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Final Report

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Introduction

The intention of this project was to assess the potential for a fixed-gear (trap) fishery for summer flounder (*Paralichthys dentatus*) in the coastal waters of Virginia, and further establish a live-fish market for local fishermen. The idea of using traps for harvesting fin fish is not new, but has more recently become a possible alternative to traditional methods. Trapping of fin fish has distinct political and resource conservation advantages over traditional methods of harvesting fish (bottom trawls, gill nets, and long lines) including the reduction of by-catch and the associated mortalities to by-catch, little to no impact to the bottom substrate, and provides for a more targeted fishery. Further, since trap caught fish are less stressed and in top physical condition upon harvesting, the quality of the fish is at its highest, which in turn allows for its entry into higher-value specialty markets. Current markets exist for live finfish, such as flounder and croaker, both domestically and overseas.

The summer flounder supports an extensive commercial and recreational fishery along the east coast of the United States. In the state of Virginia over 5 million pounds of this flatfish were landed by the commercial sector of the fishery, during the year of 1992 alone. At an average ex-vessel price of $1.87 per pound, the summer flounder fishery supports a multi-million dollar industry for participating commercial fishermen.

Historically, trawling has accounted for roughly 94% of the summer flounder landings in the state. Prior to 1989, extensive portions of state waters (the entire Chesapeake Bay, and from the shoreline out to three miles) were open to trawling. All-time high landings were recorded in 1979, the year that the greatest area of state waters were open to trawling. In 1989, however, due to gear conflicts, by-catch issues, and management concerns, the state waters of Virginia were closed indefinitely to trawling and encircling gillnets. This resulted in the loss of productive and lucrative fishing grounds to local commercial fishermen. A possible solution to the problem is the development of alternative gear types, which may once again open up the productive waters of the Chesapeake Bay to more watermen.

Fixed gear, and more specifically fish pots, represent a possible gear option versus trawling and gillnets in the summer flounder fishery. Although the trapping of flatfish is not well documented, other types of finfish have successfully been trapped and new trap fisheries are being developed in other parts of the world in response to similar gear conflicts. One such example is taking place in the Alaskan waters of the North Pacific. The Pacific cod fishery, which had been dominated by trawl and longline gear types, was plagued by high by-catch of halibut and other commercially valuable species. This had the effect of precipitating area closures due to levels of by-catch that exceeded management limits. These area closures had a devastating effect on entire fishing communities which depend on these fisheries for their survival. A solution has been developed, in which modified crab pots are used with great success to harvest Pacific cod with greatly reduced levels of by-catch. Although this Pacific cod pot fishery is still developing, the future looks very promising.

The use of traps as an alternative fishing gear has some decided advantages over more traditional methods. These advantages include reduction of by-catch and an increase in the quality of fish. By-catch mortality can be greatly reduced or even eliminated due to the fact that fish captured in the traps, especially with short soak times, are in excellent condition. The excellent physical state of trap caught fish allows the release of sub-legal and non-target fish with very low mortality rates. In addition, ingress of some non-target species can be virtually eliminated by modifications in trap design. Trap-caught flounder have the potential to be of much higher quality than trawl-caught fish. As a result, the potential exists for a higher ex-vessel price for trap caught flounder. There has recently also been a developing niche export market for high quality summer flounder. In addition to this export market, a demand exists in some ethnic urban markets for live summer flounder. These markets are characterized by high prices paid to the vessel for either high quality processed or live fish.

Successful development of this alternative gear type, which does not have some of the problems associated with trawling, could once again open up commercial fishing opportunities for watermen in the state waters of Virginia. A successful effort could expand commercial fishing opportunities in the state with increased economic benefits for entire communities.

Trap Designs

Trap design is a factor of vital importance, simply because of the radical differences in the body plan of the summer flounder in relation to other species of finfish that have historically been harvested in traps. Although there is virtually no documented precedent for flatfish trap designs, our study was based on research performed by the Fishery Industrial Technology Center (FITC) at the University of Alaska in Kodiak and at the University of Rhode Island Fisheries Center (personal communications). Both research groups based trap design on the use of specific funnel entrances called Neptune entrances, manufactured by Neptune Marine Products, Inc., Seattle, Washington (Appendix A). Neptune entrances consist of a horizontally oriented rectangular (8" x 32") opening with 3/8" wide x 9" long plastic "fingers" or "triggers" extending inward and angled in a manner as to form a funnel. These Neptune entrances were proven successful in the Alaskan cod trap fishery, and therefore are referred to as Alaskan Cod Triggers.

Initial traps designed for this study were constructed of heavy gauge, black PVC coated, 1.5 inch wire mesh overlaid on a framework of 5/8" re-bar with horizontally placed Neptune Cod Triggers as entrance funnels (Figure 1). Thirty fish traps were constructed comprising three different variations with regards to funnel placement and number of funnels. All of the traps basic dimensional design were consistent (4' x 4' x 1.5'), with the variations as follows: Ten traps having two funnels (entrances) each placed at the bottom of opposing trap sides; ten traps also with two funnels but each placed centrally (6" off bottom) on opposing sides; and, of the remaining ten traps, three were made with 3 funnels centrally positioned (6" off bottom), four with 3 funnels positioned one mesh off-bottom (1.5"), and three with 4 funnels (one on each trap side) positioned on bottom of trap sides. Each trap was rigged with a internal, centrally-positioned bait well, and a hinged access panel on the top side of trap for fish removal. The bait well was constructed from half-inch plastic coated wire mesh and had a bottom-opening access door for re-baiting. The bait wells large mesh would allow for a greater plum development within the water, as well as facilitating the escapement of bait pieces during feeding by trapped fish which will further attract fish to the traps. All traps were rigged with a bridal attached to the re-bar for hauling (Figure 2).

A second group of traps were tested, which were smaller and more easy to handle. Two, 2' x 2' x 2' traps were constructed from the same material as the 4' x 4' traps but with smaller (8" x 16") Neptune Cod Triggers entrances. Two other (2' x 2' x 2') traps were constructed using traditional crab pot wire (1.5" hexagonal, galvanized, 16 gauge wire): a traditional blue crab pot with two opposing 4" diameter conical entrances, central bait well and modified internal parlor entrance (entrance was opened up almost its entire length); and one which the wire on two opposing trap sides were horizontally cut 3" from the bottom and bent inwards to create a 3" x 16" "slit" entrance, and containing only a central bait well. The last trap type tested was the Fathoms Plus trap (Fathoms Plus, San Diego, CA), an elliptical (41" x 32" x 14") trap made of black polyethylene with two conical/elliptical funnel entrances (12" diameter outside, tapering to an elliptical 5" x 8" opening inside). The Fathoms Plus trap uses two interior bait wells, one placed in-line with each of the two off-centered entrances.

Fish-Trap Interaction

The process of understanding the nuances of fish capture entails the coupling of fish behavior with the physical characteristics of the gear. Upon examination of fish-gear interactions, gear technologists, and fishery biologists have the opportunity to scrutinize the dynamic situation created when fish and gear meet. The task of observing fish gear interactions was once very difficult, but this situation has been eased by technological innovations of the present day. Video technology has opened the pathway to direct observations of fishing gear that were once unviewable. These direct observations of fish behavior in both field and laboratory settings can provide a wealth of information regarding many fish species and types of gear.

Within Coastal Waters

One aspect of the project evaluating the use of fixed gear for the harvest of summer flounder in Virginia, was the examination of flounder behavior in relation to the experimental traps. To accomplish this objective we sought to film flounder behavior in the vicinity of the traps via a specialized underwater camera. This camera apparatus was the product of years of development and refinement by Christopher Bublitz. Chris, a faculty member from the University of Alaska, Fishery Industrial Technology Center on Kodiak Island, has used the camera in many fisheries related studies (Bublitz, 1996; Bublitz, 1988). A tripod is mounted directly on one of the 4' x 4' x 1.5' traps. A light intensifying camera, and floodlight are then mounted on the tripod and the camera/floodlight can be moved by a pan and tilt unit. An umbilical, from the vessel to the trap, controls the pan and tilt and sends images to an onboard monitor/recorder. Video recordings of fish interactions with the gear, would attempt to provide information as to how and why the traps were both effective and ineffective for the capture of summer flounder.

Christopher Bublitz was in Virginia at VIMS from 27 October 1996, to 9 November 1996. Our goal was to obtain sufficient behavior video via the underwater camera to analyze the behavior of the flatfish. Analysis of this behavior would further enhance our understanding of fish-gear interactions, and provide clues to modification of trap designs in order to increase trap efficiency. The following is an account of the trips made to attempt to film summer flounder in the vicinity of a baited experimental trap.

On 31 October 1996, the VIMS research vessel *Fish Hawk* was contracted to make a short trip in the York River. The purpose of this short trip was to determine if the equipment was working properly and to get acquainted with protocol involved with operating the system. It was thought that due to the rapidly dropping water temperatures, and the time of year, that it was unlikely that large numbers of flounder were still present in the York River. The *Fish Hawk* anchored up at a position adjacent to the Guinea Marshes at 10:00 AM in roughly 25 feet of water. It was a clear day with high light conditions from a bright, overhead sun. The baited trap/camera apparatus was lowered off the transom via the onboard winch to the bottom. The system was operational when powered up, but visibility was poor. The high suspended particulate load in the river, coupled with scattering of the sunlight off of those suspended particles resulted in an effective visibility of roughly 1-1.5 feet. This level of visibility was unacceptable for our purposes since the trap could not even be seen through swirling cloud of particles. The vessel pulled anchor and moved to shallower water (10 ft.) in hopes of finding clearer water, but the clarity of the water remained constant. The trip was then ended and it was decided that our efforts be concentrated around the mouth of the Bay where the likelihood of clearer water, and concentrations of summer flounder seemed greater.

To facilitate our filming efforts in the lower Chesapeake Bay a large, seaworthy vessel, with a bigger, more stable working platform was needed. The *Gloria J*, a 50 ft. trawler from Seaford, Virginia was contracted for this purpose. Four days of filming (11/3, 11/4, 11/6, 11/7) were scheduled. This number of days would allow latitude in order to locate both clear water and summer flounder. The area from Cape Charles to Cape Henry (Bayside and oceanside) was thought to have the highest probability for containing concentrations of summer flounder. (See Figure 4 for plots of areas fished) This hypothesis is corroborated by both VIMS trawls surveys, and anecdotal evidence from the commercial and recreational summer flounder fisheries.

On 3 November 1996, the *Gloria J* anchored off of Kiptopeke in 23 ft. of water. This area was chosen because of the large numbers of flounder encountered there three weeks earlier by a VIMS researcher. Four other traps were set in the immediate vicinity to sample the area for the presence of flounder. Upon deployment of the camera, the visibility was only slightly better than in the York River. Suspended sediment still reduced the effective viewing distance to roughly 2.5-3 feet. This problem was accentuated by the strong tidal flow along the sediment-water interface, which stirred up the sediment and reduced visibility even more. A faint outline of the trap was visible, but this level of visibility was still inadequate to view the behavior of flounder in the vicinity of the trap. The *Gloria J* remained on station for 4 hours, over the change of tide to see if an improvement in visibility occurred. When no improvement came over the slack tide, the decision was made to try a different area the following day. This decision was bolstered by the lack of flounder in the other traps that were set in the area.

On 4 November 1996, the *Gloria J* anchored in 25 feet of water, 2 miles off of Virginia Beach. This area was chosen because of reports from local commercial fishermen stating that flounder were showing up in their catches. The visibility in this area was similar to that off of Kiptopeke (2-3 ft.). A strong N-S tidal flow stirred the up bottom and further obscured the visibility. The trap was barely visible and in the interest of finding clearer water, the *Gloria J* moved one mile further offshore. It was hoped the tidal flow would be reduced in a little deeper water (45 ft.). This was not the case, and the visibility remained at a constant 2-3 feet. This level of visibility could barely provide an outline of the pot, and nothing could be seen on the sediment water-interface. We decided to stay over the change of the tide, to see if the visibility improved. The slack tide provided no improvement, and we decided to attempt to find clearer water, and fish offshore the following day.

Efforts on 6 November 1996, focused on an offshore area where the trawl fleet had been catching flounder before the quota had been reached in late October 1996. The *Gloria J* anchored in 55 ft. of water. There was very little current, and the visibility was good. The camera could see roughly 7-10 feet, and the trap and bottom were readily visible. The pot was soaked for roughly 4 hours, and the images were recorded. Numerous species (crab, clearnose ray, scup, bluefish, conch) interacted with the trap, but no flatfish were seen. At 2:30, the anchor was pulled, and the *Gloria J* moved inshore to a 33 ft. area. There, however, the visibility was poor (2-3 ft), and this area was abandoned promptly. Upon the return trip, four traps were set just to the east of the Chesapeake Bay Bridge Tunnel (CBBT), to determine if that might be an acceptable place to film the following day.

The final day of filming, 7 November 1996, concentrated on an area east of the CBBT. One area, in 25 feet of water, near some pound nets produced some of the worst visibility yet. The sediment load was very high and this was accentuated by strong currents, keeping the visibility to approximately 2 feet. This area was abandoned, and we moved to where the traps were set. Upon pulling the traps, no flounder were caught, but 4-6 large croaker were caught in each trap, demonstrating that finfish can indeed be caught in the traps. The visibility at the CBBT in 40 feet of water was slightly better than inshore, but still was at roughly 2-3 feet. The *Gloria J* remained at this station for roughly an hour, before returning to port.

In conclusion, video images can provide a wealth of direct evidence regarding fish behavior in relation to fishing gear. Our efforts, however, to examine flounder behavior in relation to experimental fish traps were hampered by two factors. First, for the camera to produce useful images, a degree of visibility is needed. Secondly, a concentration of fish are needed in order to be viewed interacting with the gear. Our attempts to find suitable water quality that held concentrations of flounder was unsuccessful. This was likely due to the high particulate load inherent to the Chesapeake Bay. The lack of high concentrations of flounder, could possibly be due to the unseasonably cool summer with high rainfall, that may have prompted an early exodus from the Chesapeake Bay.

Within Controlled Environment

Behavioral studies of fish-gear interactions in the laboratory can have some distinct advantages due to the controlled nature of the environment. In the laboratory setting, fish availability and environmental conditions can be set to the investigator's specifications. Observational conditions are ideal, and as a result, the behavior of individual fish can be followed and focused upon. The flounder trap project at VIMS sought to utilize underwater video in a controlled laboratory setting to gain a better understanding of flatfish behavior in relation to the experimental flounder traps. Documentation of this behavior would provide justification for subsequent design modifications to the gear.

On 1 October 1996, 15 summer flounder *(P. dentatus)* were captured by otter trawl from the tidal creeks inside the barrier islands at Wachapreague, Virginia. These fish ranged from young-of-the-year individuals to larger fish in the 3 pound class. The fish were kept alive on-board the boat in aerated live wells. At the end of the collecting period, fluke were then transferred to a large outdoor fiberglass tank at the VIMS field station also located at Wachapreague. These fish were then allowed to acclimate to their new surroundings for 3 weeks. During this time the fish were fed to satiation twice a week.

On 21 October 1996, an attempt was made at filming the behavior of the captive flounder in relation to the baited experimental pots. To observe and document the fish-gear interaction, a video camera enclosed in a waterproof camera housing was placed in the tank. Video output was viewed and recorded on a VCR and monitor located alongside the tank. Two different trap designs (4 funnel and 2 funnel inset) and two types of bait (squid and bay anchovy) were tested. It was hoped that the introduction of the baited experimental traps into the tank would produce a variety of behaviors by the now acclimated summer flounder. The fish, however, were inactive, and tended to remain in the dark, shaded portion of the tank. The activity level of the fish remained subdued even when bait was present in the tank. One fish did enter the trap, and the presence of this fish in the trap seemed to arouse the interest of others in the tank. The low level of activity of the fish in the tank did not allow for much information to be obtained from this trial, as the flounder did not seem to be interested in feeding. This fact coupled with onset of rapidly dropping air and water temperatures in the coming weeks prompted a take-down of the experiment and release of the experimental fish back into the ocean.

Fishing Trials

Flounder are not considered schooling fish, therefore areas where flounder may congregate, providing the highest possible densities, were sought. Effort was focused during fall periods when flounder move out of the Bay, traveling in more concentrated numbers within narrower Bay corridors. Locations chosen for fishing trials were based on fishermen catch reports, time of year, natural bottom topography, water temperature, or a combination of these. Sites where trapping trials occurred are shown in Figure 3.

Recreational fishermen within the Bay routinely catch flounder using live minnows, squid, various cut baits, or a combination of these. Baits used for our fishing trials were: whole squid (previously frozen then thawed *Illex illecebrosus*); whole hard clams (*Mercenaria mercenaria*) which were smashed at time of placement into trap; cluster of 6 silvery, plastic 1/4" x 8" strips tied at one end to form a shiny streamer; and, live bullhead (Mummichog) minnows (*Fundulus heteroclitus*). Minnows were placed into clear, plastic, 2-liter containers fixed to the centrally located bait well within the traps. Baits were used either singularly, or in combination. Soak times varied throughout trials from short 2 hr. soaks in areas where flounder were confirmed to be present by hook-and-line sampling, to day soak periods (18-24 hr.) in areas were flounder were theorized to inhabit. (An unplanned 96 hr. soak occurred due to weather conditions which prevented scheduled trap retrieval). All fish and shellfish trapped were landed in excellent condition, with 100% survival noted on all finfish and, presumably, all invertebrates returned to the water.

Trial I

The initiation of this trap project began in the early summer of 1997 by providing 12 experimental traps to a commercial fisherman who was currently participating in both the off-shore whelk trap fishery and the in-shore gill net fishery. The fisherman possessed a 32 ft work boat with a swing boom and pot-puller, making it ideal for fishing the large 4' x 4' fish traps.

The traps were first deployed off Lynnhaven Inlet, just inside the Chesapeake Bay-Bridge Tunnel in a location where flounder were reported by sport fishermen to be readily caught on hook-and-line (Trial I, Figure 3). Twelve traps were fished, with traps varying by the number and placement of funnels, and the type of bait used (Table 1).

The harvested specie assemblage of this trial set consisted of 49 croaker (Micropogonias undulatus), 26 spider crabs (*Libinia dubia*), 17 channel whelk (*Busycon canaliculatum*), 2 flatfish hog-chokers (*Trinectes maculatus*), 1 spiny dogfish (*Squalus acanthias*), 1 oyster toadfish (*Opsanus tau*), 1 silver hake (*Merluccius bilinearis*), and 1 summer flounder (*Paralicthys dentatus*). Sizes of finfish was given as total length in inches, with the exception of croakers which were given as small (5-7"), medium (7-9") and large (>9").

During this fishing period there was a strong run of croakers throughout the Bay, which is reflected in the trap catch. Trap design (ie. funnel number and positioning) did not seem to affect catch numbers. Catch differences were slightly realized by bait type. Traps baited with squid caught more finfish, while whelks and crabs seem to prefer clams. The two traps which caught flatfish were baited with squid solely, or in combination with a visual stimulus (shiny strips).

The fishermen indicated that the traps were too large, bulky and awkward to handle, and they believed the traps could be reduced in size without impacting catch rates. Further, they believed that finding the right bait will be the key to trapping flounder.

Trial II

The second trial to trap flounder was conducted in the Middle Grounds area just off-shore from trial I along the western slope of the Thimble Shoals channel. This trial occurred in July when Bay surface temperatures were 24-26°C and flounder were presumably settling into deeper waters. Results from Trial I indicated that flounder may be more influenced, or enticed to enter the trap by a visual stimulus, or at least in combination with a cut bait. As in Trial I, finfish were more attracted to squid than clam bait in Trial II (Table 2). Further, all non-croaker finfish were caught in traps baited with a combination of squid and a visual stimulus, either a shiny streamer or live minnows. One flounder was caught with squid and live minnows as bait.

Trials III and IV

In the fall, flounder begin to migrate from the river systems into the Bay and then to off-shore waters for spawning. During this movement out of the Bay, flounder are believed to follow the deeper channels, which, in theory, would allow for a higher concentration of flounder in a given area, thus improving catch rates. Trials III and IV were performed with this concept in mind.

For Trial III, traps were tested in the lower York River within a natural channel in which recreational fishermen were reporting good catches. This trial was a quick attempt to see if flounder were congregating, thus only four traps baited with squid or clams were used (Table 3). If flounder were proven to be passing through this channel, then more traps with varying bait types were planned. No flounder were caught in this attempt. All finfish trapped were caught using squid as bait. Poor weather conditions for an extended period prevented further testing at this location.

Trapping efforts shifted to just outside the mouth of the Bay in Trial IV, where deep, narrow channels funnel fish (and debris) in and out of the Bay with the tide exchange. Strong currents were experienced in this location. The make-up of the catch primarily consisted of scavenger-type species, including crabs, snails, whelks and dogfish. Again, invertebrates preferred clam bait while finfish preferred squid or the combination of squid with a visual stimulus. No flounder were caught. Traps also contained a lot of debris, including detached sea grasses and trash (cans, plastic bags, etc.) which suggested a strong bottom current. With a strong current, the flexible fingers of the Neptune entrances will bend, allowing for an enlarged entrance. This resulting larger entrance may allow for increased escapement of trapped fish.

Trial V

Smaller traps, as described in Trap Design section, were used for Trial V. This effort teamed-up with an on-going flounder hook-n-line mortality research program on the Bay side of the Eastern shore of Virginia. Reports from research partners established strong runs of flounder off Cape Charles in the Guise Point area. Testing for the presence of flounder in this area was conducted by hook-n-line sampling using live minnows. The boat was allowed to drift through our targeted area. Within 15 minutes of sampling, 4 flounder were caught, ranging from 11-15 inches, and released. A line of traps were set extending through this sampling with all traps first baited with clams only (Table 5a) for a 2 hour soak, then re-baited with squid or squid and live minnows as bait (Table 5b) for an additional 2 hour soak. No flounder were trapped in either effort.

Summary

Attempts to trap flounder in this study were unsuccessful given the testing parameters of bait type, trap design and fishing areas. Other species readily trapped, those which are generally considered scavenger feeders as croakers, hake and dogfish. These species rely more on olfactory capabilities to secure food than sight. The few flounder trapped in this study were done so using a combination of baits; squid, to create a plum, and live minnows or shiny streamers to provide a visual stimulus. As strongly believed by recreational and meat fishermen, flounder seem to be aggressive sight feeders, which need a visual Que to react to a bait. Further, as a result from video observations and trapping trial in this study, flounder seem to be very hesitant to enter structure (traps).

Of the various traps tested, trap design or size did not seem to be as crucial as bait type. If the right stimulus is present for a given species, it will apparently enter a trap regardless of its size or design. Reports by crab fishermen of catching numerous fish species, including flounder, in their crab pots is common even though the crab pot funnel is considerably smaller and restrictive than the experimental trap entrances. It is believed that the large 4' x 4' x 18" traps used in this study may be adequate for offshore use, but are too large for Bay use. The large traps limit fishermen participation because of the required boat size and hauling equipment needed to fish them.

Of the baits tested in this trap study, it was clear that clams were preferred by invertebrates and squid effectively attracted finfish. Croakers were easily trapped by both baits, due to their high numbers in the Bay and their behavior of opportunistic feeding. Baits for the more finicky feeders, as flounder, need to be determined.

Success in commercially trapping any species is largely dependant upon the density of the targeted species. Attempts in this study were made to conduct trap trials in areas where flounder were thought to congregate. Without knowing flounder densities within areas tested, it is difficult to assess success or failure of trapping efforts. Even with a preferred bait, without an opportunity to trap in an area of high flounder densities, low catch rates would preclude commercial trapping. Targeting other finfish, as croaker, which are present in high densities and are more susceptible to trapping, can provide for a trap fishery in the Bay. The live market for finfish, including croaker, is very strong worldwide.

Recommendations

It is evident from this study that flounder are wholly or partially sight feeders and become cautious around bottom structures. A specific bait needs to be researched and established specifically for flounder, one which will be strong enough to entice the animal into a structure (trap). A bait may need to be two-fold, allowing for olfactory and visual stimulus. Something to attracting the fish to the trap by scent, then a second visual Que to cause the fish to become aggressive towards the bait, thus overcoming its cautious nature towards structure. The development of a flounder specific bait is beyond the scope of this study, but may be essential for successful trapping of flounder for commercial interests.

Trap size was not considered a limiting factor in this study. However, it is believed that when trapping large, cautious, non-schooling fish, traps should be as large as possible given vessel and gear hauling equipment available. Larger traps provide more "parlor" space within the trap, which may reduce apprehension of aggressive fish from entering an occupied trap. Traps used for schooling, opportunistic feeding species, as croaker, should be sized according to the harvesters equipment capabilities.

Trapping remains the most conservation oriented method of harvesting fish, and provides for the highest product quality possible. Targeting a high valued species with a strong domestic and international market, as flounder, can conceivable easily provide for a premium payed for trapped-caught fish. Local restaurants have indicated that they would be very interested in securing trap-caught fish for the higher flesh quality. Further value could be attained within the live fish market, where only trap-caught fish or cultured fish could supply that market. Other fish species within Virginia waters have the potential to increase their value through trapping, including spot, croaker, trout and sea bass. It has been demonstrated in this study that croaker can easily be trapped. With the international market for croaker, especially live croaker, continuing to expand, commercial trapping for croaker may be feasible. Live-fish holding and shipping techniques will have to be developed for any Virginia species entering the live-fish market. Depending upon catch rates, and live-hauling and shipping arrangements, a holding, or "pounding" step will likely be needed.

Literature Cited

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Table 1. Fish trapping trial off Lynnhaven Inlet near the Chesapeake Bay Bridge Tunnel (5/29/97). Traps were fished individually.

Trap Design	Bait Type	Depth (ft)	Soak (hrs)	Catch
4' x 4' x 18", 2 funnels placed on bottom	squid	26-30	18	8 medium croakers, 4 spider crabs
4' x 4' x 18", 2 funnels placed on bottom	clams, live minnows	26-30	18	2 medium croakers, 6 channel whelk, 5 spider crabs
4' x 4' x 18", 2 funnels placed on bottom	squid, shiny streamers	26-30	18	7 medium croakers, 1 spiny dogfish (15")
4' x 4' x 18", 2 funnels placed centrally	clams, shiny streamers	26-30	18	10 small-medium croakers, 3 spider crabs, 2 channel whelk
4' x 4' x 18", 2 funnels placed centrally	squid	26-30	18	6 medium croakers, 2 spider crabs, 1 hog-choker (9.5")
4' x 4' x 18", 2 funnels placed centrally	squid, live minnows	26-30	18	4 large croakers, 1 oyster toadfish (14")
4' x 4' x 18", 3 funnels placed 1 mesh off bottom	clams	26-30	18	6 channel whelk, 4 spider crabs, 2 medium croakers
4' x 4' x 18", 3 funnels placed 1 mesh off bottom	squid, shiny streamers	26-30	18	6 medium-large croakers, 1 flounder (12"), 1 hog-choker (9.5"), 1 hake (10"), 4 spider crabs, 2 channel whelks
4' x 4' x 18", 3 funnels placed 1 mesh off bottom	squid, live minnows	26-30	18	4 medium croakers, 4 spider crabs, 1 channel whelk

Table 2. Fish trapping trial on the Middle Grounds north of the Chesapeake Bay Bridge Tunnel along the western slope of Thimble Shoals channel (7/18/97). Traps were fished individually.

Trap Design	Bait Type	Depth (ft)	Soak (hrs)	Catch
4' x 4' x 18", 2 funnels placed on bottom	squid	48-52	18	6 medium croakers, 2 small spider crabs
4' x 4' x 18", 2 funnels placed on bottom	clams, live minnows	48-52	18	6 channel whelk, 4 spider crabs, 3 medium croakers
4' x 4' x 18", 2 funnels placed on bottom	squid, shiny streamers	48-52	18	4 medium croakers, 1 spiny dogfish (21"), 1 large oyster toadfish (16"), 1 hake (11.5")
4' x 4' x 18", 2 funnels placed centrally	clams, shiny streamers	48-52	18	4 small-medium croakers, 3 channel whelk
4' x 4' x 18", 2 funnels placed centrally	squid	48-52	18	8 medium croakers, 2 channel whelks
4' x 4' x 18", 2 funnels placed centrally	squid, live minnows	48-52	18	5 med-large croakers, 3 spider crabs, 1 flounder (12.5"), 1 hog-choker (9.5"), 1 oyster toadfish (13")
4' x 4' x 18", 3 funnels placed 1 mesh off bottom	clams	48-52	18	4 channel whelk, 3 spider crabs, 3 medium croakers
4' x 4' x 18", 3 funnels placed 1 mesh off bottom	squid, shiny streamers	48-52	18	4 medium-large croakers, 3 spider crabs, 2 spiny dogfish (19" and 21")
4' x 4' x 18", 3 funnels placed 1 mesh off bottom	squid, live minnows	48-52	18	6 medium croakers, 6 spider crabs, 1 spiny dogfish (18")

Table 3. Fish trapping trial in the York River off Allens Island, VA (10/23-10/28/97). All traps were fished individually.

Trap Design	Bait Type	Depth (ft)	Soak (hrs)	Catch
4' x 4' x 18", 4 funnels one mesh off bottom	squid, whole	20	24	5 channel whelk 1 spider crab
4' x 4' x 18", 4 funnels one mesh off bottom	squid, whole	20	96	10 channel whelk 2 large croakers 1 medium sea bass
4' x 4' x 18", 3 funnels on bottom	6 clams, whole, cracked	24	24	7 channel whelk 1 female blue crab
4' x 4' x 18", 3 funnels on bottom	6 clams, plus whole squid	24	96	18 channel whelk 6 large croakers

Table 4. Fish trapping trial (11/11-11/12/97) at the mouth of the Chesapeake Bay off Cape Henry (N 3655616, W 7557676). Traps were fished in a trawl, 5 traps strung 80 meters apart and anchored on both ends, which was deployed on the slope of a trough running parallel to the contour.

Trap Design	Bait Type	Depth (ft)	Soak (hrs)	Catch
4' x 4' x 18", 2 funnels placed centrally	squid, shiny streamers	46-50	24	20 small spider crabs, 9 medium croakers, 4 Cancer crabs, 1 clear nose skate, 1 spiny dogfish
4' x 4' x 18", 2 funnels placed centrally	clams	46-50	24	15 small spider crabs, 12 Cancer crab, 5 channel whelk, 5 medium croakers
4' x 4' x 18", 2 funnels on bottom	clams	46-50	24	12 small spider crabs, 9 Cancer crabs, 6 channel whelk
4' x 4' x 18", 3 funnels on bottom	squid, shiny streamers	46-50	24	1 large (34") spiny dogfish, 1 Cancer crab, 1 spider crab
4' x 4' x 18", 3 funnels on bottom	squid	46-50	24	12 small spider crabs, 12 moon snails (1.5-2"), 10 Cancer crabs, 4 medium-large spiny dogfish (25-36"), 4 large croakers, 1-12" hake, 1-4" spade fish

Table 5a. Fish trapping trial south of Cape Charles on Eastern shore of Virginia (Guise point, 10/12/98). Traps were fished individually using clams only as bait.

Trap Design	Bait Type	Depth (ft)	Soak (hrs)	Catch
2' x 2' x 2', crab pot wire, two 3"x 16" slit funnels 3" off bottom	clams	16	2	nothing
2' x 2' x 2', crab pot wire, 2 cod trigger funnels placed on bottom of sides	clams	24	2	nothing
2' x 2' x 2' Crab trap	clams	22	2	1 channel whelk
4' x 4' x 18", 2 funnels on bottom	clams	22	2	2 channel whelk, 1 pig fish (5")
Fathoms Plus trap	clams	24	2	nothing

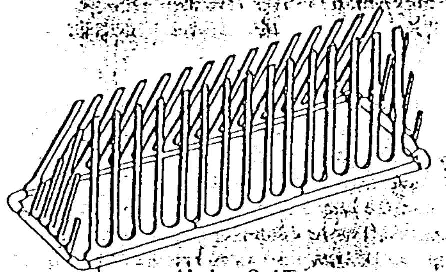
Table 5b. Fish trapping trial south of Cape Charles on Eastern shore of Virginia (Guise point, 10/12/98). Traps were fished individually using squid or squid and live minnows as bait.

Trap Design	Bait Type	Depth (ft)	Soak (hrs)	Catch
2' x 2' x 2', crab pot wire, two 3"x 16" slit funnels 3" off bottom	squid, live minnows	16	2	1 black sea bass (7")
2' x 2' x 2', crab pot wire, 2 cod trigger funnels placed on bottom of sides	squid, live minnows	24	2	1 pigfish
2' x 2' x 2' Crab trap	squid	22	2	1 black sea bass (8") 2 pigfish
4' x 4' x 18", 2 funnels on bottom	squid, live minnows	22	2	Nothing
Fathoms Plus trap	squid	24	2	nothing

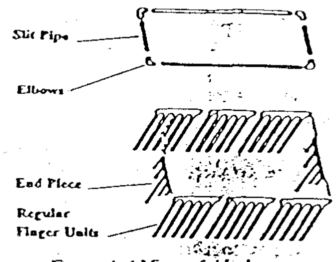
Appendix A

A NEW ERA IN POT FISHING HAS ARRIVED!

Neptune entrances have proven effective and durable in various pot and trap fisheries around the world. From Alaska to South Africa, from New Zealand to the North Atlantic, the use of Neptune Trap Entrances is starting to change the way fish and shellfish traps are designed. Both the design and use of Neptune's patented plastic components have proven to be very durable under harsh fishing conditions. Neptune's Cod Trigger has been used for 8 years in Alaska's pot fishery for cod and crab with excellent results.

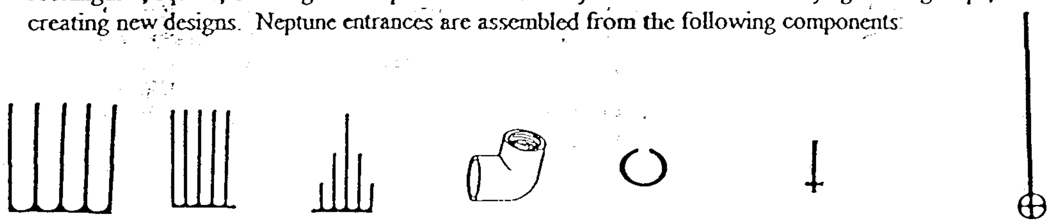


Alaskan Cod Trigger
35" x 8" (890mm x 215mm)



Expanded View of Alaskan Cod Trigger Model

Neptune's plastic entrances can be ordered fully assembled or they can be self-assembled into any number of rectangular, square, or octagonal shapes and sizes. They are suitable for modifying existing traps, or for creating new designs. Neptune entrances are assembled from the following components:



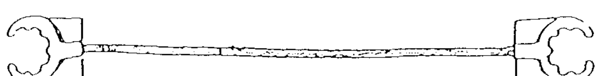
Once the components are assembled they are solvent welded using cement that fuses the plastic parts. Stainless steel screws can be added to provide additional strength.

COD FISHING WITH POTS

The Alaska Cod Trigger was originally developed to modify Alaskan king crab pots to catch Pacific Cod for the baiting of crab pots. This method of catching cod has proved effective and resulted in the development of a directed fishery for Pacific Cod using large (7' x 7' x 3') modified king crab pots.

Catch rates vary throughout the year with the best catches coming in the months prior to spawning. Average catches of 200 LB per pot are not unusual. The use of bait bags that contain finely chopped bait has proven to be the best method of baiting. As the first cod start to tear at the bait bag, other fish enter the pot to join this "feed". This impression of a feeding frenzy is one of the main reasons why pots work well for cod. The other requirement for good catches is the use of large multi-entrance traps. A net lead going to the entrance is preferred over placing cod triggers on a pot's flat sides. Cod pots fish "Fast" with most of the cod caught within 6 hours of setting the pots. This fast fishing feature allows fishermen to use less pots by pulling the gear more often. It's often common for cod pot boats to fish around 100 pots, pulling them twice per day. Best results have been seen in 3 entrance pots.

In addition to being very effective in catching cod, pot fishing is very selective in it's pursuit of target species or in pursuit of a certain sized fish. The use of Neptune's Cod Triggers in the Alaska cod pot fishery has proven to be very species selective. Dividers called Excluders are required across the vertical plane of the entrance to keep halibut and crab from entering the pot when targeting Pacific cod. This capability has resulted in additional fishing time due to it's "clean" fishing nature.



NEPTUNE EXCLUDER