Fishing Smarter:

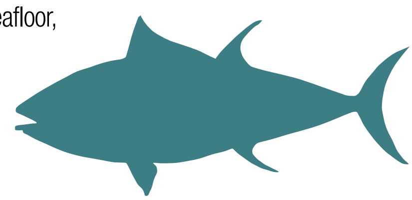
Improving Harvesting Technology Through the Study of Animal Behaviour

by Paul Winger

Those of you who have ever fly-fished for salmon, jigged a codfish, or hauled a lobster trap know how important it is to understand the behaviour of the animal you are trying to catch. Whether it is recreational or commercial fishing, those doing the catching are constantly trying to outthink the animal they are targeting. In fact, humans have learned to hunt all manner of marine species over the years, whether they be fish, shark, crab, snails, or squid. If it has worth, we have probably figured out how to exploit the resource.

Indeed fishing has been perfected over thousands of years and is perhaps among the oldest professions on the planet. Assuming even the earliest fishermen had a desire to be efficient and selective in what they caught, we can safely surmise they spent a great deal of time perfecting their techniques, equipment, and knowledge of animal behaviour.

Today not much has changed in many regards. Commercial fishing enterprises still spend considerable time making practical (and tactical) decisions about the type of fishing gear to use and its operation. And yet for many fisheries, low catch rates of the target species together with high bycatch of non-targeted animals is routine. Unfortunately, steaming to new fishing grounds is often not enough to improve efficiency or avoid unwanted species. Often the only way forward is to modify one's fishing gear to be more selective by species and size. A critical step in this process is understanding how animals interact with fishing gear. You might be surprised to know that the likelihood of capture has just as much if not more to do with an animal's behaviour than with the fishing gear used to catch it. And it is highly variable. Each species varies in its behaviour, and even this changes daily, seasonally, and with the growth of the animal. Not to mention daily and seasonal differences in environmental conditions, such as water temperature and ambient light intensity near the seafloor, together with an individual's hunger level and experience can all



have a big influence on the response threshold and behaviour toward fishing gear.

The study of animal behaviour in relation to fishing gear began as a formal scientific discipline among developed countries in about the 1960s. Since that time, an increasing number of government laboratories and universities have developed research capacity in this area. It is usually centred around either 1) the fundamental need to understand and improve stock assessment, or 2) applied R&D for the fishing industry to improve harvesting efficiency and selectivity. Together, this scientific body includes members from dozens of countries that meet annually to share new discoveries and developments.

Types of Technology Used

Prior to the industrial revolution, observational techniques for studying animal behaviour in relation to fishing gear were undoubtedly limited to watching from the riverbank, peering over the side of a boat, and snorkelling. While simple and effective even today, they are severely handicapped in their ability to observe at greater depths, reduced light, increased turbidity, and cold temperatures. It was not until the post-war years that significant technological advancements occurred in underwater breathing apparatus, optical camera systems, and acoustic technology. In many cases, it has been technology developed for military and medical use that fishing gear technologists and fish behaviourists soon found a way to adapt for the study of fish capture behaviour.

Figure 1: SCUBA diver filming from the headline of a bottom trawl.

Direct observations by scuba divers was one of the first technological strides in the 1960s. With the advent of SCUBA, humans could now stealthily descend onto the fishing grounds and observe interactions between animals and fishing gear. At first it was static gears such as baited traps and impounding gears such as weirs and cod pots. But it was not long before divers developed the skill to dive on mobile fishing gears such as bottom trawls, scallop drags, and clam dredges. The technique is still in use today and has been perfected to include the use of multiple support vessels, two-way communication among divers, manned vehicles, etc. The approach is used by research teams at the Fisheries Research Services (FRS) Marine Laboratory in Scotland as well as the National Oceanic and Atmospheric Administration (NOAA) Southeast Fisheries Science Center Laboratory in Pascagoula, Mississippi, USA. It is particularly useful where investigations can be conducted in shallow well-illuminated waters.

Underwater cameras are perhaps the most widely used instrument for observing animal behaviour in relation to fishing gear. They are small robust tools for the recording of information in the field that can be later analyzed in the comfort of the laboratory. Early versions were hand held but engineers soon developed water-tight, self-contained recording units that could be deployed onto fishing gear without the intrusion of a diver. Early versions were only capable of still photography. The technique has proven to be particularly ideal under dark conditions as animals do not perceive the device until the flash is released and the photograph taken. It is an unbiased means of recording animal behaviour without the worry that your recording device may be altering the behaviour you are trying to observe. But researchers soon yearned for motion pictures (video). Introduced in the 1960s, charge-coupled devices known as CCD cameras and silicon intensifier tube (SIT) cameras became available. Not long after, there were intensified CCD cameras (ICCD) and intensified SIT cameras (ISIT), helping propel scientific enquiry into deeper and darker waters where humans had never before observed. Uptake of these devices in fisheries research grew rapidly through the 1990s due to their small size, relative robustness, and relatively low cost. In the 21st century, we are now seeing researchers

Figure 2: Gear technologist preparing a camera system for deployment.

employing multiple-camera systems throughout the full length of a bottom trawl, stereophotography for precise size and swimming speed measurement, as well as infrared lighting and laser scanning technology to push the limits of the depths and distances that optical systems can function.

One of the common obstacles of underwater video cameras is the storage of the images. In shallow applications, an umbilical to the surface is often successful. It is real-time and cost-effective. But for deeper applications this is not always practical or cost-effective. One approach pioneered in Norway was the wireless acoustic transmission of live underwater video to the surface. But poor image quality and low frame rate transmission has prevented its wide-scale uptake. Another more popular approach has been to store the video in a recording bottle underwater and then retrieve it at a later time. Early versions were purpose built customized devices. Today several companies have now developed commercial off-the-shelf products. These recording bottles have internal clocks that are pre-set to turn on and off at determined times, contain batteries that send power out to the camera and lights (if desired), a capture board that digitizes the returning video, and a recording device to store the images. In fact, some of the recent designs can operate

Figure 3: Deployment of video system with umbilical to the surface.

Figure 4: Preparing a self-contained underwater recording bottle.

several cameras simultaneously. But storage and power are still major obstacles. Unlike an umbilical that provides unlimited power and recording ability, these systems eventually fill-up, burn-out, and must be brought to the surface for download and recharging. Short-term deployments on bottom trawls (< 2 hour tows) are a common application. But 72 hour deployments on a baited crab trap or fish pot are still technically challenging. Technological advancements in solid-state memory and battery life have and will continue to provide significant improvements, expanding the applications for these devices.

Acoustic systems have also proven effective in the study of animal capture behaviour, mainly because of their increased operational range and ability to penetrate dark and turbid waters where traditional optical (camera) systems fail to function. These systems include traditional echosounders, sonars, and telemetry. Downward-looking echosounders and various sonars have been used to investigate avoidance behaviour of pelagic and demersal fish species to approaching vessels and trawls. They are most often mounted on vessels, but more recently on towed bodies, remote operated vehicles (ROVs), and even autonomous underwater vehicles (AUVs). Advances in split-beam and multi-beam technology now provide multiple echoes of an individual fish while it is within the beam pattern, allowing estimation of its 3D displacement, orientation, and swimming speed. They can provide meaningful data on fish behaviour in complete darkness, strong turbidity, and at ranges (> 100m) optical systems could never match. Their main handicap is that they cannot track individual fish for more than a few seconds. So many observations are typically aggregated to give researchers an indication of what fish are doing at the school level.

Telemetry is a complimentary acoustic technology that operates at the scale of the individual animal. Using small animal-borne transmitters, researchers track the movements and behaviour of individual animals prior, during, and after an encounter with fishing gear. Attaching the transmitters (called "tagging") is usually the first challenge. Every effort must be made to ensure the catching, handling, anesthetizing, and tagging doesn't affect long-term behaviour once the animal is released. Different techniques have been developed, including external attachment, implantation in the body cavity, and in the case of larger fish like cod, insertion into the stomach. In an effort to minimize stress on the animals, some have even developed *in situ* techniques in which the animals are tagged underwater, including voluntary ingestion of transmitters wrapped in bait (Atlantic cod off Newfoundland), underwater surgery by SCUBA divers (rockfish off California), and subsea robotic surgery piloted from the surface (redfish off Iceland). Once the animals are tagged, a number of techniques can be used to "track" the animals and monitor their behaviour. Studies investigating capture behaviour in relation to fishing gear usually employ an array of fixed (listening) hydrophones in a relatively confined study area. Based on differences in the time of arrival of the pings emitted from the transmitters at the hydrophones, accurate positions of the animals can be computed every few seconds. This technology has been used to study the reaction distance and search behaviour of crab toward baited traps, cod toward baited longlines, as well as optimal reaction distance of plaice and cod toward approaching bottom trawls at different times of day and year.

Figure 5: Attaching a camera and recording bottle to the headline of a bottom trawl.

Figure 6: Underwater observations of Atlantic cod inside baited fish pots.

Looking Forward

As we look to the future, it is reasonably apparent that the commercial fishing industry worldwide will continue to face increasing pressures, including new regulations, bycatch restrictions, species- and size-selectivity, and concerns over ecosystem impact. More than ever, the industry is now faced with re-inventing fishing as a sustainable and conservation-oriented means of exploiting the oceans natural resources. This is a complex issue that requires time and resources to resolve.

Part of the solution to this challenge is a better understanding of how animals interact with fishing gear. What kind of better understanding you ask? The answer I believe is two-fold:

Figure 7: Attachment of an acoustic transmitter to an adult American plaice.

i) First, we must strive for improved integration and processing of observational data from multiple technology sources. Though much has been learned since the earliest studies in the 1960s, there are still many gaps in the current understanding of how animals encounter, get caught, and escape from fishing gear. Each technology, whether optical or acoustical, has its own inherent benefits and limitations, and a combination of multiple instruments is often necessary to understand the capture process from start to finish. Integrating these data with an emphasis on the quantification of animal behaviour, not just descriptions of behaviour, is required.

ii) Armed with this information, we must seek to understand *why animals do what they do*. Future research must attempt to tackle the functional explanations behind behavioural expression. We need to explore the costs and benefits associated with the decisions that animals make and how to predict the probable (optimal) decision under different conditions. For example, what are the behavioural trade-offs that fish make in response to an attractive odour plume when simultaneously engaged in spawning, or by contrast, what is the optimal avoidance distance to an approaching trawler when actively engaged in feeding?

In summary, several technologies now exist for the observation of animal behaviour in relation to fishing gear. Depending on the application, researchers may use one or more optical or acoustic technologies in order to understand the behavioural ecology of animals, their capture process, and how it varies with species, size, and environmental conditions. This leads to informed decisions about fishing gear design and engineering, improving the species- and size-selectivity of the gear, reducing unwanted bycatch, and unnecessary discarding.

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