Communication Beneath the Waves

How do marine animals communicate in the often dark and vast featureless oceans?

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HUMAN beings have a well-developed language having scripts and phonetics for communication purposes. We also sense our surroundings by mostly visual and auditory input. But how do marine organisms communicate with each other and sense their surroundings in a vast featureless ocean?

This is mainly achieved by either employing a single type of signal consisting of visual, acoustic, chemical, magnetic, electrical and bioluminescent signal or a combination of two or more types of signals to locate food, mate, habitat, and even to avoid predators.

Visual Signals

Fishes, dolphins, whales and other invertebrates such as crabs and shrimps rely on their eyes to communicate effectively in the vast ocean during the daytime. Even sea birds like gannets, grebes, loons, cormorants, and penguins use their vision to catch fishes underwater.

The eyes of all these animals possess two types of cells called rods and cones within the retina. The rods help in visualising in low light conditions whereas cones remain active in high light conditions and are useful in colour vision.

Additionally, some animals such as dolphins have a reflective layer behind the retina, called tapete lucidum, which helps them to see their environment in low light deeper waters by reflecting lost light back into the retina for the second time. The information received by the eye is converted into a visual image by the brain of the receiver in real-time, and the desired objectives (recognising the relatives, predators or food) are carried out.

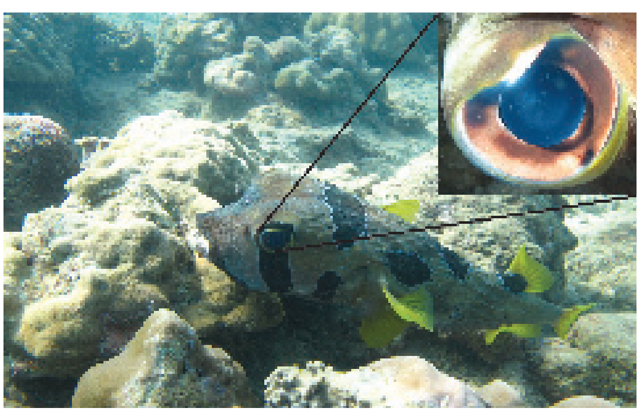
The limitations of this signal are: (a) it is not receiver specific and (b) is effective during day-time and in the euphotic zone (light penetration depth ~ 100m) only. Even in the euphotic zone where light is available, visibility is still comparatively much less than that in the air; because water is a denser medium and often bears sediment particles which further attenuate the light intensity.

Acoustic Signals

Marine mammals such as whales and dolphins are notable examples using acoustic signals (sound) for the acquisition of information from the environment. Aristotle (384 to 322 B.C.) was the first biologist who described in his famous book *Historia Animalium* that dolphins are capable of listening to underwater sounds. The marine mammals using short pulses of sound or clicks can detect food, obstacles, and even their relatives after listening to the echoes.

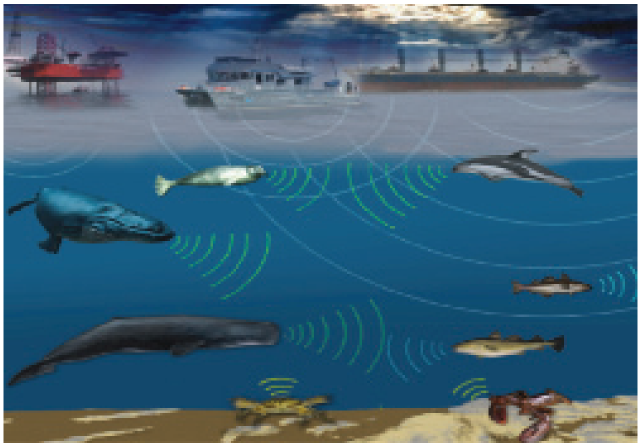
Sound production is also known in case of fishes for a mating call between male and female individuals of a species. For example, males of oyster toadfish emit a series of short-duration sounds to attract females during the breeding season. The seawater medium being denser than air propagates the sound to far off distances from the source (speed of sound: air ~ 330 m/s and seawater ~ 1500 m/s) making sound quite helpful as a signal for the communication purpose.

Due to the fast propagation of sound in seawater, baleen whales in the ocean can receive the signaling sound produced by their own relatives far beyond even from a distance of around 10 kilometres where visual signals cannot be used for the acquisition of information. But the production of sound



A pufferfish (with eye zoomed) from the coral reefs of Andaman and Nicobar Islands, India. *Courtesy: Titus Immanuel, Madras Christian College, Chennai, India*

An oyster toadfish
Photo from NOAA, *Credit: Andrew David, NOAA/NMFS/SEFSC Panama City; Lance Horn, UNCW/NURC — Phantom II ROV operator*



Communication by marine mammals using sound
Image Source: https://blog.nationalgeographic.org

by organisms is energetically costly, and hence switching to different mode at times is always advantageous in the marine environment.

Chemical Signals

Just imagine you are roaming in a big city with perpetual darkness on a hungry stomach. How will you find out your food? Obviously, it is the smell of food which will attract you towards a restaurant. This smell is nothing but volatile chemicals emanating from the cooked food.

Similarly, organisms living in the marine environment (especially deep sea) depend upon chemical signals to get information about their food, mate, habitat, and even to protect themselves.

The prey organisms often also use chemicals to obtain food without becoming food for others. This mode of communication is prevalent in all zones of ocean including the deep sea. Organisms that use visual and other modes of communication also rely on chemical signals. Chemicals are detected by receiver organisms either by olfaction at a distance from their source or by touch. The main advantage of chemical signals over visual ones is that vast areas of the ocean are actually under perpetual darkness and water is a hazy medium limiting visibility.

Sometimes food organisms undergo alteration in size and shape to avoid being eaten in response to chemical signals

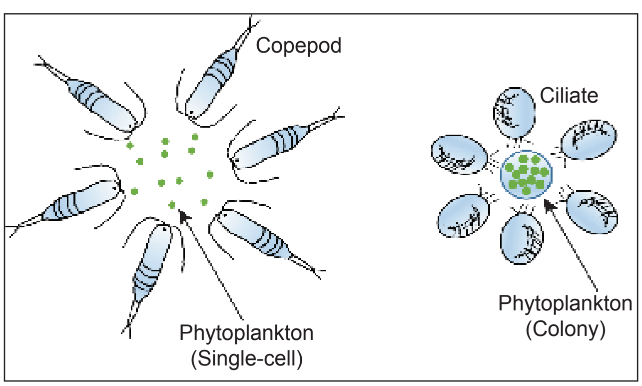


Image showing change in size and shape of phytoplankton in response to predator size

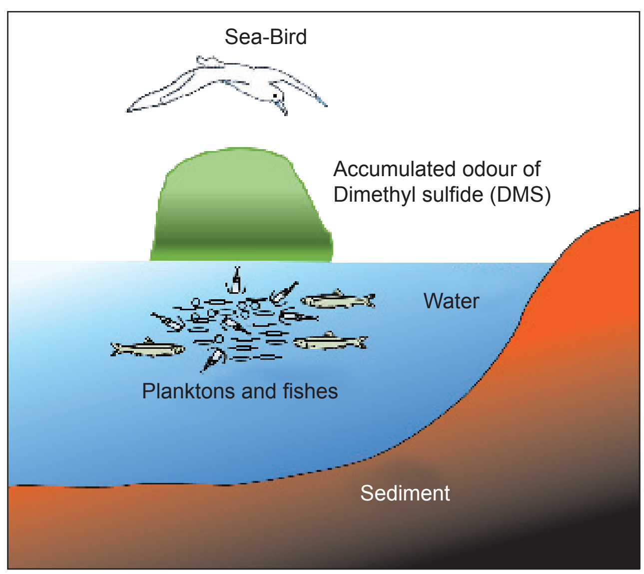
released by their predators. For example, Jeremy Long and his co-workers at the Georgia Institute of Technology proved that chemical signals from specific predators induce a shift in the shape of *Phaeocystis globosa*, a phytoplankton. When copepods are in the surrounding medium, *P. globosa* remains as single cells to avoid grazing, because copepods lose interest due to the small size of cells. On the other hand, when ciliates dominate in the medium to graze, the *P. globosa* cells form large colonies so that ciliates cannot engulf them.

Now, how do sea birds detect fishing grounds in the sea? It is quite obvious that they cannot detect those productive areas from several thousands of kilometres? The answer is Dimethyl Sulphide (DMS), a gaseous compound released into the atmosphere when zooplankton feed on phytoplanktons in the water column. This was reported by sensory biologist Gabrielle Nevitt at the University of California in the 1990s.

According to him, the seabirds fly great distances, sometimes thousands of square kilometres to reach a productive area using DMS as a signpost and once there, they then can use both odour and vision to pinpoint and catch fishes directly. So, more DMS released from an area means more zooplankton feeding on phytoplankton indicating a potential fishing zone where sea birds such as storm-petrels, albatrosses, petrels, shearwaters and others can fill their stomach.

An investigation led by chemical ecologists Danielle Dixson and Mark Hay from Georgia Institute of Technology, USA, revealed that corals send out an emergency call in the form of a chemical signal in a matter of minutes when toxic seaweed *Chlorodesmis fastigiata* overgrow them in their vicinity. After detecting this emergency signal, the broad-barred goby fish (*Gobiodonhistrio*) reaches the site and eats the seaweed, accumulating the toxin which in turn protects the goby fish against predators.

Although marine organisms have the capability to detect the chemical signals from the water column, some chemicals are tightly associated with the body surface of the organisms and convey information in a surface-bound form to their own larvae when touched physically. For example,



Courtesy: Conceptualisation by Gabrielle Nevitt, University of California, USA

Photo source: Danielle Dixson, Georgia Institute of Technology, USA

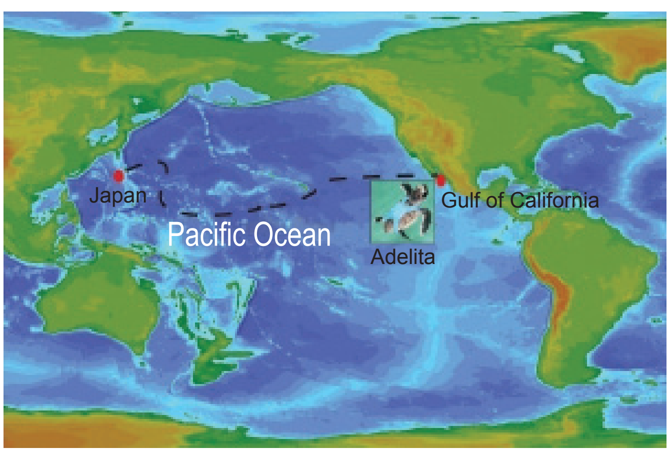
the Settlement-inducing Protein Complex (SIPC) associated with the barnacle shell promotes the gregariousness (living in groups) of barnacles. This protein complex was initially purified from the adults of barnacle *Balanus Amphitrite* by a team of Japanese biologists led by Nobuhiro Fusetani in 1998.

The SIPC is a glycoprotein which induces the settlement of the barnacle larvae near their own relatives. In 2013, a research team led by ecologist Hebert Ely Vasquez from Nagasaki University, Japan, also isolated a glycoprotein from the shell of pacific oyster *Crassostrea gigas* and proved a similar role in the gregariousness of oysters. Recognising these glycoproteins (molecular markers) is nature's gift to the larvae for finding a suitable home in a vast ocean.

Magnetic Signals

The Gahirmatha coast of Odisha is the largest nesting site in the world for Olive Ridley turtles. Lakhs of these animals arrive there for nesting purpose from the beginning of November every year. So how do these animals recognise their birthplace?

It has been reported that sea turtles can travel long distances with greater accuracy towards a specific destination. Turtle biologist Wallace J. Nichols in 1996 tracked the spectacular journey of Adelita, a young loggerhead sea turtle called *Carettacaretta* in the Pacific Ocean using a satellite tag. Adelita was rescued by the researchers from a fisherman after being caught in the Gulf of California and was reared in captivity. As she grew up, Wallace Nichols decided to initiate a research project by tracking this animal in the wild. So they decided to release her in the Gulf of California with a satellite tag fixed to her shell. Fortunately, the tag remained functional for almost one year and transmitted signals indicating Adelita's journey. To his surprise, Wallace noticed that the turtle crossed the entire Pacific Ocean at a speed of almost 100 km a week and reached a Japanese nesting beach.



Courtesy: Map- Srikanta Dora, CSIR-National Institute of Oceanography, Goa; Adelita Photo- Discover magazine (http:// blog.geogarage.com/2011/02/turtles-use-earths-magnetic-field-as.html)

A subsequent investigation by a team of researchers at the laboratory of Ken Lohmann in the University of North Carolina revealed that the turtles have an unusual capability to sense the magnetic field of the earth for navigational purposes.

The magnetic feature of the earth does not fluctuate with season or weather making it a robust signal for migratory animals in the ocean. It is believed that turtles have tiny magnets called magnetites (iron-based minerals containing Fe_3O_4), which respond to the earth's magnetic field.

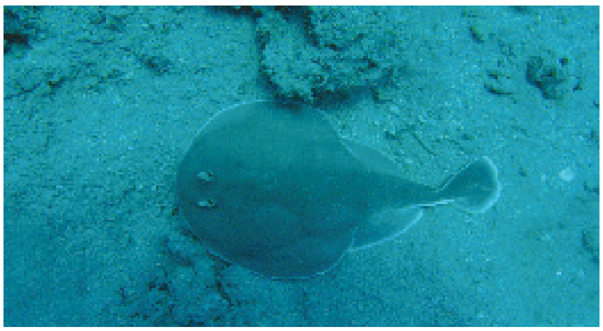
Besides turtles, magnetic signals also help in the navigation of sharks, lobsters and salmon. This signal basically provides dual information to the animals: the position and direction. The magnetic field acts as a Global Positioning System (GPS) and indicates the accurate position (latitude and longitude) in the ocean during navigation and the compass information helps the animals to orient themselves in a particular direction such as north or east.

Electrical Signals

Some marine vertebrates such as skates have the capability to communicate with each other during social and reproductive interactions using weak electric currents (usually less than one volt). The electricity is generated in the nerve cells or muscle cells of almost all animals for signal transduction; but in electric fishes, the electric field is produced outside the body by electric organs consisting of densely packed cells. The weak electrical signals can help in the recognition of own species and mates, information about attacks, or environmental conditions.

The signal emitted by one individual is detected by specialised sensory cells (electroreceptors) in the skin of a

A deep water skate from the waters of Andaman and Nicobar Islands, India
Courtesy: S. Venu and Ravi Ranjan, Pondicherry University, India



An electric ray from the coasts of Andaman and Nicobar Islands, India
Courtesy: Titus Immanuel, Madras Christian College, Chennai, India

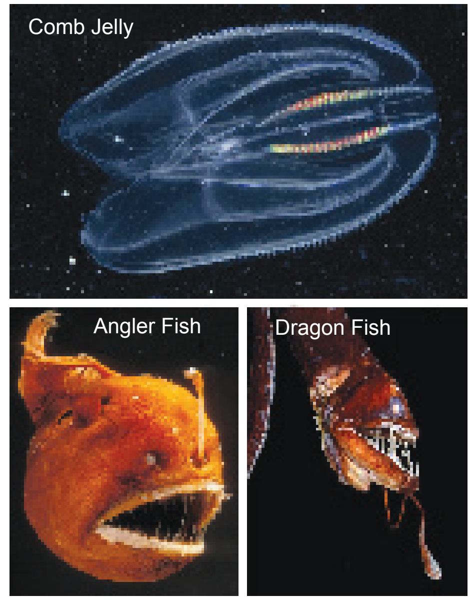


Image source: National Geographic. George Grall, USA(Comb jelly), Norbert Wu, USA(Angler fish) and Matt Davis, UK(Dragon fish)

receiving individual. Although this type of signal works well in the marine environment because seawater is a good conductor of electricity due to the presence of ions, it rapidly fades out in the medium if discontinued. Compared to the visual signal which depends upon sunlight and works during the daytime, electric signals can be effectively used during night time in the ocean for communication purposes.

In contrast to weak electric fishes, few species such as electric rays (torpedos) use strong electric currents (10 to 600 volts) to first paralyze their prey and ingest the meal thereafter.

Bioluminescent Signals

Bioluminescent signal is the light emitted by organisms. Compared to the terrestrial environment, organisms relying on the bioluminescent signals for communication purpose are more widespread in the ocean especially at depths where sunlight never penetrates. Around 76% of the main taxa living in the deep sea are bioluminescent animals such as comb jellies, tunicates, anglerfishes, hatchet fishes, dragon fishes, squids, jellyfishes, octopuses, and crustaceans.

The bioluminescent signals in the deep sea are used for finding food, attracting mates, and avoiding predators. The organisms also have functional eyes to detect bioluminescent signals. The light is produced by special cells present in the body called photocytes, or the luminescent chemicals are directly released into the seawater. The colour can vary from the dominant blue/green to the rare red/yellow/violet.

Blue light as a bioluminescent signal dominates in the ocean because of its far travelling capacity and is often found in organisms living in the water column, whereas green is the second most common colour and is found in the sediment-dwelling organisms.

Although blue and green light are emitted by several bioluminescent organisms, deep-sea dragon fishes are an exception. They emit red light instead of blue, and their eyes are also sensitive to red light. So, they use red light as a unique strategy for communicating with each other in an environment where blue light is commonly used as a bioluminescent signal by others.

In the case of other organisms including lanternfishes and hatchet fishes, the distinct arrangement of light organs on the body may help in the recognition of their species and the opposite sex. An in-depth study of the light patterns emitted by these animals and the chemical complexities lying behind the bioluminescence will help us to understand the biological interactions in the deep sea and may also decode many more mysteries of the deep sea from where the first seed of life is believed to have germinated.

In spite of advancements in technology to retrieve samples from the deep sea and improvement in analytical skills, we are still far from a complete understanding of the basic languages that marine organisms speak. A better understanding of these languages will enable us in sustainable management of the ocean's biological resources.

But before we fully understand these languages, we have already started adulterating the ocean with different water-soluble compounds having odour released from cosmetics and personal care products as well as with man-made noise. Continuous introduction of these chemical compounds into the marine environment and production of noise might hamper the chemical and auditory mode of communication negatively leading to a devastating future for marine organisms.

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