Observation of Fish Behavior in Trawls: Finding Ways to Reduce Bycatch

Bycatch, defined as unintended fish mortalities resulting from fishing operations, significantly impacts several important fisheries in the North Pacific Ocean. Bycatch includes the discard of undersized or unmarketable fishes and of species that are prohibited to a fishery and is a growing concern of management agencies, the fishing industry, and the general public. With the goal of mitigating bycatch problems, the Resource Assessment and Conservation Engineering (RACE) Division of the Alaska Fisheries Science Center (AFSC) has conducted research to aid development of fishing gear technology capable of both effective fishing and bycatch reduction. In recent years, research conducted by the Division in cooperation with industry and other research agencies has focused on the use of underwater video to study fish behavior in and around operating bottom trawls. In situ observation of fish behavior has provided new data on both how and why a modification succeeds or fails, making it a powerful tool for developing and testing fishing gear.

Fishing Gear Changes to Reduce Bycatch

One way to mitigate bycatch problems is to use selective fishing gear that catches target fish while allowing bycatch species and unmarketable fishes to escape. The most common example of gear changes to improve gear selectivity is the use of nets with larger mesh sizes to reduce the catch of undersized fishes. In addition to fish size, fish behavioral patterns are also exploited to make fishing gear more selective. However, information on the behavior of North Pacific fishes as they encounter different elements of fishing gear has been extremely limited. Traditionally, all gear modifications have been tested by comparing catches from comparable fishing efforts conducted both with and without the specific gear modification at issue. Such comparisons have been prone to errors due to differences in fish species encountered and physical conditions encountered during each fishing effort and have provided no data on why a modification succeeds or fails.

Equipment for Fishing Gear Observations

In 1990 the RACE Division entered a cooperative research project with the International Pacific Halibut Commission and the American Factory Trawlers Association to reduce halibut bycatch in trawl fisheries. Bycatch of Pacific halibut, *Hippoglossus stenolepis*, during bottom trawl fisheries has been one of the most problematic bycatch issues in North Pacific fisheries. The focus of the research project was to compare halibut behavior in bottom trawls with the behavior of Pacific cod, *Gadus macrocephalus*, and rock sole, *Pleuronecetes bilineata*, species which are both commercially harvested with bottom trawls.

The first step in the project was to develop an underwater video system to observe the behavior of bycatch and target species in the vicinity of trawl nets. A silicon intensified target (SIT) video camera with sensitivity at light levels as low as 10^{-3} lux was selected for the project. The sensitivity of the camera permitted observation to a depth of 40-100 m without requiring artificial lights, which can affect fish behavior.

Although towed remotely operated vehicles had been developed to independently maneuver a camera around a trawl during towing, such a system was determined not to be within the budget of the research project. Instead, it was decided to attach the video camera directly to the trawl. While limiting the mobility of the camera, this solution assured that the camera would be at the selected location throughout the tow.

To allow for real-time viewing, the camera was mounted on a manipulator, which allowed the camera to be aimed in a range of directions,

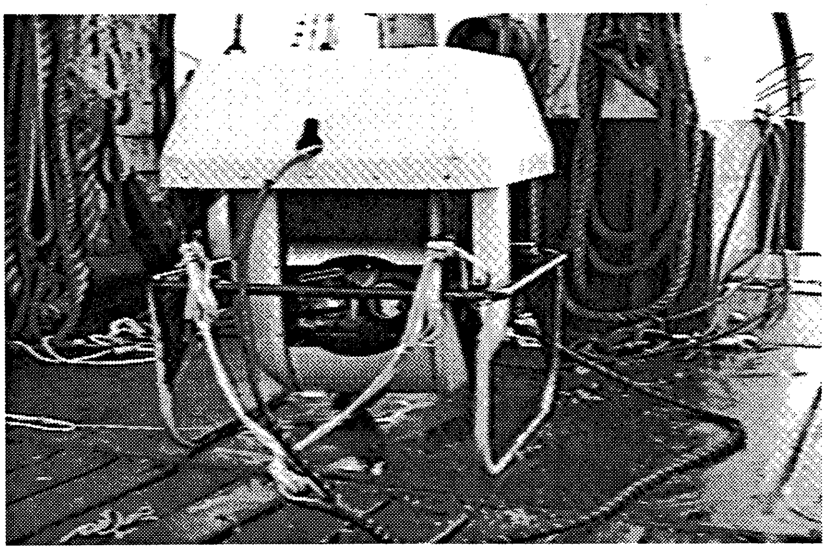

Figure 1. Trawl-mounted camera and sonar aiming system used to observe fish behavior.

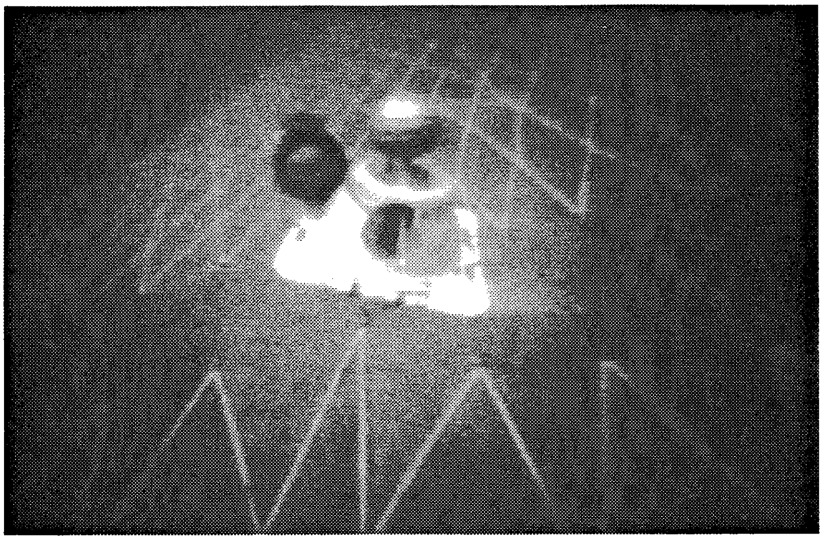

Figure 2. Self-contained camera system mounts on a large mesh trawl. Camera is under the plastic dome, while batteries and recorder are in the black tube to the left.

with an umbilical link to the towing vessel. The initial system used an off-the-shelf manipulator in a protective cage. The hydrodynamic forces resulting from towing at 3 knots caused this aiming device to fail frequently. A custom aiming device with movable farings to avoid flow problems was designed and built for the project in 1993 (Fig. 1). That same year, a small scanning sonar was added to supplement the video camera, providing range information and the ability to monitor the operating shape of the trawl. A 16-conductor electro-mechanical cable linked the trawl-mounted observation package to the surface. A 5,000-kg Kevlar strength member and a winch, which pays out cable when cable tension exceeds a set value, were added to the system to prevent cable breakage. The system was designed to be tied into the upper mesh panel of the trawl or towed within the trawl using auxiliary lines (Fig. 2). Video and sonar data could be viewed during the tow, with the sensors aimed anywhere below or to the sides of the mounting point.

In 1993, a self-contained system using the same camera was designed for observations where use of the cable-controlled equipment was not practical (Fig. 3). The camera was mounted on a fixed plate attached to the fishing gear with a pressure housing containing batteries and a video recorder trailed behind. While lacking real-time feedback, this simple system has been very convenient for short cruises, for mounting locations where the cable could excessively distort the trawl, or for use aboard vessels during commercial operations. This system has provided useful data in a wide range of situations.

Fish Behavior Observations

Test fishing grounds were located near Kodiak, Alaska, where Pacific halibut, Pacific cod, and rock sole were found in depths less than 75 m. The halibut encountered ranged from 65 to 85 cm in length, while cod were 55-75 cm, and rock sole 25-45 cm. Initial testing of the video system was conducted during short trips aboard industry-provided vessels in August 1990 and May 1991. Commercial vessels were chartered in July or August 1991-94 for four annual research cruises to observe fish behavior around bottom trawls. The trawl used during most of the cruises was an Aberdeen style bottom trawl with 46-cm diameter bobbin roller gear fished behind 2 X 3-m steel V doors. The trawl opened about 12 m between the wings and 4-5 m at the center of the headrope. Of the trawls available for the project, the Aberdeen style trawl was the most similar to those being used in the fishery and was an appropriate size for the low horsepower vessels that the project used initially.

Figure 3. Launch of the video system, installed behind the headrope of a bottom trawl.

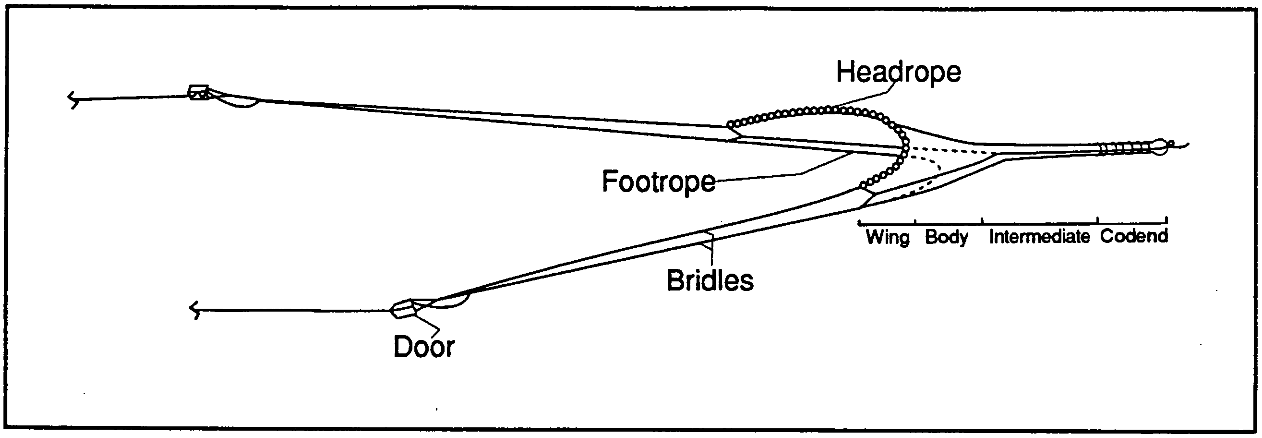

Figure 4. Parts of a bottom trawl.

The camera systems were placed most easily on the top centerline of the trawl between the headrope and the codend. More recently, the self-contained system was attached near the sides of the trawl and towed in the mouth of the trawl from lines attached to the trawl wings. This has allowed observations of fish behaviors and their reactions to trawl modifications over the entire length of the trawl. Some examples of behavior observations and testing of resulting trawl modifications are described below.

Fish Behavior Ahead of the Footrope

Bottom trawls are conically shaped nets which are pulled across the seafloor (Fig. 4). The front edge of the trawl contacting the seafloor (footrope) moves across the bottom in a U shape with the open end forward. Fishes are herded down the arms of the U (the wings) into the center where they generally turn and swim with the net before dropping back over the footrope.

Placing the camera above the center of the footrope allowed good viewing of fishes as they swam ahead of the trawl. Halibut swam in this area for up to 8 minutes at 3 knots speed, remaining 2-10 m ahead of the footrope most of the time. As halibut tired, they showed a pattern of dropping back toward the footrope and then bursting into fast swimming when they got close to it. Most of the fish swam within 1 m of the bottom when they were first herded by the trawl but rose more than 1 m off the seafloor just before drifting or swimming over the footrope and into the trawl.

Rock sole demonstrated much less endurance than the halibut did. Rock sole were quickly herded into a small area 0-2 m ahead of the middle 3 m of the footrope, where they swam for 10 seconds to 1 minute before turning and swimming into the trawl or under the footrope between the bobbins. Rock sole passed very low (< 1 m) over the footrope when they entered the trawl.

Pacific cod behavior depended on whether the fish encountered the trawl singly or in schools. Single cod behavior was similar to that of halibut, showing a pattern of swimming for several minutes ahead of the trawl and then rising when entering it. In schools, cod spent much less time immediately ahead of the footrope than individual cod or halibut did, with entire schools passing into the trawl in less than 2 minutes.

Fish Behavior in the Intermediate

In the intermediate section of the trawl, (the narrow tunnel of net between the funnel-shaped body of the trawl and the closed end where the fishes accumulate, known as the codend), cod and halibut again demonstrated similar behavior. Both species spent most of their time swimming well above (>15 cm) the bottom panel of the intermediate, occasionally striking the side and top panels as they were moved tail-first through the net. Cod and halibut were quite capable of maintaining their positions or swimming forward against the water flow, though they eventually were forced back toward the codend. Nearly all of the rock sole remained within a few centimeters of the bottom panel as they passed through the intermediate. Weaker swimmers than cod and halibut, the rock sole were barely able to maneuver or to slow their progress into the trawl.

Testing Modifications to Reduce Bycatch

Underwater video technology has proved to be an efficient tool not only for developing trawl modifications intended to reduce bycatch, but also for evaluating the success of those modifications. Researchers have used in situ video technology to observe the behaviors of different fish species as the fishes encounter trawls and have designed modifications to those trawls to reduce the bycatch of

Figure 5. A halibut near the starboard lower wing extension of the Aberdeen trawl. Note the gap between the rubber covered extension and the mesh of the upper wing.

nontargeted and prohibited species. With underwater video cameras, researchers are able to quickly determine whether a species' expected reaction to a trawl modification indeed occurs and whether sufficient numbers of nontargeted or prohibited species escape while targeted species remain. If a change to a trawl appears successful, then more rigorous counts from a videotape are used to estimate escape and retention rates. For modifications that do not work, the video camera can show how behavior differed from expectations, making iterative improvements toward a working system possible.

A range of trawl modifications have been tested through the the Division's cooperative bycatch reduction project. These modifications have come from individuals and organizations in the fishing and fishing gear industries, as well as from participants within the project. Distribution of videotapes compiled from field work has elicited further ideas for testing.

Lower Wing Extensions and Herding Ahead of the Trawl

In situ observations of the superior ability of halibut to swim ahead of the Aberdeen style trawl indicated that it might be possible to herd the fish out of the path of the trawl while retaining target species. In many trawls such as the Aberdeen, the forward lower corners of the net where the trawl is attached to the towing cables is removed and replaced by a cable strung with rubber bobbins or disks. This design eliminates a section of netting that is very vulnerable to tears, but still herds most fishes into the net. Underwater video observations showed that the gap between the lower wing extension and the upper wing is one area where halibut swim ahead of the trawl. Fowlweather Trawl, a trawl builder in Newport, Oregon, suggested arranging herding lines to direct fish ahead of the trawl toward the area of the lower wing extensions.

The self-contained camera system made it possible for researchers to view the area of the wing extensions closely. When viewed without use of the herding lines, a substantial number of halibut escaped between the extension and the upper wing (Fig. 5), while most of the cod and rock sole were herded toward the trawl mouth. A camera in the cable-connected system mounted above the footrope made it possible for project members to count the fishes being caught and compare that number with the number of fishes escaping (Table 1). Those counts showed a difference between halibut and cod escapes, with 79% of the halibut escaping, while still catching 59% of the cod. Herding lines were added ahead of the trawl to increase the number of fish moving near the wing extensions. This increased the proportion of halibut escaping to 88%, with no significant change in the number of cod escaping.

Openings in the Side Panels of the Intermediate

The observed differences between the behavior of rock sole and that of cod and halibut in the intermediate section of the net showed potential for further investigation. Because halibut and cod swam higher and contacted the intermediate side panels often, Dave Fraser, captain of the *Muir Milach*, the fishing vessel chartered for the 1993 research cruise, suggested cutting holes in the sides of the intermediate. Initial tests of this concept showed both halibut and cod

Table 1. Counts of fish escaping through holes in the side panels of trawl intermediate section.

Without cross lines	Caught	Escaped	% Esc.
Halibut	379	165	30
Cod	237	94	28
Rock sole	295	4	1
With cross lines			
Halibut	186	185	50
Cod	196	228	54
Rock sole	398	30	7

escapes with little loss of rock sole. The holes were expanded so that most of the top two-thirds of the side panels opened for a length of more than 3 m (Fig. 6). This design produced even better results, with 30% of the halibut escaping while only losing 1% of the rock sole (Table 2). Because video observations showed that both halibut and cod hit the side panels more frequently when many fishes were present, a series of lines were strung across the intermediate to simulate the bumping that takes place in crowded conditions. This modification raised the halibut and cod escapes to 50%, though the rock sole loss increased to 7%.

Figure 6. Halibut swimming in the trawl intermediate. Holes have been opened in the side panels to allow halibut to escape.

Where Next?

The two trawl modifications described above show good potential for reducing bycatch. There seems to be no reason why the holes in the side panels could not be extended to cover more of the upper intermediate to allow more halibut and cod bycatch to escape. The low loss rate of rock sole demonstrates that these trawl modifications could be used in rock sole fisheries without a great cost in foregone catch. The next step for investigation of these trawl modifications is to test them under commercial conditions. Such testing is necessary to assure that the bycatch reductions observed during research conditions hold up under the range of conditions encountered during commercial fishing.

Currently the wing extensions and herding lines are the most promising research direction for separating halibut from cod catches, but the loss of cod catch is probably too high at this stage of development for useful application. Because the catch rate of cod in the modified gear was 59% of the original rate, harvesters using the modified gear would have to spend 69% (1/0.59=1.69) more fishing time than they do now to harvest the same number of cod. This extra fishing time also increases the number of halibut encountered, decreasing the halibut bycatch reduction. While only 12% of the encountered halibut would be caught, 69% more would be encountered, resulting in a real bycatch reduction of 80% instead of 88%. Even though an 80% reduction in halibut bycatch is substantial, the 69% increase in fishing time would definitely discourage harvesters from using this modification as it now exists. Future research will compare a variety of leading lines and wing extensions.

Table 2. Counts of fish (by species) escaping over the wing extension of a trawl.

	Caught	Escaped*	% Esc.
Without herding lines			
Halibut	248	914	79
Cod	141	96	41
Rock sole	445	82	16
With herding lines			
Halibut	193	1142	88
Cod	239	152	39
Rock sole	315	120	28

*Two times count of escape over starboard extension (assumed equal on port side).

In situ video is a powerful tool for developing methods to reduce bycatch. Because the goal of the joint research efforts of the RACE Division, the International Pacific Halibut Commission, and the American Factory Trawlers Association is to facilitate the development of technology to reduce bycatch, the RACE Division has made this tool available to several groups with bycatch research projects. These groups include the Alaska Fisheries Development Foundation for testing a selective cod trawl, the University of Washington for experiments to determine the survival rates of discarded halibut, and the Canada Department of Fisheries and Oceans to test a grid system for reducing halibut bycatch.

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