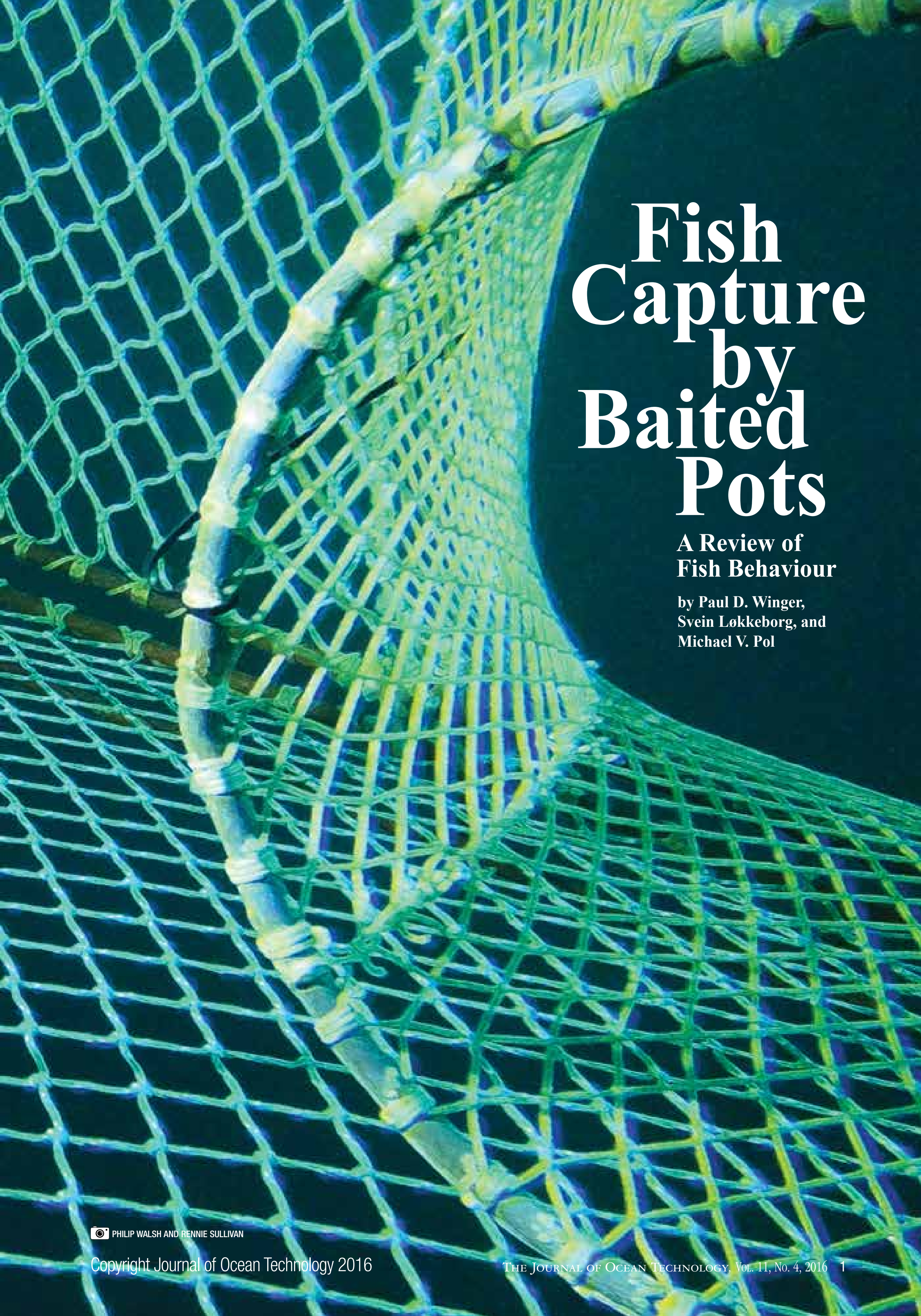

Fish Capture by Baited Pots

A Review of Fish Behaviour

by Paul D. Winger, Svein Løkkeborg, and Michael V. Pol

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Figure 1: Bait plays a primary role in attraction by producing a plume of odour. Fish chemically elicited to the presence of bait swim upcurrent to find the odour source.

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Introduction

Fishing with baited pots is documented back over two millennia, but likely dates to pre-history. The technique has long been popular in developing countries because the fishing gear is often low cost, easy to build, and transportable. Today, baited pots are receiving renewed and wider attention for new reasons. Market-driven forces, sustainability certifications, and eco-labels are increasing pressure for "greener" fishing technologies. Pots are attractive because they are fuel efficient, species-selective, produce low seabed impacts, yield high quality fish, and offer low discard mortality of non-targeted species.

We consider the behaviour of fish towards baited pots in three phases. Fish must first sense and be attracted to the gear. Once they have located the gear, they must decide to enter, which is followed by retention of correct species and sizes of fish. Each phase of the capture process involves a suite of senses, reactions, and choices. This essay discusses the current knowledge concerning

fish behaviour at each phase, building upon previous reviews by Norwegian scientist Dag Furevik in 1994 as well as Bjarti Thomsen of the Faroes and co-authors in 2010. It responds to the recent acceleration of scientific exploration of pots, which has been driven by a number of new factors, namely low cost underwater cameras, LED technology, market demand for high quality sustainably caught fish, and mitigation of mammal by-catch. These drivers did not exist to the same extent a few years ago and have led to several dozen new published and unpublished studies (including this issue of the JOT). In some cases we even have new knowledge for previously disregarded species of fish, such as white hake (*Urophycis tenuis*), American plaice (*Hippoglossoides plattessoides*), and Greenland halibut (*Reinhardtius hippoglossoides*).

Phase One – Attraction

Bait plays a primary role in attraction by producing a plume of odour. Fish chemically elicited to the presence of bait swim upcurrent to find the odour source (Figure 1). Chemically

Figure 2: The degree to which fish are alone or among conspecifics (i.e., fish of the same species) can exert a powerful influence on the behavioural expression of individual fish. It is believed to be related to perception of risk and, based on the information collected from neighbouring conspecifics, can result in an individual conforming its behaviour in a group setting (restricting its behavioural expression) or increasing expression of a particular behaviour (social facilitation).

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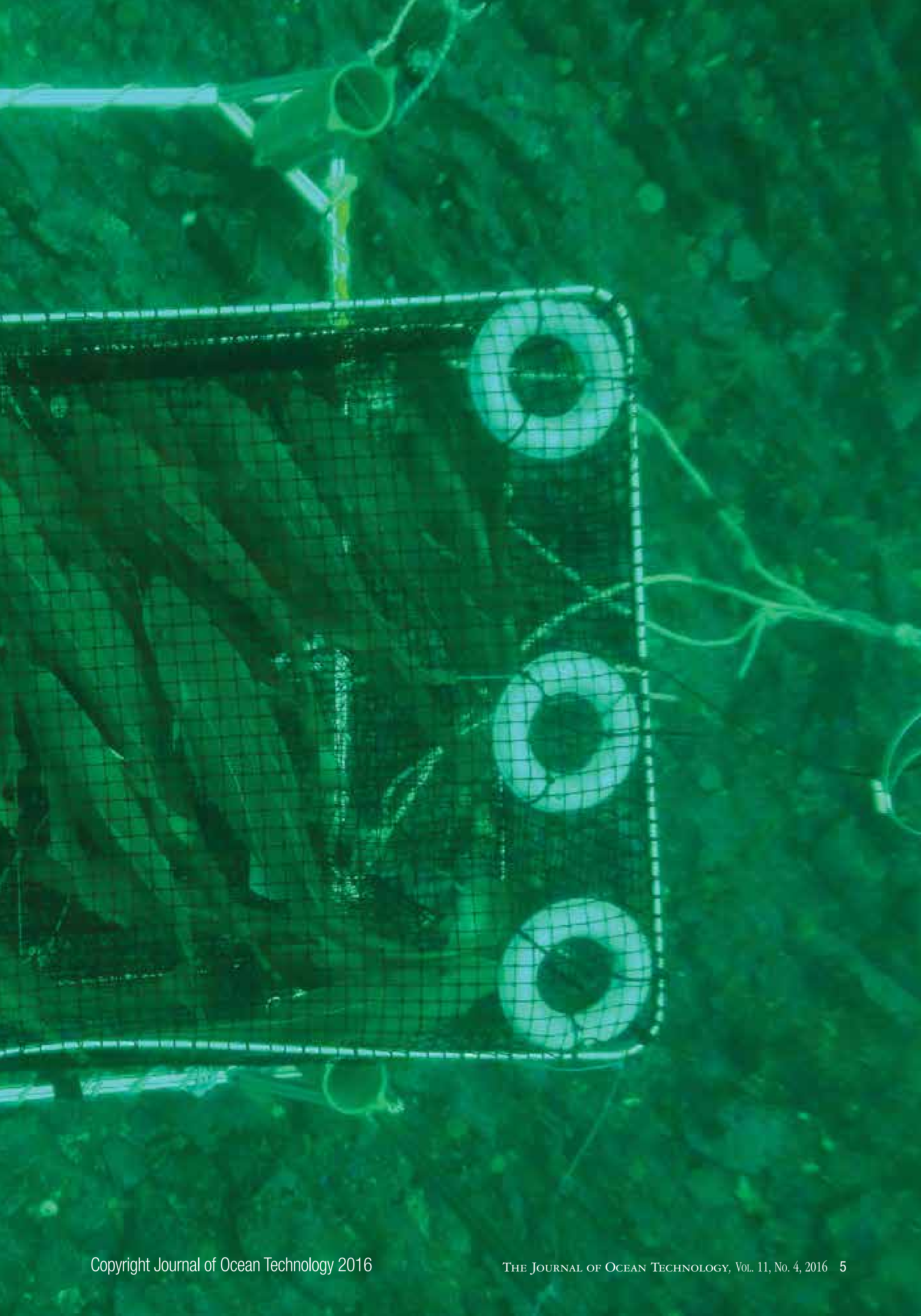

stimulated rheotaxis is the most likely mechanism used by fish and crustaceans to locate odour sources. Gradient search behaviour, where an animal reacts to a concentration gradient that increases as the distance to the odour source is reduced, is an alternative mechanism but less likely because small scale turbulence often make gradients weak and inconsistent. Olfactory arousal followed by rheotactic orientation to locate the chemical source has been documented in several species. The shape, intensity, and persistence of the plume are affected by many variables. The probability of entering and detecting an odour plume, the tendency to respond to the odour, and the likelihood to locate the odour source are also influenced by a great number of biological and physical variables.

Success finding the plume source is affected by internal factors such as activity rhythms and feeding motivation (hunger state) as well as the external environment (e.g., light, current, temperature). Several species of fish exhibit diel rhythms in swimming and feeding. Variation in activity is often attributed to changes in ambient light level, which can have a direct impact on food search behaviour. This observation is supported by studies of gadoids (cod, haddock, whiting) in which the peak in activity in the morning changed in connection with the change in the time of sunrise. According to these findings, the success of fishing with baited gears should be influenced by the relative time of day when the fishing gear is being deployed at sea. Supporting evidence comes from other fisheries: longlines deployed before dawn catch twice as much haddock compared to later in the day. More cod have been shown to locate baits during periods of high (day) rather than low (night) activity, and cod located baits 50% faster during the day.

Once a plume is encountered, hunger state and feeding motivation may affect response threshold, food searching behaviour, and response intensity toward baits. Sablefish responded to lower bait odour concentrations when tested after four days of food deprivation, compared to satiation feeding. Response intensity (swimming speed and turning rate) and duration to bait odour were also increased with increasing food deprivation. Similarly, Pacific halibut were shown to locate more baits, and found baits more quickly, as deprivation increased. Hunger status and motivation state also affect food searching behaviour and responsiveness to prey. Such effects will alter response thresholds, and therefore the distance from which the fish will start a food search, the resulting search pattern, location time, and time spent searching for the odour source. Thus under increased food need, fish intensify their search for food and may therefore increase the probability of locating a food odour source, whereas fish with low hunger level are less likely to search for food.

External factors such as ambient light level, water current, and water temperature also affect how fish interact with baited pots. Light level has a direct effect on locomotion and the ability to locate bait, independent of the effect of diel rhythms discussed above. Current velocity may affect food-search strategy due to its effect on swimming activity. As food-searching fish swim predominantly upstream to an odour source, it would be energetically advantageous to be active during periods of moderate or low current velocity, and to stay in shelter when the current is strong. On the other hand, current is the most important agent for dispersion of chemicals in seawater, and a long ranging odour plume can only be created when the current velocity is sufficiently high because the rate of diffusion in water is very low. Water temperature is the third physical variable that can influence fish interaction with baited gears. Increasing temperature increases the scope of activity and swimming activity in fish (up to a point); higher ambient temperature may lead to more activity and more encounters with the bait odour plume and thus the gear. Temperature is also known to increase the metabolic and gastric evacuation rates of fish, therefore increasing food consumption and feeding motivation, and leading to stronger responses to bait.

Phase Two – Capture

Sense of smell brings a fish into closer, perhaps visual, contact with a baited pot. Underwater observations have shown that baited pots only capture a fraction of the fish that respond to the odour plume. Fish that subsequently enter a pot have overcome the inhibition of entering a restricted space, or have higher levels of attraction to the pot. Fish that do not enter are in the opposite condition. Therefore, understanding the attractive and inhibiting factors of pots can assist the improvement of efficiency.

As with attraction, feeding motivation, primarily hunger, is believed to be one of the most important stimuli for fish to enter pots – hungry fish are expected to behave less cautiously than satiated fish. Fish that choose to bite baited hooks often have empty stomachs or are in poor condition. The same may be true for fish that enter pots. In contrast, when hunger levels are low, pot entries appear to decline. Low catches in pots coincide with the presence of plentiful prey items. Consequently, variation in potting success is strongly related to the seasonal presence and absence of prey.

At the same time, fish are receiving input visually on possible risks associated with entering a pot to reach the desired bait. Several species of fish have been shown to be relatively unsuccessful in locating and attacking baits in darkness, suggesting that vision is an important component of bait location. Details of pot construction such as the angles, sizes and shapes of entrances have been found to decrease inhibition toward pot entry.

The degree to which fish are alone or among conspecifics (neighbouring fish of the same species) can also exert a powerful influence on behavioural expression. Behavioural ecologists call this "social learning" or "social facilitation," and it has been widely documented in marine and freshwater species of fish. It is believed to be related to an individual's perception of risk and, based on the information collected from neighbouring conspecifics, can result in an individual conforming its behaviour in a group setting (restricting its behavioural expression) or increasing expression of a particular behaviour (facilitation) (Figure 2). Dominant or bold fish thus may act as social facilitators, either encouraging other fish that the pot is safe to enter, or demonstrating how to enter. Evidence has shown that leaving a fish in a pot can encourage entry by others, although other researchers have reported that conspecifics can guard an entrance and deter other fish from entering.

The use of artificial light has received renewed interest due to technological advancements. Light emitting diodes (LED) are now available in a wide variety of colours, intensities, and formats (e.g., individual lamps or in ribbons) (Figure 3). Swedish scientists found that a small green LED lamp in a pot increased the catch efficiency of large cod by up to 80%. A subsequent study in Canada found that pots equipped with green lamps caught greater numbers of cod and American plaice. However, the same study also showed that Greenland halibut avoided pots with light, so the effect may be species specific. Works carried out in Iceland demonstrated that unbaited pots with lights caught large numbers of cod; video observations showed that the cod were feeding on krill attracted by the light source. Why artificial light attracts or inhibits fish entry is still unknown, but may have something to do with visually assisting entry, visually identifying conspecifics or competitors, attraction of prey species, or other factors.

Inhibition to entry may be reduced by increasing prior experience with pots themselves. This suggestion derives from lobster pot fisheries, where undersized lobsters are capable of entering pots, feeding, and exiting several times in their lives before growth prevents exit and capture results. Laboratory experiments with juvenile cod

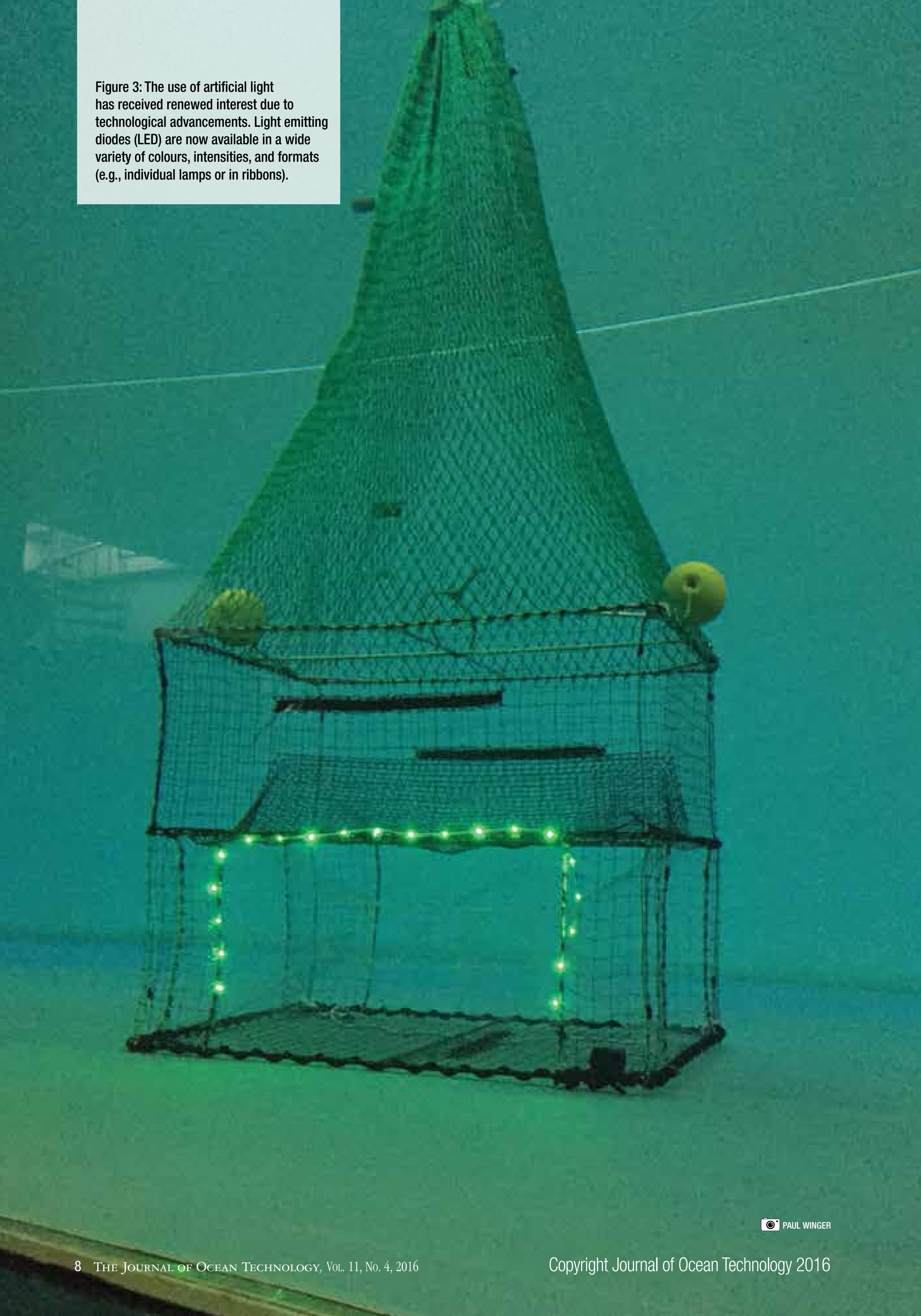

Figure 3: The use of artificial light has received renewed interest due to technological advancements. Light emitting diodes (LED) are now available in a wide variety of colours, intensities, and formats (e.g., individual lamps or in ribbons).

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have shown that the complexity of the rearing environment influences decisions toward shelter or to school in later life.

Entry may also be increased by altering pot volume, shape, entrance characteristics, and pot rigging. Several studies have documented that larger pots tend to catch more fish than smaller pots when tested side-by-side. The alignment of entrances with the direction of fish approach has also been shown to be important. Video observations suggest that some species may not actively search for entrances if they do not lie upstream, which could be due to poor vision, or an inability to locate the bait after leaving the plume. The characteristics of the entrance are also important as they determine the likelihood of a fish committing to enter the pot. Shape of the entrance opening, slope of the ramps leading to the entry, and funnel length have all been shown to affect catch rates.

Phase Three – Retention

Several competing factors encourage or discourage fish to remain inside a pot once they have entered. Tipping the balance to encourage targeted species and sizes to remain is key to successful fishing. Factors encouraging exit include decreasing odour stimuli due to bait exhaustion or depletion, competition with other species in the pot, as well as the selective removal of non-targeted species and sizes using by-catch reduction technology (e.g., mesh size, escape vents, etc.). On the other hand, retention is encouraged by continued bait stimuli, presence of conspecifics, and novel design features such as fish retention devices and secondary chambers.

Non-targeted species can create competition for space and resources. Underwater observations have shown that hagfish (*Myxine glutinosa*) commonly compete for bait in fish pots depleting the bait, and altering and weakening the bait plume, and even preying on the target species inside the pot (Figure 4). A recent study in Canada documented snow crab (*Chionoecetes opilio*) predation upon American plaice in baited pots targeting flatfish. While pots are known to produce low stress in fish, these examples demonstrate the possibility for negative encounters with other species (interspecific competition) which may encourage fish to leave a pot.

Several studies have also shown that changing the mesh size and/or inserting escape vents in pots influence the size selectivity of the fishing gear and the resulting length frequency of fish captured. Using innovation in gear design to achieve size-selectivity of this nature has been documented for coral reef fish traps, black sea bass traps, Australian demersal fish traps, and most recently in Sweden for floating cod pots. The Swedish experiment is particularly interesting because not only did fish size increase with increasing mesh size, fishing power of the pot was also improved – i.e., the catch of large fish increased in pots with large mesh escape windows relative to pots without the selectivity device.

Fish retention devices (sometimes called triggers or non-return devices) installed in the entrances to pots are a common method for encouraging fish to remain. Various designs exist, but they commonly incorporate either fingers or one-way gates. A study in the western USA showed that these devices significantly improved the retention of Pacific cod. However, the effect is likely to be species specific. A Canadian study found that adding retention devices to baited pots significantly reduced the capture of white hake. Using underwater cameras, Norwegian researchers documented individual variation among cod toward the devices. Most cod were unaffected by the device, but some individuals would avoid entering the pot. The findings suggest that in some cases, retention devices might actually deter fish from entering, implying variation in successful application will occur both between and within species.

Finally, pots often feature secondary chambers to encourage retention of fish in pots, typically in the form of a floating roof or a mesh panel that divides the pot interior. In both

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these cases, bait is often not present in the secondary chambers of the pots; rather they capitalize on the behaviour of certain species. Underwater video observations have shown that gadoids in particular, for reasons that are not clear, tend to rise once they enter a pot. Current cod pot designs include secondary chambers to exploit this rising behaviour to lead cod away from the entrances.

Concluding Remarks

An acceleration in scientific exploration has occurred in the last few years toward the goal of developing commercially viable baited pots. Much of this work has focused on groundfish in the North Atlantic in response to new drivers for high quality sustainably caught fish and the need to mitigate mammal by-catch in certain fisheries. Advances in low cost underwater cameras have provided a novel tool for researchers and have led to significant growth in underwater video observations. We have provided a model of attraction, entry, and retention to assist the understanding of behaviour, which is then incorporated into design. What has become clear with this increasing research enterprise is the degree of variation in behavioural expression between and within species of fish, and across regions, which creates challenges in experimentation and design. Notwithstanding changes in fish availability (which we have not discussed), it is now abundantly clear that the vulnerability of fish to capture by baited pots will continue to vary widely through time and space with so many internal and external factors at play. Moving from frustratingly low catch rates toward reasonable and predictable catch rates will be important to the financial viability of fishing enterprises and the continued adoption of this innovative fishing technique.

Acknowledgments

Images courtesy of Philip Walsh, Rennie Sullivan, Brett Favaro, Philip Meintzer, and Paul Winger. This is Contribution #70 from the Massachusetts Division of Marine Fisheries.

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