APPENDIX WC 1
Sphere Deployment for EK60/80 Target Strength Calibration

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I/B Oden SWERUS-C3 Leg 2

OVERVIEW

This plan describes an *in situ* beam pattern measurement procedure for the Simrad ES18-11 split-beam scientific echosounder transducer installed aboard the Swedish icebreaker *Oden*. These procedures were developed during SWERUS-C3 Leg 2 (19 Aug – 4 Oct 2014) using the Simrad EK60 transceiver (18 kHz) installed permanently aboard *Oden* and a Simrad EK80 wideband transceiver (10-30 kHz) installed temporarily for the expedition.

The primary task during calibration is deployment of a target sphere in the echosounder field of view (FOV) to enable comparison of measured target strength (TS) to calculated target strength for the sphere. Because the theoretical target strength depends on sphere parameters, frequency of ensonification, and ambient environmental conditions, a CTD profile should be conducted prior to calibration to obtain temperature and salinity depth profiles. Measurements on the main response axis (MRA) are of primary importance to provide a general offset for TS in the center of the beam pattern. If no other data are collected elsewhere in the echosounder FOV, this MRA offset may be used in conjunction with beam pattern models to estimate TS corrections across the beam pattern. If conditions and time constraints allow, and only after MRA data have been collected, it is also useful to collect data with the sphere in positions across the beam pattern to provide beam pattern corrections directly.

From our experience, preparation of the materials on deck and selection of favorable sea conditions can save several hours of ship time. It is ideal to minimize current relative to the ship, such as by drifting in light winds and calm seas, because relative currents of 1 kt or more will severely complicate sphere deployment and control. More importantly, stress and failure of the lines, rods, and reels increase the chances of losing the sphere and may present hazards to personnel on deck. The first calibration of SWERUS-C3 Leg 2 was performed with both the EK60 and EK80 transceivers connected individually to the ES18-11 transducer at anchor off Barrow, Alaska. Calibration sphere deployment and control was severely complicated by 1+ kt currents during this exercise. A second calibration using only the EK80 transceiver was completed mid-cruise while drifting in open water with a relative current of 0.5 kt or less, a swell height of ~1 m, and light winds; these conditions greatly simplified sphere deployment and control.

The calibration procedure described here is broken into sections describing materials and personnel needed, preparation, deployment, data collection, and retrieval. This procedure is only one of many methods that could be employed, so it should be taken as a rough guide and improved (and documented) whenever possible.

MATERIALS AND PERSONNEL

The following materials and personnel were used for calibration and are listed here for reference.

Description	Qty.	Comments
Assistants and software operator with radios	3	2-3 people on deck, 1 person on bridge
Calibration sphere with loop or harness for hanging	1+	63 mm copper sphere on bridge
Several hours of ship time for data collection	4+	SWERUS calibrations ran 4-8 hours
Deep sea reels ('downriggers') with 100+ m high strength line	3	Green 'spectra' line is excellent
Deep sea reel mounts with aluminum base plates	4	Screws are ¼" x 20 thread, not metric
Large C-clamps for securing reel mount base plates to rail	8	2 C-clamps per reel location
Extendable/nesting fiberglass outrigger rods with locking pins	3	Pins are color-coded for sections
Large stainless hose clamps for securing outermost rod sections	12	4 hose clamps per rod location
20 m length of monofilament line with locking hook for sinker	20 m	At least 20-lb test line
10 m length of monofilament line with locking hook for sphere	10 m	At least 20-lb test line
Spool (or fishing reel) of monofilament line for sphere control	100 m	At least 20-lb test line
Three-way swivel for connecting bow, port, and starboard lines	1+	
Short ladder for installing aft mobile outriggers during deployment	1	Crew should be aware of work near rail

PREPARATION

OVERVIEW

The ES18-11 transducer is located slightly to starboard of centerline at frame 93, or approximately the alongship position of the forward bulkhead of the bridge. Three lines on reels with outrigger rods are used for positioning the sphere within the beam. Control over the sphere position within the beam requires approximately equiangular and equidistant spacing of rods and reels with respect to the transducer. Because of the broad bow on *Oden*, the calibration setup requires a sphere and sinker to be suspended beneath the ship using three lines from rods and reels secured at the bow rail, midship port rail, and midship starboard rail.

The main lines and sinker must be deployed from the bow and moved aft to their calibration positions; to speed this process, some pieces of equipment are installed beforehand at their calibration positions and some equipment is placed initially at the bow. The sphere is deployed along the bow line using an independent monofilament line for control *only after* all rods and reels are in place and the sinker is clearly visible in the echosounder field of view. Having the rods, reels, lines, sinker, sphere, and personnel prepared and in place before the calibration will save many hours of ship time.

Figure 1 provides a general overview of the calibration setup, with more detailed preparation notes following.

SHIP

Oden should be drifting in deep water (>100 m) with engines secured, calm seas, and light winds. Current relative to the ship should be 0.5 kt or less and swell should be 1 m or less. Though these conditions may be rare, they are practically necessary and more than worth the wait. No other activities should be planned on the foredeck (namely, anchoring or CTD winch operation) or along the rail on the forward half of the ship. The captain and mate on watch should be aware of the plan to deploy gear over the side and that people will be working near the rail. In particular, securing the two aft rods involves standing on a ladder near the rail; it is mandatory to have at least two people

with radios on site during this operation and best to consult with the crew on proper safety measures.

OTHER ECHOSOUNDERS

All other echosounders should be secured, including the bridge fathometer. The EK60/80 will be operated in 'standalone' mode (i.e., not triggered by any other system) with a ping rate of approximately 1 Hz and recording range of at least twice the expected sphere depth to get an idea of the ambient scattering environment. Ideally, depending on the ship's needs for heat, the steam valves audible in the galley (and visible in the EK echograms) should be secured.

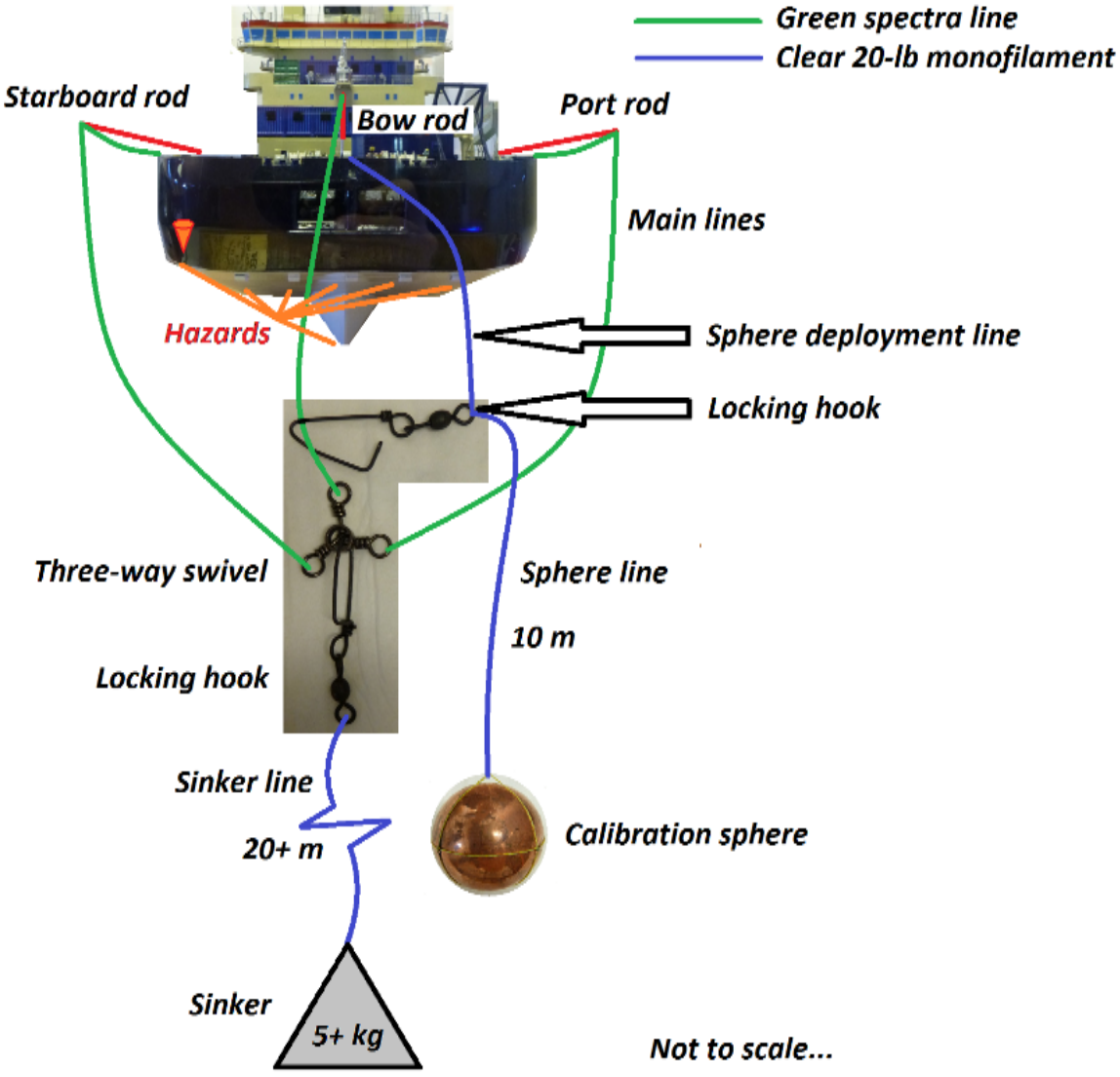

Figure 1. General layout of rods, lines, sinker, and sphere.

SPHERE AND SPHERE LINES

The sphere will be suspended from a 10 m monofilament line and must have some means of attachment to this line. A tight-fitting harness may be made of spectra or monofilament (Fig NUMBER) or, in the case of the ship's 63 mm copper sphere, a monofilament line may be embedded

in the sphere. A bucket of warm water and dish detergent should be ready for washing the sphere immediately before entry to the water to ensure a clean water-metal boundary after handling.

Figure 2. Detail of calibration sphere and harness (64 mm provided by UNH CCOM; 63 mm available on bridge).

To prepare for deployment, the sphere is attached to a 10 m monofilament line with a locking hook on the upper end. This hook, in turn, has a separate monofilament line running to a spool or separate small fishing reel. Once all other equipment is in place, the hook is locked around the bow line and the sphere is gently lowered along the bow line toward the three-way swivel under control from the separate monofilament line on a spool or fishing reel. Controlling the sphere in this manner reduces risk of sphere loss during line setup and provides two additional forms of security. If the upper monofilament breaks, the sphere is still supported by the bow line; likewise, if the bow line breaks, the sphere is still supported by the upper monofilament. If both lines break, then it's time to starting knitting a harness for the back-up sphere while waiting for better conditions. The separate monofilament line can also be used to reduce load on the bow line during retrieval, when the sinker is also being retrieved. Be sure to lock the hook around the bow line before deployment.

SINKER AND SINKER LINES

A sinker with mass of 3-5 kg should be procured and attached to a 20 m length of monofilament line with a locking hook at the end. This sinker keeps a slight amount of tension on the lines to reduce the drag effects of current during deployment and minimize risk of snags on the hull. The sinker also serves as an initial, low-risk echosounder target to verify line positioning before lowering of the more valuable target sphere. High-density, low-drag sinkers are preferred and should be wrapped in electrical tape to minimize chafe on the monofilament, as this line is strong in tension but extremely susceptible to impacts and cuts when cold. Large shackles and spare C-clamps have been used successfully as sinkers; spare gym weights are also likely candidates. The locking hook at the end of the 20 m monofilament line will be locked through the center of the three-way swivel prior to deployment from the bow. It is recommended that the line handler wear tough gloves for handling the monofilament with the sinker attached, as the line can be both slippery and painful to handle with bare hands.

REELS

The reels ('downriggers', Fig. 3) are controlled with large winch handles; cranking clockwise locks the reel and retrieves line, whereas cranking counterclockwise unlocks the reel and releases line. Care should be taken to avoid excessive counterclockwise cranking to release line, as the handle may unwind off the spool shaft entirely and lead to ill-timed disassembly of the locking mechanism. Reels

should be checked well before calibration for proper functions of the handles and counters. Each reel should have at least 100 m of high-strength spectra line ready for deployment without tangles, knots, or damaged sections. Dried goop from previous deployments should be removed and the lengths of line inspected by hand for signs of chafe. These lines scrape against the hull during deployment and retrieval, and must be in good condition to maximize chances of sphere survival. The counter is reset to 000 by sliding the counter mechanism to the right and spinning the gear to reset the digits, then sliding back into contact with the main gear on the spool. All counters should read 000 at the start of deployment.

Figure 3. Detail of deep sea reel ('downrigger') and counter.

Four reel mounts are available and should be secured to the ship rail in four specific locations: the rail beneath the port aft rod, the rail beneath the starboard aft rod, the rail beneath the bow rod, and a spare on the bow rail offset to starboard. Figure 4 indicates the positions of the two bow mounts; the starboard bow mount will be used to secure the starboard reel during deployment and while the port reel is moved aft.

Figure 4. Detail of bow reel mounts. Mount on left is center bow mount for securing bow reel throughout deployment and calibration; mount on right is starboard bow mount for temporarily securing starboard reel during line deployment and port line movement.

OUTRIGGER RODS

Three fiberglass outrigger rods, each comprised of multiple nesting sections with stainless locking pins, are employed to provide outboard line clearance from the hull. Rod preparation involves securing the outermost (largest diameter) section of each rod to various deck features using stainless hose clamps. As shown in Figure NUMBER, the bow rod is secured to the atmospheric instrument platform railing and the two aft rods are secured to the aft-most deck drain pipes (mirrored positions

on port and starboard main deck). These positions are compromises between achieving desirable line clearance and minimizing the obstruction to normal deck operations.

Figure 5. Detail of outrigger positions and means of attachment to hull features.

Because the aft rods extend much further than necessary, their outermost (largest diameter) sections may be mounted 'upside down' with the locking pin at the bottom (inboard) to keep the remaining inner sections from sliding down/inboard. All other sections, except the two innermost (smallest diameter) sections, are left inside the rods in their secured position. The two innermost (smallest diameter) sections of all three rods should be removed and assembled/pinned into three 'mobile outriggers' with eyelets at the ends; these will be used for line deployment from the bow and then inserted in the larger sections once in place. If desired, electrical tape can be wrapped around the end of each section to keep it from sliding within the next largest section. This should be done to the third innermost section, which will receive the 'mobile outrigger' during line deployment.

Notes: A possible improvement would be to add a small carabiner to each eyelet. Pulleys or blocks should not be used, as the line may skip off the wheel and chafe against the body. A caribiner at the end of each rod would allow the three lines to be tied to the three-way swivel before clipping into the rods, rather than requiring the lines to run through the eyelets before tying to the swivel. It may be helpful to use electrical tape to hang a few extra pins of appropriate sizes at each rod so they are readily accessible when needed.

SOFTWARE

The EK60 software has a 'calibration' mode which can be employed to locate the target sphere (or shackle, initially) in the echogram and provide a visual tracking record of sphere detection coverage within the echosounder field of view. The software operator should test and become familiar with 'calibration' mode prior to shackle and sphere deployment, even if only to use the target tracking feature.

The EK80 software used during SWERUS-C3 Leg 2 has a 'calibration' mode which is not functional as of this writing. In lieu of this mode, sphere data may be collected while pinging normally with a reasonable recording range (~300 m) and ping rate (~1 Hz). As of this writing, a 'fish detection' function is available which works for CW transmission but not for FM transmission. This fish detection feature can be used while transmitting in CW mode to locate the shackle and sphere within the echosounder field of view. Once the target sphere is located on the MRA, the transmission mode may be switched to FM for data collection. The range visible on the screen directly controls the range of fish detections.

In both cases, it is essential to make sure that data are being recorded in the settings desired for calibration (pulse length, power, frequency, etc.) and to a range sufficient to cover the sphere and shackle. As long as the sphere appears near the MRA in the echogram being recorded, the data are likely to be useful for calibration. In the worst-case scenario for both the EK60 and EK80, no calibration mode or fish detection feature is functioning properly to determine target coverage throughout the echosounder field of view. In this case, calibration can still be performed by finding a sphere location close to the MRA by methodically moving the sphere fore-aft and port-starboard until the apparent sphere scattering strength reaches a maximum in the echogram (i.e., it reaches a highest value or color). Data would be collected throughout this process and then for some duration once the sphere is believed to be on the MRA.

DEPLOYMENT

This list provides an outline of the order of operations used during SWERUS-C3 Leg 2 EK60/80 calibrations.

FINAL PREPARATION

1) Prepare sphere, sinker, lines, rods, reels, software, ship, personnel, etc., as outlined above.
2) Retrieve lines on all reels and reset counters to 000
3) Create three 'mobile outrigger' rods using the two innermost sections of each outrigger (with eyelet at end)
    a) Place these with reels at the bow, keeping one to port of the atmospheric platform, one at the center forward reel mount, and one at the starboard forward reel mount
4) Secure the bow reel in the center bow reel mount
5) Secure the starboard reel in the forward starboard reel mount for temporary use during deployment
    a) The port reel will be the first for repositioning aft and does not have a temporary mount on the bow
6) Place the port reel with the port mobile outrigger between the CTD A-frame and the atmospheric platform
7) Run each line through the eyelet on its corresponding mobile outrigger
8) Pass the port line around the forward side of all atmospheric platform supports and underneath the triangular bow extension to ensure the line will run freely through the eyelet, over the port rail, and toward the center forward reel with no hull or anchor chain obstructions
    a) If at anchor, a boathook will be needed to pass the line between the hull and the anchor chain; ask a crew member for assistance
9) Securely tie all three main lines to individual eyelets on the three-way swivel so each line can rotate independently

a) ‘If you can’t tie a knot, tie a lot’

10) Verify that all three lines will run directly into the water with no hull obstructions once the sinker is attached
11) Connect the locking hook on the end of the 20+ m sinker line to the center of the three-way swivel, being careful to keep lines from tangling or getting caught underfoot; the deck has many small sharp edges
12) Pass the bow mobile outrigger up to the atmospheric instrument platform and use a pin to secure it in the outrigger sections secured to the rail
    a) Ensure the outrigger extension is at least two sections beyond the bow for line clearance (see picture)

Figure 6. Detail of bow outrigger.

13) Lean the starboard mobile outrigger against the rail such that the starboard line will run freely from the starboard reel (in its temporary mount) and into the water during sinker deployment
14) Lean the port mobile outrigger against the rail such that the port line will run freely from the reel (placed temporarily on deck) and into the water during sinker deployment
15) Release all drag on the port and starboard reels (counterclockwise on the handle)
16) Take all slack out of the bow line and lock the bow reel (clockwise on the handle)
17) The final preparation is complete and the sinker is ready for deployment

(SINKER DEPLOYMENT)

18) When the ship is ready, the bridge crew is notified, and all personnel are properly caffeinated, lower the sinker over the bow rail by handing out the monofilament sinker line
    a) Be careful to keep the line from touching the hull as much as possible
    b) Gloves should be used to reduce cuts and burns from the monofilament under tension
19) Once the sinker is at the end of its 20 m line, gently release the monofilament so that the load is transferred as smoothly as possible to the locked bow line
20) Release the bow line and lower the sinker slowly to a bow reel count of 150-200 (approximately 50-65 m)
    a) The port and starboard reels should be releasing line freely as the sinker is lowered but should be adjusted to keep slight tension to avoid tangling
21) Once the sinker has reached its initial depth, lock the bow reel and note the counter number
22) The port line is ready for movement to its aft station

(PORT LINE MOVEMENT)

23) With at least two people on deck, begin slowly moving the port mobile outrigger and reel along the rail
    a) It is ideal to have one person dedicated to spotting the line, one person on the reel, and one person on the mobile outrigger; the observer can assist for 'hand-offs' in tight spaces and at the deck break
    b) Keep the mobile outrigger as far outboard as possible to provide maximum hull clearance for the line
    c) Release reel tension as necessary to relieve stress on the outrigger handler
    d) The widest portion of the hull is likely the most hazardous for the line (Fig. 7, left); move swiftly through this region while still allowing the sinker to settle and the line to keep up with your progress aft
    e) Hand-offs of the rod and reel from one person to an extra person will need to take place at the deck break and for maneuvering around containers and lifeboat lines
    f) All handlers should be aware of the line status and proceed only when the line appears free of the hull
    g) It may be useful to have a boathook handy for small hazards and moving the lifeboat lines
24) At the port aft station, secure the reel in its rail mount and install the mobile outrigger in the outer sections previously secured to the deck drain (Fig. 7, right).
    a) Installing the rod with tension on the line will be very difficult, especially if there is a current
    b) To relieve outrigger load, support the sinker line by hand and release several meters of line on the reel
    c) Two people may be necessary to handle the outrigger, especially if wind or swell are present
        i) Consult with crew on safe operations near the rail
    d) Make sure the eyelet on the outrigger is pointed down and the line runs smoothly through it

Figure 7. Details of widest hull section (left) and port aft station (right).

25) Lock the port reel and note the counter number
26) At this point, it is possible that the sinker is on the edge of the EK60/80 field of view
    a) The software operator should provide updates on visibility of any new targets

(STARBOARD LINE MOVEMENT)

27) Movement of the starboard reel and rod to the aft station is performed in the same way as the port side
    a) Apply the port line movement instructions to the starboard line
    b) WARNING: At the time of writing, there is a major line hazard on the starboard forward quarter (Figs. 1 and 8); be sure the line clears this feature using the mobile outrigger or a long boathook

Figure 8. A line hazard with sharp edges on the forward starboard quarter

(INITIAL TARGET POSITIONING)

28) Once all reels and outriggers are secured in their stations, the sinker position should be adjusted to be well within the echosounder field of view before sphere deployment
    a) A good starting point is to have equal line released from all reels (approximately 200 on all counters); in very low currents, the sinker should settle near the MRA and be readily visible in the calibration mode (EK60) or using the fish detection feature (EK80)
29) Adjust reels in increments of 5 or 10 counter clicks to achieve a sinker position near the echosounder MRA and at least 20 m below any prominent scattering layers visible in the echogram
30) The sinker may take a minute to settle after each major move
31) Once the sinker is very close to the MRA, the sphere is ready for deployment

(SPHERE DEPLOYMENT)

32) Attach the sphere line locking hook around the bow line
33) One person will control the lower sphere monofilament line for initial entry to the water
34) One person will control the upper sphere monofilament line, ready to support the sphere
35) Lower the sphere over the bow rail by handing out the lower monofilament sphere line
    a) Be careful to keep the line from touching the hull as much as possible
36) Once the sphere is at the end of its 10 m lower line, gently release the monofilament so that the load is transferred as smoothly as possible to the upper sphere line (on a spool or fishing reel, under control of a second person on deck)
37) Release monofilament line from the spool or fishing reel to allow the hook to slide down along the bow line
    a) Assuming small currents and a sufficiently deep sinker bow line, the sphere will descend until the hook reaches the three-way swivel; at this point the sphere should be hanging (and visible in the echogram) approximately 10 m below the swivel and 10 m above the sinker

b) Assuming small currents, the monofilament tension will decrease when the sphere reaches the swivel

38) Several additional meters of monofilament should be released and the spool or fishing reel should be secured on deck to prevent additional line running out under drag from the current
    a) Additional monofilament will need to be released if the bow line is released for repositioning the sphere

(DATA COLLECTION)

39) Ensure the EK60/80 software is pinging in standalone mode at a reasonable ping rate, with all other echosounders secured, and recording to a range greater than the sinker depth
40) Under direction from the software operator, adjust reels to position the sphere on the MRA and outside any scattering layers visible in the echogram
    a) Range on the software should be adjusted to exclude the sinker from target detection to avoid confusion with the sphere
    b) The EK80 target detection method is not supported in FM mode as of this writing; CW mode must be used for sphere positioning, then data collection may be performed in FM or CW as necessary
41) Adjust parameters for target detection (EK60 calibration mode; EK80 normal pinging with fish detection feature) so the sphere is the most readily visible target detected in the field of view
    a) As a test, reel in line on the bow reel and ensure that the target moves accordingly in the echosounder software; release the same amount of line to return the sphere to the MRA after this test
42) Collect data as long as desired for each combination of settings
    a) The sphere will drift throughout the echosounder field of view depending on currents and vessel motion; if the average position is near the MRA, then this drift may actually be quite advantageous for beam pattern corrections off the MRA
    b) If time constraints and currents are negligible, it may be possible to manually move the sphere throughout the echosounder field of view with small adjustments to reels; this was found to be nearly impossible to control in a current greater than 0.5 kt, and should not take precedence over data collection on or near the MRA
    c) During SWERUS-C3 Leg 2, calibration data were collected in 15-minute blocks for each combination of settings to provide approximately 900 pings and sphere detections for each mode
    d) During EK80 FM calibration, it was necessary to check the sphere position in CW mode between data collection blocks; some modes were repeated because the sphere (again, not visible in the fish detection feature using FM mode) was determined to have drifted away from the MRA during data collection
43) Adjust the sphere position and repeat data collection as necessary for all combinations of settings that have been or will be used for normal EK60/80 data collection underway
44) After data collection is complete, notify the crew that the sphere is ready for retrieval
    a) The ship typically needs at least 30 minutes to warm up the engines to get underway as soon as the sphere and sinker are out of the water

(RETRIEVAL)

45) Retrieval of the sphere and sinker consists generally of the same steps as deployment, though these steps are performed in reverse order
46) Remove the starboard mobile outrigger and reel and move forward along the rail while maintaining as much line clearance from the hull as possible
    a) Be sure to clear the hazard on the starboard forward quarter (Figs. 1 and 8)
47) At the bow, place the starboard reel in the temporary mount and rest the outrigger rod against the rail in the same position used for sinker deployment
48) Remove the port mobile outrigger and reel and proceed toward the bow in the same fashion as the starboard side
49) At the bow, place the port reel on deck and rest the outrigger rod against the rail in the same position used for sinker deployment
50) With all three lines running clearly from the bow to the water, prepare for sphere retrieval by slowly bringing in line on the bow reel, starboard reel, and sphere monofilament line
    a) This method reduces strain on any given line and improves the chance of successful sphere retrieval
    b) The port reel may also be used to take up slack on the port line, but the majority of lifting should be performed with the bow and starboard reels
    c) It is advisable to proceed slowly and ensure that the bow and starboard reel counters are approximately the same, with slight tension on the monofilament line
    d) As the counters approach 000, prepare to retrieve the three-way swivel by hand
51) Grab the three-way swivel by hand to support the sphere and sinker lines
52) Pull in the sphere and sinker monofilament lines together until the sphere is in hand
    a) The sinker should still be in the water when the sphere is in hand
    b) Ensure the sphere is safely on deck before continuing with sinker retrieval
53) When the sinker and sphere are both safely on deck, the main lines may be cut near the three-way swivel, all rods and reels secured on deck, and the bridge notified that all equipment is out of the water

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