Supplement 1: Further technical details of the Motion-compensated Upward and Downward Looking (MUDL) net

The Motion-compensated Upward and Downward Looking (MUDL) net was designed by scientists and engineers at the British Antarctic Survey. It is comprised of two conical nets mounted on an aluminium frame with the deployment wire attached to a spring loaded mechanism (Fig. S1). It is deployed tethered to a wire that lowers it to a predetermined depth where it remains for a set period before recovery back onto deck. The purpose of the MUDL is to trap zooplankton that enter the net through their own upwards or downwards swimming. This type of trapping allows the level of simultaneous upward and downward flux of these organisms to be determined over a designated period of time.

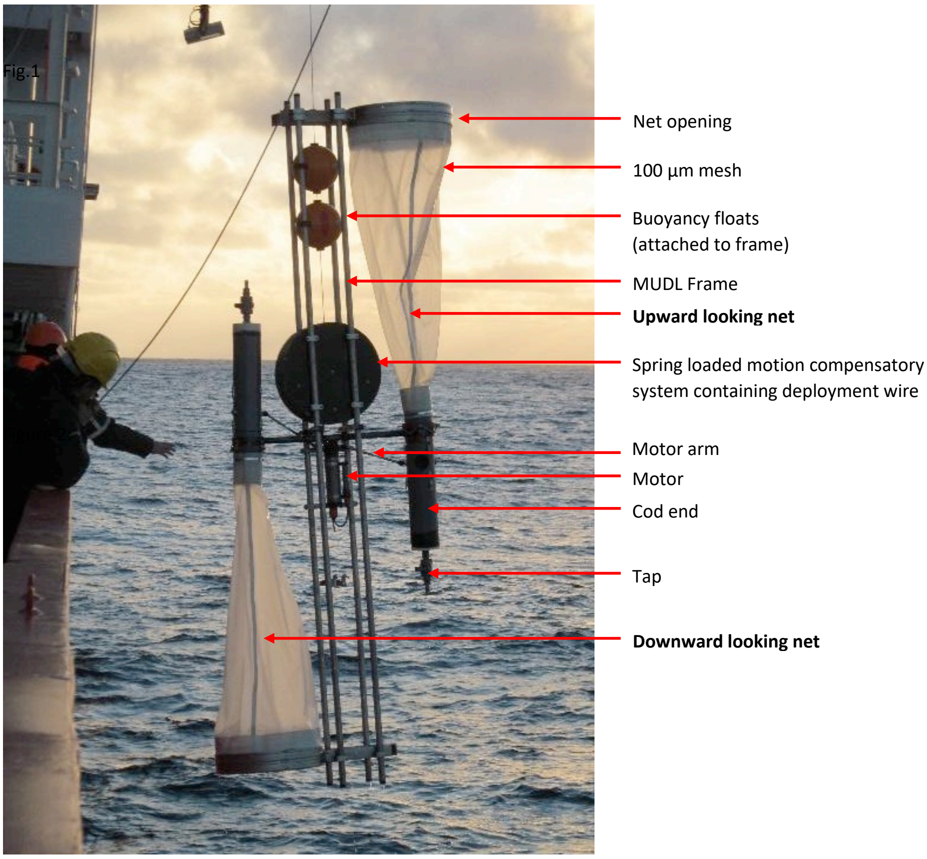

Fig. S1. Motion-compensated Upward and Downward Looking (MUDL) net being deployed in the Scotia Sea (Dec 2016)

Both the upward looking and downward looking nets have a rigid cylindrical opening with a diameter of 61 cm, with a 100 µm nylon netting tapering to cod ends 2 m away. The spring loaded motion compensatory mechanism that sits in the centre of the frame allows the net to maintain its vertical position and remain stable during deployment. In essence, it compensates for the effect of swell on the deployment vessel that would otherwise be transmitted down the deployment wire to which the MUDL net remains tethered throughout the period of deployment. Buoyancy floats positioned towards the upper part of the main frame are there to keep the MUDL net as vertical as possible during deployment.

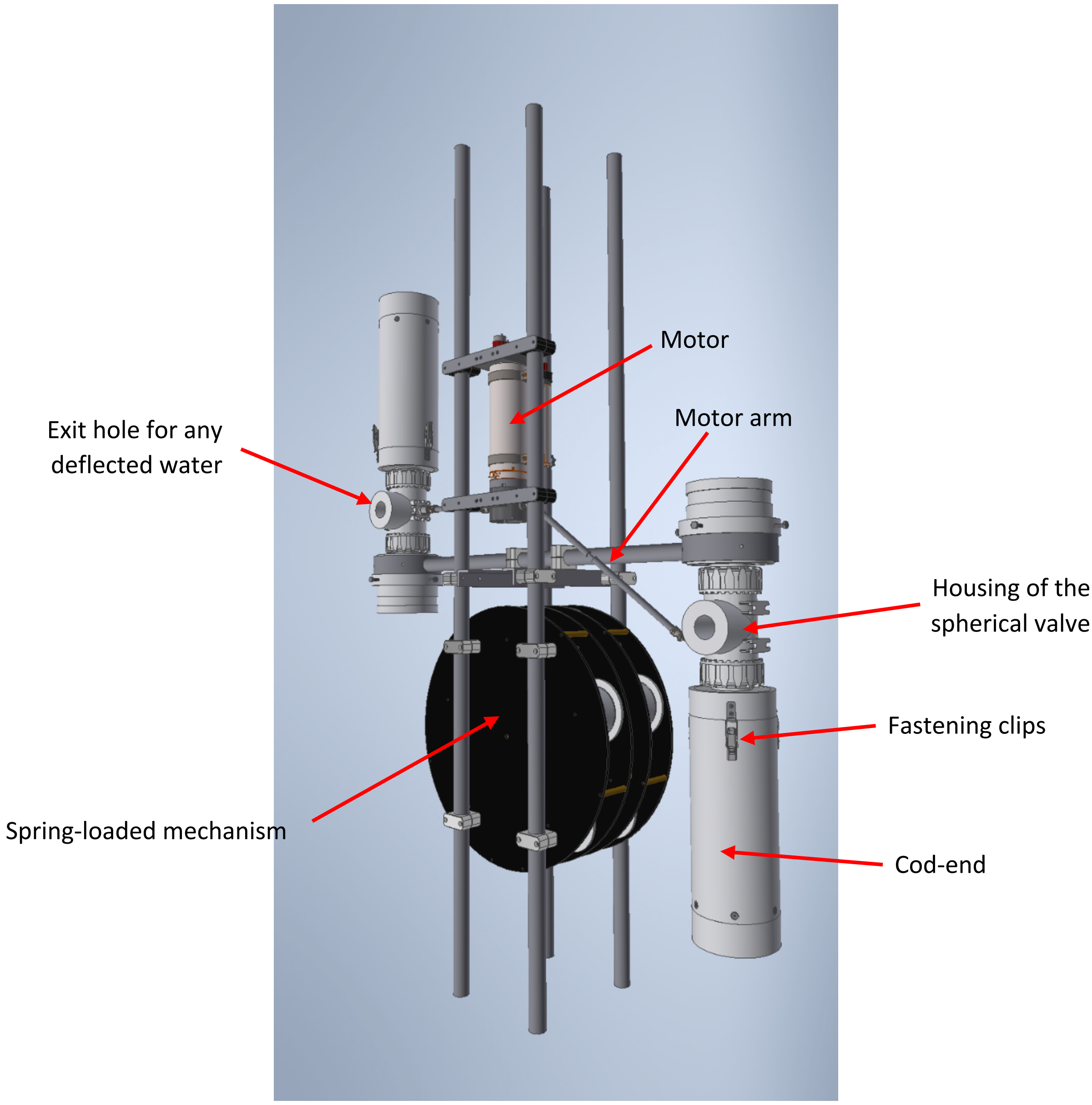

Fig. S2: Schematic of the cod-end mechanism (NB. Taps at ends of cod-ends not shown). Figure courtesy of Scott Polfrey and Daniel Ashurst, British Antarctic Survey, Engineering and Technology

At the entrance of the cod ends is a spherical valve contained within a housing (Fig. S2). This valve is hollow with three circular holes cut into it. The rotation of this valve starts and ends sample collection. In one position, a valve is opened into the cod-end that allows organisms to swim in. In other positions, this cod-end is sealed. There are exit holes next to the spherical valve that allows any water funnelling through the net (for instance, during downward deployment and upward recovery) to be deflected away. The two spherical valves (one in each cod-end) are rotated by a single motor which is connected to the spherical valves via motor arms.

Prior to deployment

1. Motor and programming: The motor was custom supplied by Hydro-Bios Apparatebau GmbH and is based around the motor that drives their MultiNet system. To the motor, we

fitted a bespoke gearing mechanism to drive two motor arms that rotate the spherical valves. The Hydro-Bios motor was programmed via a customised version of their Ocean-Lab 3 software where times were set for the motor to rotate first to move from a closed to open position and then to move from an open to closed position.

2. Cod-end preparation: The spherical valves sealed off the cod-ends prior to deployment. To avoid pressure differentials during downward deployment, it was necessary to fill the cod-ends with water prior to deployment. For the upward looking cod-end, clips could be unfastened, the cod-end detached from the device and filled with water, and then re-attached and the clips refastened. For the downward looking cod-end, it was necessary to fill the cod-end via a tap at the end of the cod-end (see Fig. S1). We used seawater taken from a CTD water sample taken just prior to the MUDL net deployment, at a similar depth to the intended MUDL net collection depth.

Deployment

The net is deployed using the same method as for a standard WP2 or Bongo net, with the net being lowered vertically over the side of the ship and then the deployment wire paid out at an approximate rate of 0.3 m s^{-1}. Once reaching its maximum designated depth, the MUDL net remains there for a preset period of time during which the entrances to the cod-ends open and organisms can swim in. For the present study, this collection period was set to 20 mins. The net was then recovered at a hauling-in rate of approximately 0.3 m s^{-1} and secured upright on deck.

Post-deployment

The sample within the upward looking cod-end could be recovered through simply opening the tap and letting the contents gently drain into a bucket partially prefilled with filtered seawater to cushion the flow of organisms into it. For the downward looking cod-end, firstly it was necessary to untether the bottom narrow end of the net from the cod-end. A partially prefilled bucket was then held underneath the cod-end. Direct communication with the motor was established and it was instructed to rotate and unseal the cod-end, allowing the contents to flow out into the bucket.

Spherical valve mechanism

The different positions of the spherical valve are illustrated in Figs. S3 to S4, in which the outer housing has been cut away to show the valve itself. At the start of the deployment, the valve is in the closed position (Fig. S3). The cod-end is sealed and any water flowing through the net, as it travels downward, is deflected through the exit holes.

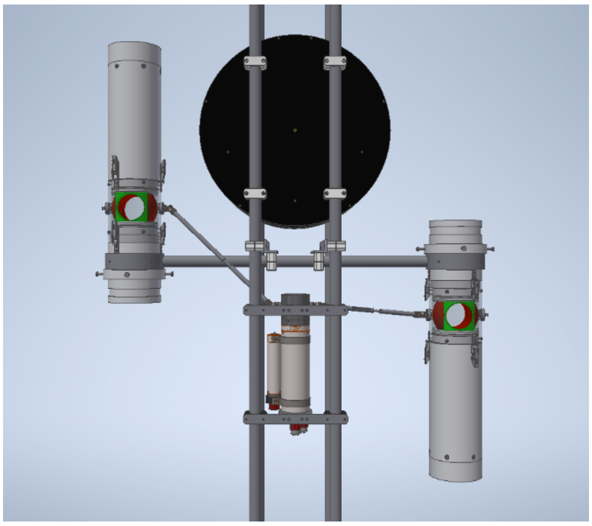

Fig. S3. Position during downward deployment. Cod ends are sealed, water is deflected out of exit hole (NB. Taps at ends of cod-ends not shown). Figure courtesy of Scott Polfrey and Daniel Ashurst, British Antarctic Survey, Engineering and Technology

Once the net reaches the deployment depth, the valve rotates, which opens up a conduit from the net to the cod-end and seals the exit holes (so avoiding any individuals taking a short-cut into the cod-end; Fig. S4)

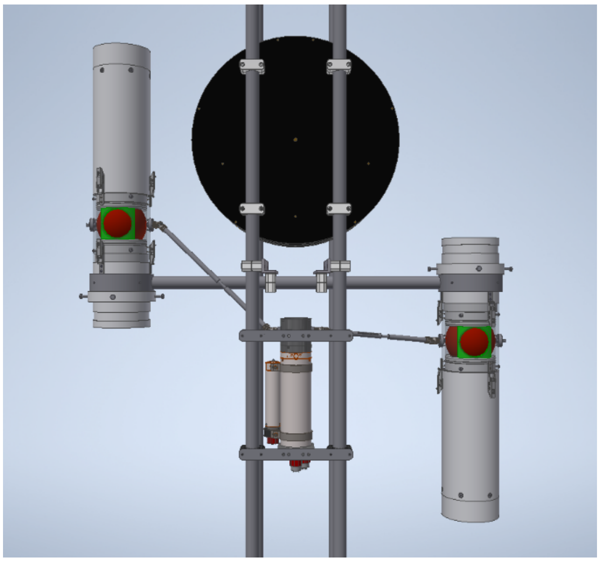

Fig. S4. Position during sample collection. The entrance to the cod-end is now open, allowing organisms to swim in (NB. Taps at ends of cod-ends not shown). Figure courtesy of Scott Polfrey and Daniel Ashurst, British Antarctic Survey, Engineering and Technology

At the end of a preset time (see above), the valve rotates once more, sealing off the cod-end so that it is in the same position as during downward deployment (Fig. S3). This means that any water passing through the net is deflected through the exit holes during upward recovery and the sample within the cod-ends is sealed from any contamination.

Supplement 2: Comparison of catches between MUDL net and vertically deployed mini Bongo net

Rationale

To provide a context for the capture efficiency of the MUDL net, a mini Bongo net was deployed vertically to a maximum depth of 70 m at approximately the same time as a MUDL net deployment at Polar Frontal Zone station PF4. We report on the total number of organisms captured by the respective nets as well as the proportional composition of different zooplankton taxonomic groups.

Methods

The design and method deployment of the MUDL net is described in detail in the main manuscript and will not be further described here. The mini-Bongo net had an 18 cm mouth diameter with 53 µm meshed net tapering to the cod end. Both nets were deployed at Polar Frontal Zone station PF4 (53.930°S, 49.154°W) within one hour of each other on 4/1/2017 (mini-Bongo between 21:32 and 21:37 GMT; MUDL between 21:42 and 22:20). The mini-Bongo went to a maximum depth of 70 m, the MUDL was sent to a depth of 100 m and opened for 29 mins before subsequent recovery. Both nets were within the mixed layer as defined by the temperature and salinity profiles (Fig. 3). Upon retrieval, the mini-Bongo sample was filtered and preserved in 95% ethanol. The preserved sample was sent to Morski Instytut Rybacki, Poland for zooplankton taxonomic analysis, using the following protocol: any organisms larger than 10 mm were removed from the aliquot and recorded before the sample was sorted; the aliquot was then sorted and all plankton identified to the lowest possible taxonomic level; the raw counts of each species were multiplied by the inverse of the sample fraction to give a whole sample count for each species/ stage recorded. The MUDL net samples were frozen and subsequently preserved back at the home laboratory before taxonomic identification and abundance analyses under a light microscope (see the main manuscript for full details).

Results

We found the MUDL net to catch approximately 4.5 % and 0.3 % of the total mini-Bongo net catch in the downward looking and upward looking nets, respectively (Figure S5). In terms of the patterns of proportional taxonomic composition of the two net types, catches were broadly similar, with cyclopoid copepods being the most abundant taxa across all samples (Figure S6a). Nevertheless, certain taxa found in the mini-Bongo net were absent from the MUDL net, including annelids, appendicularians and tunicates. Furthermore, an ANOVA on Ranks found significant differences in the composition of the two net types ($F_{2,26}$=21.29, P <0.001), further resolved by Dunn's pairwise tests (mini-Bongo net versus downward looking MUDL net: P < 0.001; mini-Bongo net versus upward looking MUDL net, P=0.001). Most notably, the proportional abundance of the dominant taxonomic groups, calanoid copepods, was significantly greater in the MUDL net samples, accounting for almost 40 % and 30 % of the total catch in the downward and upward looking nets as compared to less than 20 % in the mini Bongo net sample (Figure S6b). There were other minor differences between net types in the proportional abundance of rare taxa such as Euphausiidae, Gastropoda and Harpacticoids, but this is as likely to be influenced by natural variation as to net selectivity.

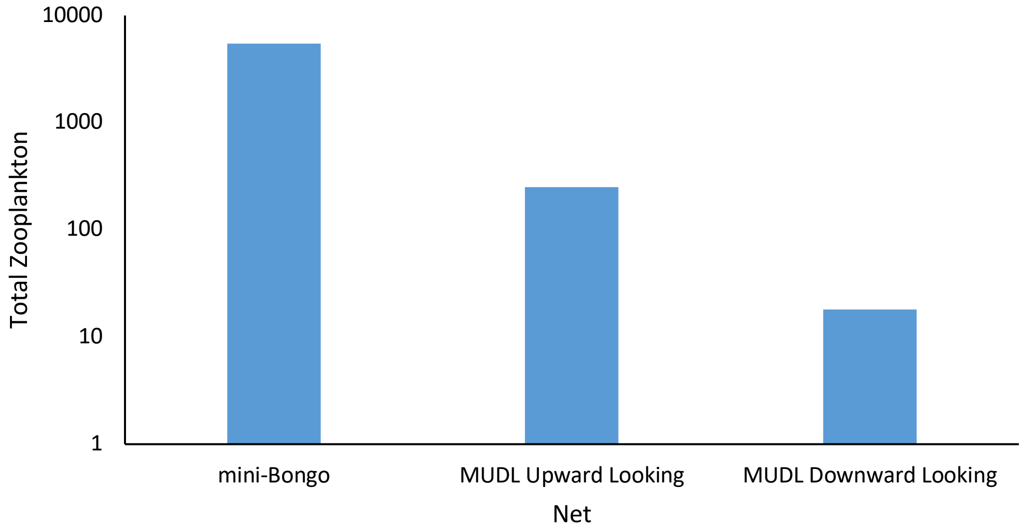

Figure S5: Total number of zooplankton caught in each of the mini-Bongo, upward and downward looking nets at PF4. All nets were deployed to 100 m. The mini- Bongo net was vertically hauled to the surface from 100 m, while the MUDL net only sampled whilst stationary at 100 m.

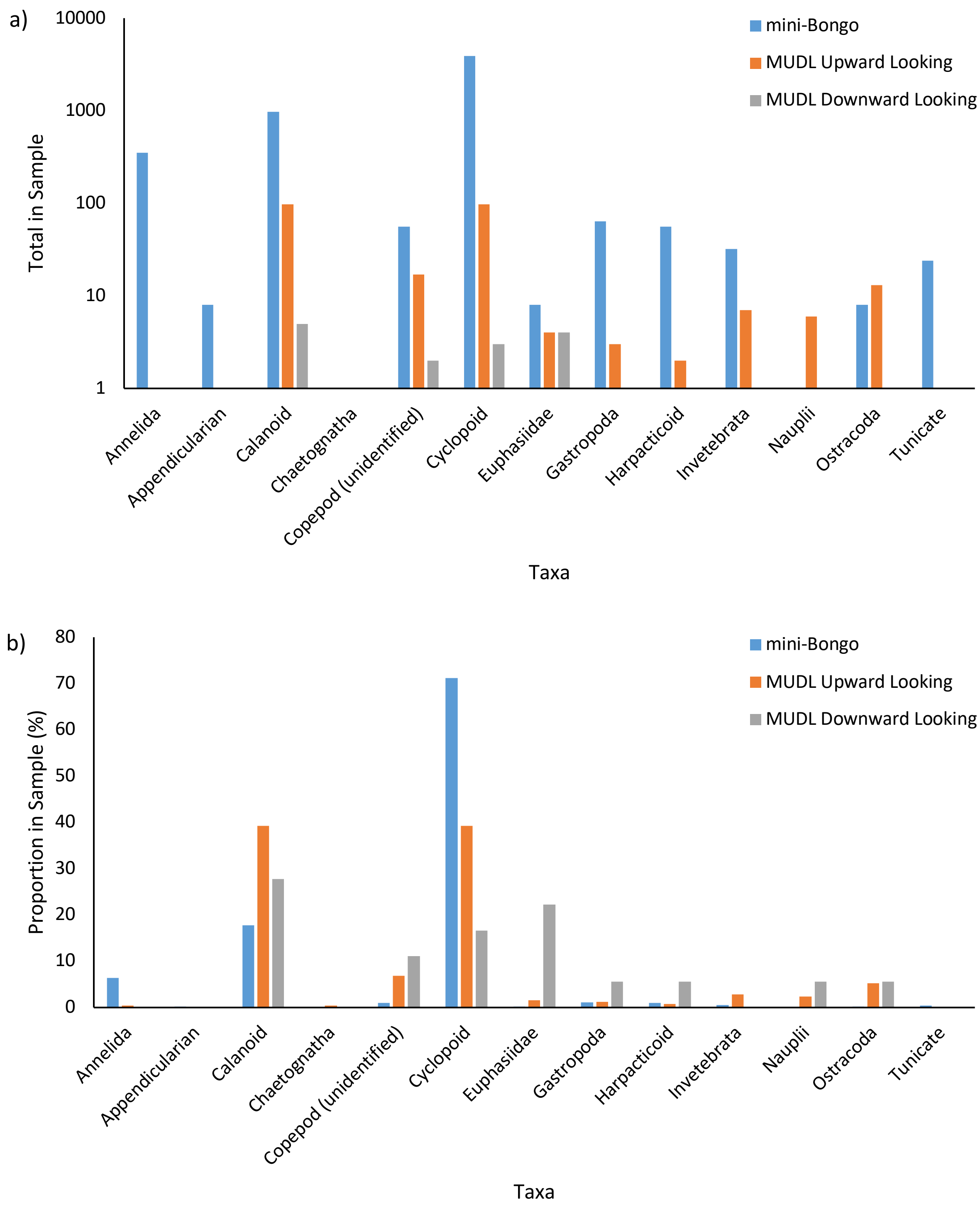

Figure S6: Comparisons of MUDL and mini-Bongo nets. (a) Total abundance of zooplankton in each taxa found in the mini-Bongo (blue), the upward looking MUDL net (orange) and the downward looking MUDL net (grey). (b) Relative proportions of each zooplankton taxa found within each of the net samples for the mini Bongo net (blue), the upward looking MUDL net (orange) and the downward looking MUDL net (grey).

Conclusions

It is unsurprising that vertical integration of the water column, as performed by the mini-Bongo net, will collect far more organisms per unit area compared to the MUDL net into which organisms must swim in order to be captured. However, the proportional composition of different taxonomic groups was comparatively similar between the two net types. Differences between dominant taxa were found, with the MUDL net more likely to catch a greater proportion of calanoid copepods and the mini-Bongo net, a greater proportion of cyclopoid copepods. This may reflect the greater swimming capabilities of the calanoids, making them more likely to move into the net than the less motile cyclopoids.