Species identification in the deep and dark: using Loch Etive's Bonawe Deep as a proving ground for new technology

Andrew S. Brierley, Roland Proud and Yang Yang
Pelagic Ecology Research Group, Scottish Oceans Institute, University of St Andrews

Background

In September 2019, Brierley and Proud were awarded a NERC Capital-Equipment grant (c. £185k) for a self-contained, submersible echosounder and stereo-camera pair ('Seaquest DSV: a compact Deep-water Sonar and Visual sampler for exploring the marine twilight zone'). The equipment was to enable synchronous acoustic and visual observation of fish, crustaceans and gelatinous plankton (including siphonophores) in the mesopelagic (the 200 m to 1,000 m depth horizon) to improve our understanding of biomass in, and ecology of, this 'twilight zone'. It has been suggested that mesopelagic fish may be the last major untapped protein source on the planet, and the decline of conventional fisheries resources is making mesopelagics increasingly attractive to fishers. However, there is considerable uncertainty around the biomass of mesopelagic fish because a) fish probably avoid nets, b) acoustic properties of mesopelagic fish are not well known, and c) echoes from gas-bearing siphonophores may bias analysis of acoustic survey data. In the absence of accurate biomass estimates, there is a danger that fishing (which would take place predominantly in Areas Beyond National Jurisdiction, so would potentially be unregulated) could rapidly impact stocks and the ecosystem services they may provide.

The echosounder component of the DSV (a Simrad WBAT operating at 38, 120, 200 and 333 kHz) was delivered in late 2019, and engineers in the School of Physics at St Andrews quickly built a frame for its deployment. The Covid-19 pandemic then hit. Delivery of the bespoke stereo camera pair and lights (both contracted, after tender, to Marine Imaging Technology in the USA) was delayed substantially by the pandemic. The EFLD award from MASTS enabled us to deploy the complete DSV package for the first time (in Loch Etive, from SAMS Oban), and hence to progress further towards making the instrument available to the wider UK community (which is an objective of the NERC Capital Funding scheme).

Configuration of the Seaquest DSV

The Seaquest DSV is designed to be self-contained (in terms of power and data-logging) and, as far as is possible, compact. Large echosounder/camera combinations have been built previously (for example as modifications of CTD rosettes), but there is concern that these large packages cause avoidance such that target animals are not observed. The echosounder, cameras and lights are mounted on a deployment frame (total system weight = 125 kg), and can be configured to observe horizontally or vertically downwards. The package is deployed on a vertical wire (it does not require a conducting cable).

The echosounder component of the DSV is a Simrad WBAT. This is a submersible (maximum depth capability = 1,500 m) broadband echosounder similar to the EK80 fisheries echosounder. The WBAT can have 4 transducers attached (we have 38, 120, 200 and 333 kHz), and can sample using 3 of these at any one time (2 split beam and 1 single beam). WBAT opertion is controlled by software that enables different frequencies to be turned on/off at different times through a 'mission'.

The stereo camera component of the DSV comprises 2 Sony UMC-S3CA video cameras (90 mm lenses) housed in purpose-built housings (maximum depth capability = 1,500 m) with dome ports. The cameras each log to internal SD cards, and are powered from a 42 volt supply in a separate battery/control-computer housing. The lights (red and white DSPL LEDs, 43 W, 24 volt) are controlled and powered in the same way. Control software enables 'missions' to be pre-programmed such that lights can be turned on/off at set times. Both red and white light options were included because different species have different avoidance and/or attraction responses to different wavelengths of light.

Both the echosounder and the camera pair require to be calibrated, the echosounder such that gains give true echo intensities, and the camera pair so that stereo images can be interpreted to give size of target organism. There is an expectation that echo intensity varies with size of the target animal, so camera and acoustic data together will enable progress towards future acoustic-only interpretation of multifrequency acoustic survey data to infer target identity, size and, hence, abundance and/or biomass.

Equipment trials on Loch Etive

We wished to conduct trials of the DSV in Loch Etive because the loch offers deep (up to c. 150 m off Bonawe) water containing appropriately-sized organisms in a (usually) sheltered setting with relatively easy access. The Bonawe Deep can be reached in about 1.5 hours from SAMS on RV *Seoul Mara* (there are tidal restrictions, with flow in the Connel Narrows periodically preventing safe navigation by this vessel). The EFLD grant enabled us to take the DSV to Oban (by van) and deploy it on Loch Etive from RV *Seoul Mara* on three days over the course of a week (week starting Monday May 16 2022).

Day 1 Narrative – Monday May 16th

The DSV was loaded aboard RV *Seoul Mara* from 07:30. We left the jetty at 08:00 in time to pass the Connel Bridge narrows before the full ebb. Weather was challenging, with the force 4 winds from the ESE producing white horses. We deployed the DSV east of the Bonawe deep site (56° 27.444 N, 5° 10.35 W) and sampled on a drift for about 1 hour. This was followed by a CTD cast: temperature and salinity profiles are required for quantitative interpretation of echosounder data, and light intensity data are useful for understanding depth-distributions of vertically-migrating organisms. Sampling was curtailed when we were asked by the coastguard to join a search for canoeists: the search consumed the remainder of the day.

Day 2 Narrative – Thursday May 19th

We left the jetty at 09:00 and reached the Bonawe deep site at around 10:30. We logged light intensity (PAR) from the deck of the vessel throughout the day, and obtained underwater light profiles as part of a CTD cast.

We carried out 3 (all successful) deployments of the DSV (see Table 1 for details). During the 3 deployment, we captured images of krill (*Meganyctiphanes norvegica*) on the cameras (see 'Krill observations') and observed avoidance behaviour of fish and zooplankton to both red and white light (see 'Avoidance behaviour of Loch Etive zooplankton and fish').

Deployments

For all deployments, the DSV cameras, lights and echosounder transducers were oriented vertically (downwards facing) to detect an echosounder calibration sphere (38.1 mm diameter tungsten carbide) that was suspended at a range of c. 4 m beneath the DSV on 4 lines of monofilament (fishing line). The cameras were pre-set to focus at the range of the sphere, i.e. between 4 and 5 m (F 5.6, shutter speed = 1/60, ISO = AUTO). We hoped to be able to capture images that would enable us to measure its size, and hence to ascertain measurement uncertainty for objects of a similar size.

The DSV was programmed to sample different light combinations and different times, and various depths were sampled by adjusting wire out (see Table 1). It became apparent from observation of the vessel's depth sounder (50 and 120 kHz) display that organisms (both zooplankton and fish as inferred from these acoustic observations) avoided the DSV when the lights were on (both red and white). However, we did manage to capture a few images of krill (all be it out of focus) during some of the deeper deployments.

Number	Start time	End time	Position	Start Volt	End Volt	Protocol	Depths
1	11:35:44	12:05:24	56° 27.444 N, 5° 10.35 W	39.1	38.8	5 mins delay 4 x [2 mins white light, 2 mins red light and 2 mins wait]	Surface 10 m, 55 m, 55 m, 90 m
2	12:48:00	13:21:13	56° 27.439 N, 5° 10.826 W	39	38.6	5 mins delay 1 min red 10 mins delay 20 mins white	Surface Surface Move 90 m
3	13:48:40	14:42.14	56° 27.451 N, 5° 10.84 W	38.8	?	5 mins delay 1 min red 5 min wait 20 mins white 2 mins wait 20 mins white	Surface Surface Move 40 m Move 80 m

Table 1. Summary of Day 2 DSV deployments.

Krill observations

Images of krill (*Maganyctiphanes norvegica*) were captured by the cameras. Krill were also detected by the echosounder (see Figure 1 and 2), and tracked as single targets (using Echoview software (v. 12.1.0)). Images of krill were generally blurred (Figure 1A) since they were captured at ranges outside the pre-set focus range (4-5 m). The calibration sphere was observed during all 3 deployments (Figure 1B).

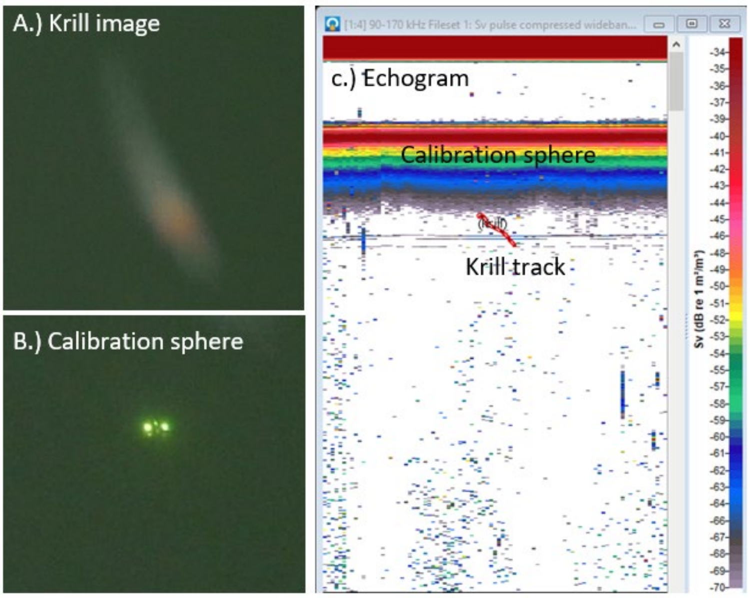
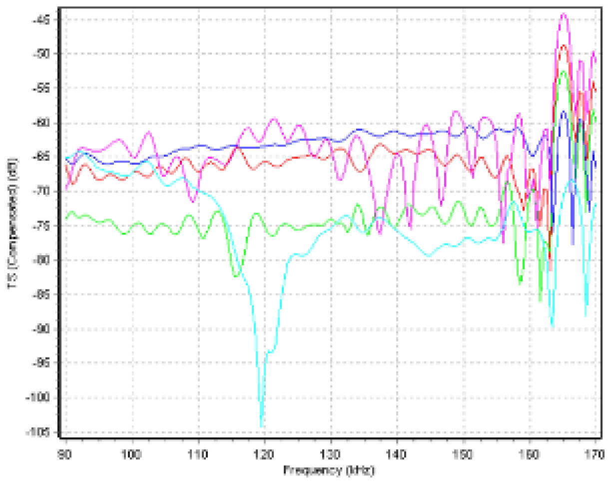


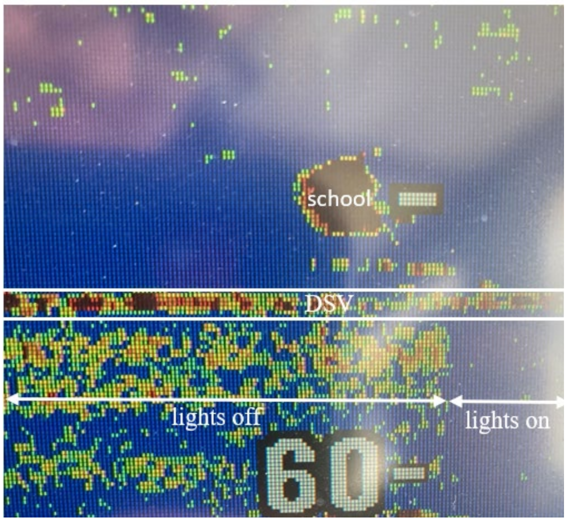
Figure 1. Coincident image and echosounder observation of krill and calibration sphere at 11:54:08 on 19/5/2022. The observation was made at 55 m depth using white light.

Figure 2. Frequency response (90 – 170 kHz) of the krill target detected at 11:54:08 on 19/5/2022. Target strength is a stochastic variable, so ping-to-ping variability is expected. Detected echo intensities are consistent with target strength models of small euphausiids.



Avoidance behaviour of Loch Etive zooplankton and fish
During all deployments, we observed on the vessel echosounder a clear avoidance response of fish and zooplankton (e.g. see Figure 3) to the DSV coinciding with times when the lights turned on.

Figure 3. Avoidance response as revealed by inspection of the RV Seoul Mara echosounder. Fish and zooplankton move immediately away from the DSV when the lights are turned on, but do not appear to avoid the unilluminated DSV package. DSV depth is c. 40 m.



Day 3 Narrative – Friday May 20th
We left the jetty at 09:00, reached the Bonawe deep site at around 10:30, and performed a CTD cast whilst the DSV lithium battery was charged. We planned to calibrate the DSV echosounders, and capture images of the camera-calibration-cube.

For all deployments, the DSV cameras, lights and transducers were all aligned vertically. The cameras were pre-set to focus at a range of between 4 and 5 m (F 5.6, shutter speed = 1/60, ISO = AUTO).

Echosounder calibration
A calibration of the 4 DSV transducers (38, 120, 200 and 33 kHz) was carried out between 10:30 and 12:00 at the Bonawe deep site on the 20/5/2022. This was the first calibration, and its completion was a major step in the commissioning of the DSV. We monitored acoustic data collection live using a 30 m wet-pluggable cable between the WBAT and a surface computer: the echosounder calibration did not therefore constitute a deep-water deployment. The calibration was conducted using a 38.1 mm tungsten carbide standard target. The sphere was positioned under the transducers at a range of 4 m by tying 4 lines (fishing line) to the bottom 4 corners of the DSV frame and connecting the other ends of the lines to the sphere.

The calibration was conducted at the surface and the DSV was held in place using the vessel winch. Prior to performing the calibration, temperature and salinity profiles of the water-column were obtained using a CTD. The average temperature and salinity in the top 4 m (distance to sphere) was 11.5° and 19.7 respectively. Using this information, we calibrated each transducer following the guidelines in Demer et al. (2015). Results are given in Table 2.

	Frequency (kHz)			
	38	120	200	333
Power (W)	225	200	75	25
Frequency band (kHz)	35-45	90-170	185-255	283-383
Pulse duration (us)	1024	1024	1024	1024
Ramping	Fast	Fast	Fast	Fast
Central Δ gain (dB)	2.68	2.32	2.76	-0.11
Mean RMS	0.18	0.11	0.19	0.47
Centre coverage %	100	96	53	37
Overall coverage %	68	90	81	80

Table 2. Summary of echosounder calibration results.

Calibration of the 38, 120 and 200 kHz transducers were deemed good (as per their RMS values being < 0.2; see Demer et al., 2015) but the results for the 333 kHz were poor (RMS > 0.4) and corresponding values should be treated with caution.

Camera calibration cube

After the echosounder calibration, the DSV was held at the surface using the vessel winch and the camera calibration cube was positioned directly under the cameras at a range of 4 m (i.e., in focus) using two pre-measured lengths of twine (see Figure 4).

Figure 4. Calibration of stereo cameras. LEFT: Image of calibration cube near surface in murky water. RIGHT: Picture of calibration cube prior to deployment.

Deployment

After the near-surface calibrations, an one autonomous (i.e. fully self logging) deployment of the DSV was conducted, and included capturing images of the stereo camera pair's calibration cube. During the deployment, the DSV was lowered slowly (15 sec/m) from the surface to 70 m depth and then hauled back to the surface at a similar rate. The DSV reached a depth of 70 m at 13:31:11.

Number	Start time	End time	Position	Start Volt	End Volt	Protocol	Depths
1	13:00:20	13:48:42	56° 27.456 N, 5° 11.041 W	39.1	?	5 mins delay 1 min red 1 min wait 20 mins white 1 min wait 20 mins white	Surface Surface Surface Slow descent to 70m 70m Slow ascent to surface

Table 3. Summary of day 3 DSV deployments.

Conclusions

During the MASTS-funded DSV trials on Loch Etive, we were able, for the first time, to capture simultaneous video images and acoustic detections of *in situ* zooplankton. This was a major step in commissioning this new apparatus. We also observed substantial avoidance behaviour of fish/zooplankton to the DSV lights, and learnt valuable lessons with regards to deployment protocols. For future deployments we will:

- Establish robust power-monitoring and management procedures now we know the failure voltage (<37.6 v on a nominal 42 v battery pack).

- Prioritise capture of images lit using white lights (red-lit image quality in the peat-dark waters of Loch Etive were too poor for species ID).

- Program camera and lights to minimise avoidance behaviour.

Water clarity was very poor during deployments in Loch Etive, and we expect image quality to be better in open-ocean environments.

Images included in this report are 'raw' (i.e. not processed). In future work, we will use post-processing software to improve image quality and improve potential for species identification.

We plan to further analyse the images captured during this trial and estimate uncertainty in stereo-camera-based length measurements of the echosounder calibration sphere. This may require using local facilities, such as the SMRU pool, to re-calibrate the cameras.

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Reference

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