

Methods for the Deployment and Maintenance of an Acoustic Tag Tracking Array: An Example from California's Channel Islands

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INTRODUCTION

As the technology for acoustic tracking has evolved, the sophistication of applications and data analyses has also evolved (see papers this issue). A field that was once restricted to the manual tracking of a single animal has largely been replaced by the use of remote data-logging hydrophones that can track hundreds of animals at the same time (Klimley et al., 1998). An array of remote hydrophones can be an extremely valuable tool in the growing field of marine protected area (MPA) science (Starr et al., 2001; Lowe et al., 2003). The acoustic tracking array can be used to identify preferred habitats, seasonal movements, home range and behavioral patterns of tagged marine animals (Bolden, 2001; Starr et al., 2001; Simpfendorfer et al., 2002; Lindholm and Auster, 2003; Lowe et al., 2003; Cote et al., 2004). Investigators planning to use this technology for the first time may find the deployment and maintenance of an array to be a daunting task. The use of methods that minimize the loss of hardware and data are one of the most important aspects of conducting studies with an acoustic tracking array.

In an effort to assist other field researchers, I describe here techniques developed for the deployment, recovery, and maintenance of an acoustic tracking array. Overly technical terminology was purposely avoided to reach as wide an audience as possible. These methods evolved

from practical experience gathered through the establishment of a large array that now consists of 94 hydrophones deployed in a net around the Channel Islands of southern California. This array has been in continuous operation since 1999 and is now tracking over 200 individual fishes from several studies, including giant sea bass (*Stereolepis gigas*), white sea bass (*Atractoscion nobilis*), kelp bass (*Paralabrax clathratus*), California sheephead (*Semicossyphus pulcher*), and ocean whitefish (*Caulolatilus princeps*). The methods described here are not meant to be the only means of conducting such a study, but they are methods that can be broadly applied and minimize the risk of equipment loss and the time spent in the field. Fish tagging and surgery are not covered here because these techniques have been well described by previous authors (see for instance, Winter, 1996; Bridger and Booth, 2003).

All tags and remote data-logging hydrophones used for our study were manufactured by VEMCO Ltd. (Shad Bay, Nova Scotia). VEMCO Ltd. is one of several companies currently offering both tags and hydrophone systems for use in aquatic environments. We have used tags that are coded for depth (e.g. V16-P) and non-coded tags (e.g., V8SC). The omni-directional, single-channel (69 kHz) VR2 acoustic hydrophone we use is capable of tracking 256 individual tags and has a battery life of up to a year.

Plotting Hydrophone Locations Prior to Deployment

Ideally an array is established so that there is minimal overlap between the reception fields of adjacent hydrophones. This maximizes the coverage area for a given number of hydrophones. The spatial resolution of data that comes from an acoustic tracking array will depend on the signal strength of the tags used for the experiment. Greater spatial resolution will be obtained from low power tags since the hydrophones will have to be spaced closer together. Greater spatial resolution results in a higher cost project due to the increased number of hydrophones necessary to cover a given area. Pre-existing knowledge of the spatial distribution of habitat types within the study area is useful when determining the desirable spatial scale and what equipment to order.

The radius of the reception area will depend on the frequency and power of the tags being used, as well as the acoustic environment (see Priede, 1986, 1992; Voegeli and Pincock, 1996). In general, the following factors can lessen the reception field: shallow water, surf, wind waves and sources of biological noise (e.g. snapping shrimp); all of these things can produce sounds near the frequency of the tags making it more difficult for the receiver to detect tags. *In situ* range testing must be conducted to determine the maximum distance the tags can be detected by the hydrophone. Ideally range testing will be done under various sea states. Once the radius of the reception field is

determined the array can be plotted using navigational charting software (e.g. Offshore Navigator, Maptech, Amesbury, MA), GIS software (ArcView) or paper charts. Circles are drawn to reflect the reception field of each VR2 and then distributed around the study site to maximize coverage. The array around Anacapa Island (Figure 1) is an example that illustrates how concentric rings of hydrophones can produce complete coverage from the shore to a depth of over 150 m. In this case, range testing indicated that a 500 m radius for each hydrophone would maximize coverage so hydrophones were spaced 500 m from shore and 1 km from each other.

Very large-scale tracking studies are often too costly to provide continuous hydrophone coverage; in these cases hydrophones can be strategically placed at points where the fish would be expected to pass when traveling from one region to the next. Examples would be channels between land masses/reefs (Figure 2) or points of land that extend out into the sea (Figure 3). The coordinates for each hydrophone can be taken from a chart and entered into a GPS for deployment of the equipment.

FIGURE 1

Anacapa Island surrounded by two concentric rings of continuous hydrophone coverage. Tagged fishes swimming near this island will be continuously monitored.

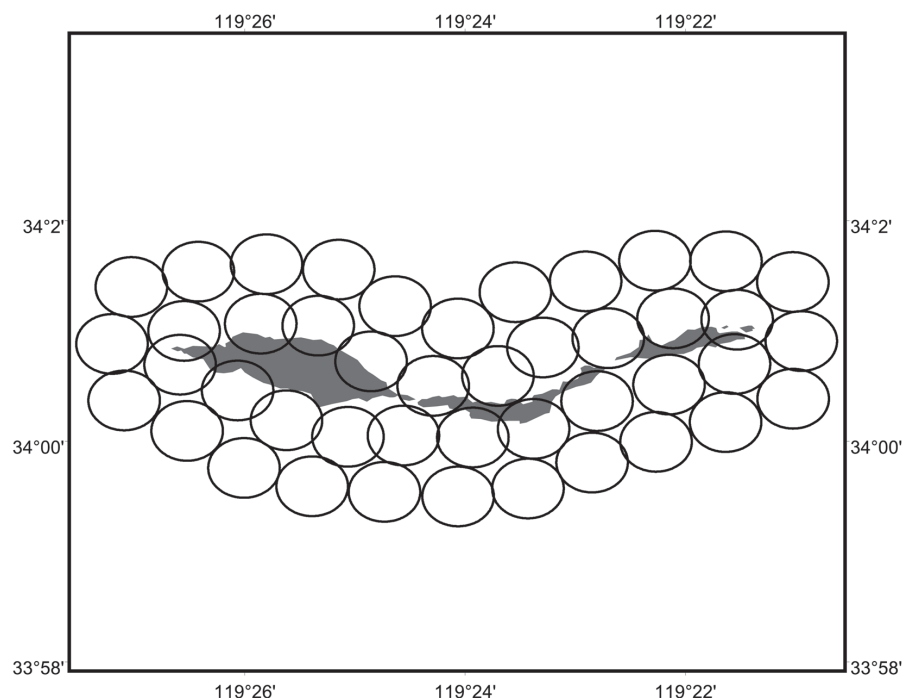
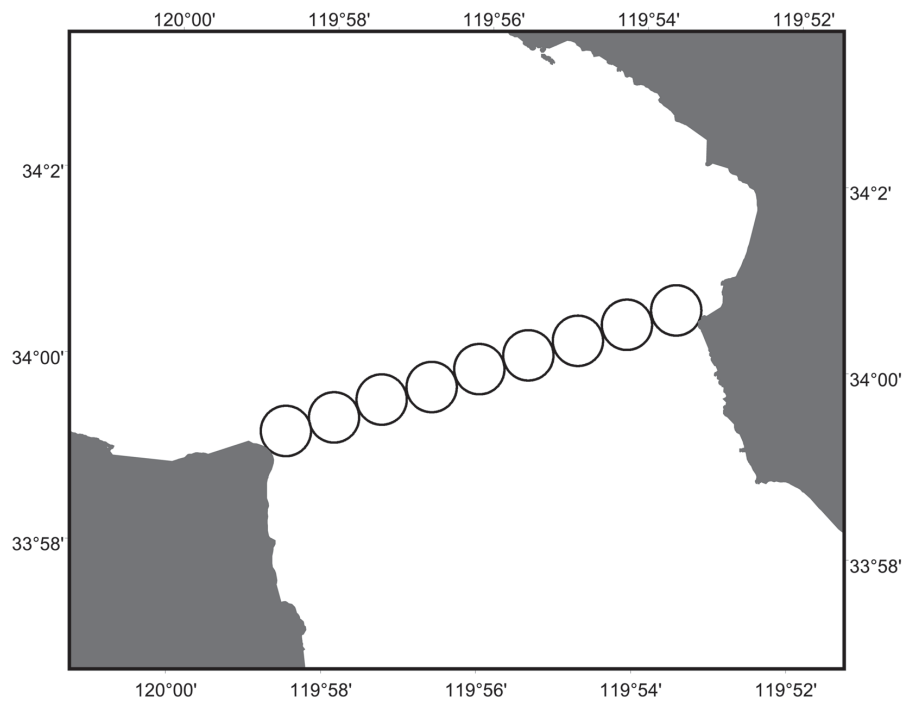


FIGURE 2

The gap between Santa Cruz Island and Santa Rosa Island covered with a single transect of hydrophones. Tagged fishes swimming through this channel will be recorded.

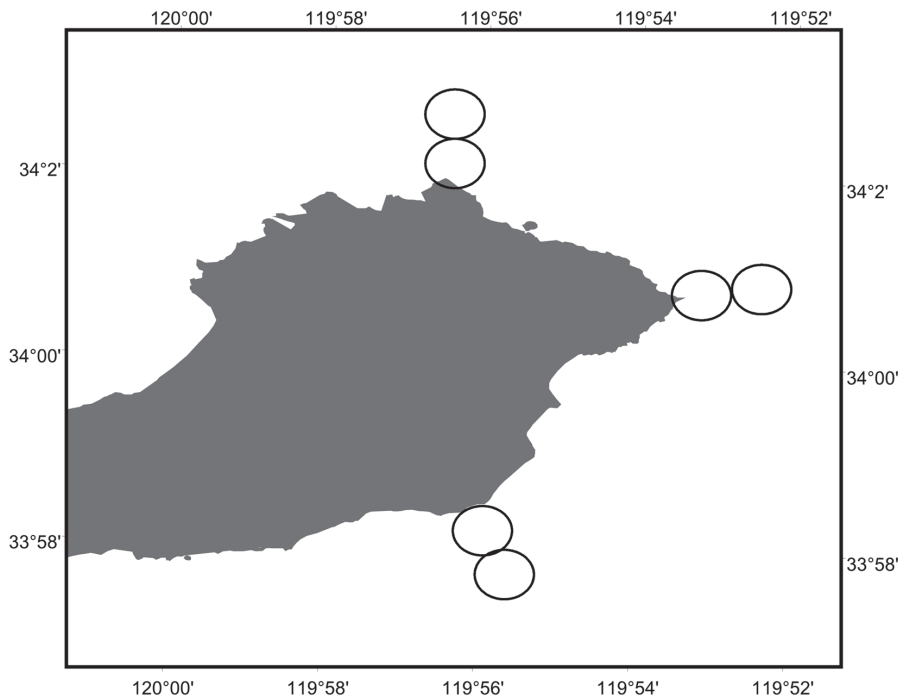


Deploying Hydrophones

Precision is the single most important aspect of placing a hydrophone mooring. The ease of recovering hydrophones/data is directly related to the precision used to initially deploy each station and record its position. There are two aspects to achieving the necessary precision; one is the use of a suitable Global Positioning System (GPS) receiver and the second is skilled vessel handling. Since the United States Department of Defense discontinued the use of Selective Availability in the year 2000, an ordinary GPS receiver can achieve accuracy of about 10 m. Greater accuracy (1-2 m) can be obtained in certain regions through the use of land and satellite based signal correction (e.g.: Differential GPS (North America); Wide Area Augmentation System (North America); Multi-Functional Satellite Augmentation System (Asia), Euro Geostationary Navigation Overlay Service (Europe)). GPS receivers that utilize these correction systems should be used wherever possible. Also, higher quality GPS receivers update the displayed information much faster than

FIGURE 3

Points around the southeast end of Santa Cruz Island are covered with a shallow and deep hydrophone. Tagged fishes swimming from one part of the island to another should be detected when they go around the point.

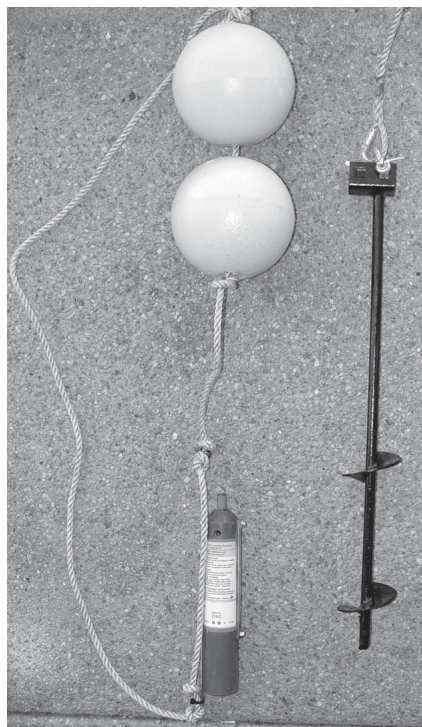


inexpensive units; an important attribute when working from a moving vessel. When in sight of land, sets of recognizable landmarks can be aligned (often called lineups) to help deploy and relocate hydrophones even in the absence of a GPS receiver.

Hydrophones should be moored so that the reception range is maximized and the chances of losing the hydrophone, or having it vandalized, are minimized. Although recovery is easiest when using a mooring with a surface float, this is not recommended in areas frequented by persons not associated with the research program (divers, fishermen etc.). I have developed a subsurface mooring system that requires a diver to retrieve the hydrophone but minimizes lost equipment. The mooring tackle consists of an anchor (described below), a short length of 10 mm diameter polypropylene line (actual length depends on topography, generally about 5 m), and flotation is provided on the top end by two hard plastic Nokalon trawlnet floats (Panther Plast A/S, Vordingborg, Denmark) (Figure 4). A thimble is whipped onto one end of the line

FIGURE 4

The components of a typical hydrophone mooring. Two hard floats provide flotation and the screw anchor secures the mooring to the bottom. The VR2 can be seen beneath the floats.



for attachment of the anchor and the hydrophone is secured about a meter below the floats (Figure 4). Heavy duty wire-ties are used to secure the hydrophone to the mooring allowing for rapid attachment and removal (Figure 5). Each wire-tie is secured to the mooring line between two closely spaced knots; this prevents the hydrophone from slipping up or down the line (Figure 6). Since the hydrophone is moored near the bottom, the transducer is oriented towards the surface.

FIGURE 5

Tools often used to deploy and maintain hydrophone moorings. From the top going clockwise: carriage bolts for screwing the anchor into the sand; wire-ties for securing the VR2 to the mooring (and for closing sandbags); rope loop used for sandbag moorings; wire loop used for ARC-1 moorings; nickel-chromium wire used for ARC-1 moorings; shackle and marlin spike for securing mooring to screw anchor; and center, wire cutters used to cut hydrophones clear of mooring.

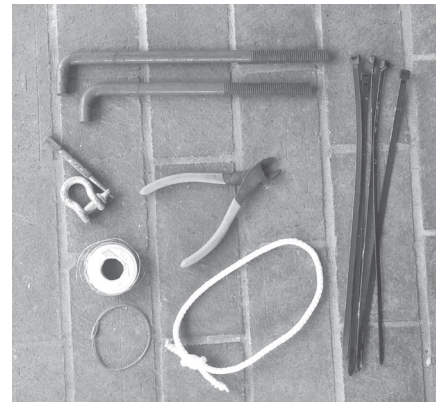


Figure 6

Securing hydrophone between knots on the mooring line.



Two types of anchors are used depending upon the substratum. If the substratum (etc.) is soft, a screw-type anchor is used (Imperial Stamping, Elkhart, IN, USA; model #MHA SB7) (Figure 7). The thimble of the mooring line is run through a stainless steel shackle that is then affixed to the screw through one of the holes on the mounting bracket (Figure 8). If rocky substrate prevents the use of a screw, a number of sandbags are tied together to anchor the mooring (Figure 9). The sandbags are not filled all the way so that the top of the bag can be gathered and folded over a loop of line. The doubled over sandbag material is then secured with a wire-tie and the loop of line is what is used to secure the mooring line to the anchor (Figure 9). The number of sandbags used will depend upon the size of the float. Two floats are used for each mooring (total of 5 kg of buoyancy) and 5 sandbags to anchor the mooring. A thimble is not necessary when using sandbags; the end of the mooring line is simply passed through the loops on each sandbag and then tied to itself with a bowline (Figure 9). Each sandbag weighs 15-20 kg (above water, dry). The idea is to make an anchor that will not be moved by current, recreational fishing tackle (if accidentally snagged) or divers. Commercial fishing gear and windlasses used for pulling anchors will be capable of moving this type of mooring. In areas where a shallow layer of sand covers rock or reef, the sandbags gradually sink into the substrate over time making them invisible and adding to the strength of the mooring. I have used the same sandbag moorings for almost 5 years without ever changing the bags.

When working in a region that is well charted, the charts give some indication of substrate type and can be used to estimate how many screws and sandbag anchors will be necessary. The technique for deploying each type of mooring is different but each requires skilled vessel maneuvering; the best GPS in the world cannot substitute for poor boat handling.

Deploying a sandbag mooring is very simple; the entire mooring is put together on the deck of the vessel and the sandbags are pushed off the vessel when positioned right

FIGURE 7

The screw anchor.



over the coordinates. A system of communication between the boat operator and the mooring crew must be devised so that the mooring crew immediately deploys the mooring when signaled. Since our research vessel is relatively large, making it difficult to effectively communicate by voice, I use a horn to signal the deck crew when over the coordinates. It is advisable to send divers down to inspect the mooring once it has been deployed. The divers can move the mooring with a lift bag if it has settled into a spot that negatively affects its ability to receive signals. For example, the mooring could be in a depression or adjacent to a large rock that would block signals. When working in coral reef habitats it may be necessary to carefully place each sand bag mooring with divers so that live coral is not damaged. Whether or not the mooring is moved, the divers should carry a line connected to a surface float so that the mooring location can be checked and corrected from the boat. The marker line can be deployed as described below.

FIGURE 8

Securing the mooring line via thimble and shackle to the screw anchor.

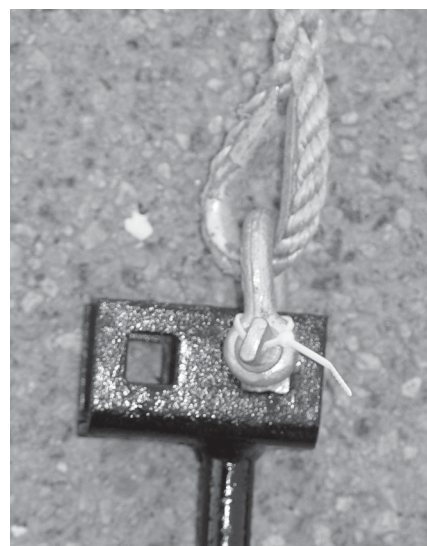


FIGURE 9

Sandbag anchors used for hard substrate moorings and deep acoustic release moorings.



Divers must be used to affix the screw-type anchor. A marker line with a lead weight and surface float is used to mark the hydrophone site from the vessel prior to the dive. The hydrophone/mooring can also be attached to the weighted end of this marker line (prior to dropping it overboard) so that it is waiting for the divers at the bottom. Once the divers reach the bottom they must screw the anchor into the sediment as close to the marker as possible. If the mooring must be moved, new coordinates must be recorded. Reasons for moving a mooring from its pre-plotted position includes a small patch of hard bottom that prevents the screw from penetrating (larger patches of hard bottom would require substitution with a sandbag anchor) or

FIGURE 10

Method for using carriage bolts as handles to screw anchor into the sand.



a high relief rock or reef that would obstruct the acoustic signal. It is often easiest to screw the anchor into the bottom without the shackle and mooring line attached. These can be attached once the screw is in place. Carriage bolts, or other scrap iron, can be slid through the holes of the mounting bracket on the screw anchor (Figure 5 and Figure 10) to serve as handles for screwing it into the sediment. Using a screw anchor is preferable to the sandbags so this method should be used wherever practical.

Recovery of hydrophones can benefit from notes taken by divers at each station during initial deployment or recovery. Recording the depth, substrate type and recognizable bottom features will help divers find the mooring in the future.

It is often desirable to moor hydrophones in depths that exceed the limits of safe diving. The ability to deploy and recover hydrophones to depths up to 100 m (depth rating of VR2) can greatly increase the size of the array as well as cover relatively deep habitats that cannot be studied with divers-serviced hydrophones. The use of an acoustic release is the simplest method of recovering a deep hydrophone station. The acoustic release is added to the mooring system described above, placed between the anchor and the mooring line (Figure 11). Sandbag

FIGURE 11

Position of acoustic release in mooring.



anchors are used to deploy the mooring, but for these deeper stations two sandbags are used instead of five. Fewer sandbags are used in our situation because there is little chance of interaction between the mooring and divers or fishermen and the anchors are relatively temporary since they are changed each time the mooring is recovered.

Prior to my work, several types of acoustic releases were commercially available but they had been designed for the deployment of heavy equipment in very deep water making them too expensive (US\$2,000-5,000 each) for my budget. In collaboration with Desert Star Systems, LLC (Marina, CA), we developed a relatively low cost, light-duty acoustic release called the ARC-1. The ARC-1 uses a nickel-chromium wire to hold down a gate that secures the mooring to the anchor (Figure 11 and Figure 12). When signaled from the surface the ARC-1 charges capacitors that then discharge through the nickel-chromium wire, explosively melting it instantaneously. When the wire is blown the gate opens and the mooring floats to the

FIGURE 12

Two ARC-1 acoustic release; the left one shows the gate in the open/release position while the right one shows the gate in the closed position. Nickel-chromium wire holds the gate shut and a loop of nylon coated braided wire is held by the gate, to which the sandbag anchors are tied. The rest of the mooring is tied to the opposite end of the ARC-1 (figure 11).



surface (Figure 12). The ARC-1 is interrogated from a surface hydrophone through a computer interface that allows the user to determine the battery condition of the ARC-1 as well as the distance between the vessel and mooring. The depth rating of the ARC-1 is 300 m and it is capable of year-long deployments between battery changes.

Moorings that use the ARC-1 are deployed in the same manner as the shallow sandbag anchor stations. They are simply dropped over the side when the vessel is directly over the station. It is advisable to check that each ARC-1 is communicating with the surface station prior to putting it in the water. This can be done on the vessel by holding the surface station transducer against the ARC-1 transducer.

Recovering Hydrophones/Data

Hydrophones and acoustic releases must be recovered periodically to retrieve data and change batteries. Although newer VR2's have D-batteries and can be left in the field for up to a year, it is advisable to visit the moorings more frequently to recover data. If a hydrophone is lost or malfunctions after deployment, the potential of losing data increases the longer the time interval between data downloads. The pattern of human activity around the study site may dictate a recovery schedule. For example, we have found that hydrophones more frequently go missing

during the commercial lobster and squid seasons. Knowing this, data are recovered just prior to these seasons and certain stations that routinely get lost to these fishing activities are temporarily removed. Recovering data 3–4 times per year is reasonable for our very large array. This schedule also allows for routine preventative maintenance.

The most efficient means of recovering data requires at least one extra hydrophone; this allows the recovery team to make a single dive to exchange hydrophones rather than two separate dives (one to recover the hydrophone and another to put it back after the data download). The dive team needs to carry a pair of wire cutters to free the hydrophone by cutting the plastic wire-ties, and new wire-ties to secure the replacement hydrophone. When using a system that exchanges hydrophones it is critical to keep thorough records that detail which hydrophone (identified by ID#) is at each station at all times. Making a mistake in this area will invalidate the study.

The precision and notes taken during the deployment of the hydrophone moorings reaps rewards when it is time to recover data. A weighted marker line with a surface float is first dropped on the mooring coordinates as a reference for the dive team. Divers then swim down the marker line to begin a search for the hydrophone. In good visibility the divers will see the mooring as they descend; poor visibility or a poor marker drop may require the divers to conduct a search. If the hydrophone is not located within a few minutes the divers should resurface and the boat should drop the marker again. If the divers do not immediately find the mooring on the second dive, a more extensive search should be conducted before resurfacing. Electric scooters are very useful for searching and recovering hydrophones. If a hydrophone is located a distance from the marker, the marker should be moved to the hydrophone mooring so that the boat can get a new fix for future reference (this should only occur on the initial recovery). If a hydrophone mooring is truly lost, remnants are often found on the bottom (such as line or sandbags). If the mooring is in place but the hydrophone is missing a search of the surrounding bottom

should be made for the hydrophone. I have had three occasions where the hydrophone was found lying nearby; likely removed by a diver and then discarded or broken free by fishing gear or the anchor line of a vessel. Missing moorings/hydrophones need to be replaced.

ARC-1 moorings are easily retrieved by putting a hydrophone into the water at the station coordinates and signaling the mooring to release and surface. The GPS will alert the crew as to which direction and approximate distance to watch for the surfacing floats. Once at the surface, the vessel picks up the mooring and then maneuvers over the site to drop the new mooring into position.

Acoustic release devices can fail resulting in lost equipment unless a remotely operated vehicle (ROV) is available to recover the mooring. During the development of the ARC-1, we routinely recovered experimental units that failed with a Shark Marine (St. Catharines, Ontario) Sea-Wolf ROV equipped with a manipulator arm and cutter. We developed an ROV recovery technique that uses an ARC-1 to attach two burlap rock bags to the tether approximately 25 m from the ROV. The rock bags are similar to the plastic sandbags except they quickly biodegrade on the seafloor. The research vessel is positioned over the station coordinates and then the rock bags and ROV are simultaneously dropped over the side. The rock bags anchor the tether near the hydrophone mooring and the ROV can freely move within the 25m radius of tether to search for the mooring. Once found, the line attaching the ARC-1 to the sandbags is cut and the mooring floats to the surface. If the line cannot be cut, it can be grabbed with the manipulator and the entire mooring hauled up by the tether. When it is time to recover the ROV the ARC-1 that is anchoring the tether is released, leaving the rock bags on the bottom, allowing the ROV to easily surface. We have found that integrating a communication hydrophone (Desert Star STM1) on the ROV allows for a directed search since the surface station will display a distance to the ROV and target mooring. The ROV can maneuver in a direction that shortens the distance until the mooring is found. Although the purchase and operation of an ROV is expensive, very large

arrays greatly benefit from its use. During the course of a long-term project, the recovery of lost equipment can compensate for much of the initial cost of the ROV. Smaller projects can service the array more frequently to lessen the chance of acoustic release failure.

Array Maintenance

Preventative maintenance needs to be periodically performed to ensure that the array remains intact. For example, each year hydrophones and floats need to be coated with antifouling paint. Even the transducer on each hydrophone should be painted since fouling organisms will have a greater effect on acoustic performance than the paint. Lines should be removed and cleaned or replaced every 18 months to two years. Thimbles and shackles should be inspected and likely replaced every 18 months. During replacement of the shackle, the bracket on the screw-anchor should be inspected for wear; if the hole has worn and expanded to an unacceptably large size, one of the three remaining holes should be used. Eventually the screw may have to be replaced. Of course VR2 O-ring maintenance should be routinely performed per the manufacturer's recommendation.

Conclusion

The increasing application of spatial management measures such as MPAs to the conservation and management of marine fishes will require detailed information on the movement of fishes relative to seafloor habitats and the boundaries of MPAs. My experience suggests that the ultimate success of such efforts will require that the details of deploying and maintaining an acoustic hydrophone array be considered at the same time that hypotheses are developed and an experimental design is produced. In this way, the exchanges involved in implementing a tagging project in a given environment (particularly with respect to the cost of operations) can be considered up front. The methods described here are intended to serve as a point of departure for the development and maintenance of an acoustic hydrophone array.

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