy bleeding categories.

Overview Tank Experiments 2-5

Except in Experiment 2, all release mortality occurred in deep-hooked fish. Overall for Experiments 2-5, deep-hooked fish accounted for 95% of mortalities (37 of 39 fish), and of such fish, 76% were hooked in the esophagus, 16% in the gills and 8% in the deep mouth-tongue area. Mortality rates for the referenced wound locations were 42.4%, 28.6% and 12.5%, respectively, with significant differences only between esophagus and deep-mouth/tongue-hooked fish (G=5.72, df=1, p< .05).

Considering total release mortality for the experiments (N=39), 80% of the mortalities occurred within 24 hours of hooking the fish. However, some mortality occurred after longer periods, i.e., 48-72 hours in Experiment 2 and 120 hours in Experiment 3. These somewhat delayed mortalities accounted for 15% and 5%, respectively, of the total mortality observed.

With nearly all release mortality occurring in deep-hooked fish, hook wound location was the only variable consistently associated with mortality in all four experiments (Table 13). Bleeding demonstrated mixed results, and hook point orientation was only examined in deep-hooked fish in Experiment 3. No association could be demonstrated between mortality and the hooking options comparing hook shapes, hooks with or without barbs, and the practice of leaving or not leaving hooks in deep-hooked fish (Table 13).

Increasing the hook setting delay period produced higher rates of deep-hooked fish (36.8%-67.8%), in comparison to the preliminary experiment (18.2%), thereby increasing sample sizes for testing various hook treatments (Table 14). Rates of deep-hooked fish and hook setting delay period were correlated for Tank Experiments 1-5 (Spearman correlation coefficient = 0.89, $p<.05$); however, no correlation existed between the variables in Experiments 2-5 (Spearman correlation coefficient = 0.77, $p>.05$).

Mortality primarily occurred only in deep-hooked fish, but proportions of deep-hooked fish were significantly different among Experiments 2-5 ($G=12.53$, $df=3$, $p<.05$). Therefore, mortality rates for such fish were weighted by the percentage of all hooked fish which were deep-hooked, the weighted mortality rates ranging from 6.8% - 22.6% (Table 14 and Figure 9). The weighted mean mortality rate of the four experiments (N=4, arcsine transformed data) was 11.2% (95% CI=3.0-23.6%). Regarding the time frame in which tank mortalities occurred, 80% of mortalities were observed within 24 hours of release, 95% within 48-72 hours, and 5% 120 hours following release (N=39).

Mean tank water temperatures in Experiments 2-5 varied from 15°C (59°F) to 24°C (75°F); however, there was no correlation between weighted release mortality and water temperature (Spearman correlation coefficient = 0.00, $p>.05$). To further confirm that water temperature was not a significant predictor of weighted release mortality, a simple regression analysis was done assigning dummy variables to mean temperature extremes (temperatures < 16°C = 0; temperatures >23°C = 1); temperature was not significant ($T=.864$, $p>.10$).

Field Fishing Trials

Although the three field fishing trials were conducted over a period of four months (June through September 1995), water temperatures during each trial were similar, ranging from 23-26°C (73.4-78.8°F) with mean temperatures ranging from 23.5-24.7°C (74.3-76.5°F). Higher water temperatures were anticipated for Trial 2, conducted at Wachapreague Inlet July 31-August 4, but prevailing southwest winds during the period contributed to a band of cooler ocean water forming along the barrier island beaches which affected inlet water temperatures.

Hook types and sizes, varying somewhat among trials in accordance with volunteer anglers' consistency in using hooks provided by researchers, consisted primarily of wide gap and straight shank 2/0 or #2 hooks. In Trials 1 and 3, fish were primarily caught on 2/0 wide gap hooks (46-56%), followed by 2/0 straight shank hooks (25-29%), with a few fish also taken on smaller #2 straight shank hooks. In contrast, #2 straight shank hooks were used almost exclusively in Trial 2, accounting for 95% of the catches.

Fishing trial mortalities were examined in two modes, those occurring in boat live wells (3-5 hours post-hooking) and mortalities observed in floating cages to which fish were transferred from the live wells (24-72 hours post-hooking). Although fish were not marked or tagged when captured, low daily mortalities in live wells were recorded on fish capture log sheets. Combining trial data, deep-hooked fish accounted for 93% of all live well mortalities (N=15). With fish not being tagged, hook wound location could not be determined for cage mortalities.

From data recorded for each captured fish, it was determined that deep-hooked fish represented 20.0%, 13.3%, and 10.0% of catches for Trials 1-3, respectively (Table 15), levels considerably lower than the enhanced rates (created by increased hook setting delay periods) used in Tank Experiments 2-5 (Fig. 10). The rate of deep-hooked fish in "preliminary" Tank Experiment 1 (minimal hook setting delay period of 10 seconds) was 18.2%, within the range observed in the field trials. Rates of deep-hooked fish were not statistically different among the field trials ($G=3.23$, $df=2$, $p>.05$). For the combined field trials, deep-hooked fish accounted for 14.2% of all fish caught.

Examining release mortality across Trials 1-3, mortalities in live wells were 9.2%, 8.9% and 6.3%, respectively (Tables 16-18 and Fig. 11). Cage mortality was (7.7%) in Trial 1, but higher in Trials 2 and 3 (20.0% to 22.5%, respectively). Mortality rates in live wells were not significantly different among trials. Cage mortality rates were significantly different among the trials, but only between Trials 1 and 3. Total mortality rates (live well and cage mortalities combined) were similar among trials (16.9%, 28.9%, and 28.8%, respectively) (Table 19).

Differences in cage mortality rates were the result of several circumstances. Regarding Trials 2 and 3, transport times to the cages from the fishing areas were greater compared to Trial 1, and rougher sea conditions sometimes occurred during transport of fish to the cages. Considerable differences in ambient water temperature occurred in Trial 2 between the fishing and cage mooring areas (25°C/77°F versus 32°C/90°F), very likely adding stress to the fish. To avoid loss of significant fishing time due to the long transport time to cages in Trial 3, fish were often held 4-5 hours in live wells before transported to cages, holding times longer than for either Trials 1 and 2. Finally, the plastic mesh bottoms of cages used for Trial 3 appeared to irritate the ventral sides of fish, a condition not observed in Trials 1 and 2 where cages had smooth, wooden bottoms.

As a result of the referenced inconsistences in conditions among cage-held fish in each trial, cage mortality data were not used in determining overall mortality for the trials. Rather, short-term mortality (occurring within 72 hours) was estimated for each trial by applying deep-hooked fish mortality rates in Tank Experiments 2-5 to the number of deep-hooked fish caught in the respective trials. This provided four projected mortality estimates (numbers of fish projected to have died) for each field trial, each of the numerical values then converted to projected and weighted percent mortality based upon the number of fish captured in each trial. Projected mortality rates were positively weighted to account for the fact that only 93.3% of live well mortalities for all trials (14 of 15 fish) were deep-hooked fish (Table 20, note a). Projected mean mortality rates for Field Trials 1-3 were 8.3%, 5.6% and 4.2%, respectively, with corresponding projected-weighted rates being 8.9%, 6.0% and 4.4% (Table 20).

Both projected and weighted mean mortality rates (arcsine transformed data) were not significantly different among the three trials (Kruskal-Wallis test, χ^2= 2.036 and 2.192, respectively, df=2, p>.05, respectively). Combining trial data (Table 20), the projected mean release mortality was 5.9% and projected-weighted mean mortality was 6.3% (95% CI=4.1-9.1%). The obvious association between rate of deep-hooked fish in individual and combined field trials, and projected-weighted mean mortality is illustrated in Figure 12.

Discussion

The angler survey results for the 1993 and 1994 fishing seasons, while representing a relatively small and non-random sample of flounder anglers, provided background information based upon hundreds of flounder fishing trips. The survey data documented that Virginia's recreational flounder fishery depends almost entirely upon use of live and fresh bait, the fishing protocol used in both the tank experiments and field fishing trials. Anglers' preferences for long shank hooks and a mix of standard J-shaped hooks with wide gap hooks were also reflected in the hook mixture used throughout the tank and field fishing exercises.

In not using hooks larger than 2/0 in size, tank and field fishing protocols varied somewhat from hook preferences specified in the angler survey; however, survey results indicated 2/0 size hooks were preferred by the majority of anglers. Muoneke and Childress (1994) indicated an inconsistent pattern existed among studies examining hook size effect on mortality. Using a wide range of hook sizes (#12 to 5/0), Diodati and Richards (1996) found hook size did not have a significant effect on striped bass survival rates in a salt water pond.

Minimum post-hooking observation periods of seven days (168 hours) were used for the tank experiments and three days (72 hours) for caged fish during field trials. Unfortunately, the cage mortality data in the field trials was of questionable use as a result of inconsistencies among trials. The longer observation times in tank experiments were used to determine whether significant mortalities occurred beyond 72 hours, the period considered appropriate for determining short-term release mortality (Malchoff and Heins 1997). In one experiment (Experiment 3) release mortality in deep-hooked fish (hooks removed) occurred five days after release (5% of total experimental mortality). However, 95% of release mortality occurred within 72 hours of hooking fish, and 80% occurred within 24 hours, results similar to those of other studies (Warner and Johnson 1978; Matlock *et al.* 1993). Jordan and Woodward (1994) found release mortality in red drum held in a flow-through tank to occur primarily over a 10 day period for fish hooked in the maxilla or gills and in which hooks were removed. However, mortality in esophagus-hooked fish was essentially immediate, occurring within less that 20 minutes. Deep-hooked fish accounted for 95% of the flounder mortality in this study's tank experiments, and 76% of all deep-hooked flounder mortality occurred in esophagus-hooked fish.

Both tank experiments and field fishing trials demonstrated that hook location. i.e., hooks taken deep in the mouth, especially those "swallowed" into the esophagus, was the principal factor associated with release mortality, the deep-hook location accounting for 95% of observed release mortality in four tank experiments and 93% of mortalities observed in live wells during three field trials. Anglers associated gut-hooked fish and the difficulty of removing hooks from such fish with release mortality in the flounder fishery (angler survey). Use of live or fresh bait by the majority of flounder anglers likely contributes to the ingestion of hooks deep into the mouth and esophagus, an association well documented in other studies (Munoeke and Childress 1994). However, the relationship does not always hold, i.e., in spotted seatrout and red drum (Matlock *et al.* 1993).

Angling experience has been shown to be a significant explanatory variable associated with striped bass release mortality (Diodati and Richards 1996). Use of smaller hooks and bottom fishing rigs resulted in higher rates of red drum hooked in the gill and esophagus (Jordan and Woodward 1994). Therefore, use of delayed setting of the hook by experienced flounder anglers could contribute to higher rates of deep-hooked flounder. Rates of deep-hooked fish ranged from 10-20% in the field trials, similar to those observed in red drum (23%) (Jordan and Woodward 1994), spotted seatrout (17%) (Murphy *et al.* 1995), and striped bass (13%) (Diodati and Richards 1996).

Examining hook wound location in more detail confirmed results of other researchers that higher mortality rates occur when hooks are taken in the esophagus or gills. In Tank Experiments 2 and 3, 70-90% of observed release mortality occurred in fish which "swallowed" the hook, the barb catching in the esophagus, or the hook point lodging in the gills. All release mortality in Experiments 4 and 5 occurred in either esophagus or gill-hooked fish. In striped bass, Diaodati and Richards (1996) found depth of hook wound location in the oral cavity to be one of the more highly significant variables associated with release mortality. Jordan and Woodward (1994) observed the highest release morality in gut-hooked red drum (53%); gill-hooked fish exhibited a 32% mortality rate and jaw-hooked fish, 8% mortality. Clapp and Clark (1989) found that 75% of release mortality in smallmouth bass caught on natural baits occurred in fish hooked in the esophagus or stomach. In a study of black sea bass having a low overall release morality rate (4.7%), only esophagus-hooked fish died (Bugley and Shepherd 1991).

Comparisons of practical hook treatment options available to anglers which might reduce release mortality in flounder, i.e., using wide gap hooks, crimping hook barbs or cutting leaders and leaving hooks in deep-hooked fish, did not demonstrate significant mortality reductions. Hook shape has been examined relative to effects on release mortality. Full circle hooks have been demonstrated to result in higher hooking rates in the jaw and corner of the mouth in Alaska's chinook salmon troll fishery (Orsi *et al.* 1993) and the winter bluefin tuna fishery off North Carolina (Lucy *et al.* 1996). Concerns over frequency of gut-hooking when chumming for striped bass in Maryland resulted in field studies of full circle hooks, British circle hooks and straight shanked hooks, full circle hook reducing gut hooking in field trials (K. Lockwood, MD DNR, unpublished 1996 data).

Studies on impacts of barbed versus barbless hooks on release mortality have largely been limited to freshwater fisheries (Muoneke and Childress 1994), whereas research on hook type in saltwater fisheries has focused more on single versus treble hooks (Matlock *et al.* 1993; Diodati) and Richards 1996) or hook size (Otway and Craig 1993; Diodata and Richards 1996). Differences in mortality between barbed and barbless hooks have typically been shown to be non-significant in studies on cutthroat trout (Dotson 1982) and chinook salmon (Butler and Loeffel 1972), supporting the results of this study. In 1996-97, evaluation of effects of barbed and barbless hooks on release mortality in trout species prompted Oregon's Department of Fish and Wildlife to repeal most of its barbless hook requirements (Charles Corrarino, personal communication).

Tank experiments provided indications that not removing hooks from esophagus-hooked fish reduced release mortality. Testing larger sample sizes of esophagus-hooked fish would likely demonstrate significantly lower mortality in flounder in which hooks were not removed. Experienced anglers and fishery conservation programs typically recommend that when releasing fish, one should cut the leader in deep-hooked fish, rather than removing the hook, to reduce stress and tissue trauma in the fish, i.e., Malchoff *et al.* (1992), the Chesapeake Bay Foundation's Careful Catch Program (CBF undated), and the Virginia Game Fish Tagging Program (Bain and Lucy 1997).

Positive effects on release mortality of not removing hooks in fish hooked in the esophagus (gut hooked) have been demonstrated in smallmouth bass (Weidlein 1989) and rainbow trout (Schill 1996; Schisler and Bergersen 1996). A trend towards lower release mortality in gut-hooked fish in which hooks were not removed was shown to occur in red drum (Jordan and Woodward 1994) and in a small sample (N=5) of esophagus-hooked black sea bass (Bugley and Shepherd 1991). Loss or rejection rates of hooks left in fish were 18-25% in rainbow trout (Schisler and Bergersen 1996), similar to the hook rejection rate in one tank experiment of this study.

When cutting leaders and leaving deeply-taken hooks in rainbow trout, Schill (1996) found 60% and 74% hook rejection rates in stream and hatchery raceway caught fish, respectively.

Fish size (two size groups) in flounder was not demonstrated in this study to significantly affect mortality, findings supported by numerous studies reviewed in Muoneke and Childress (1994). Fish size was not found to be a significant factor affecting release mortality in rainbow trout caught using four different trolling techniques in a New Zealand lake (Dedual 1996). However, fish size has been demonstrated in a limited number of studies to be either positively or negatively correlated with release mortality, indicating that interaction of fish size with other fishing-condition variables may be important in evaluating this factor. Schisler and Bergersen (1996) found that mortality probability decreased with rainbow trout length, but only by 1.3% for 200 mm (7.9 in.) and 400 mm (15.7 in.) fish played for one minute. Increasing playing time to five minutes resulted in the larger fish having a 4.0% increase in mortality probability over the small fish. A study of lake trout in the Great Lakes indicated significantly higher release mortality in the smallest fish size category (457-508 mm/18.0 in. TL) compared to six larger size groupings, the largest of which was 762-813 mm/30-32 in. TL (Loftus et al. 1988). Conversely, in fresh to low salinity waters (0-4.2 ppt), mortality was positively correlated with fish length in red drum and striped bass (May 1990; Muoneke and Childress 1994). Jordan and Woodward (1994), studying red drum in salt water (30-34 ppt), showed release mortality varied somewhat with size, ranging from 23-35% in smaller fish (200-250 mm/7.9-9.8 in.) to 10-16% in larger fish (275-350 mm/10.8-13.8 in.); the higher mortality in smaller fish was attributed to a greater percentage of gill-esophagus hooking in the 250 mm (9.8 in.) size class.

Overall weighted mortality rates were 7-9% in Tank Experiments 2, 3, and 5, with the one exception being Experiment 4 (23%). Fish used in Experiment 4 were captured by trawl during September, only a few weeks following July-August mean weekly water temperatures of 24-28°C (75-82°F). This was the only tank experiment in which captured fish experienced prolonged high ambient water temperatures before being subjected to various hooking treatments in the tank. This circumstance may have contributed to greater cumulative stress associated with capture, transport to the laboratory, and handling, as compared to the other experimental fish groups. As a result, the fish may have been less tolerant of hooking and handling stress during the course of Experiment 4. Cumulative effects of typically sublethal factors may eventually lead to death, even if the factors do not individually exceed physiological tolerance limits for a particular species (Wedemeyer *et al.* 1990).

Water temperature differences among tank experiments were not shown to significantly affect release mortality. These results are in contrast to some studies on striped bass (Harrell 1988; May 1990). With respect to spotted seatrout, water temperature has not been demonstrated to consistently affect release mortality (Hegen *et al.* 1987; Martin *et al.* 1987; Murphy *et al.* 1995).

Mean field trial mortality in live wells ranged from 6-9%, projected-weighted mean mortality estimates for the field trials were 4-9%, and the projected-weighted mean mortality estimate for combined field trial data was 6%. Derived using deep-hooked fish mortality rates from Experiments 2-5, the projected-weighted mortality estimates for the field trials are likely conservative, i.e., higher than would occur under actual flounder fishing conditions. Tank-held fish experienced considerable handling and tank-associated stress which would not occur under normal fishing conditions. Likewise, fish held in live wells also likely experienced more stress than would occur in the fishery whereby undersized fish are typically released overboard immediately after being landed.

With the exception of the one tank experiment, the experimental and field trial mortality rates were similar in magnitude to those found by Bugley and Shepherd (1991) for black sea bass (4.7%), Diodati and Richards (1996) for overall striped bass mortality (9%), Malchoff and Heins (1997) in weakfish (2.6%), and Matlock *et al.* (1993) for red drum (4.1%) as well as spotted seatrout (7.3%). This study's mortality rates were lower, but likely not significantly different from those also found in red drum (16-16.1%) by Jordan and Woodward (1994), as well as in spotted seatrout (14-19% for all bays) by Hegen *et al.* (1984).

Comparing this study's estimates of release mortality to the rate of 25% used in the MAFMC Flounder Fishery Management Plan (FMP) indicates that the FMP value might be conservative (Fig.13). The weighted mean release mortality rate for Tank Experiments 2-5 was 11.2% (95% CI=3.0-23.6%), mean live well mortality in field trials was 8.1% (95% CI=4.5-12.6%), and the weighted-projected mean mortality estimate for combined field trials was 6.3% (95% CI= 4.1-9.1%). Field Trial 1, in which live well and cage-held fish were less stressed than in Trials 2 and 3, exhibited an overall mortality of 16.9%. Although derived from a small sample of anglers, the anglers' survey provided an estimated release mortality rate for flounder of 7.5% which, were it doubled (15%), would be below the FMP's current rate. Finally, a summer 1997 study on flounder caught aboard a New York party boat found a release mortality rate of 12.1% (one trial, N=124 fish; Mark Malchoff, New York Sea Grant Extension, personal communication).

In light of this study's results, it would be useful for the MAFMC, in cooperation with the ASMFC, to evaluate effects of lower levels of release mortality on annual recreational fishery catches and impacts, if any, on recreational size and bag limits required to meet target fishing mortality levels. If nothing else, such efforts might help anglers more strongly support flounder fishing regulations which take into account a range of release mortality rates based upon research results.

Considering additional research needs, further work on associations of hook shape, and possibly hook size, might reveal that the rate of release mortality in flounder, especially among less-experienced anglers, could be reduced. For example, full circle hooks are now available in smaller sizes (2/0-5/0), this hook shape having been demonstrated to reduce "gut-hooking" in other fisheries. Field studies in which significant numbers of flounder were caught, i.e., possibly using party boat anglers, would provide an opportunity to compare such hooks with more traditional hooks. Catch rates of legal size fish on the various hooks tested would also need to be examined, otherwise anglers might prove reluctant to change hook styles, even if there was evidence that circle hooks reduced release mortality. Regarding the issue of cutting leaders (not removing hooks) when flounder are hooked in the esophagus or gills, a better understanding is needed of hook rejection rates and impacts of non-rejected hooks on long-term mortality.

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Tables

Table 1. Bait and hook style preferences for flounder indicated in angler surveys.

	1993 Season	1994 Season
Bait Preferences	N = 83[a]	N = 106[a]
Live Bait	46%	49%
Cut Bait	40%	34%
Strip Bait with Skirt	10%	12%
Artificial (jig, etc.)	5%	5%
Hook Style Preferences	N = 69[a]	N = 79[a]
Standard Straight Shank Hook	35%	39%
Offset Hook	10%	14%
Wide Gap or "Kahle" Hook	55%	43%
Circle Hook	0	4%
Hook Shank Preferences	N = 53[a]	N = 73[a]
Long Shank Hook	62%	70%
Short Shank Hook	38%	30%

[a]Responses (N) may vary from number of surveys completed due either to missing responses or multiple responses to certain questions.

Table 2. Preliminary tank experiment 1 - release mortality rates, mean lengths and sample sizes of flounder.

	All Hk Fish	Control Fish	Deep-Hk Fish	Lip-Ck Hk Fish	Small Fish	Large Fish
Mortality	13.6%	0%	75.0%	0%	10.3%	20.0%
Mean TL (mm)	304	303	348	294	267	374
TL Range (mm)	212-445	213-455	273-412	212-445	212-327	336-445
N	44	44	8	36	29	15

Table 3. Tank experiment 2-release mortality rates, mean lengths, and sample sizes of flounder by category.

	All Hk Fish	Deep Hk Fish	Lip-Ck Hk Fish	HK-Rem Fish	Hk Not Rem Fish	Small Hk Fish	Large Hk Fish
Mortality	15.8%	29.4%	4.8%	25.0%	33.3%	20.0%	9.7%
Mean TL (mm)	320	341	303	320	359	270	392
TL Range (mm)	201-521	218-521	201-414	218-460	223-521	201-330	336-521
N	76	34	42	16	18	45	31

Table 4. Tank experiment 2 - factors examined for effects on release mortality rates in "all hooked fish" (N=76) and deep-hooked fish (N=34); G test significance, p≤.05*, p≤.01.**

Factor	Release Mortality (%)	Sample Sizes (N)	d.f.	G Value All Hk Fish	G Value Deep Hk Fish[a]
Deep vs. Lip-Cheek Hooked (Hk) Fish	29.4/4.8	34/42	1	6.83**	-----
Hk Removed vs. Not Removed	25.0/33.3	16/18	1	-----[b]	0.02
- Esophagus + Gill Hook Fish	27.3/25.0	11/16	1	-----[b]	0.00
Hook Wound Location[c]	AHF=2.6/25.0/21.4/30.8/42.9 DHF=21.4/30.8/42.9	76/34[d]	4/2	12.39*	1.04
Degree of Bleeding[e]	AHF=12.5/8.0/20.0/44.4 DHF=37.5/14.3/20.0/44.4	76/34[f]	3/3	5.87	2.49
Small vs. Large Fish	AHF=20.0/9.7 DHF=39.9/18.8	76/34[g]	1/1	0.80	0.82

[a]Fish hooked in esophagus, gills, or deep mouth/tongue.
[b]Hook treatment comparisons not warranted.
[c]All Hooked Fish (AHF) wound locations: lip-cheek/eye/esophagus/gills/deep mouth-tongue; Deep-Hooked Fish (DHF) wound locations: esophagus/gills/deep mouth-tongue.
[d]AHF wound locations (N=38/41/14/13/7)/DHF wound locations (N=14/13/7).
[e]Degree of Bleeding: none/slight/moderate/heavy.
[f]AHF bleeding (N=32/25/10/9)/DHF bleeding (N=8/7/10/9).
[g]AHF small vs. large fish (N=45/31)/DHF small vs. large fish (N=18/16).

Table 5. Tank experiment 3-release mortality rates, mean lengths, and sample sizes of flounder by category.

	All Hk Fish	Control Fish	Deep Hk Fish	Lip-Ck Hk Fish	Hk Rem Fish	Hk Not Rem Fish	Small Hk Fish	Large Hk Fish
Mortality	13.5%	0%	20.0%	0%	23.3%	15.0%	11.1%	17.2%
Mean TL (mm)	299	292	316	264	290	355	244	384
TL Range (mm)	180-544	178-437	180-544	181-505	180-415	193-544	180-331	333-544
N	74	27	50	24	30	20	45	29

Table 6. Tank experiment 3 - factors examined for effects on release mortality rates in deep-hooked fish (N=50), G test significance, $p \leq .05$*, $p \leq .01$.**

Factor	Release Mortality (%)	Sample Sizes (N)	df	G Value
Deep Hk/Lip-Cheek Hk/Controls	20.0/0/0	50/24/27[a]	2	15.19**
Deep Hk vs. Lip-Cheek Hk Fish	20.0/0	50/24	1	3.97*
Hk Removed vs. Hk Not Removed	23.3/15.0	30/20	1	0.13
- Esophagus - Gill Hk fish	47.7/16.7	15/18	1	2.21
- Esophagus Hk Fish	54.5/16.7	11/18	1	2.99
Hook Wound Location	31.0/25.0/0[b]	29/4/17[b]	2	9.62**
Degree of Bleeding	15.8/12.5/10.0/38.5[c]	19/8/10/13[c]	3	3.61
Hook Point Up vs. Down	4.3/33.3	23/27	1	4.83*
Small vs. Large Fish	11.1/17.2	45/29	1	0.16

[a]All fish (N = 101).
[b]Esophagus/Gill/Deep Mouth-Tongue fish groups.
[c]No Bleeding/Slight Bleeding/Moderate Bleeding/Heavy Bleeding fish groups.

Table 7. Tank experiments 2 and 3-release mortality rate comparisons within hook treatment groups, G test significance, p≤.05*.

Hook Treatment	Mortality Exp. 2	Mortality Exp. 3	N_2N_3	df	G Value
Hooks removed (all deep hk fish)	25.0%	25.8%	14/31	1	0.00
Hook removed (esophagus & gill hk fish)	22.2%	50.0%	9/16	1	0.88
Hooks not removed (all deep hk fish)	33.3%	15.0%	20/20	1	1.20
Hooks not removed (esophagus & gill hk fish)	27.8%	16.7%	18/18	1	0.16

Table 8. Tank experiments 2 and 3 (combined data)-release mortality rates in fish with hooks removed and hooks not removed, G test significance, p≤.05*.

Deep Hooked Fish Groups	Mortality Rates Hooked Removed	Mortality Rates Hooks Not Removed	Nr/Nnr	df	G Value
All deep hooked fish	23.9%	23.7%	46/38	1	0.00
Esop. & Gills & Deep tongue hooked fish	36.7%	24.3%	30/37	1	0.69
Esophagus & Gill hooked fish	38.5%	20.6%	26/34	1	1.52
Esophagus hooked fish	42.9%	20.7%	14/29	1	1.34

Table 9. Tank experiment 4-release mortality rates, mean lengths, and sample sizes of flounder by category.

	All Hk Fish	Deep Hk Fish	Lip-Ck Fish	Control Fish	St. Shank Hk Hk Fish	Wide Gap Fish	Small Fish	Large Fish
Mortality	41.7%	76.9%	0%	0%	41.7%	41.7%	33.3%	50.0%
Mean TL (mm)	312	335	285	336	312	311	240	383
Range (mm)	182-467	182-467	185-394	167-442	182-424	185-467	182-325	337-467
N	24	13	11	12	12	12	12	12

Table 10. Tank experiment 4-factors examined for effects on release mortality rates in all hooked fish (N=24); G test significance, p≤.05*, P≤.01.**

Factor	Release Mortality (%)	Sample Sizes	df	G Value
Deep Hk/Lip-Cheek Hk/Controls	76.9/0/0	12/12/12[a]	2	9.94*
Deep Hk vs. Lip-Cheek Hk Fish	76.9/0	13/11	1	11.51**
Hook Wound Location	0/0/90.9/0[b]	24	3	25.90*
Degree of Bleeding	0/33.3/80.0/83.3[c]	24	3	18.37**
Straight Shank vs. Wide Gap Hook	41.7/41.7	12/12	1	0.00
Small vs. Large Fish	33.3/50.0	12/12	1	0.17

[a]All fish (N = 36).
[b]Lip-cheek/eye/esophagus/gills.
[c]Same categories as in Table 6.

Table 11. Tank experiment 5-release mortality rates, mean length and sample sizes of flounder by category.

	All Hk Fish	Deep Hk Fish	Lip-Ck Hk Fish	Control Fish	Barb Hk Fish	Barbless Hk Fish	Small Hk Fish	Large Hk Fish
Mortality	18.4%	50.0%	0%	0%	10.5%	26.3%	13.6%	25.0%
Mean TL (mm)	298	324	283	294	296	300	231	391
Range (mm)	166-436	175-436	166-426	179-462	166-426	175-436	166-324	336-436
N	38	14	24	19	19	19	22	16

Table 12. Tank experiment 5-factors examined for effects on release mortality rates in all hooked fish (N = 38); G test significance, p≤.05*, p≤.01.**

Factor	Release Mortality (%)	Sample Sizes	d.f.	G Value
Deep Hk/Lip-Cheek Hk/Controls	50.0/0/0	19/19/19[a]	2	7.78*
Deep Hk vs. Lip-Cheek Hk Fish	50.0/0	14/24	1	11.57**
Hook Wound Location	0/0/50.0/50.0[b]	38	3	16.90**
Degrees of Bleeding	0/33.3/50.0/62.5[c]	38	3	15.76**
Barbed Hk vs. Non-Barbed Hk	10.5/26.3	19/19	1	0.70
Small vs. Large Fish	13.6/25.0	22/16	1	0.22

[a]All fish (N = 57).
[b]Same as in Table 10.
[c]Same as in Table 6 and 10.

Table 13. Factors affecting flounder release mortality in tank experiments; G test significance, $p \leq .05$*, $p \leq .01$.**

Fish Deeply Hooked vs. Not Deeply Hooked	* Exp. 3; ** Exps. 2,4,5
Hook Wound Location	* Exps. 2-4; **Exp. 5
Hook Not Removed vs. Hook Removed	ns Exps. 2 and 3 or Exps. 2 and 3 Combined
#2 Straight Shank vs. Wide Gap Hook	ns Exp. 4
Barbed vs. Barbless Hook	ns Exp. 5
Degree of Bleeding	ns Exps. 2 and 3; ** Exps. 4 and 5
Fish Size (≤ 13 in/330 mm vs. > 13 in)	ns Exps. 2-5
Hook Point Up vs. Down in Fish	* Exp. 3

Table 14. Summary of tank experiment results, including weighted release mortality of all hooked fish in each experiment.

Tank Exp. No.	Hook Size/Type	Water Temp	Experimental Hk Treatment	Total No. Fish	Percent Hooked	Percent Hk[a] Fish Dp Hk	Release Mortality Rate by Hook Group: Dp Hk Fish	Non-Dp Hk Fish	Control Fish	All Hk Fish	Weighted[f] All Hooked Fish
1	1/0 Wide Gap	63F (17C)	None-Preliminary Experiment	88	50.0 (44Fs)[b]	18.2 (8Fs)[b]	75.0% (6Fs)[c]	0% (N=44)[d]	0% (N=44)[d]	13.6% (6Fs)	2.5%
2	2/0 Long Straight Shank	75F (24C)	Removing vs. Not Removing Hk	76	100 (76Fs)	44.7 (34Fs)	29.4% (10Fs)	4.8% (2Fs)	— —[e] (— —)	15.8% (12Fs)	8.6%
3	#2 Long Straight Shank	59F (15C)	Removing vs. Not Removing Hk	101	73.3 (74Fs)	67.6 (50Fs)	20.0% (10Fs)	0% (N=24)	0% (N=27)(10Fs)	13.5%	9.1%
4	#2 Long Straight Shank & Wide Gap	73F (23C)	Standard Straight Shank vs. Wide Gap Hk	36	66.7 (24Fs)	54.2 (13Fs)	76.9% (10Fs)	0% (N=11)	0% (N=12)	41.7% (10Fs)	22.6%
5	#2 Long Straight Shank	61F (16C)	Barbed vs. Barbless Hk	57	66.7 (38Fs)	36.8 (14Fs)	50.0% (7Fs)	0% (N=24)	0% (N=19)	18.4% (7Fs)	6.8%

[a]Percent of all hooked fish which were deep hooked.

[b]Equivalent number of fish (Fs).

[c]Number fish equivalent to percent mortality.

[d]If group release mortality = 0%, N = group sample size.

[e]No "control" fish (handled and marked, but not hooked) were used to maximize sample size in hooked fish groups.

[f]Weighted "all hooked fish" mortality rate: (Mortality Rate of All Hooked Fish x Percent of Hooked Fish Deeply Hooked) = Weighted Release Mortality for All Hooked Fish; for Exp. No. 2, weighted mortality was "adjusted" for fact that only 83% of mortality occurred in deep hooked fish (10 of 12 fish), i.e. (Weighted All Hooked Fish Mortality ÷ 0.83 = "Adjusted" Weighted Release Mortality for All Hooked Fish).

Table 15. Field fishing trial parameters.

	Trials		
	1	**2**	**3**
Dates Fished (1995)	6/13-16	7/31-8/4	9/19-21
Area Fished	Wach. Inlet	Wach. Inlet	Cape Charles
Mean Water Temp (°C)	23.5 (74.3°F)	24.7 (76.5°F)	24.5 (76.1°F)
Mean Fish Total Length (mm)	316 (12.4 in)	345 (13.6 in)	316 (12.4 in)
Total Length Range (mm)	210-502 (8.3-19.8 in)	248-559 (9.8-22.0 in)	216-559 (8.5-22.0 in)
Dominant Hook Type	2/0 Strght. Shank and Wide Gap	#2 Strght. Shank	2/0 Strght. Shank and Wide Gap
Deep Hooked Fish Rate (%)	20.0	13.3	10.0
No. Anglers Fishing	9	8	8

Table 16. Trial 1 field fishing release mortalities (deep hooked fish equaled 20.0% of total catch).

Day	No. Fish Caught	Live Well No.	Mortality Percent	Cage No.	Mortality Percent	Total No.	Mortality Percent
1	19	1	5.3	0	0	1	5.3
2	17	0	0	4	23.5	4	23.5
3	16	2	12.5	0	0	2	12.5
4	7	3	23.1	1	7.7	4	30.8
Overall	65	6	9.2%	5	7.7%	11	16.9%

Table 17. Trial 2 field fishing release mortalities (deep hooked fish equaled 13.3% of total catch).

Day	No. Fish Caught	Live Well No.	Mortality Percent	Cage No.	Mortality Percent	Total No.	Mortality Percent
1	9	2	22.2	0	0	2	22.2
2	11	1	9.1	5	45.4	6	54.5
3	17	1	5.9	4	23.5	5	29.4
4	7	0	0	0	0	0	0
5	1	0	0	0	0	0	0
Overall	45	4	8.9%	9	20.0%	13	28.9%

Table 18. Trial 3 field fishing release mortalities (deep hooked fish equaled 10.0% of total catch).

Day	No. Fish Caught	Live Well No.	Mortality Percent	Cage No.	Mortality Percent	Total No.	Mortality Percent
1	26	1	3.8	11	42.3	12	46.1
2	34	2	5.9	7	20.6	9	26.5
3	20	2	10.0	0	0	2	10.0
Overall	80	5	6.3%	18	22.5%	23	28.8%

Table 19. Comparison of mortality rates in field fishing trials ($N_1/N_2/N_3$ = 65/45/80); G test significance, $p \leq .05$*; $p \leq .01$.**

Mortality Component	Mortality Rate (%) T_1	T_2	T_3	df	G Value
Live Wells	9.2	8.9	6.3	2	0.53
Cages	7.7	20.0	22.5	2	6.88*[a]
Total	16.9	28.9	28.8	2	3.39

[a]Trials 1 and 3 significantly different (G = 6.28*, df = 1).

Table 20. Projected and weighted field trial flounder release mortalities based upon trial's deep-hooked fish and tank experiment mortality rates in deep-hooked fish.

Field Trial	No. Fish Caught	Percent Fish Dp Hk	No. Dp Hk Fish	Projected/Weighted[a] Field Mortality				Projected Mean Mortality (%)	Weighted Mean Mortality (%)
				0.200[b]	0.294	0.500	0.769		
1	65	20.0	13	2.6/2.8 4.0/4.3%[c]	3.8/4.1 5.8/6.2%	6.5/7.0 10.0/10.8%	10.0/10.7 15.5/16.5%	8.3[d] (2.0 - 17.8)	8.9[d] (2.4 - 19.0)
2	45	13.3	6	1.2/1.3 2.7/2.9%	1.8/1.9 4.0/4.2%	3.0/3.2 6.7/7.1%	4.6/4.9 10.2/10.9%	5.6 (1.6 - 11.8)	6.0 (1.4 - 12.7)
3	80	10.0	8	1.6/1.7 2.0/2.1%	2.4/2.6 3.0/3.2%	4.0/4.3 5.0/5.4%	6.2/6.6 7.8/8.2%	4.2 (1.2 - 9.0)	4.4 (1.2 - 9.5)
Trials Combined	190	-----	27	--------	--------	---------	---------	5.9[e] (3.8 - 8.4)	6.3[e] (4.1 - 9.1)

[a]Projected mortality = (No. Dp Hk Fish x Tank Exp. Mortality Rate in Dp Hk Fish); weighted mortality accounts for fact that only 93.3% of live well mortalities (14 of 15 fish) in field trials were deep-hooked fish, therefore mortalities were weighted (increased) accordingly, i.e., (Projected Mortality ÷ 0.933 = Weighted Mortality).

[b]Mortality rates in deep-hooked fish from tank experiments 2-5, 30-45 second hook setting delay times (rates presented in ascending order, see Table 14).

[c]Percent projected/weighted mortality based upon number fish captured in trial.

[d]Mean percent mortality and 95% confidence interval in parenthesis (N = 4; calculated using arcsine transformed data).

[e]Mean percent mortality and 95% confidence interval in parenthesis (N = 12; calculated using arcsine transformed data).

Figures

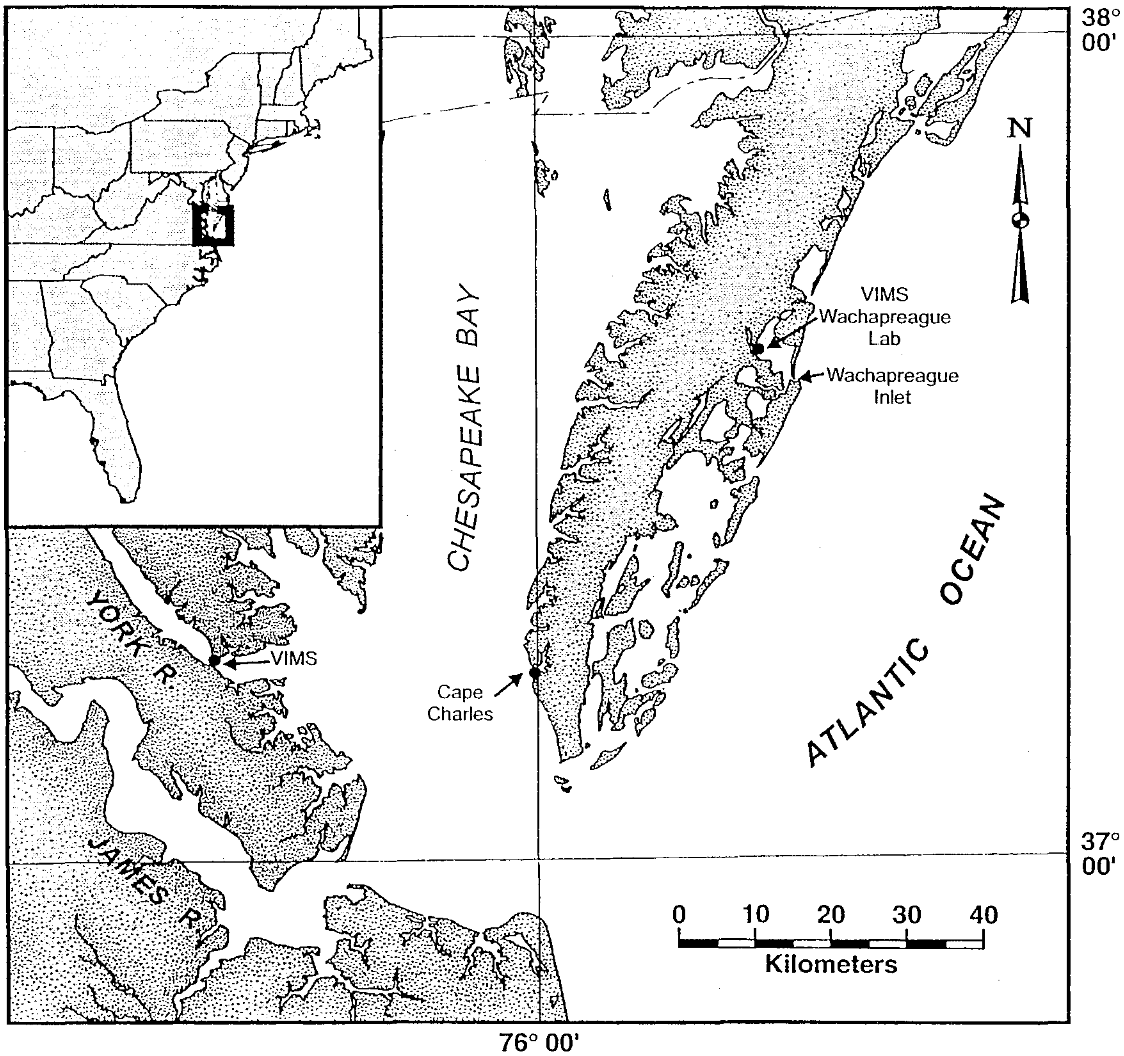

Figure 1. Location of tank experiment work (VIMS Wachapreague Lab) and field fishing trials (Wachapreague Inlet and Cape Charles).

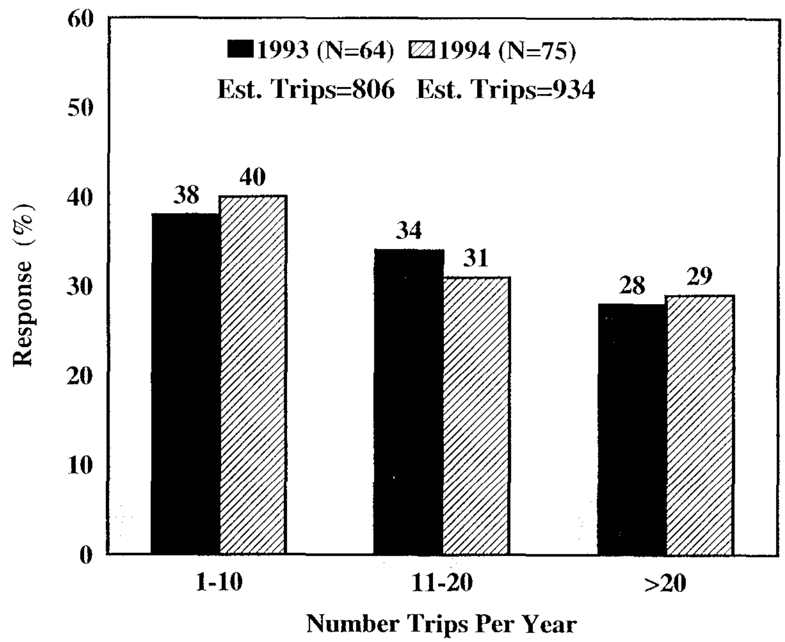

Figure 2. Anglers' flounder trips during 1993-94.

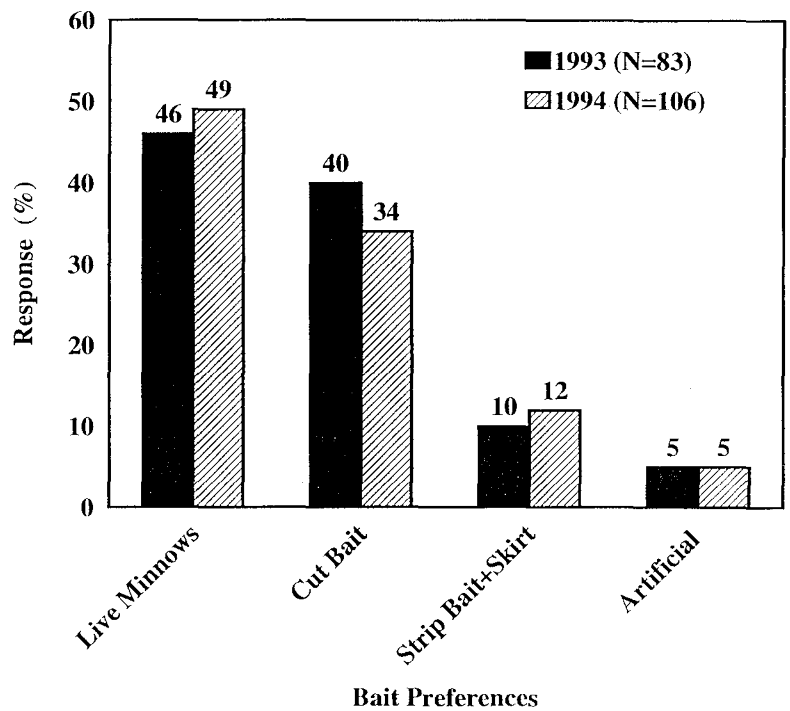

Figure 3. Anglers' primary bait for flounder.

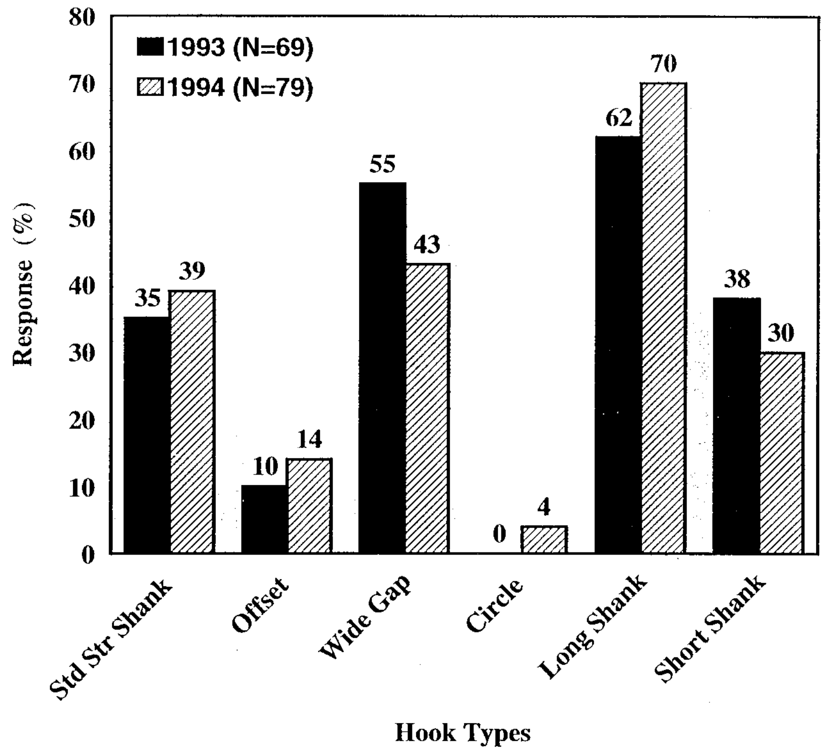

Figure 4. Anglers' preferred hook types for flounder.

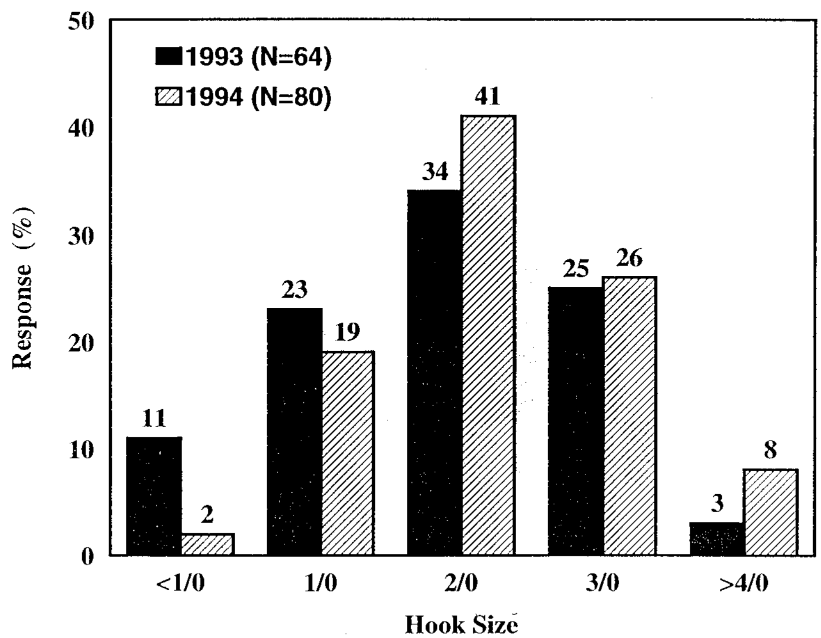

Figure 5. Anglers' preferred hook size for flounder.

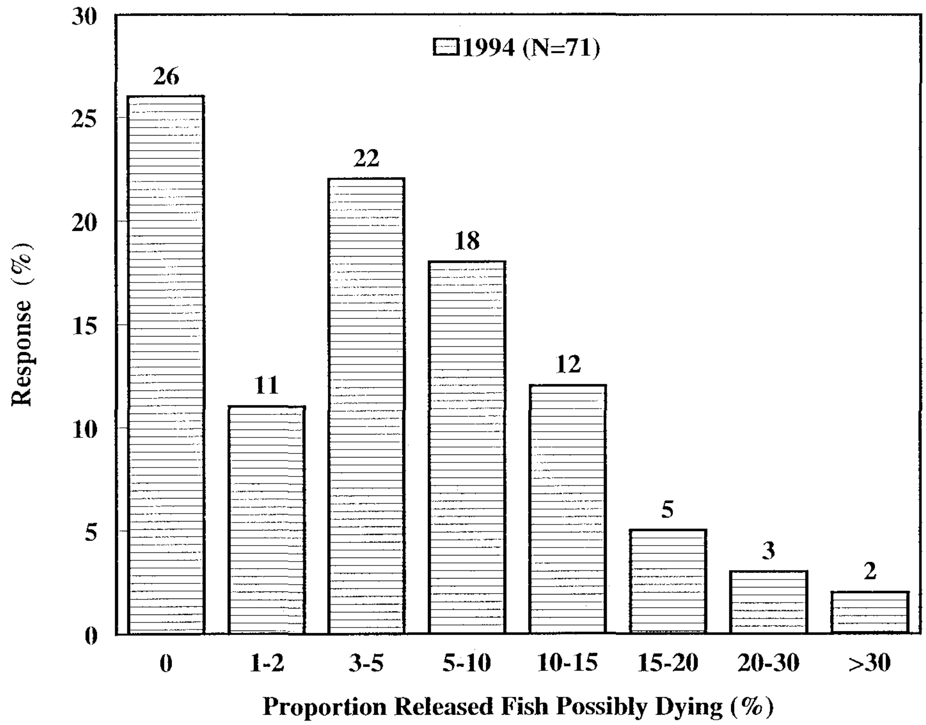

Figure 6. Anglers' estimated "possible" flounder release mortality.

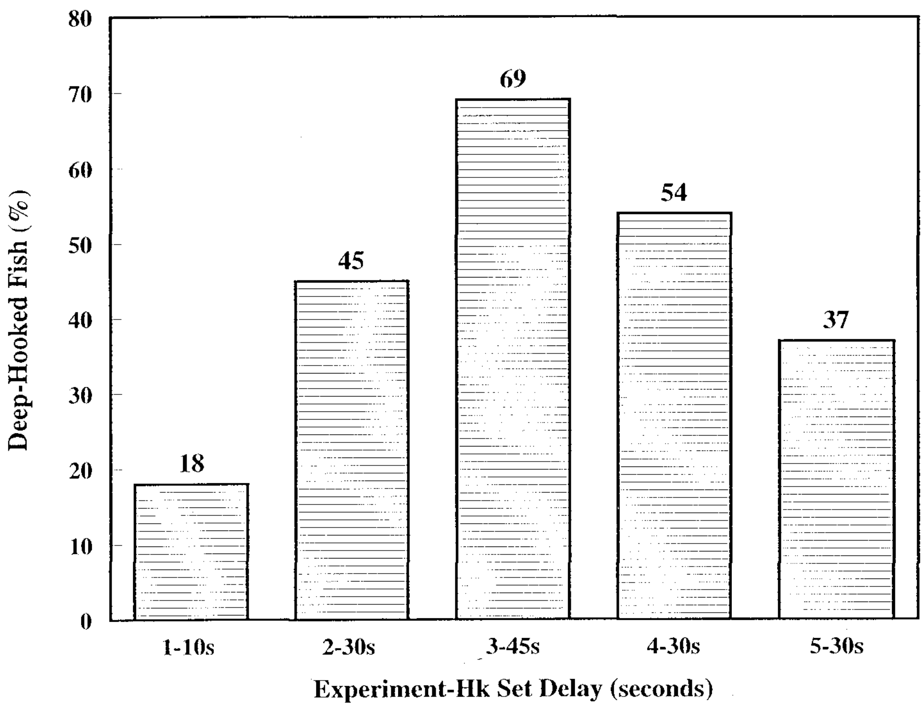

Figure 7. Delayed hook setting and frequency of deep-hooked fish.

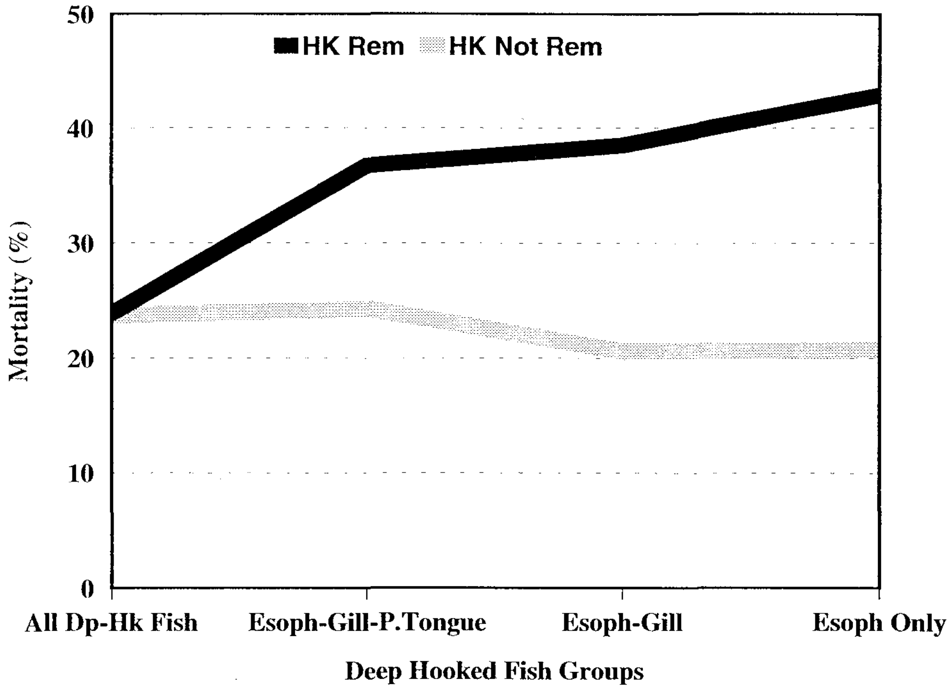

Figure 8. Release mortality as a function of removing versus not removing hooks in subgroups of deep-hooked flounder (Exps. 2-3 combined).

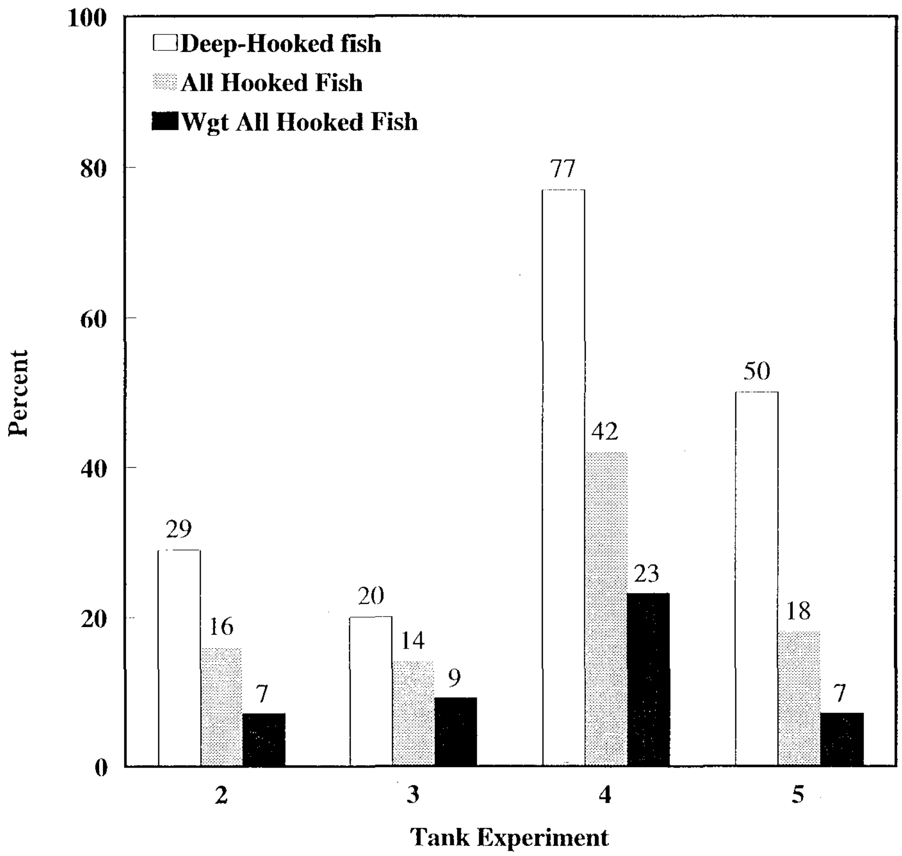

Figure 9. Observed and weighted tank release mortality (rounded to whole percent).

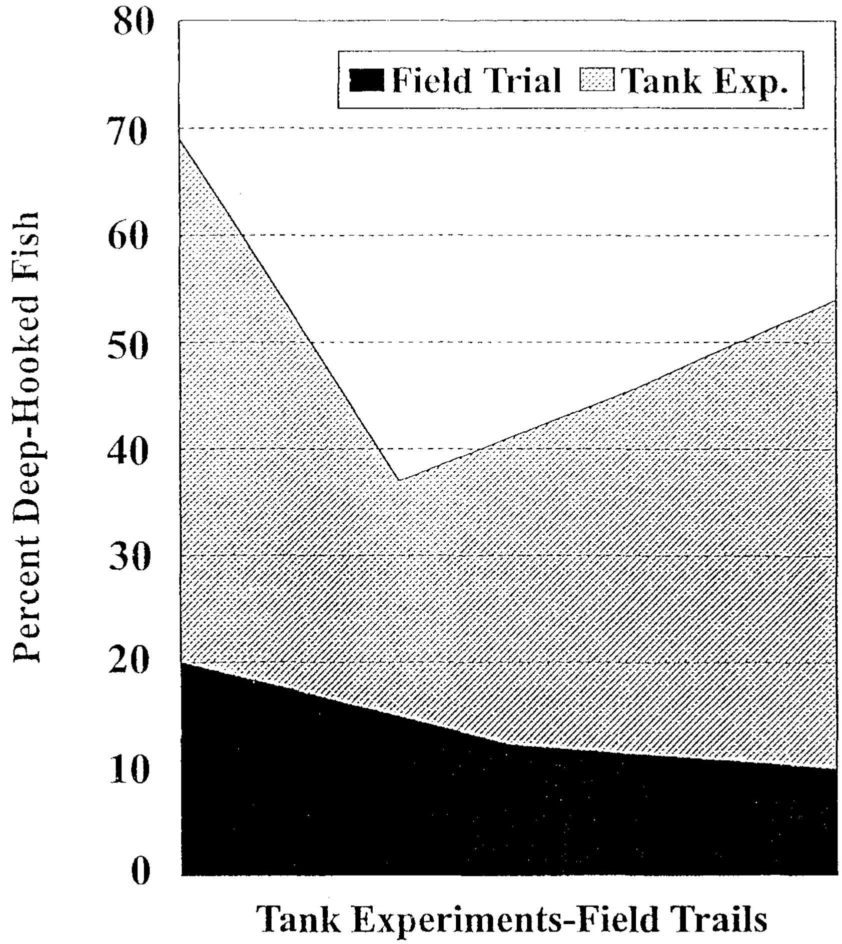

Figure 10. Rates of deep-hooked flounder in field trials versus tank experiments (Exps. 2-5).

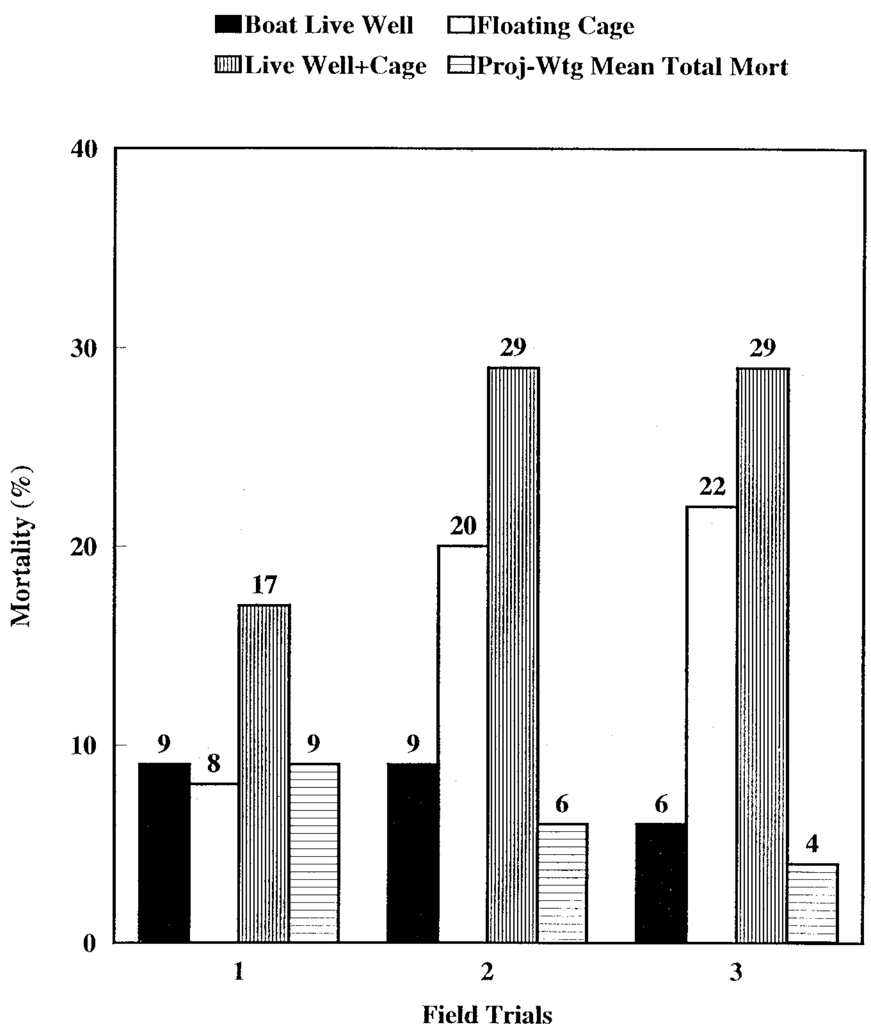

Figure 11. Actual mortality and projected-weighted mean total mortality in field fishing trials (rounded to whole percent).

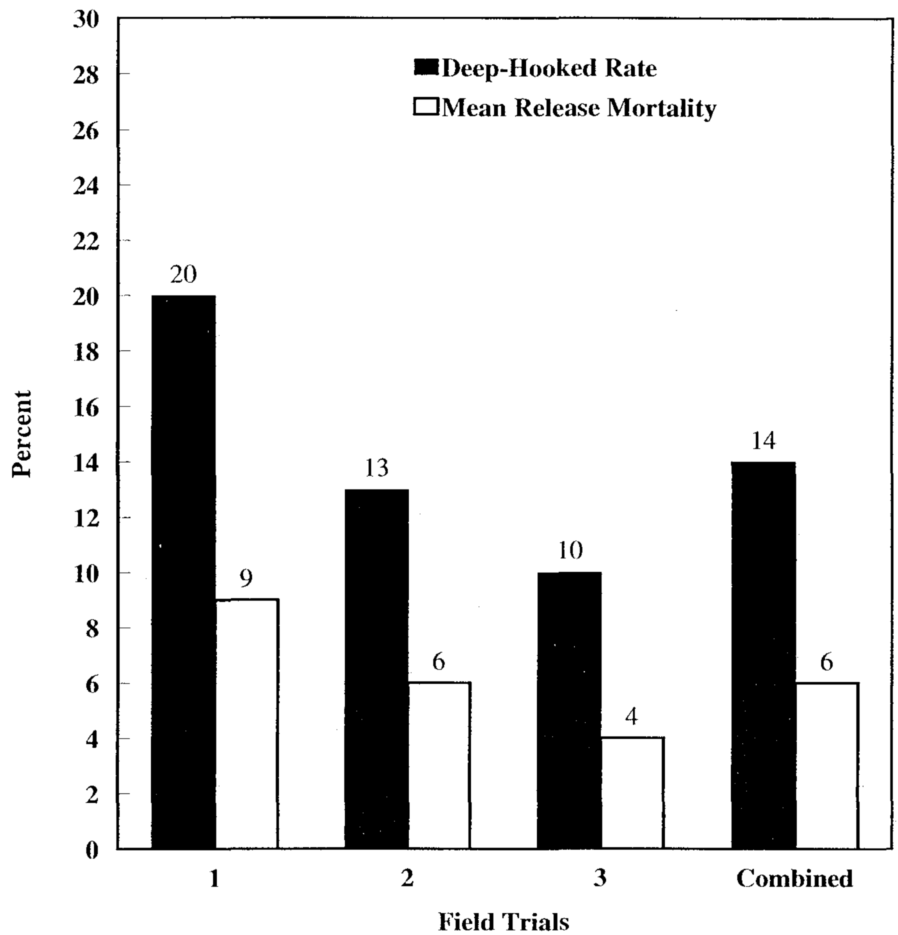

Figure 12. Angler rate of deep-hooked flounder versus projected-weighted mean field trial release mortality (rounded to whole percent).

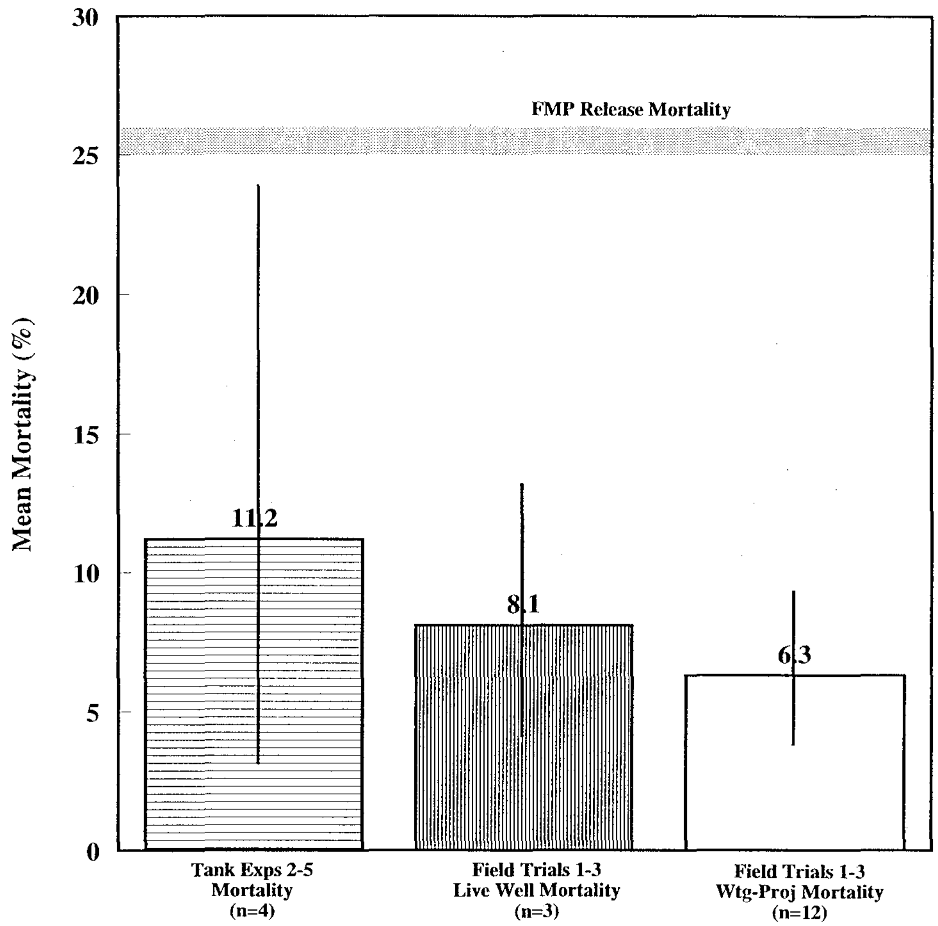

Figure 13. Mean release mortality rates (with 95% CI) from tank and field data compared to Flounder FMP value (25%).

Appendix A

Angler Survey Form (distributed as one page, printed both sides)

VIMS Summer Flounder Fishing Survey For Hooking Mortality Study

Note: The following information is confidential. Information from this survey will help characterize typical summer flounder fishing practices. Funded by saltwater license funds, the study is underway at our Wachapreague Lab. Your help in completing this survey is greatly appreciated. **Please circle the appropriate responses.**

1. How many times in 1994 did you fish for summer flounder?

   a) 0 b) 1-10 c) 11-20 d) more than 20 times

2. In what general area did you most often flounder fish?

   a) Wachapreague

   b) Chesapeake Bay Bridge Tunnel

   c) Other (specify)

3. What bait do you most often use when fishing for flounder?

   a) live bait (silversides or minnows)

   b) cut bait (squid or fish)

   c) strip bait with skirt

   d) artificial baits (jigs, etc.)

4. If fishing for flounder with live or cut bait, what hook type do you most often use?

   a) standard (straight) shank hooks

   b) offset hooks

   c) Kahle or wide gap hooks

   d) circle hooks

5. Considering your answer above, what metal or finish are your flounder hooks? ____________ Not Sure ( )

6. Do you prefer to use short sank ( ) or long shank ( ) hooks when fishing for flounder? (*Please check one)*

7. What size hooks do you generally use?

   a) less than 1/0

   b) 1/0

   c) 2/0

   d) 3/0

   e) 4/0

   f) greater than 4/0

8. Do you practice any techniques thought to reduce mortality or damage when flounder fishing (crimping barbs, use of dehooking devices, etc.)? *please specify*

Angler Observations about Injury and Survival of Released Flounder

1. During 1994 flounder trips, did you and/or your fishing party ever **release flounder that looked like they may not survive** due to major de-hooking damage or blood loss? Yes ( ); No ( ) [CHECK] (if checked YES, please continue; if NO, stop)

2a. If answered YES above, please indicate what you felt was the **one major factor** contributing to possible poor survival of the released flounder [CHECK or describe]; difficulty removing a gut-hook ( ); gill damage ( ); warm water; other situations? Describe

2b. It would help if you could SPECIFY:

Approximate **Size of Flounder** showing stress/injury problems: [CHECK] less than 10" ( ); 10-14" ( ); over 14" ( )

Hook Type and Hook Size Used at the time (long shank #2 hooks, 4/0 wide gap hooks, etc).

3. Regarding your response above (2a), please estimate the following. Of the flounder that you and/or your fishing party released, approximately **what percentage** would you say showed serious stress/injury problems? [CHECK ONE OPTION]

1-2% ( ); 3-5% ( ); 5-10% ( ); 10-15% ( ); 15-20% ( ); 20-30% ( ); 30-40% ( ); 40-50% ( ); 50-60% ( ); 60-70% ( ); 70-80% ( ); 80-90% ( ); ALL ( )

4. Finally, approximately how many flounder trips did you take in 1994? ______ (No. trips).

Of these flounder trips, on approximately **how many trips** do you recall seeing at least some flounder, when released, having the stress/injury problems indicated above? [CHECK or SPECIFY]: 1 Trip ( ); 2 Trips ( ); more than 2 Trips? _____ (indicate how many).

If you have any questions regarding this survey or overall study, or if you prefer to mail this survey at a later date, please contact or mail to: Jon Lucy or Tracy Holton, Virginia Institute of Marine Science (VIMS), Sea Grant Marine Advisory Program, College of William and Mary, P.O. Box 1346, Gloucester Point, VA 23062 (804) 642-7166.

If you are interested in obtaining the results of the Summer Flounder Hooking Mortality Study, please fill out the following:

Name: ____

Address: ____

City: ____________________ State: _____ Zip Code: __________ Phone #: Area Code ( ) ______________

Thank You For Your Help!