Bathyal demersal fishes of the Charlie-Gibbs Fracture Zone region (49°–54°N) of the Mid-Atlantic Ridge: III. Results from remotely operated vehicle (ROV) video transects

Thomas D. Linley [a,*], Claudia H.S. Alt [b], Daniel O.B. Jones [b], Imants G. Priede [a]

[a] University of Aberdeen, Oceanlab, Institute of Biological and Environmental Sciences, Main Street, Newburgh, Aberdeen AB41 6AA, United Kingdom
[b] National Oceanography Centre, European Way, Southampton SO14 3ZH, United Kingdom

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ABSTRACT

Demersal fish were assessed by remotely operated vehicle (ROV) video transects at sites to the NE, NW (54°N), SE and SW (49°N) of the Charlie-Gibbs Fracture Zone (CGFZ) at ca. 2500 m depth on the Mid-Atlantic Ridge. At each site, three different slope categories (flat, 10° slope and $>30°$ slope) were sampled with four transects, each surveying 2000 m³ of suprabenthic water. This resulted in 12 high-definition video transects at every site, covering a total of 24,000 m³ suprabenthic water. Six species were observed; which was fewer than in surveys using baited landers (19 species) and trawls (26 species) in the same area. *Bathysaurus ferox*, *Halosauropsis macrochir*, *Antimora rostrata* and *Polyacanthonotus challengeri* did not vary in density between sites, while *Coryphaenoides brevibarbis* and *Coryphaenoides armatus* were significantly more abundant at the northern sites; the latter supporting findings using baited landers. The halosaur *H. macrochir* was the only species affected by slope. The majority of observed fish showed no reaction to one or more of the stimuli produced by the ROV, however burst swimming was observed at least once in all species except *B. ferox*. The most abundant species, *C. brevibarbis*, was particularly affected by the presence of the ROV.

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1. Introduction

A fundamental problem in fisheries science is that different sampling methods yield varying estimates of species composition and density. Bottom trawls are most widely used to sample demersal fishes as they capture a wide range of species and the area surveyed can be estimated based on towed distance and trawl opening width. Differences in trawl design and size, however, result in significant variations between samples (Merrett et al., 1991). Sampling also is restricted to relatively smooth terrain (Cousins et al., this issue-a). Baited gear such as long-lines, traps and cameras (Fossen et al., 2008; Cousins et al., this issue-b) on the other hand, can be used to sample rough terrain, but they only target a subset of necrophagous species (Priede et al., 2010) and the sampling area remains largely uncertain (Priede and Merrett, 1996). Remotely operated vehicles (ROVs) are increasingly used for quantitative video assessments (Trenkel et al., 2004a; Uiblein, 2011), but it remains unclear whether video surveys are superior to bottom-trawling in evaluating fish populations (Trenkel et al., 2004b). ROV video surveys have the advantage of facilitating the sampling of different species across a wide range of bottom terrains, without disturbing the sea floor (Trenkel et al., 2004a; Stoner et al., 2008) as well as preserving information on behaviour, fine-scale distribution and relationships between fish and their environment (Anderson et al., 2009; Norcross and Mueter, 1999).

Here we report on fishes observed during ROV surveys on the Mid-Atlantic Ridge (MAR) undertaken as part of the Ecosystem of the Mid-Atlantic Ridge at the Sub-Polar Front and Charlie-Gibbs Fracture Zone (ECOMAR) project (Priede et al., this issue). Sampling was carried out at four sites, two at latitude 54°N. NW and NE, either side of the ridge axis at 2500 m depth north the Charlie-Gibbs Fracture Zone (CGFZ) and two sites at 49°N, SW and SE, also at the same depth either side of the ridge axis south of the CGFZ. The aim was to discriminate faunal differences between north and south across a potential latitudinal divide created by the topographic discontinuity of the CGFZ and the presence of the Sub-Polar Front and North Atlantic Current that traverse the MAR at around 52°N (Priede et al., this issue; Miller et al., this issue). Sampling symmetry either side of the ridge axis at 2500 m depth also had the potential to detect any longitudinal (East–West) differences. Within ECOMAR, three different types of equipment were used to sample demersal fish density and diversity; Semi-Balloon Otter Trawls (OTSB; Cousins et al., this issue-a), baited photographic landers (Cousins et al.,this issue-b) and the ROV

* Corresponding author.
E-mail address: t.linley@abdn.ac.uk (T.D. Linley).

video transects described here. The ROV studies were undertaken during cruise JC048 of the R.R.S. *James Cook* in 2010 and have also been analysed for benthic foraminifera (Gooday et al., this issue), lebensspuren (Bell et al., this issue) and benthic invertebrates (Jones et al., this issue). For fishes, the ROV provided access to rough, steeply sloping terrain (Raymond, 2008; Stoner et al., 2008; Tissot et al., 2008; Tissot et al., 2007) where it was not possible to trawl.

2. Materials and methods

At each of the four ECOMAR stations around 2500 m depth, NW (53°59′N, 36°07′W), NE (54°00′N, 34°11′W), SW (48°47′N, 28°38′W) and SE (49°02′N, 27°41′W), three slope categories were distinguished from multi-beam bathymetry: 0° (0–2° slope), 10° (8–12° slope) and 30° (>30° slopes) (Priede et al., this issue). During 1–27 June 2010, on board the R.R.S. *James Cook* the ROV *Isis* undertook four 500 m long ROV transects at each slope category at each station, resulting in a total of 12 samples per station and 48 transects overall (Supplementary material). The ROV systems used during video transects are outlined in Gooday et al. (this issue). Fish observations at 0° and 10° slopes were made with a downward-looking vertically-oriented HD camera. A second HD camera was oriented horizontally to image 30° slopes.

Fish species were identified based on size, form of the body, head and fins (Uiblein, 2011; Uiblein et al., 2003). Prior species knowledge from the area, gained from the baited lander and trawl studies, benefitted species identification. Fish too small (generally <5 cm total length) or not seen clearly enough for identification (Raymond, 2008) were not included in the results (they accounted for <10% of observations). Density estimates were calculated by dividing the number of individuals observed in transects by the volume of water imaged (Trenkel et al., 2011, 2004a). Fish densities were assessed as number of individuals m^{-3} and compared with a two-way ANOVA on rank, factoring site and slope. Comparisons with baited lander and trawl work include only the flat ROV transects.

The way fish reacted to the ROV was classified based on the semi-quantitative approach developed by Adams et al. (1995) and Trenkel et al. (2004b). The reaction of a fish to the ROV during the period it was observed was classified as: moving away (negative value) or towards (positive value) the ROV. Distinct fish movements were classified as: (0) no perceivable response, (1) deliberate movement and (2) disturbance response. The natural behaviour of the fish prior to a perceivable response to the ROV was classified when the fish first entered the field of view (Uiblein, 2011): (a) inactive stationary (remaining still on the seabed), (b) holding station (maintaining position), (c) drifting (moving with the current), and (d) transiting (deliberate movement). The orientation of the fish relative to the seabed was classified as: head down (positive value) or head up (negative value). The angle of the fish position was specified as: (0) approximately horizontal, (1) $\leq 20°$, (2) 20–45°, and (3) $>45°$. The distance above the seabed was estimated in body lengths using the following scores: (0) direct contact with sediment, (0.5) between 0 and 1 body lengths away from the seabed, (1.5) between 1 and 3 body lengths away (3) >3 body lengths away (Trenkel et al., 2004b; Uiblein, 2011). Total length estimates were made of fish close to the seabed, orientated horizontally and directly below the ROV. Tail beat frequency, as defined by Hunter and Zweifel (1971), was presented as average beats per second (Hz) over the time the fish was visible.

Percentages, means and standard deviations (SD) were calculated in Minitab 16. Owing to the semi-quantitative nature of the scored data, the non-parametric One-Sample Sign test was used to compare the reaction to the ROV by testing the null hypothesis of a median of 0 (no reaction). The distance of fish to the seabed was compared using the Kruskal–Wallis test. Tail beat frequency was assessed with a two-sample *T* test when only two groups were compared and a one-way ANOVA where several groups were compared.

3. Results

Six fish species were identified over 96,000 m^3 of water sampled by ROV video. Potential identification errors during ROV surveys (Norcross and Mueter, 1999), and difficulty in observing diagnostic features from a vertical camera (Bailey et al., 2007), were minimised by using morphological data collected during the trawl and baited camera surveys from the same area. The greatest taxonomic challenge was distinguishing between the abundant *Coryphaenoides brevibarbis* and *Coryphaenoides armatus* and other less common members of the family Macrouridae (Bergstad et al., 2008) from images alone. It is possible that some small *C. armatus* were classified as *C. brevibarbis* and that some of the rarer Macrourid species were included amongst these two species;
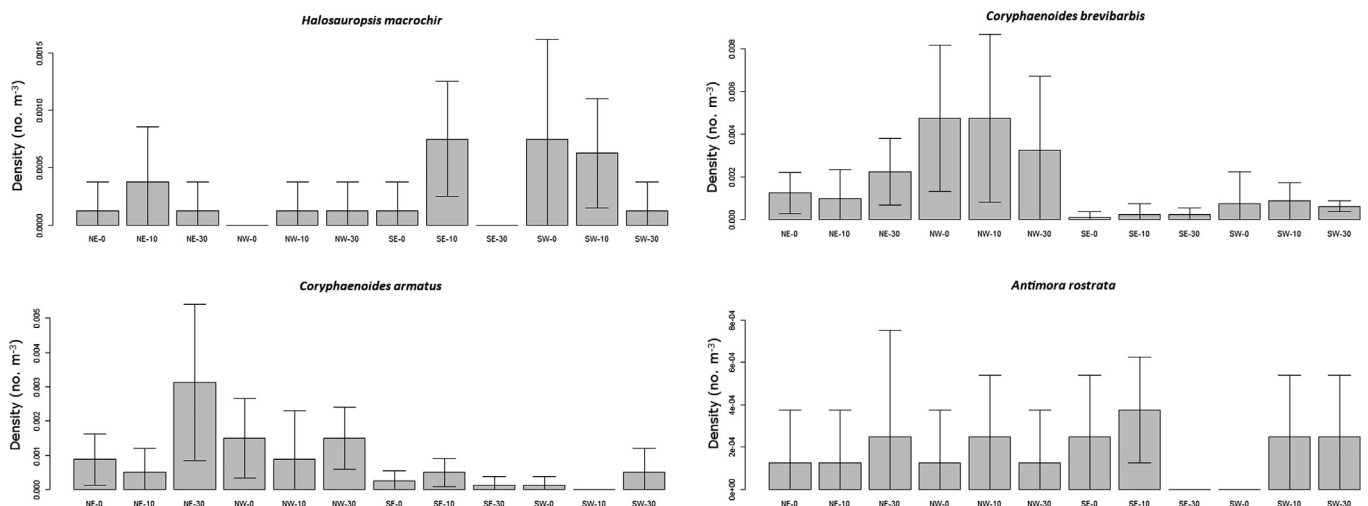

Fig. 1. Estimates of population density of species of fish observed in ROV video transects at the NW, NE, SW and SE stations. Numbers refer to sea floor slope categories nominally 0°, 10° and 30°.

Table 1
Observations on the reactions of fish to the ROV during observation. Reactions are distinguished between movements away and toward the ROV, where 'disturbance' refers to burst swimming, 'movement' to deliberate swimming in a single direction, and 'no perceivable reaction' to drifting or holding station.

Species (number of observations)	Away from ROV		Towards ROV		No reaction (%)
	Disturbance (%)	Movement (%)	Disturbance (%)	Movement (%)	
Halosauropsis macrochir (26)	7.7	3.8	7.7	0.0	80.8
Coryphaenoides brevibarbis (148)	20.9	23.6	0.7	1.4	53.4
Coryphaenoides armatus (73)	6.8	21.9	2.7	12.3	56.2
Antimora rostrata (16)	6.3	31.3	0.0	31.3	31.3

however, owing to the high densities of the two common species, the impact of such misidentification would be minimal.

3.1. Bathysaurus ferox Günther, 1878

Five individual *B. ferox* were observed, two at the NW, one at the NE and two at the SW station (Fig. 1). All individuals were stationary over soft sediment with slope $< 30°$ and did not react to the presence of the ROV. Four *B. ferox* specimens were measured and had a total length of 48.0 ± 12.07 cm (mean $\pm$ SD).

3.2. Halosauropsis macrochir (Günther, 1878)

H. macrochir was the third most abundant species, with 26 individuals observed. They typically occurred over flatter areas, with the exception of two individuals on slopes $> 30°$ (Fig. 1). Densities did not differ between sites ($F = 2.054$, d.f. $= 3$, 36, $p = 0.124$), but were generally lower in steeper areas ($F = 4.1.3$, d.f. $= 2$, 36, $p < 0.05$). There was no indication that density differences between slopes were site-dependent ($F = 1.062$, d.f. $= 6$, 36, $p = 0.403$). *H. macrochir* were holding station in 65% and drifting in 35% of observations when they first entered the field of view. The lack of any reaction in most cases (81%, Table 1) suggests that this species tends not to be affected by the presence of the ROV (one-sample sign Test $p = 1$, $n = 26$). A low average tail beat frequency of 0.3 ± 0.28 Hz (mean $\pm$ SD, $n = 19$) was observed. The average total length of *H. macrochir* was 45.0 ± 14.86 cm ($n = 18$).

3.3. Polyacanthonotus challengeri (Vaillant, 1888)

Four individuals of *P. challengeri* were encountered; one in the NE, one in the NW and two in the SW. *P. challengeri* was always observed holding station in a horizontal orientation, undulating the distal part of its tail with an average frequency of 2.6 ± 0.13 Hz (Mean $\pm$ SD, $n = 3$). The mean body length was 46.1 ± 0.28 cm (mean $\pm$ SD, $n = 3$).

3.4. Coryphaenoides brevibarbis (Goode & Bean, 1896)

C. brevibarbis was the most abundant fish species with 161 specimens, representing almost 50% of the total fish count. This species was six times more common at the northern stations, particularly the NW, with densities nearly three times greater than at the NE ($F = 9.652$, d.f. $= 3$, 36, $p < 0.001$). Slope did not affect the density of *C. brevibarbis* ($F = 0.182$, d.f. $= 2$, 36, $p = 0.834$) and there was no interaction between site and slope ($F = 0.684$, d.f. $= 6$, 36, $p = 0.664$, Fig. 1). Upon first entering the field of view *C. brevibarbis* was holding station in 57% of the observations and tended to be orientated with its head down (mean $\pm$ SD $= 0.82 \pm 1.182$, $n = 148$). Specimens were drifting with the current in 34% of cases. Of those drifting, 60% held their body at an angle greater than 45° to the sediment. Head-up or head-down postures were observed in approximately equal amounts. Individuals that drifted and held station had a significantly ($F = 6.81$, d.f. $= 4$, $p < 0.01$, following

Log$_{10}$ transformation) slower tail beat frequency (0.58 ± 0.589 Hz, mean $\pm$ SD) than the 9% transiting (1.16 ± 0.843 Hz). The average total length of this species was 18.5 ± 7.12 cm (mean $\pm$ SD, $n = 74$). The presence of the ROV affected 47% of *C. brevibarbis* noticeably during the period of observation (one-sample sign Test $p < 0.001$, $n = 148$; the median differed significantly from 0). Individuals often sank to the seabed and remained motionless when the ROV approached. Specimens swam away a quarter (24%) of the time, while a further 21% showed a startle response and burst swam away from the ROV.

3.5. Coryphaenoides armatus (Hector, 1875)

C. armatus was the second most abundant fish species, with 79 individuals encountered. This species was more abundant at the northern sites ($F = 6.625$, d.f. $= 3$, 36, $p < 0.01$). Overall, the density of *C. armatus* did not differ between slopes ($F = 2.411$, d.f. $= 2$, 36, $p = 0.104$, Fig. 1), despite a complete absence at the SW site at 10° slopes and more than double the density at the NE $> 30°$ compared to other northern slope categories. There was no interaction between sites and slopes ($F = 1.606$, d.f. $= 6$, 36, $p = 0.174$). When first entering the field of view *C. armatus* was holding station facing into the bottom current in 72% of observations with a tail beat frequency of 0.6 ± 0.43 Hz (mean $\pm$ SD, $n = 57$) and most often in a head lowered position (mean $\pm$ SD $= 0.56 \pm 1.130$, $n = 73$). The distance (in body lengths) above the sediment differed significantly with slope (Kruskal–Wallis $H = 9.98$, d.f. $= 2$, $p = 0.007$). On slopes $> 30°$ specimens were more than twice as far above the seafloor than in flatter areas (mean distance of 0.5, 0.6 and 1.3 body lengths above the sea floor for 0°, 10° and 30° slope categories, respectively). *C. armatus* showed no reaction to the ROV in 56% of observations, and its median reaction did not differ significantly from 0 (one-sample sign test $p = 0.11$, $n = 73$).

3.6. Antimora rostrata (Günther, 1878)

With 17 observations *A. rostrata* was the fourth most abundant fish species. *A. rostrata* was absent only from the $> 30°$ slopes in the SE and the flat area in the SW. Density did not differ between stations ($F = 0.155$, d.f. $= 3$, 36, $p = 0.926$) or slopes ($F = 1.216$, d.f. $= 2$, 36, $p = 0.308$, Fig. 1). When entering the field of view *A. rostrata* was only observed transiting (67% of observations) or holding station (33%) with its body horizontal or with the head slightly elevated (-0.1 ± 0.57 mean $\pm$ SD, $n = 13$). The average tail beat frequency was 0.9 ± 0.59 Hz (mean $\pm$ SD) during transit, and 0.4 ± 0.07 Hz whilst holding station. *A. rostrata* showed no response to the ROV in 31% of observations; a startle response occurred only once (Table 1), however this species was frequently observed within the field of view of the ROV rear camera, following the vehicle at a distance of several metres.

4. Discussion

The ROV surveys confirm some of the main conclusions from the baited camera lander surveys on the MAR (Cousins et al., this issue-b) showing that the macrourid *C. armatus* occurs at all stations but with higher abundance in the north compared with south of the CGFZ. *A. rostrata* also occurred at all sites in both studies but with the lander results indicating a higher abundance in the south. *H. macrochir* was found to be most abundant in the south in both the trawl and ROV surveys. ROV and trawl surveys also both identified the NW as an area of exceptionally high abundance of *C. brevibarbis* (Cousins et al., this issue-a).

Species numbers observed in the ROV video survey at the MAR were noticeably fewer than in other studies in the Atlantic Ocean that used imagery from submersibles; for example Ross and Quattrini (2007) reported 66 fish species off the western Atlantic coast and Baker et al. (2012) found 74 species off the Grand Banks, Newfoundland. These differences may result from methodological differences (wider field of view in Ross and Quattrini (2007) and faster sampling speed in Baker et al. (2012)), but most likely reflect the much wider bathymetric sampling range (e.g. 351–2245 m in Baker et al. (2012) and 366–738 m in Ross and Quattrini (2007)) of these studies compared to the present work (2100–2800 m).

The lack of reaction (positive or negative) to the ROV, evident in more than half (55.9%) of all observed fish at the MAR, is also common to other studies (Uiblein, 2011; Baker et al., 2012). A total of 15.4% of individuals, across all species, exhibited a burst swimming escape response during observations, with the exception of *B. ferox*. Such responses may be stimulated by light, sound, electromagnetic or hydrodynamic disturbance caused by the ROV (Spanier et al., 1994; Trenkel et al., 2004a, 2004b; Stoner et al., 2008; Ryer et al., 2009; Uiblein, 2011). Some species might even react to the presence of a ROV before recording commences (Stoner et al., 2008; Ryer et al., 2009). Indirect effects, such as possible prey attraction through light and sediment disturbance (Stoner et al., 2008) might have also affected fish behaviour. In an ecological study such as this one, it is important to understand which behaviour is natural and which artificial (Uiblein, 2011). *A. rostrata*, for example, showed signs of natural behaviour as specimens were observed to swim actively with a tail beat frequency double that of 'holding position', while *H. macrochir* and *P. challengeri* minimised energy expenditure by holding station. *C. brevibaris* was frequently observed drifting with the current, suggesting this as a mode of locomotion. *B. ferox*, which are capable of short high-speed bursts (Whitehead et al., 1984), was not observed swimming at all in this study. This could be caused either by individuals not being affected by the ROV presence or because they remain motionless to avoid detection by the perceived threat (Uiblein et al., 2003). *C. armatus* was mainly observed holding station near the seabed. This was unexpected as other studies report species from this genus up to 1000 m above the seabed (Priede et al., 1990; Uiblein et al., 2003; Uiblein, 2011). Hence, it is possible that the presence of the ROV evoked an unnatural response in *C. armatus* as was noted by the tendency for *C. brevibarbis* to move towards the seabed during observation. Reactions to ROVs and the particular stimulus species react to seem be species specific (Uiblein, 2011; Uiblein et al., 2003). Thus, an unbiased density estimate through ROV surveys requires the assessment of individual species (Trenkel et al., 2004a; Ryer et al., 2009). For example, *C. brevibarbis* was the only species that showed a significant reaction to the ROV in the current study. As the smallest species, its vigilance may be a reflection of its vulnerability to predation (Uiblein, 2011).

Both *C. armatus* and *A. rostrata* are regularly observed in baited lander studies, the latter often being the first to arrive at carcasses (Cousins et al., this issue-b). *Antimora rostrata* were observed to easily keep pace with the ROV (travelling at 0.13 m s^{-1}) in the rear camera, confirming previous studies describing their fast swimming speed (Collins et al., 1999; Henriques et al., 2002). Density estimated with baited landers (Cousins et al., this issue-b) did not differ for *A. rostrata* between sites, but a significantly greater density of *C. armatus* was observed to the north, a trend also confirmed here. This pattern was not apparent in the trawl data but was clear in the baited lander study (Cousins et al., this issue-b).

Hydrolagus affinis, a very abundant species in the lander study (Cousins et al., this issue-b), was absent from the ROV video survey. As submersibles are reported to deter shelf species that are attracted by baited-camera systems (Raymond, 2008), *H. affinis* likely are sensitive to disturbances produced by ROVs (Trenkel et al., 2004a), which is supported by the observation of several *H. affinis* circling an amphipod trap that immediately dispersed upon arrival of the ROV (personal observation). *H. macrochir*, on the other hand, is rarely observed in baited lander studies. It has a strong benthic association, is not necrophagous and mainly preys on benthic invertebrates (Whitehead et al., 1984). The ROV survey revealed a greater density of this species over flatter, sedimentary ground, most likely reflecting the foraging strategy. *B. ferox*, a sit-and-wait predator (Froese and Pauly, 2012; Whitehead et al., 1984), was also absent from the lander study. It likely relies on flatter sedimentary areas to ambush prey and therefore is rarer at higher slopes. The most abundant species observed in the ROV survey was *C. brevibarbis*, and was similarly abundant in the trawl survey (SW = 436/750, NE = 1519/1250, NW = 5740/4750 km^{-2}, trawl and ROV respectively, Cousins et al., this issue-a).

The number of species (6) identified with the ROV video survey was much lower than the 19 species attracted to bait (Cousins et al., this issue-b) and 26 species captured in trawls (Cousins et al., this issue-a). This is somewhat surprising in view of the close correlation between species numbers from trawls and ROV videos by Ross and Quattrini (2007) in the western Atlantic Ocean which identified 68 species. It is evident that the video transects in the current study were highly selective for a small proportion of species reported from the MAR. It is important in ROV video surveys that study mobile fauna to take into account the reaction of the organisms to the ROV beyond the field of view (Uiblein, 2011). The present survey was flown at an altitude of just 2 m and the data would indicate that many fish were able to avoid being imaged in the resulting small field of view.

The randomised ROV transects were designed to assess benthic invertebrates (Gooday et al., this issue; Jones et al., this issue) but also gave an insight into fish assemblages, in particular where conventional methods, such as trawling and baited landers, cannot easily be used, e.g. rocky terrain and steep slopes. This study highlights that ROV video surveys can add valuable information on the behaviour and the distribution of those fish not affected by the ROV presence. This is particularly the case for non-necrophagous species that cannot be targeted by baited landers, traps or long-lines. Thus, in conjunction with other methods (e.g. baited landers and bottom trawls) ROV video surveys can give a unique overview of the ecology of fish population in an area.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.dsr2.2013.08.013.

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