Improving the Selectivity and Utility of Demersal Hook Fishing

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Abstract

The two major contemporary issues in the Northeast groundfish fisheries are habitat degradation and by-catch. Hook fishing, such as longlining, offers high potential selectivity combined with low impact to habitat. However, the potential for species-selectivity is rarely realized because of the small number of natural baits available to fishermen. Additionally, because of the popularity of trawling in New England, little research has been done on expanding the demersal longliner's range of species fished. This project combines at-sea underwater video observation of fish behavior towards baited hooks, and captive fish research to expand our knowledge of the behavior of commercially important groundfish (e.g., cod, haddock, flounder) towards a variety of natural and artificial baits. The preliminary results from our project strongly suggest that our methods for testing and developing artificial bait are successful at narrowing down the selection of bait types. Future success for this project will give hook fishermen access to additional species and reduce by-catch.

Introduction

Longlining is a major fishing method worldwide, and offers many advantages over other gear types. Longlining does not have great impacts on seafloor features, generates only small amounts of ghost gear (abandoned gear), and is more size-selective than other fishing methods. A

Norwegian study on fishery management predicts that a higher biomass will remain in the sea if a given catch quota is taken with longlines than with trawls (Bjordal and Laevastu 1990). A bio-economic study comparing longline and trawl fishing showed that not only yield but also the employment effect were superior for longlines (Oboyle et. al. 1989).

However, longlining is not without problems. Baiting presents a major drawback, because it is messy, time-consuming and frequently painful to put bait on thousands of hooks. From an ecosystem point of view, bait production extracts millions of pounds of fish from the ocean that could either be used for human consumption or as food for other fisheries. Since the same few types of bait (clam, herring, or squid) are used for all species, longlining can be non-species selective and will generate a by-catch rate that could be unacceptable. Also, the limited supply of natural baits leaves fishermen at the mercy of bait suppliers and to seasonal variations in bait availability.

Some experts have suggested that longlining could be highly species-selective and have suggested that the development of artificial baits could improve the selectivity of longlining (Lokkeborg and Bjordal 1992). Using the techniques of modern food technology, artificial baits can be manufactured, incorporating a variety of attractants, matrix materials, and other characteristics. Seafood processing wastes can comprise the major portion of such baits because their incorporation into appropriate matrix materials lets soft or liquid materials stay on the hook. Manufactured baits offer the possibility of consistent quality, ease of handling, economy, and elimination of wasted parts, since there are no soft tissues that fall off the hook or tail sections that fish poorly. These baits can be manipulated (size, shape, mouth-feel, attractant release rate, and other factors) thus allowing exploitation of the potential for selectivity. Much of the research on longline gear has been summarized by Bjordal and Lokkeborg (1996). The importance of bait has been underlined by Lokkeborg, who looked at the type of bait, the size and shape of bait, attractant release by baits, and the possibilities offered by artificial bait (Lokkeborg 1990, Bjordal and Lokkeborg 1996). Natural bait such as clam, herring and squid tends to be non-species selective and can generate high levels of by-catch. Therefore the future potential for increased selectivity in hook fishing will be found in artificial baits.

A successful artificial bait must have two major characteristics: the correct mix of attractant chemicals, and the ability to release attractant throughout the fishing period (Lokkeborg 1989). Much of the work accomplished thus far with successful artificial bait comes from field trials in Alaska (Erickson et. al. 2000a). Artificial bait developed by Marco Marine (Seattle, WA) and scientists from the Center for Applied Regional Studies (Cambridge, MA) for the Pacific halibut and sablefish longline fisheries, was very successful in catching target species while excluding dogfish and skate (Erickson et. al. 2000b). By drawing upon the recent successes in the Pacific demersal hook fishery, research could begin using with artificial baits in the New England demersal hook fishery.

The overall goal for this project was to increase the utility of commercial hook fishing by increasing the range of target species, and improving the species selectivity. This study was divided into four parts in order to expand and improve the selectivity of the demersal hook fishery in New England waters. Artificial bait was manufactured and tested in three ways by: 1) recording observations of captive live fish reactions to different artificial baits; 2) sea trials

comparing one artificial bait matrix against natural bait; and 3) recording observations of fish reactions to several artificial baits in the field. Lastly, to test the viability of a commercial flatfish hook fishery an attempt to target flatfish with appropriate hook and natural bait was made by contracting two industry vessels and observers.

1) Recording observations of captive live fish reactions to different artificial baits:

Methods and Materials

General:

Laboratory observations were accomplished in two phases and used the Woods Hole Oceanographic Institute's (WHOI) Environmental Systems Laboratory (ESL). The ESL's facilities consisted of flow-through raceways, using sea water. Bait was placed so that the odor would be carried through the raceway tanks in the direction of water flow. This ensured that the fish approached the baits from the down-stream end of the tank.

Each raceway tank was approximately forty feet long by four wide, filled with five feet of water, and covered with sheets of Styrofoam. Raceway ends were fitted with a curved wall made from a culvert pipe to prevent fish from bumping their snouts into the square ends when swimming in the tanks. Two walkways were constructed from wooden lumber and placed across three raceway tanks, one walkway at the standpipe end and the other walkway at the head-end. Temperatures were recorded on mini loggers and solar powered thermometers to monitor the water temperatures during all treatments.

Fish behavior in each raceway was recorded using 12-volt real-time underwater camera systems, monitors, and VCRs. The underwater cameras were attached to 6 ft. long, galvanized metal poles and positioned two feet off the bottom of the tank. Each pole was attached to the wooden walkway at the head end of the tank and placed four feet upstream from the position of the baits. Behavioral observations were recorded on log sheets to the time code of the corresponding tape and raceway. Preliminary observations were classified as: no activity, mouthing, eating or active swimming (Figures 1-4). At the end of each trial recording was stopped; leftover bait and cameras were removed from the tanks. Trials lasted until all bait was consumed but no longer than two hours.

Individual treatments compared three baits that varied in only one characteristic, either: attractant, matrix (chemical composition), or attractant preparation. Baits were labeled with letters, numbers, percentage of gum, or by the type of attractant in the matrix. Pieces of bait were presented to the fish on monofilament line (Figure 5) when possible; otherwise pieces of bait were dropped into the tank. Two baits were compared in each raceway, and each bait was tested in two raceways. Baits were rotated over a three-day trial period so that every comparison occurred in each raceway.

Day one: Raceway 1 (A vs. B); Raceway 2 (B vs. C); Raceway 3 (A vs. C)
Day two: Raceway 1 (B vs. C); Raceway 2 (C vs. A); Raceway 3 (B vs. A)
Day three: Raceway 1 (C vs. A); Raceway 2 (A vs. B); Raceway 3 (C vs. B)

First Raceway Phase:

The first phase of the raceway work was performed from February 2001 through April 2001, and focused strictly on Atlantic cod, purchased from Cape Live Seafood (an industry supported holding facility in Harwich, Massachusetts). A portable (1000 Liter) holding tank was used to transport each new fish sample. Around fifteen fish were purchased for each treatment, and were usually acquired five days prior to experimentation. Fish were acclimated and fed squid, clam or scallop meats each day before each treatment. Feeding occurred at the downstream end of the raceways. A total of four basic types of attractants were presented to the fish, some had fibers imbedded in the matrix and some had no fibers. The types of attractants included: clam, Alaskan pollock, crab, and squid. A total of five treatments were tested with each using four to six fish per raceway.

The first treatment occurred between 28 February and 2 March and compared three different clam attractant matrices, labeled "A", "B", and "C". Each of the baits had fibers embedded in the matrixes to give the baits tensile strength. The second treatment took place from 21-27, March. The duration lasted longer than other treatments due to poor water quality from a storm. The first treatment's artificial baits were repeated because water temperatures were higher in this treatment. The third treatment began on 4 April 2001 and lasted through 9 April 2001. The three baits offered to the fish were "A", "D", and "E". Baits "D" and "E" had different gum percentages and neither one of the baits had fibers. The fourth treatment began on 20 April 2001 and ended on 24 April 2001. The three baits tested in this treatment were labeled bait "G", "H", and "I" and had no fibers. Bait "G" had Alaskan Pollock processing waste as the attractant, while bait "H" had crab attractant, and bait "I" had squid attractant. The fifth treatment started on 25 April 2001 and stopped on 27 April 2001. Unlike previous treatments this one had only two days of filming. However, a three-day trial was simulated by limiting tests to one hour with two trials performed on one day. Fish were exposed to three bait types which were labeled "J", "K", and "L" and were without fibers. Bait "J" had squid with the ink sack in the matrix, bait "K" had squid without the ink sack in the matrix, and bait "L" had crab as the attractant.

Second Raceway Phase:

The second phase was completed between December 2001 and January 2002 and focused on behavioral observations from Yellowtail flounder and Atlantic cod. Both fish species were directly received from the fishermen, but not from Cape Live Seafood. The Yellowtail flounder were received from a fisherman in Scituate, Massachusetts, while Atlantic cod were purchased from a fisherman in Harwich, Massachusetts. Again, a portable (1000 Liter) holding tank was used to transport each new fish sample. The number of cod varied between treatments but each sample was divided up equally among three raceways. The fish were not fed in the days prior to testing during this raceway phase. Crab was the only attractant used in this phase of raceway testing and none of the baits had fibers.

The sixth treatment started on 18 December and stopped on 20 December. Treatment six had a total sample of 34 Atlantic cod and 19 Yellowtail flounder distributed among the raceways. Baits were labeled as "bait 1", "bait 2", and "bait 3". Crab was the attractant in all three baits; but, within each of the baits, the attractant was prepared differently. The seventh treatment began on

26 December and ended on 28 December. There were 79 Atlantic cod spread among the three raceways. Yellowtail flounder were not available for this treatment. Baits that were tested included: “crab #1”, “crab #4”, and “bait 2”. The eighth (last) treatment began on 2 January and was completed on 4 January. A total of 37 Yellowtail flounder were tested with baits: “bait 3”, “crab #1”, and “crab #4”.

Preliminary Results

First Raceway Phase:

During Treatment Atlantic cod showed limited interest in the artificial matrix labeled “A” (Table 1). The behavior they exhibited was characterized as “mouthing” a piece of bait: a fish sucked on a piece of bait and spat it back out (Figure 3). No fish were observed to eat any of the artificial baits that they were offered in this treatment. Stomach analysis showed this sample of fish had not eaten the artificial bait, and two out of sixteen fish had small pieces of squid or clam in their stomachs (Table 2). Activity in all raceways was low and water temperatures were around 1° C.

During the second treatment, fish exhibited very little interest in bait “B”, but they responded to baits “A” and “C” through “mouthing” (Figure 3). There were more fish interactions with bait “A” than bait “C” (Table 1). Again, no baits were consumed when recording was completed. Stomach contents confirmed no artificial baits were consumed, and also revealed that only some fish ate pieces of clams and scallops (Table 3). Water temperatures were around 4.5^{o} C.

Fish from treatment three showed positive interest in baits “D” and “E”, whereas bait “A” held little interest to the fish. Some fish consumed both baits “D” and “E”, but bait “A” remained uneaten by the fish (Table 1). Stomach analysis confirmed nine instances where fish ate bait “E” and seven instances when fish consumed bait “D” (Table 4). Fish activity was increased over the previous 2 treatments. Water temperatures were between $6\text{-}8^{o}$ C.

Fish in the fourth treatment, mouthed all the types of baits, but fish consumed only bait “H”. Fish activity was low overall with some raceways showing no activity (Table 1). Stomach analysis was not performed after the three-day trial for this treatment. However, when stomach contents were analyzed after the next treatment using these fish, stomach contents found only bait “H” was consumed by four different fish spread across all the raceways (Table 5). Water temperatures were around 10° C.

During treatment five, fish in raceways two and three showed the best response to the baits (Figure 4). All baits were consumed on the last day in those raceways (Table 1). Stomach analysis confirmed that fish in raceway one had no artificial bait from this treatment, while fish from raceways two and three ate baits “J”, “K”, and “L” (Table 5). Water temperatures were around 11° C.

Second Raceway Phase:

In the sixth treatment, Yellowtail showed minimal activity in the raceways, while cod had variable activity. All bait combinations that were offered in raceway 2 were consumed on all three days; conversely, no bait combinations in raceway 1 were consumed at all during the three days (Table 1). Fish in raceway 3 ate bait only during the second and third days. These variable observations made it difficult to conclude which bait (1, 2, or 3) was preferred. Stomach analysis confirmed that cod only from raceways 2 & 3 consumed all three bait types (Table 6).

During treatment seven, fish were very active in raceways 1 and 2 throughout the entire treatment, whereas the fish in raceway 3 were active on the last day of testing. The fish usually approached and consumed "crab #1" or "crab #4" before they went to "bait 2" when compared against "bait 2". When stomach contents were checked, analysis showed 9 fish consumed "crab #1" while 4 fish consumed "crab #4" (Table 7).

In treatment eight, Yellowtail flounder were not active in the raceways, showed no interest in the baits, and had not consumed any bait (Table 1). Stomach analysis confirmed all observations made over the three-day trial (Table 8). Twenty-five fish stomachs were empty, while there were 10 fish stomachs filled with polychaetes and 2 fish stomachs contained other food.

Discussion

Raceway experimentation proved to be very labor intensive and the logistics of acquiring fish when desired were difficult. However, the raceways provided a good controlled environment to perform bait tests. Fish density and water quality are critical factors for consideration. Water temperatures may have played an important role in the activity level of the fish. While the data have not been completely analyzed, some types of artificial bait appear to be more attractive to cod than other types. Matrix composition may be a limiting factor for bait preference, but the effects of fibers are unclear. Stomach contents revealed that a small portion of the treated fish actually ate. Stomach analysis also provided a means of determining the quantity and type of bait consumed. Video footage and stomach analysis seem to indicate the possibility of behavioral differences between individuals.

<u>2) Sea trials comparing one artificial bait matrix against natural bait:</u>

Materials and Methods

Artificial bait was manufactured in large quantities by Dr. Susan Goldhor and put on standard demersal longline gear and compared to natural squid bait used by the industry. Day trips were conducted between 14-24 August 2001 using one artificial bait matrix and attractant compared against natural bait. The F/V Sea Holly was contracted to have standard demersal longline gear with the artificial bait. Most trips had two hook types (circle hooks or french "J" hooks) used on standard longline gear to target Atlantic cod. However, one trip had artificial bait on smaller hooks to target flatfish. Two Massachusetts Division of Marine Fisheries (MADMF) employees observed all trips, and information was recorded on federal observer program log sheets. Fish were counted, measured and total catch weights were estimated from a representative sub-sample

for each haul/string. Hauls or strings of artificial bait that were compared to natural bait were deployed as close together as possible enabling the same proportion of fish to encounter both types of baits. Catch rates of Atlantic cod, Winter flounder and Yellowtail flounder were calculated by the number of fish caught divided by the number of hooks fished for each haul/string.

Preliminary Results

Five trips were completed onboard F/V Sea Holly with twenty-one hauls observed and approximately 17900 hooks soaked (Table 9). The total number of Atlantic cod caught was 1490. Out of the 1490 Atlantic cod caught there was about 377 (25%) discarded fish and 1113 (75%) kept fish. Atlantic cod catch rate over the twenty-one hauls (includes hauls with bait comparisons and hauls without comparisons) was approximately 8 fish for every 100 hooks over-all (Table 9). Catch rate for kept Atlantic cod was 6 fish for every 100 hooks and a discard rate of 2 fish per 100 hooks.

Out of the total number of hauls, 8 hauls compared natural squid against the artificial clam bait matrix with 7200 hooks soaked (Table 10). There were 122 (27%) discarded fish and 328 (73%) kept fish for a combined total of 450 fish caught in all 8 compared hauls. The Atlantic cod catch rates with natural bait were consistently higher than the artificial clam bait matrix. The highest number of cod caught with the artificial bait was 21 fish.

Discussion

The artificial bait used for this test was one that had not performed well in the raceways. The rationale behind this test was to confirm the observations that were recorded. The artificial clam bait was out-performed by natural squid. A more appropriate test would have compared natural squid against artificial squid bait, instead of clam. Due to the intricacies of seasonal bait preferences by fish; the industry changes their types of baits throughout the course of the year. This information is important to the timing of artificial bait field-testing.

<u>3) Recording observations of fish reactions to artificial bait in the field:</u>

Material and Methods

Two metal trapezoidal frames (Figures 6-7) were constructed to field test several artificial bait matrixes and attractants. Each frame (10 feet long, 3 feet wide at far end, 1 foot wide at camera end) had between ten to twelve baited hooks. Trips were conducted opportunistically from January 2002 through July 2002. Two camera frames with video cameras in underwater housings were deployed in areas that were typically fished by the industry. The artificial bait attractants that were used included: clam, crab, or krill with a total of five matrix combinations. Three attractants with five matrixes were tested in depths ranging from seventeen to thirty-five fathoms. Artificial bait was used throughout this part of the study except on two trips natural bait was placed on the camera frames. All trips were contracted with the F/V Sea Holly out of Wychmere Harbor in Harwich, Massachusetts and the areas fished were typical cod-fishing grounds. Trip information was recorded on log sheets which included date, weather, sea

conditions, position, depth, camera frame number, attractant, matrix, made by, time deployed, and time retrieved. Upon retrieval videotapes were reviewed and fish behavior was recorded on log sheets. Each frame was allowed to record up to one hour of footage.

Preliminary Results

Occasional technical difficulties occurred on some of the trips during this part of the study (Appendix I). The first trip had one frame deployed, which allowed half the amount of bait tested on that day. Other difficulties that were experienced included the frames landing upside down, bait falling off the hooks, and tapes prematurely turned off. One trip was too deep, limiting the amount of ambient light for the camera to record any reactions of fish to the baits. Marine life observed in front of the camera included Atlantic cod, Spiny dogfish, Winter flounder, Winter skate, Longhorn sculpin, Ocean pout and miscellaneous crabs. Fish that were hooked included Atlantic cod, Spiny dogfish, Winter flounder, Winter skate, Ocean pout and Longhorn sculpin.

Winter flounder appeared to show interest in most of the artificial baits without regard to attractant or matrix. On most of the trips that had good behavior of Winter flounder were observed to eat the baits off the hooks without becoming caught (Figures 8-9). There was one trip that caught a (52 cm) Winter flounder on a hook baited with artificial crab bait and this occurred with natural squid bait, present.

Cod showed limited interest in the artificial baits, and cod clearly favored real squid bait when both baits were present on the same frame. Other fish that showed interest in the artificial baits were Longhorn sculpins and Ocean pout. Spiny dogfish did not show much interest in the artificial bait when compared to real squid, and three Spiny dogfish were hooked on squid baited hooks. One Winter skate was caught on a hook that was baited with real squid. Longhorn sculpins exhibited mixed responses to artificial bait, because there were trips when sculpins had no interest in artificial and trips when they ate or were caught with artificial bait.

Discussion

Information that was recorded by the camera drops was very useful. A variety of marine life was seen interacting with the baits. This method may be the best way to capture fish behavior unaltered. However, the effect of the camera frame on fish behavior remains to be addressed. There were positive reactions by winter flounder during the trips which occurred in late June and early July. An interesting fact was that dogfish and skates seemed not attracted to the artificial baits. This shows good potential for reducing the by-catch of these two species for longlining. Sculpins showed variable responses and it may be difficult to draw any strong conclusions about their interest in the bait. A limiting factor with the bait seemed that it was difficult to maintain integrity on the hooks with some matrix and attractant combinations. Further analysis of video footage is needed to better understand fish responses to the artificial bait.

4) Sea trials targeting flounder with two industry fishing vessel:

Material and Methods

In May and June 2001 two fishing vessels, the F/V Sea Holly and the F/V Sea Winn, were contracted to target flounder. Areas fished were left up to the discretion of the fisherman in order to locate significant numbers of fish. Observers were provided by the Cape Cod Commercial Hook Fishermen's Association (CCCHFA) to sea-sample all trips. MADMF provided log sheets to the CCCHFA to distribute to the observers for recording all pertinent information regarding the trips. Information recorded included date, location, time set, time retrieved, number of hooks soaked, and the composition of catch for each haul/string. The total catches of Yellowtail flounder and Winter flounder were grouped as "flounder" because not all observers identified the fish to individual species. Catch rates of flounder were calculated by the total number of fish caught divided by the number of hooks fished for the haul that fished the experimental gear.

Preliminary Results

A total of nine trips were completed by both vessels (5 trips by F/V Sea Holly and 4 trips by F/V Sea Winn). Total catches of flounder were low for both vessels; however, the F/V Sea Holly caught more flounder than the F/V Sea Winn. Catch rates for most of the hauls were calculated to be 1 flounder for every 100 hooks (Table 11). The highest total catch of flounder occurred with the F/V Sea Holly on 9 June 2001, with a total of 23 fish for the day. The trip on 4 June 2001 (for both vessels) caught large numbers of Spiny dogfish and catch of flounder for each haul could not be determined from sea-sample data. Observers also recorded notes regarding problems with the gear when hauling. The light gangions (which are needed for smaller hooks) got caught in the hauling-knife and tangled the lines.

Discussion

The attempt to diversify fishing activity by the experimental flounder-selective gear proved to be difficult and not cost effective at this time. There were a limited number of trips completed; and not enough flatfish were caught in commercial quantities to recommend this type of fishery. According to one fisherman, the low market value of flatfish compared to codfish makes it cost-prohibitive to target flounder. Other problems to overcome would be: constant repairs to the light gangions and the dogfish presence.

Fishermen's comments recorded on log sheets by the observers indicated that the time of year may have been too early. Both fishermen would like to repeat this experiment with this gear around July or August. This might show more positive results especially since the information collected with the camera drops (in late June and early July) saw large densities of Winter flounder responding positively to the artificial bait.

Preliminary Conclusions

Early conclusions from the laboratory work that has been accomplished to date show that an artificial bait matrix is capable of being produced to be attractive to Atlantic cod. However, the

complications of maintaining the baits' integrity on hooks remain unsolved. The raceway work showed interesting and important behavioral differences in bait and feeding preferences by Atlantic cod. The differences between individuals are important pieces of information that will prove useful in determining the behavior of these fish relative to baited hooks. Therefore a more detailed analysis of the many hours of video footage is necessary and will be accomplished in the weeks and months to come.

The mass production of artificial bait to complete the sea-trials was useful in confirming that the raceway work served as a good model to start bait testing. The only questions which remain unanswered are: Should the bait comparison have been done with artificial squid or should the test have been done at the time of year when real clams are used? It is not certain that artificial squid in that particular matrix would have fished as poorly as the artificial clam against the real squid. More sea trials at different times of the year with correct comparable baits would be useful. Therefore, a definitive conclusion about whether the artificial clam matrix used, is capable of catching fish remains vague. This is an area for future work in concert with new artificial bait testing.

The attempt to target Yellowtail flounder and other flatfish was not commercially viable. Therefore, recommendations of changing gear to catch flounder cannot be made. Even if the timing of such activity were to be changed, the investigators feel that catch rates were too low to warrant further investigations using natural baits. Perhaps the answer will lie in the potential of an artificial bait that is attractive to these flatfish and not to dogfish and skates. Also, investigations into the historical account of a past fishery might suggest what kind of gear modifications would eliminate problems with the hauler. Until that is determined, further tests with real bait should not be done in future work.

The camera footage taken during the camera drops is an important tool for narrowing the selection of potential artificial baits. This critical piece of information gave the researchers a brief glimpse into the hooking behavior and bait preferences of the fish encountered. One question remains concerning the effects of the camera frame on fish behavior. This could be answered relatively through review of footage collected of a trip when the baits fell off hooks while on its way down to the bottom. There were positive responses from Winter flounder attacking and eating the artificial baits on several of the trips. The potential for manufacturing a bait for this commercially important species may prove fruitful and this needs further development. Therefore, the video footage collected during camera drops will be scrutinized further in the weeks and months to come.

Future Recommendations

Recommendations for future work would include a further detailed analysis of the many hours of video tape footage from both the raceway experimentation and the camera frame deployments. This information is critical to determine which bait produced the best results and can be used for future testing. Other directions which show potential for future research would be the development of a bait and gear that could efficiently catch flounder species while reducing by-catch of dogfish and skates. This area shows the most potential from work accomplished thus far.

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Table 1: Summary of video footage and comments from all eight treatments completed through duration of the raceway experiment.

Dates	Treatment	Bait #	Attractant	Gum %	Fibers (Y/N?)	Species	Matrix	Comments
Phase I								
2/28/01-3/2/01	1	A	clam	?	Y	Atl. Cod	?	no baits were eaten, but "A" was mouthed
2/28/01-3/2/01	1	B	clam	?	Y	Atl. Cod	?	water temps very low perhaps reason for inactivity
2/28/01-3/2/01	1	C	clam	?	Y	Atl. Cod	?	
3/21/01-3/27/01	2	A	clam	?	Y	Atl. Cod	?	no baits were eaten, but "A" and "B" was mouthed
3/21/01-3/27/01	2	B	clam	?	Y	Atl. Cod	?	slighty higher water temps. w/ little more fish activity
3/21/01-3/27/01	2	C	clam	?	Y	Atl. Cod	?	
4/4/01-4/9/01	3	A	clam	?	Y	Atl. Cod	?	not much interest in "A", but "D" and "E" were eaten
4/4/01-4/9/01	3	D	clam	1.0%	N	Atl. Cod	?	and there was very good response in some raceways
4/4/01-4/9/01	3	E	clam	3.5%	N	Atl. Cod	?	
4/20/01-4/24/01	4	G	AK pollock	?	N	Atl. Cod	?	low activity in some raceways while others had none
4/20/01-4/24/01	4	H	crab	?	N	Atl. Cod	?	All baits were mouthed-more H than I or G
4/20/01-4/24/01	4	I	squid	2.0%	N	Atl. Cod	?	H only bait observed eaten in RW #3 only
4/25/01-4/27/01	5	J	squid w/ ink	?	N	Atl. Cod	?	all baits were eaten in the raceways
4/25/01-4/27/01	5	K	squid w/o ink	?	N	Atl. Cod	?	best activity on 4/27 in raceways 2 & 3
4/25/01-4/27/01	5	L	crab+	?	N	Atl. Cod	?	uncertain if "J" is preferred over "K" but all liked "L"
Phase II								
12/18/01-12/20/01	6	1	crab	?	N	AC & YT	?	RW 2 ate every day all baits offered
12/18/01-12/20/01	6	2	crab	?	N	AC & YT	?	RW 1 never ate, cod & Y-tail swim around on day 2
12/18/01-12/20/01	6	3	crab	?	N	AC & YT	?	RW 3 ate on days 2 & 3
12/26/01-12/28/01	7	Crab #1	crab w/o meat	?	N	Atl. Cod	C-2 matrix	codfish ate both crab#1 & crab #4
12/26/01-12/28/01	7	2	crab	?	N	Atl. Cod	?	rw1 had poor activity for day 1
12/26/01-12/28/01	7	Crab #4	crab w/ meat	?	N	Atl. Cod	C-2 matrix	only small no. of fish ate baits out of total sample
1/2/02-1/4/02	8	Crab #1	crab w/o meat	?	N	Y-tail Fldr.	C-2 matrix	Yellowtail flounder didn't show much interest in the
1/2/02-1/4/02	8	3	crab	?	N	Y-tail Fldr.	?	artificial baits. Fish showed very little action.
1/2/02-1/4/02	8	Crab #4	crab w/ meat	?	N	Y-tail Fldr.	C-2 matrix	No baits were eaten.

Note: The first 5 treatments of fish were conducted in the first phase of raceway work, while the last 3 treatments were conducted in the second phase of raceway work.

Table 2: Summary table of the stomach analysis of the first treatment of Atlantic Cod.

3/2/2001						
Raceway #	**Species**	**Length**	**Sex**	**Stomach Contents**	**Artificail Bait**	**Comments**
?	Cod	51	male	Empty	no	
?	Cod	49	male	Empty	no	
?	Cod	52	male	Empty	no	
?	Cod	52	male	Empty	no	
?	Cod	50	male	Empty	no	
?	Cod	48	male	Empty	no	
?	Cod	52	male	Empty	no	
?	Cod	53	male	Empty	no	
?	Cod	53	male	clam, squid	no	
?	Cod	52	female	Empty	no	
?	Cod	53	female	Empty	no	
?	Cod	48	female	Empty	no	
?	Cod	53	female	Empty	no	
?	Cod	53	female	clam, squid	no	
?	Cod	Unkn.	Unkn.	Empty	no	not measured, can't ID sex
?	Cod	Unkn.	Unkn.	Empty	no	not measured, can't ID sex

Table 3: Summary table of the stomach analysis of the second treatment of Atlantic cod.

3/27/2001						
Raceway #	**Species**	**Length**	**Sex**	**Stomach Contents**	**Artificail Bait**	**Comments**
1	Cod	52	male	squid beak	no	
1	Cod	51	male	empty	no	
1	Cod	50	male	empty	no	
1	Cod	50	female	clam, scallop	no	
2	Cod	50	female	empty	no	
2	Cod	49	male	scallop	no	
2	Cod	50	female	empty	no	
2	Cod	50	female	clam, scallop	no	scarback
2	Cod	53	male	clam, scallop	no	
3	Cod	50	female	empty	no	
3	Cod	49	female	empty	no	
3	Cod	53	female	clam	no	
3	Cod	52	female	empty	no	

Note: All fish lengths were measured to the nearest centimeter.

Table 4: Summary table of stomach analysis of the third treatment of Atlantic cod.

4/9/2001						
Raceway #	**Species**	**Length**	**Sex**	**Stomach Contents**	**Artificail Bait**	**Comments**
1	Cod	48	female	clam	no	
1	Cod	49	male	empty	no	
1	Cod	49	female	clam, artificial bait	(D & E)	full stomach
1	Cod	50	male	clam, artificial bait	(E)	full stomach
1	Cod	50	female	clam, artificial bait	(D & E)	full stomach
1	Cod	51	male	artificial bait	(D & E)	1/2 full stomach
2	Cod	51	male	clam, scallop	no	
2	Cod	48	female	empty	no	
2	Cod	51	female	clam, artificial bait	(D & E)	
2	Cod	49	male	empty	no	
2	Cod	49	male	clam, artificial bait	(D)	
3	Cod	53	female	artificial bait	(E)	full stomach
3	Cod	55	female	scallop	(D & E)	full stomach
3	Cod	49	male	artificial bait	(D & E)	full stomach
3	Cod	49	female	clam, scallop	?	
3	Cod	50	male	artificial bait	(D & E)	full stomach

Table 5: Summary table of stomach analysis of the fifth treatment of Atlantic cod.

4/27/2001						
Raceway #	**Species**	**Length**	**Sex**	**Stomach Contents**	**Artificail Bait**	**Comments**
1	Cod	55	female	empty	no	
1	Cod	48	female	squid	no	
1	Cod	51	female	artificial bait, clam	(H)	artificail bait from treatment 4?
1	Cod	49	male	empty	no	
2	Cod	51	female	artificial bait, clam	(K & L)	
2	Cod	46	female	empty	no	
2	Cod	52	female	artificial bait	(H, J, K, & L)	
2	Cod	55	female	empty	no	
2	Cod	48	female	empty	no	
2	Cod	52	female	artificial bait	(H & J)	
3	Cod	52	female	artificail bait, squid	(J & L)	
3	Cod	48	female	empty	no	
3	Cod	48	female	crab, clam	no	
3	Cod	52	male	artificial bait, clam	(H)	not 100% sure it maybe (L) too
3	Cod	48	female	artificial bait	(L)	

Note: All fish lengths were measured to the nearest centimeter and these are the same fish tested in both the fourth and fifth treatments.

Table 6: Summary table of stomach analysis of the sixth treatment of Atlantic cod and Yellowtail flounder.

12/20/2001						
Raceway #	**Species**	**Length**	**Sex**	**Stomach Contents**	**Artificial Bait**	**Comments**
2	Cod	82	male	real crab	no	
2	Cod	59	female	empty	no	Empty stomach
2	Cod	64	female	real crab	no	
2	Cod	53	female	empty	no	Empty stomach
2	Cod	64	female	real crab	no	
2	Cod	61	female	empty	no	Empty stomach
2	Cod	58	female	all artificial bait	baits 1,2(?), & 3	Full stomach
2	Cod	56	male	empty	no	Empty stomach
2	Cod	61	female	empty	no	Empty stomach
2	Cod	56	male	empty	no	Empty stomach
2	Cod	62	female	all artificial bait	baits 1,2(?), & 3	Full stomach
2	Cod	59	female	empty	no	Empty stomach
2	Yellowtail	34	male	empty	no	Empty stomach
2	Yellowtail	34	male	empty	no	Empty stomach
2	Yellowtail	34	female	empty	no	Empty stomach
2	Yellowtail	35	male	empty	no	Empty stomach
2	Yellowtail	32	male	real sand dollars	no	green slurry
2	Yellowtail	35	male	empty	no	Empty stomach
2	Yellowtail	31	female	empty	no	Empty stomach
3	Cod	85	female	empty	no	Empty stomach
3	Cod	69	female	empty	no	Empty stomach
3	Cod	62	male	empty	no	Empty stomach
3	Cod	63	female	empty	no	Empty stomach
3	Cod	63	male	all artificial bait	baits 1 & 3	1/2 full stomach
3	Cod	68	male	empty	no	Empty stomach
3	Cod	61	male	empty	no	Empty stomach
3	Cod	64	female	empty	no	Empty stomach
3	Cod	62	male	real crab	no	
3	Cod	58	male	all artificial bait	batis 1 & 2	1/2 full stomach
3	Cod	69	female	real squid	no	
3	Yellowtail	35	male	empty	no	Empty stomach
3	Yellowtail	32	male	real sand dollars	no	green slurry
3	Yellowtail	34	male	real sand dollars	no	green slurry
3	Yellowtail	33	female	empty	no	Empty stomach
3	Yellowtail	30	male	empty	no	Empty stomach
3	Yellowtail	32	female	empty	no	Empty stomach
1	Yellowtail	31	male	real sand dollars	no	*died in raceway*

Note: All fish lengths were measured to the nearest centimeter.

Table 6: Stomach analysis continued.

Raceway #	Species	Length	Sex	Stomach Contents	Artificial Bait	Comments
1	Cod	54	male	empty	no	Empty stomach
1	Cod	55	female	empty	no	Empty stomach
1	Cod	57	female	empty	no	Empty stomach
1	Cod	57	female	real fish eggs	no	undeveloped yellow eggs
1	Cod	58	female	empty	no	Empty stomach
1	Cod	68	female	real fish eggs	no	developed yellow eggs
1	Cod	57	male	real crab	no	
1	Cod	56	male	empty	no	Empty stomach
1	Cod	60	male	empty	no	Empty stomach
1	Cod	58	female	empty	no	Empty stomach
1	Cod	70	male	empty	no	Empty stomach
1	Yellowtail	35	female	empty	no	Empty stomach
1	Yellowtail	33	female	empty	no	Empty stomach
1	Yellowtail	35	male	real bait unknown	no	
1	Yellowtail	29	male	empty	no	Empty stomach
1	Yellowtail	37	female	empty	no	Empty stomach

Note: All fish lengths were measured to the nearest centimeter.

Table 7: Summary table of stomach analysis of the seventh treatment of Atlantic cod.

12/28/2001						
Raceway #	**Species**	**Length**	**Sex**	**Stomach Contents**	**Artificial Bait**	**Comments**
1	Cod	56	female	real clam large piece	none	
1	Cod	57	female	fish eggs	none	the eggs could be sculpin eggs?
1	Cod	54	female	fish eggs	none	the eggs could be sculpin eggs?
1	Cod	55	female	real clam, crab 4 & 1, eggs	crab #4 and #1	crab #4 in gullet, 6 pcs of crab#1 in stomach
1	Cod	58	male	fish eggs	none	
1	Cod	54	female	empty	none	
1	Cod	58	female	empty	none	
1	Cod	55	female	empty	none	very ripe
1	Cod	56	male	empty	none	
1	Cod	55	female	empty	none	
1	Cod	55	male	empty	none	
1	Cod	53	female	empty	none	
1	Cod	54	female	empty	none	
1	Cod	55	male	empty	none	
1	Cod	55	female	empty	none	
1	Cod	58	female	real crab	none	probably cancer spp. (juvenile)
1	Cod	57	male	empty	none	
1	Cod	52	male	all artificial bait	crab #1	3 pieces of artificial bait (regurgitated)
1	Cod	55	male	empty	none	
1	Cod	58	male	empty	none	
1	Cod	55	male	empty	none	
1	Cod	55	male	all artificial bait	crab #1	4 pcs in stomach and 3 pcs in gullet
1	Cod	59	female	empty	none	
1	Cod	54	male	empty	none	
1	Cod	56	male	empty	none	
1	Cod	58	male	fish eggs, crab #1	crab #1	pooped fish eggs, 1 pc in stomach & 3 in gullet
1	Cod	56	female	hermit crab	crab #4	2 pcs of crab #4 in gullet
2	Cod	54	female	empty	none	ripe
2	Cod	53	female	empty	none	ripe
2	Cod	55	male	empty	none	
2	Cod	55	female	empty	none	
2	Cod	56	female	empty	none	
2	Cod	58	female	empty	none	
2	Cod	59	male	empty	none	
2	Cod	54	male	hermit crab	none	
2	Cod	53	female	all artificial bait	crab #4	1 piece
2	Cod	55	female	all artificial bait	crab #1	8 pieces
2	Cod	56	female	empty	none	
2	Cod	58	female	empty	none	

Note: All fish lengths were measured to the nearest centimeter.

Table 7: Stomach analysis continued.

Raceway #	Species	Length	Sex	Stomach Contents	Artificial Bait	Comments
2	Cod	57	female	empty	none	
2	Cod	56	male	empty	none	
2	Cod	53	male	small operculum	none	
2	Cod	58	male	fish eggs & clam meat	none	
2	Cod	57	male	empty	none	
2	Cod	54	female	empty	none	
2	Cod	54	female	small algae	none	
2	Cod	56	male	empty	none	
2	Cod	56	female	empty	none	
2	Cod	56	male	empty	none	
2	Cod	55	female	empty	none	ripe
2	Cod	55	female	empty	none	
2	Cod	56	female	all artificial bait	crab #1	8 pieces
3	Cod	57	female	empty	none	
3	Cod	56	female	empty	none	
3	Cod	66	female	fish eggs	none	eggs developed
3	Cod	59	male	all artificial bait	crab #1 or #4	3 pieces
3	Cod	55	female	fish eggs	none	
3	Cod	58	male	all artificial bait	crab #1	3 pieces some digested
3	Cod	54	male	empty	none	
3	Cod	55	male	empty	none	
3	Cod	53	male	empty	none	
3	Cod	54	male	empty	none	piece of cheese cloth
3	Cod	57	male	empty	none	piece of cheese cloth
3	Cod	56	male	empty	none	
3	Cod	56	female	all artificial bait	crab #1	1 piece
3	Cod	56	male	empty	none	
3	Cod	69	male	operculum	none	
3	Cod	55	female	empty	none	
3	Cod	55	male	empty	none	
3	Cod	57	female	real clam meat	none	
3	Cod	56	female	empty	none	
3	Cod	55	male	empty	none	
3	Cod	55	female	hermit crab claw	none	
3	Cod	54	male	empty	none	
3	Cod	55	male	empty	none	
3	Cod	54	male	empty	none	
3	Cod	59	male	clam parts	none	
3	Cod	58	male	empty	none	
3	Cod	56	male	clam	none	

Note: All fish lengths were measured to the nearest centimeter.

Table 8: Summary table of stomach analysis of the eight treatment of Yellowtail flounder.

1/4/2002						
Raceway #	**Species**	**Length**	**Sex**	**Stomach Contents**	**Artificial Bait**	**Comments**
3	Yellowtail	37	male	polychaetes	no	died & worked up 1-3-02
2	Yellowtail	35	male	clams	no	died & worked up 1-3-02
1	Yellowtail	33	male	empty	no	died 1-4-02
1	Yellowtail	36	female	empty	no	
1	Yellowtail	36	female	empty	no	
1	Yellowtail	33	male	polychaetes	no	
1	Yellowtail	35	female	polychaetes	no	
1	Yellowtail	41	female	empty	no	
1	Yellowtail	33	male	polychaetes	no	
1	Yellowtail	35	male	empty	no	
1	Yellowtail	35	male	empty	no	
1	Yellowtail	36	female	empty	no	
1	Yellowtail	35	male	empty	no	
1	Yellowtail	35	male	empty	no	
1	Yellowtail	34	male	empty	no	
1	Yellowtail	30	male	polychaetes	no	
1	Yellowtail	35	male	empty	no	
2	Yellowtail	39	female	polychaetes	no	died 1-4-02
2	Yellowtail	35	male	polychaetes	no	died 1-4-02
2	Yellowtail	31	male	empty	no	died 1-4-02
2	Yellowtail	33	male	polychaetes	no	died 1-4-02
2	Yellowtail	33	male	polychaetes	no	died 1-4-02
2	Yellowtail	31	female	polychaetes	no	
2	Yellowtail	35	female	polychaetes	no	
2	Yellowtail	35	male	empty	no	
2	Yellowtail	36	female	empty	no	
3	Yellowtail	35	male	empty	no	died 1-4-02
3	Yellowtail	35	male	empty	no	
3	Yellowtail	33	male	empty	no	
3	Yellowtail	38	male	empty	no	
3	Yellowtail	34	female	empty	no	
3	Yellowtail	33	male	empty	no	
3	Yellowtail	38	female	empty	no	
3	Yellowtail	33	male	empty	no	
3	Yellowtail	35	male	empty	no	
3	Yellowtail	35	female	empty	no	
3	Yellowtail	31	male	empty	no	

Note: All fish lengths were measured to the nearest centimeter.

Table 9: Atlantic Cod catch during the sea-trials comparing squid and artificial clam bait.

Date	# of Bundles	Haul #	Bait type	# of Hooks	Discards	Kept	Total Catch	Catch Rate
8/14/2001	*3*	*1*	*3 SQ*	*900*	*28*	*72*	*100*	*11*
8/14/2001	*3*	*2*	*3 AB*	*900*	*3*	*7*	*10*	*1*
8/14/2001	3	3	3 SQ	900	17	67	84	9
8/14/2001	3	4	1 AB, 2 SQ	900	12	48	60	7
8/16/2001	3	1	3 AB	850	2	17	19	2
8/16/2001	3	2	2 SQ, 1 AB	850	21	47	68	8
8/16/2001	3	3	3 SQ	900	31	71	102	11
8/16/2001	2	4	2 SQ	600	25	73	98	16
8/16/2001	3	5	3 SQ	900	33	108	141	16
8/16/2001	3	6	3 SQ	900	29	122	151	17
8/17/2001	*3*	*1*	*3 AB*	*900*	*3*	*7*	*10*	*1*
8/17/2001	*3*	*2*	*3 SQ*	*900*	*11*	*34*	*45*	*5*
8/17/2001	1	3	1 SQ	300	1	10	11	4
8/17/2001	3	4	2 SQ, 1 AB	900	20	48	68	8
8/22/2001	*3*	*1*	*3 AB*	*900*	*10*	*11*	*21*	*2*
8/22/2001	*3*	*2*	*3 SQ*	*900*	*23*	*64*	*87*	*10*
8/22/2001	3	3	2 SQ, 1 AB	900	18	66	84	9
8/24/2001	*3*	*1*	*3 AB*	*900*	*3*	*14*	*17*	*2*
8/24/2001	*3*	*2*	*3 SQ*	*900*	*41*	*119*	*160*	*18*
8/24/2001	3	3	3 SQ	900	31	56	87	10
8/24/2001	3	4	3 SQ	900	15	52	67	7
	Totals	21		17900	377	1113	1490	8
					25%	75%	**Percent Catch**	
					2	6	**Catch Rates**	

Note: Lines in italic are the hauls that were paired against (natural vs. artificial). Catch rates are shown as the number of fish caught per 100 hooks.
SQ. = Squid bait, AB = Artificial Bait

Table 10: Atlantic cod catch for the paired hauls of squid against artificial clam.

Date	# of Bundles	Haul #	Bait type	# of Hooks	Discards	Kept	Total Catch	Catch Rate
8/14/2001	3	1	3 SQ	900	28	72	100	11
8/14/2001	3	2	3 AB	900	3	7	10	1
8/17/2001	3	1	3 AB	900	3	7	10	1
8/17/2001	3	2	3 SQ	900	11	34	45	5
8/22/2001	3	1	3 AB	900	10	11	21	2
8/22/2001	3	2	3 SQ	900	23	64	87	10
8/24/2001	3	1	3 AB	900	3	14	17	2
8/24/2001	3	2	3 SQ	900	41	119	160	18
	Totals	8		7200	122	328	450	6
					27%	73%	**Percent Catch**	
					2	5	**Catch Rates**	

Note: Catch rates are shown as the number of fish caught per 100 hooks.
SQ. = Squid bait, AB = Artificial Bait

Table 11: Summary of trips targeting flatfish by two industry vessels.

Vessel	Date	Haul #	# of Hooks	Hook Type	# of Flounder	Catch Rate
Sea Winn	6/3/01	3	500	small "J"	2	0
Sea Winn	6/4/01	*				
Sea Winn	6/5/01	1	500	small "J"	5	1
Sea Winn	6/6/01	2	500	small "J"	7	1
Sea Holly	5/29/01	1	750	small "J"	7	1
Sea Holly	5/29/01	2	750	semi-circle	7	1
Sea Holly	6/1/01	1	750	small "J"	5	1
Sea Holly	6/1/01	2	750	semi-circle	5	1
Sea Holly	6/4/01	*				
Sea Holly	6/7/01	1	750	small "J"	5	1
Sea Holly	6/7/01	2	750	semi-circle	6	1
Sea Holly	6/9/01	1	750	small "J"	9	1
Sea Holly	6/9/01	2	750	semi-circle	14	2
		Totals	7500		72	1

Note: Trips on 6/4/01 caught large quantities of Spiny dogfish and no flounder.

Table 12: List of Equipment purchased with funds from this study.

Equipment Purchased		Project Purchased Under
Base controller for Zoom camera		Artificial Bait
New Equinox camera housing		Artificial Bait
Sanyo VHS VCR		Artificial Bait

Figure 1: Two Atlantic cod show “sniffing” behavior.

Figure 2: One Atlantic cod swims around the baited strings.

Figure 3: One Atlantic cod “mouths” a piece of artificial bait.

Figure 4: Two Atlantic cod eat pieces of artificial bait.

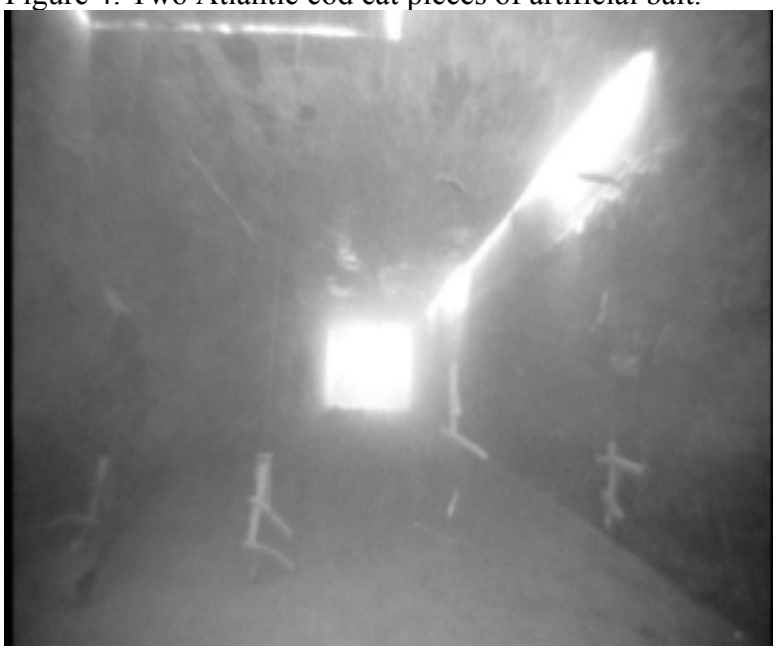

Figure 5: Baits are presented on 4 strings of monofilament line.

Figure 6: Trapezoidal camera frame w/ camera housing.

Figure 7: Front shot of camera frame showing hooks.

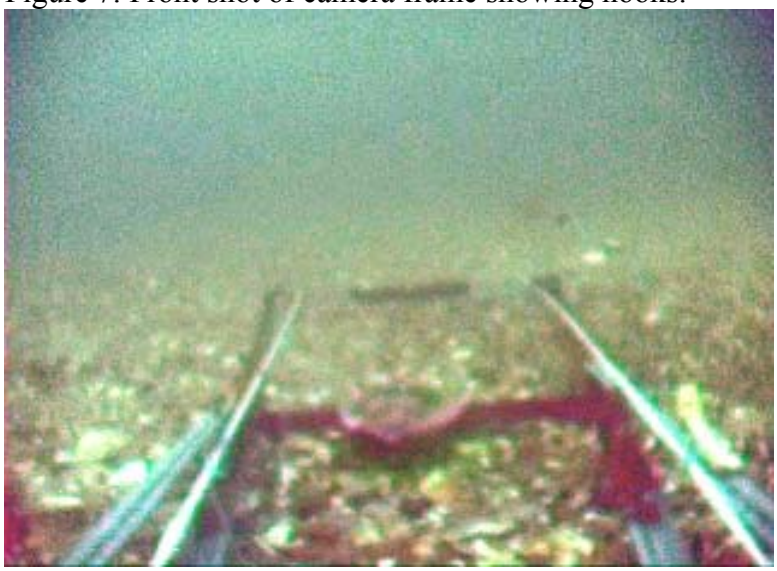

Figure 8: Winter flounder swimming in center of frame.

Figure 9: Winter flounder comes in and eats the artificial bait.