Fisheries & Conservation Science

Impact of scallop dredging on benthic communities and habitat features in the Cardigan Bay Special Area of Conservation

Part II – Physical environment

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1. Introduction

Habitat alteration through changes to the physical environment can lead to long-lasting effects on the animals living there (Collie *et al.* 1997). These habitats may also be features of conservation importance. In the case of Cardigan Bay SAC, reefs were a qualifying feature (JNCC 2015). The reefs in Cardigan Bay SAC consist predominantly of pebbles, cobbles and boulders (CCW 2009). These reefs may be subjected to natural or anthropogenic disturbance that can lead to short-term or long-term impacts on the physical environment.

Side scan sonar can be used to identify fishing activity and the amount of disturbance (Friedlander *et al.* 1999), which can include changes to the topography as well as sediment composition. Sediment surface roughness is increased by repeated trawling (Schwinghamer *et al.* 1998), as seabed disturbance can lead to the suspension, and subsequent loss, of fine sediments. Mobile fishing gear can also leave troughs in the seabed and move cobble and boulders. The visibility of fishing impacts depend very much on the impacted sediment. For example, marks left by otter trawling are less visible in sandy sediments due to lower depth of penetration and movement of surface sediments by waves and tides (Krost *et al.* 1990).

The persistence of fishing marks depends on the sediment, environmental conditions and the nature of the impact. Schwinghamer *et al.* (1998) found that otter trawling caused change to surface sediments but that these changes recovered within a year despite being below the depth of wave-induced sediment transport. Where tide and wave energy is high at the seabed then physical impacts will be visible for a shorter time. Gilkinson *et al.* (2015) found wave energy to create more disturbance than tidal currents, but sediment transport may vary between years (Schwinghamer *et al.* 1998). Recovery of benthic fauna is slower if the spatial scale of impact is larger (Collie *et al.* 1997) and this may also be true of the physical environment.

Not all physical changes will be detected using side-scan sonar and the detection ability will depend of the system and settings used. Towing direction is also important, as fewer trawl marks are detected when the side-scan sonar is towed perpendicular to the direction of fishing (Smith *et al.* 2007). It may not be possible to separate coarse sediments from mixed sediments using backscatter data, as the gravel content dominates the backscatter return (Diesing *et al.* 2014). Therefore, in mixed gravelly sediments it may be more difficult to detect physical changes.

2. Methods

For details on the experimental design and sampling protocols see Lambert et al. 2015b.

2.1 Seabed disturbance by wave action

Data were obtained from the Aberporth wave buoy on hourly wave period from October 2012 to March 2015. Wavelength was then calculated to provide an indication of how often the seabed was likely to be disturbed by wave action, assuming movement would be minimal at a depth equal to half the wavelength.

2.2 Seabed disturbance by fishing

A C-MAX CM2 side scan sonar system was used to identify dredging within the experimental area. The system uses a 300m steel armoured twisted pair cable on a 24V battery powered winch. A sonar range of 100m (total swath 200m) and a sonar frequency of 325kHz was used. Each of the 17 lanes was surveyed with the side-scan sonar in March, May and September 2014, with three tows conducted in each lane. Eleven of the lanes were also surveyed in March 2015, with two tows conducted in each lane. The entire length of each sidescan record was examined in C-Max MaxView for the presence of dredge scars. Bitmap images of the records were also examined in ImageJ following enhancement of contrast. The exact position of the side scan towfish was unknown. Therefore, for a subset of records across a range of intensities, seabed features were matched in side scan images from each survey to determine whether seabed features had changed or not.

The multi-beam system used on the research vessel Prince Madog was a RESON SEABAT 7125 dual frequency system. For the first two surveys the higher frequency (400kHz) was used whilst for the last survey, in September 2014, the low frequency (200kHz) was used because problems at the higher frequency. The main difference is the achievable depth. i.e. the high frequency is usable down to 100m depth while the low frequency can be used down to 300m. In addition to this, an Applanix POSMV Wavemaster Inertial Navigation system was used for positioning and motion compensation. The data was acquired using Reson's PDS2000 data acquisition system. The results of the multibeam surveys will be presented in future reports.

Grab samples were taken within each lane with a Hamon grab, which had a bucket area of 0.1m^2 and sampled down to 10cm deep in the sediment. Five to nine grab samples were taken in each lane. The samples were spread out inside the fishing box and positioned away from the edges as much as possible (Figure 2B) so it would capture the impact from fishing and recovery away from unfished areas of the seabed which can bias results because of local immigration of fauna. A sediment subsample (a handful – about 40 grams) was taken from each sample and frozen for particle size analysis in the lab. See Lambert *et al.* (2015b) for further details on methodology.

3. Results and Discussion

3.1 Seabed disturbance by waves

In all but two months between October 2012 and March 2015 average wavelength was less than 60 m (Figure 1). However, in all but three months there were wavelengths of 80 m or greater, indicating that there was likely to be some wave disturbance at all survey sites during most months. Wavelength tended to be highest between October and March. The fact that dredge marks were visible at most sites in September 2015 (Table 1) probably reflects the lower levels of disturbance from wave energy during the summer months.

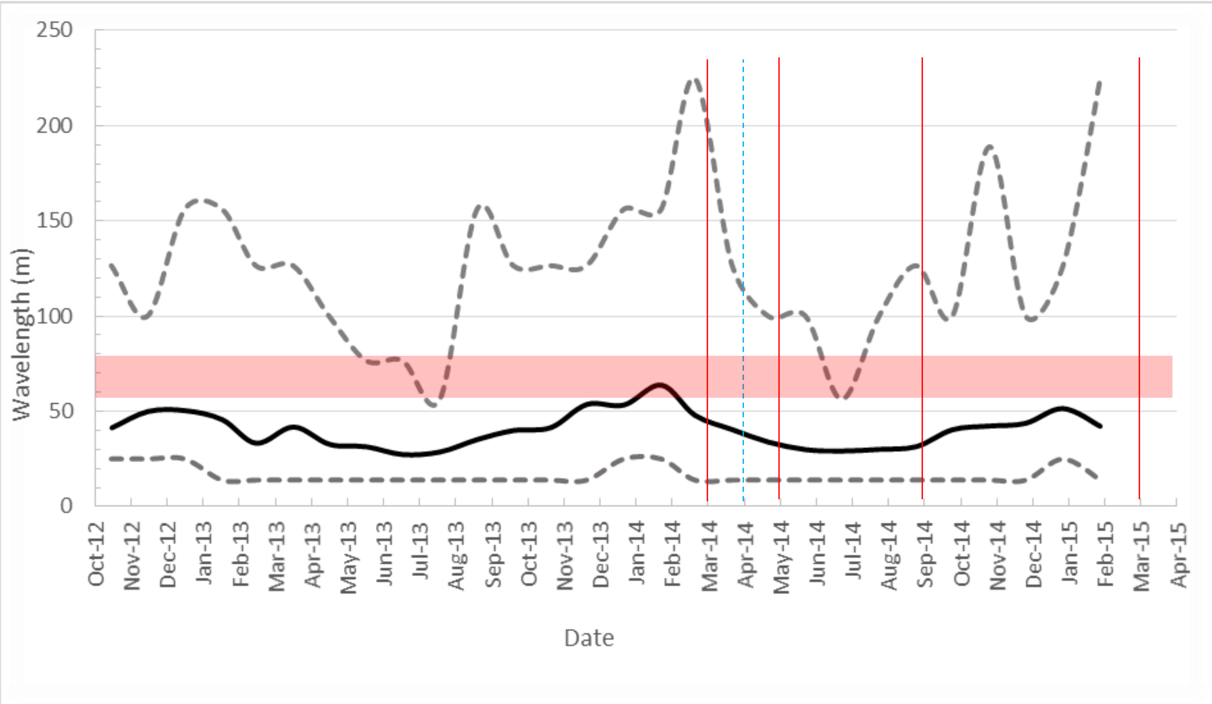

Figure 1. Mean wavelength (solid black line), and minimum and maximum wavelength (dashed grey lines) recorded by Aberporth wave buoy (Data provided by Met Office). Surveys were undertaken in March, May, September 2014, and March 2015 (vertical red lines). Fishing took place in April 2014 (dashed blue vertical line). Shaded red area indicates the approximate minimum wavelengths required to disturb the seabed over the study area.

3.2 Sediment composition

Sediment composition was highly patchy (Figure 2). Lanes consisted of mixtures of sand, gravel and pebbles. Overall, mean particle size in samples collected in Hamon grabs ranged from 0.1mm to 14mm. Sediments within individual grab samples included a range of particles sizes. These mixed sediments may have consisted of surficial veneers or more homogeneous mixtures (Van Heteren and Van Lancker 2015) of sand, gravel, pebbles and cobbles. Some areas appear to consist of cobbles covered by mobile sand (Hinz *et al.* 2010; e.g. see Figure 9).

Over 37% of the variation in sediment between lanes could be explained by the pebble and gravel component as opposed to silt/clay through to medium sand component. Over 29% of variation was explained by the coarse and very coarse sand components (Figure 3). Lanes 1, 2, 9, 12, 13, 14 and 17 were characterised by finer sediments (silt/clay – medium sand), with Lane 17 also contained a high percentage of coarse sand. Lanes 11 and 16 were also characterised by coarse and very coarse sand. Lanes 3, 4, 5, 7, 8 and 10 were dominated by gravel or pebbles. Lanes 6 and 15 contained substantially proportions of fine sediments as well as pebbles.

Of the five lanes that were fished at the highest intensities (>3 times swept) only lanes 3 and 16 showed an impact by March 2015. Lanes 11 and 16 were very similar in composition. The fishing impact in Lane 16 (6.07) was only slightly higher than in Lane 11 (5.33) suggesting that Lane 16, which was in deeper water, was exposed to less natural disturbance resulting in marks that took longer to disperse. Lane 2 and Lane 3 were fished at a similar intensities of 3.05 and 3.82, respectively; these two lanes contained a high proportion of pebbles, at 26% and 27%. However, Lane 2 contained 23% fine sand compared to 11% in Lane 3. No significant differences were found in the proportion of any one sediment component between surveys (General Linear Model, Proportion~Lane*Survey. Data were arcsine transformed).

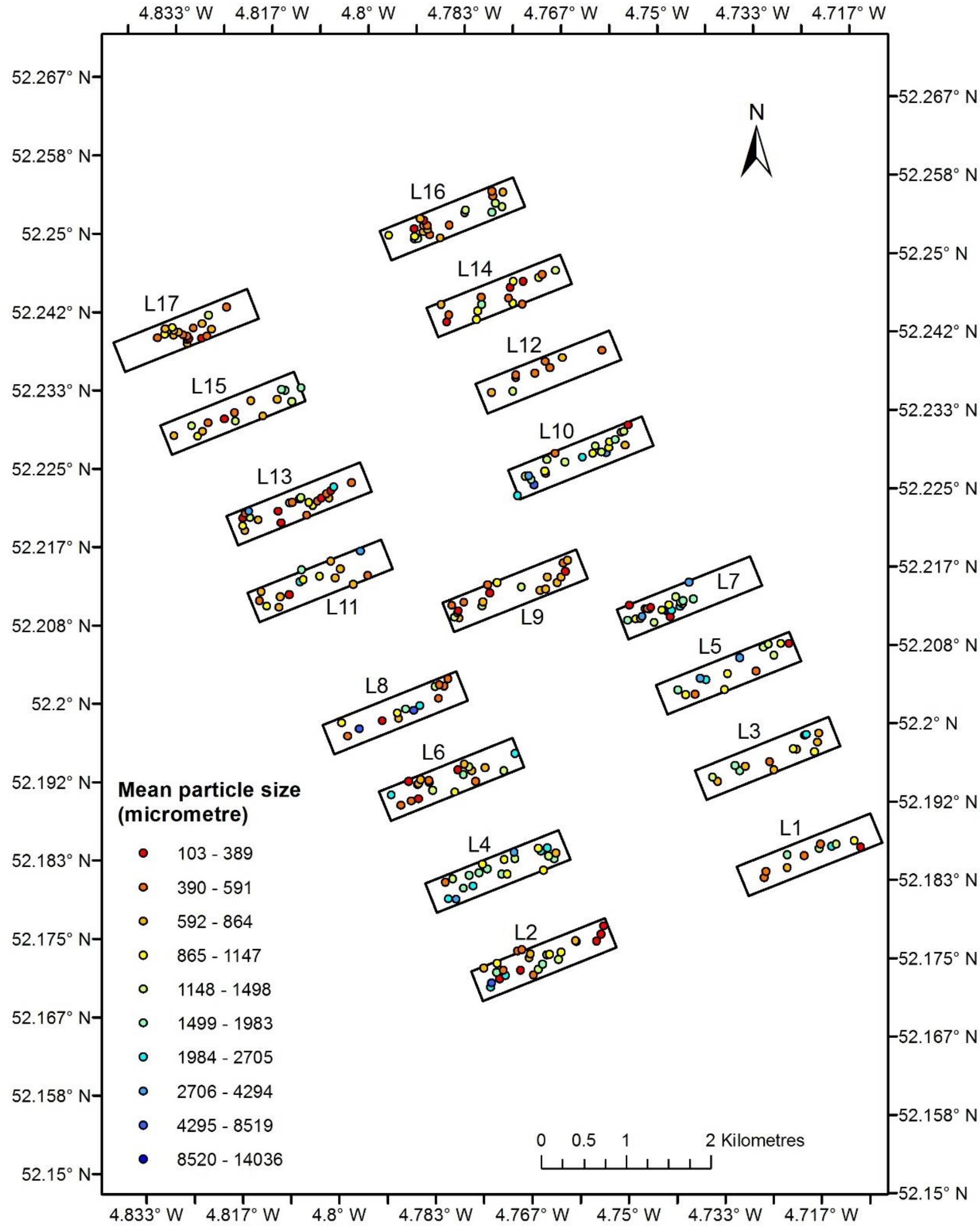

Figure 2. Mean particle size in 305 Hamon grab samples collected in March, May and September 2015 from the experimental area.

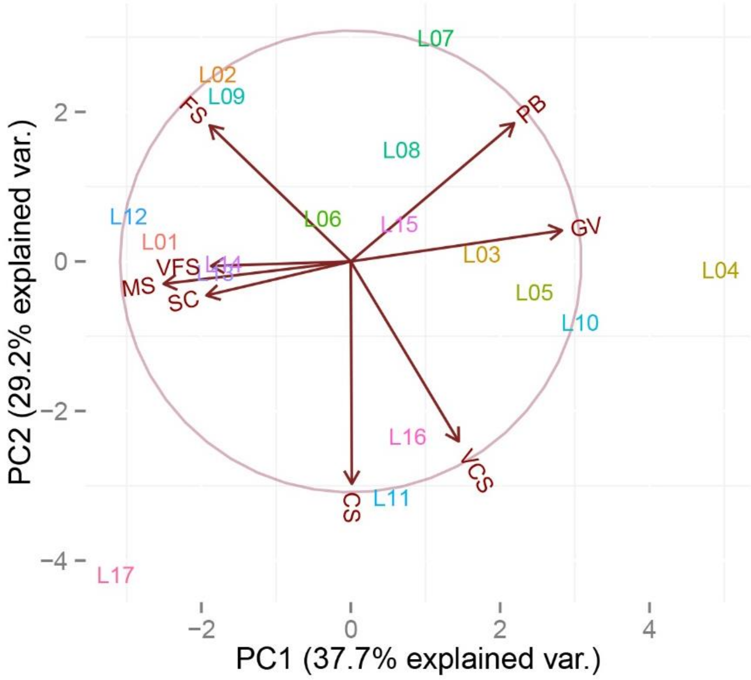

Figure 3. Principal Component Analysis of average sediment composition within each of 17 lanes. SC: Silt/Clay, VFS: Very Fine Sand, FS: Fine Sand, MS: Medium Sand, CS: Coarse Sand, GV: Gravel and PB: Pebbles.

3.3 Side-scan Sonar surveys

Marks left in the paths of individual dredges were visible on a range of sediments and up to a year after fishing. However, the visibility of the dredge scars varied from being very faint to quite prominent (Figure 4). In May 2014 dredge scars were visible in all fished lanes (Table 1). By September 2014 dredge scars were visible in all but the lane fished at the lowest intensity. In all cases the dredge scars were less prominent in September than May. By March 2015 scarring was visible only in lanes 3 and 16. The impact of fishing on habitats tends to increase with water depth and stability of the sediment (Jones 1992; Jennings and Kaiser 1998), with many communities being tolerant of some level of natural disturbance (Kaiser *et al.* 2001). However, trawl tracks may remain for five years in sandy mud (Jones 1992). Hamon grab samples revealed that Lane 3 comprised sandy gravel and gravelly sand. Some pebbles were also apparent in seabed images along with some areas with high densities of brittlestars, *Ophiothrix fragilis* (Figure 5). Lane 16 comprised gravelly sand, sandy gravel and slightly gravelly sand. From seabed images it was apparent that some areas of Lane 16 comprised only sand, while boulders were present in other areas of the lane (Figure 6).

While a single pass of scallop dredges had a physical impact on the seabed (Figure 7; Figure 12), in most cases the physical impact appeared to be less severe than in the lanes dredged multiple times (Figure 8; Figure 10). In some cases dredging appeared to have little impact on sandy, surface sediments but left tracks in underlying, coarser substrate (Figure 9).

At the highest fishing intensity dredge tracks were prominent in May (Figure 10) and still visible in September on some areas of seabed. However, Lane 16 appeared to have changed substantially between March and May, making it difficult to match seabed features. In other lanes there was very little obvious change, even over a whole year. In Lane 4, which was not fished, patches of coarser sediment and isolated rocks were apparent in March 2014 and March 2015 (Figure 11). Lane 8 (fished 0.51 times) appeared to be more dynamic, although there were still common features (Figure 12). Dredge marks in sandy sediment visible in September 2014 were no longer apparent in March 2015. This is due to the movement of surface sediments by tides and waves (Krost *et al.* 1990). Similarly, in Lane 12 (fished 2.29 times) faint dredge marks were visible in September 2014 but not March 2015 (Figure 13). In contrast, in Lane 3 (fished 3.82 times) dredge tracks were visible in March 2015, although only faintly (Figure 14). Dredge marks were apparent both on coarse and finer substrate, suggesting that this area was not subjected to a high level of natural disturbance over the study period. By comparison, dredge marks were apparent in Lane 16 predominantly in coarser sediment (Figure 15), indicating that this lane may have been subjected to higher levels of disturbance. This is emphasised by the fact that it was not possible to match features in records from September 2014 and March 2015.

Table 1 Side-scan sonar survey sites. Numbers indicate number of tows completed within each lane within each month. Shaded boxes indicate lanes in which dredge scars were visible.

		Date			
Lane	*Fishing intensity*	*Mar-14*	*May-14*	*Sep-14*	*Mar-15*
L04	0	3	3	3	2
L07	0	3	3	3	0
L09	0	3	3	3	0
L13	0	3	3	3	0
L10	0.23	2	2	3	0
L15	0.29	3	3	3	0
L08	0.51	3	3	3	2
L01	1.09	3	3	3	0
L06	1.24	3	3	3	2
L05	1.56	3	3	3	2
L17	1.87	3	3	3	2
L12	2.29	3	3	3	2
L02	3.05	3	3	3	1
L03	3.82	3	3	3	2
L14	3.87	3	3	3	2
L11	5.33	3	3	3	2
L16	6.07	3	3	3	3

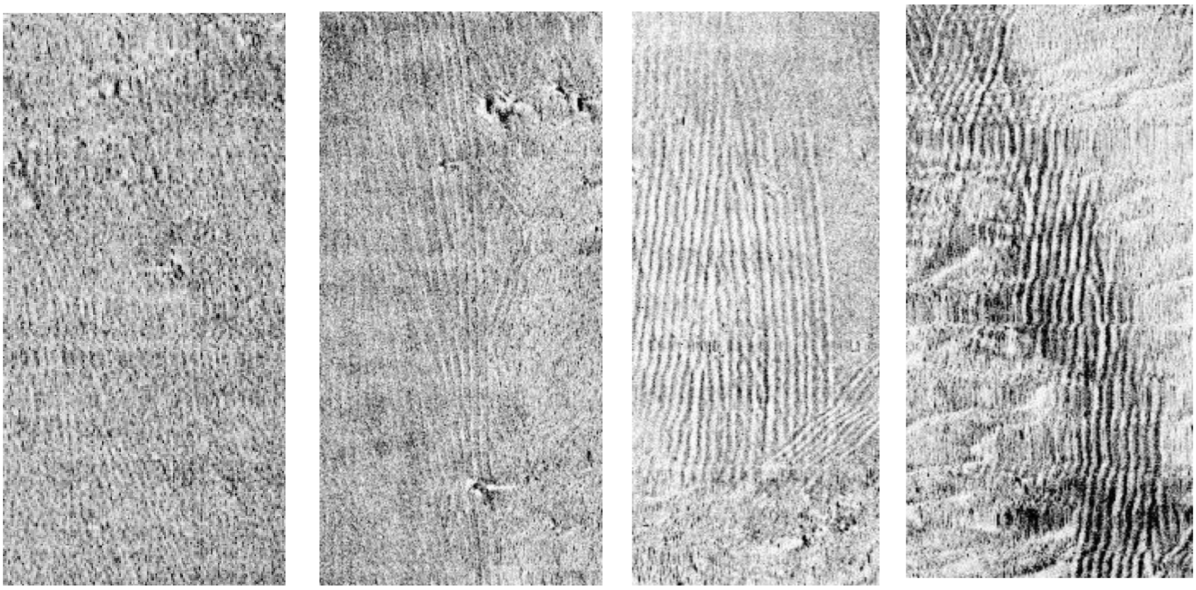

Figure 4. Examples of dredge scars on the seabed visible in side-scan sonar records.

Figure 5. Images selected from Lane 3 (May 2014 and September 2014) showing the range of substrates.

Figure 6. Images selected from Lane 16 (September 2014) showing the range of substrates.

Figure 7 Side-scan sonar records from a section of Lane 1 (Fishing intensity: 1.09 times swept) in March 2014 (top), May 2014 (middle) and September 2014 (bottom). Red lines highlight some common features. Yellow lines highlight areas in which dredge marks were visible in May.

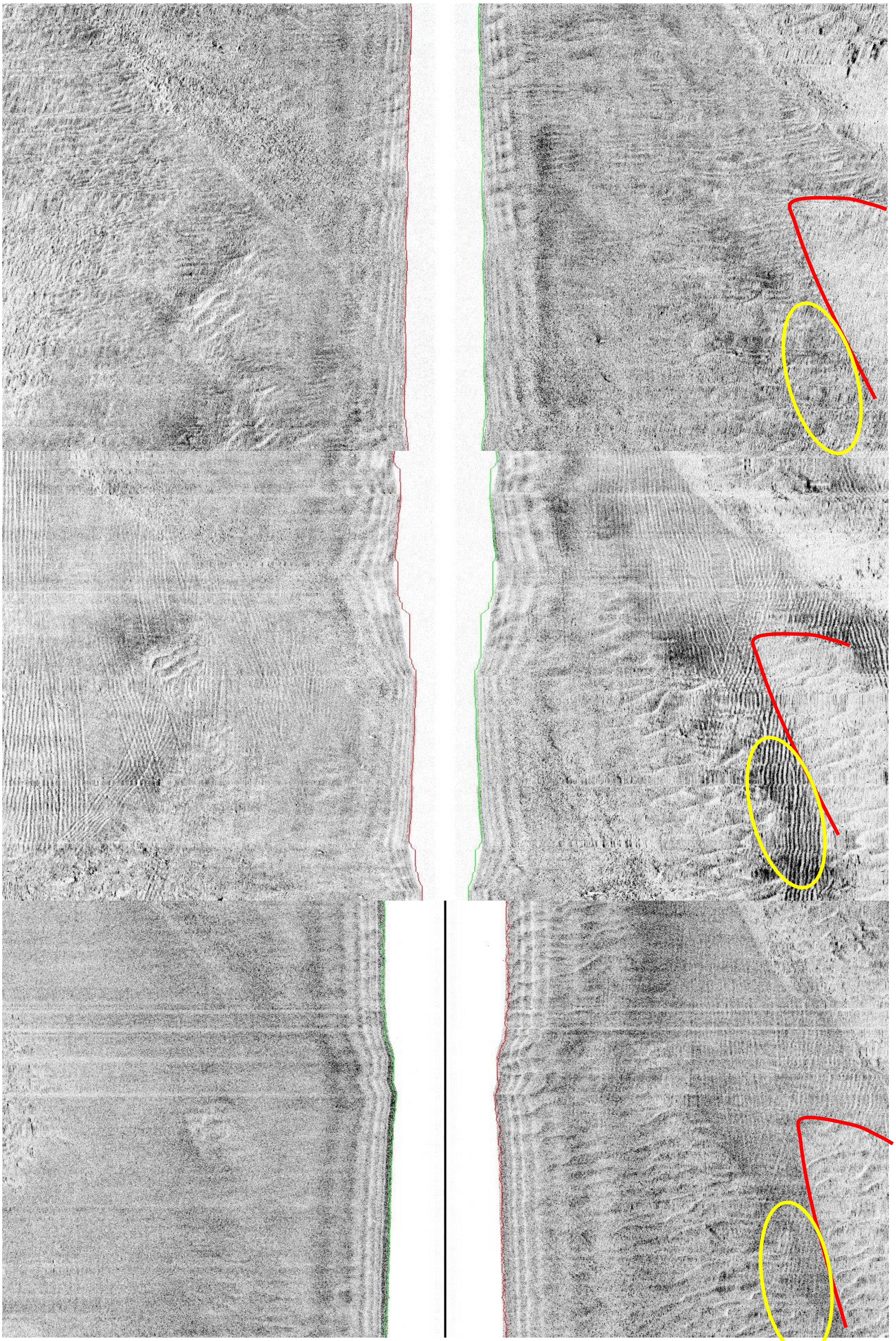

Figure 8 Side-scan sonar records from a section of Lane 12 (Fishing intensity: 2.29 times swept) in March 2014 (top), May 2014 (middle) and September 2014 (bottom). Red lines highlight some common features. Yellow lines highlight areas in which dredge marks were visible in May and September.

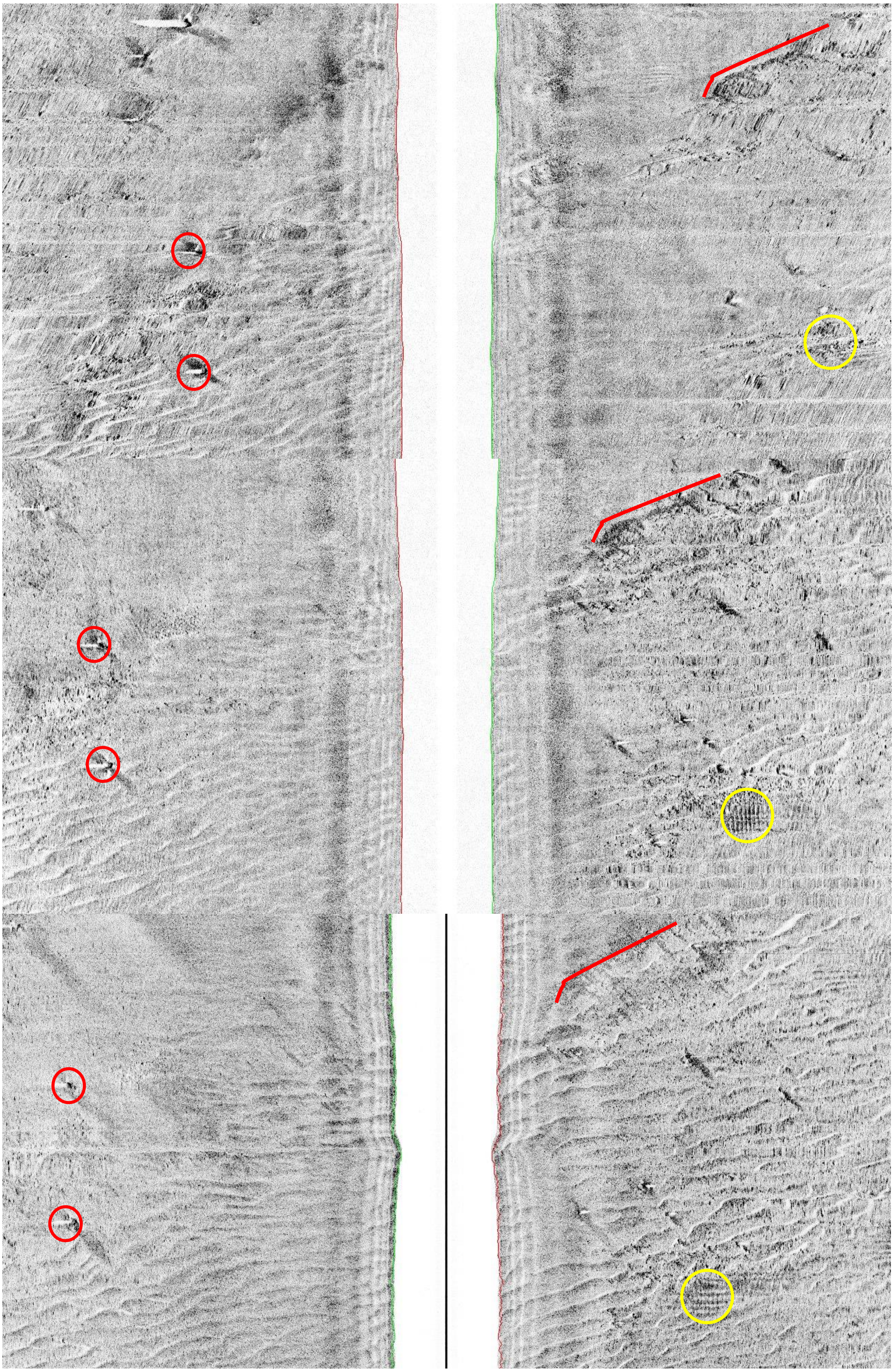

Figure 9. Side-scan sonar records from a section of Lane 14 (Fishing intensity: 3.87 times swept) in March 2014 (top), May 2014 (middle) and September 2014 (bottom). Red lines highlight some common features. Yellow lines highlight areas in which dredge marks were visible in May and

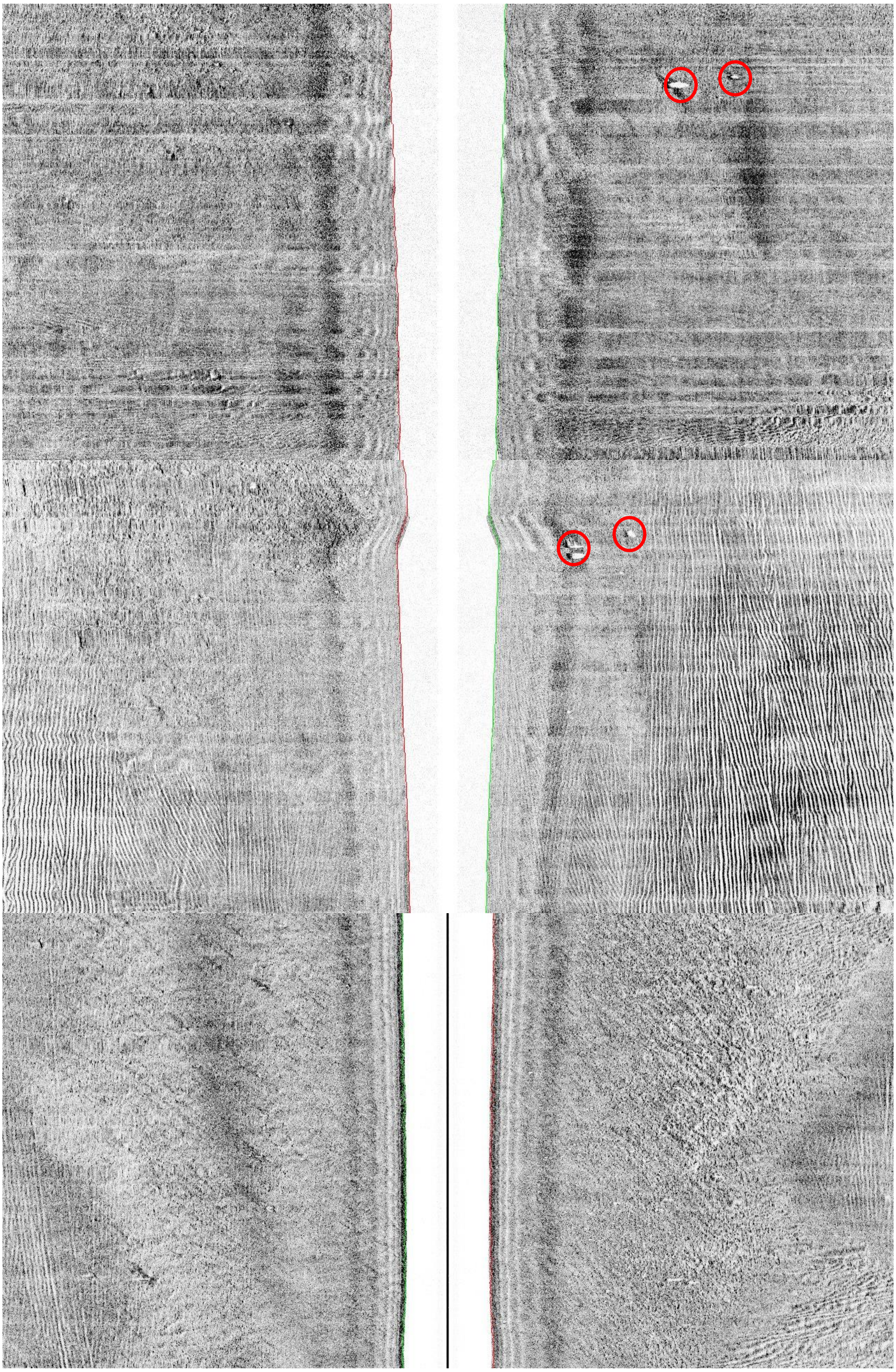

Figure 10. Side-scan sonar records from a section of Lane 16 (Fishing intensity: 6.07 times swept) in March 2014 (top), May 2014 (middle) and September 2014 (bottom). Red lines highlight common some features. NB. The image from September is from approximately the same area as the March and May images but it was not possible to match features. Dredge marks are visible in all images.

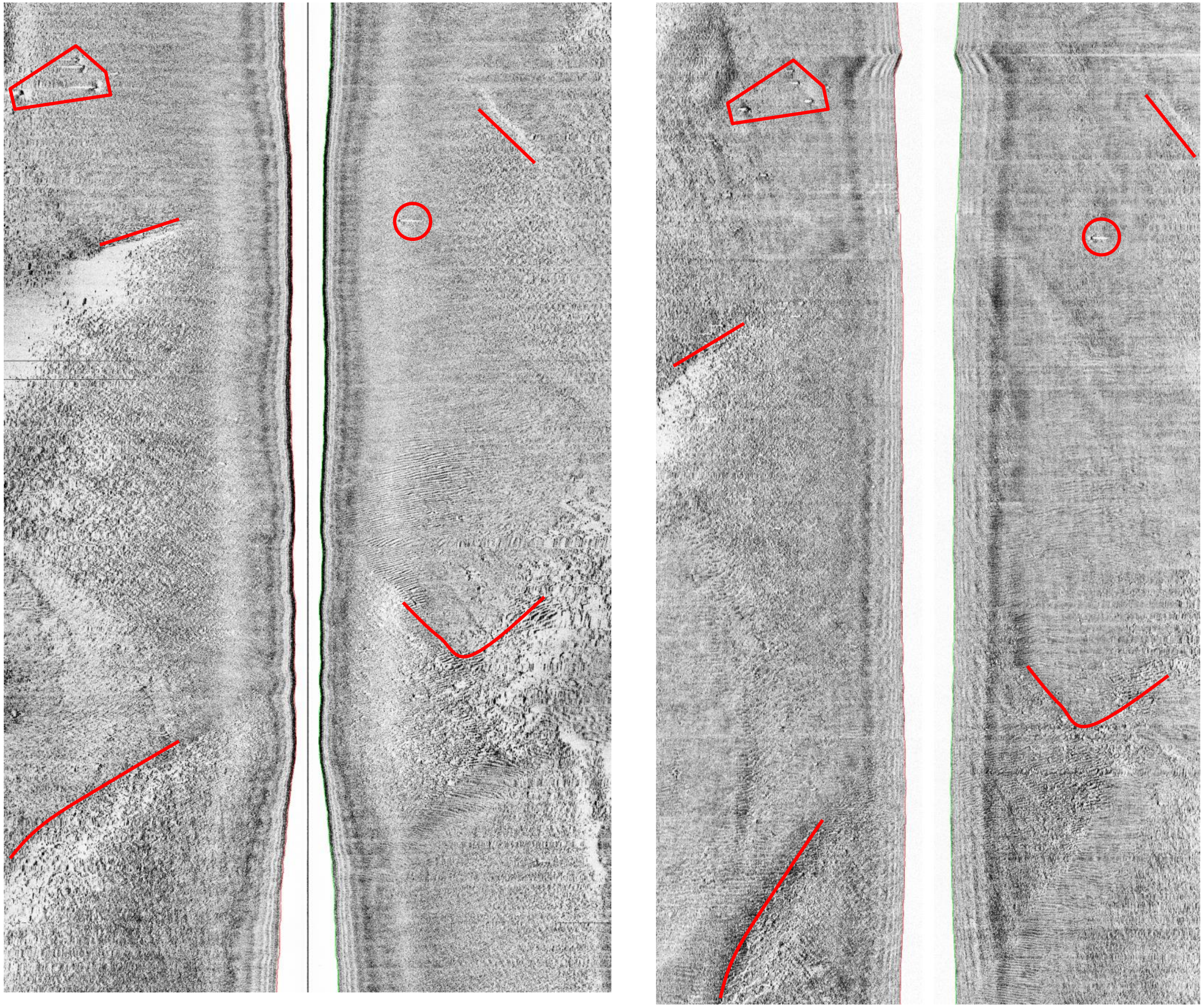

Figure 11. Section of side-scan sonar record from of Lane 4 (0 times swept) in March 2014 (left) and March 2015 (right). Red highlights indicate some common features in each image. Note the difference in geometry between images.

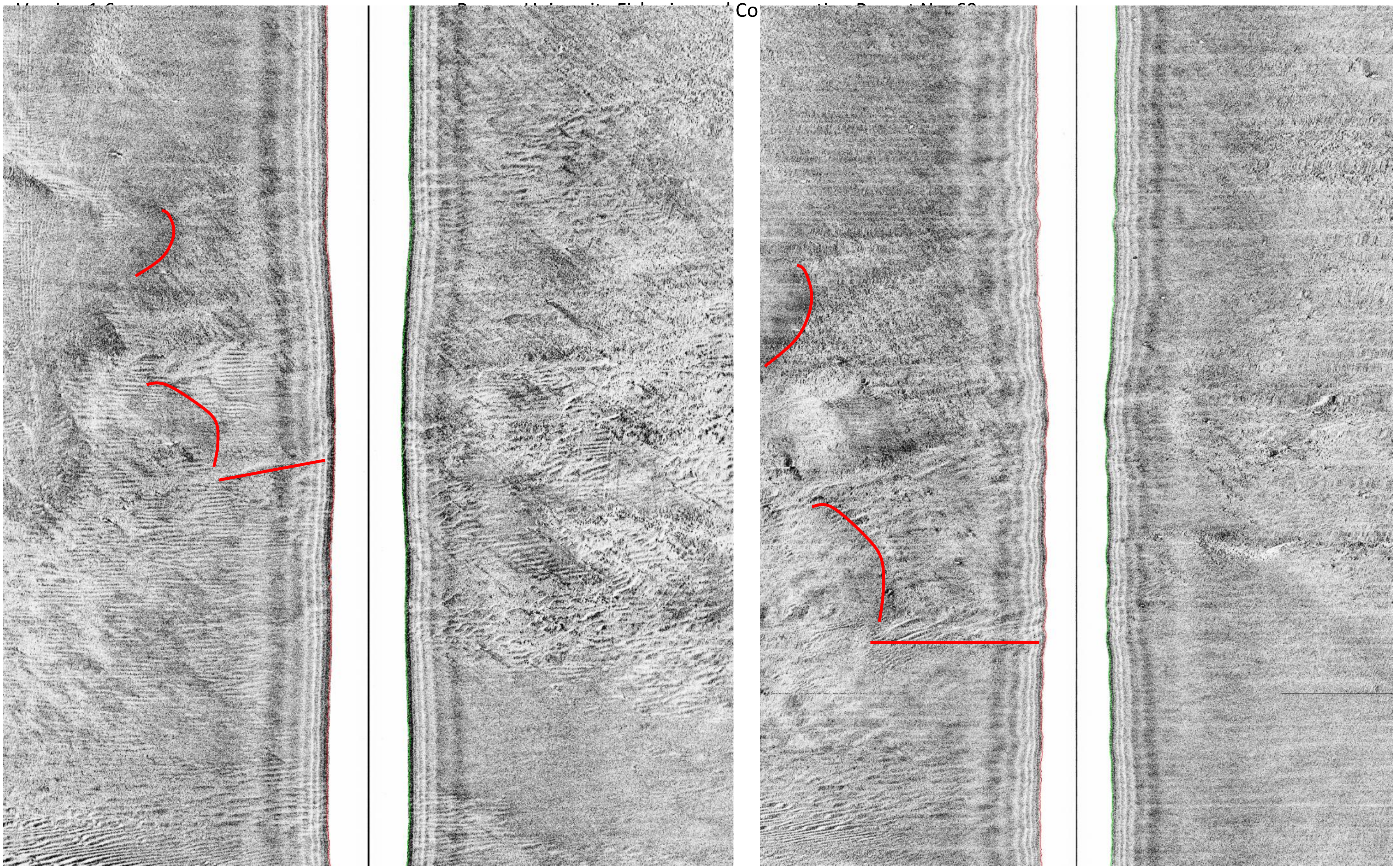

Figure 12. Section of side-scan sonar record from of Lane 8 (0.51 times swept) in September 2014 (left) and March 2015 (right). Red highlights indicate some common features in each image. Note the difference in geometry between images.

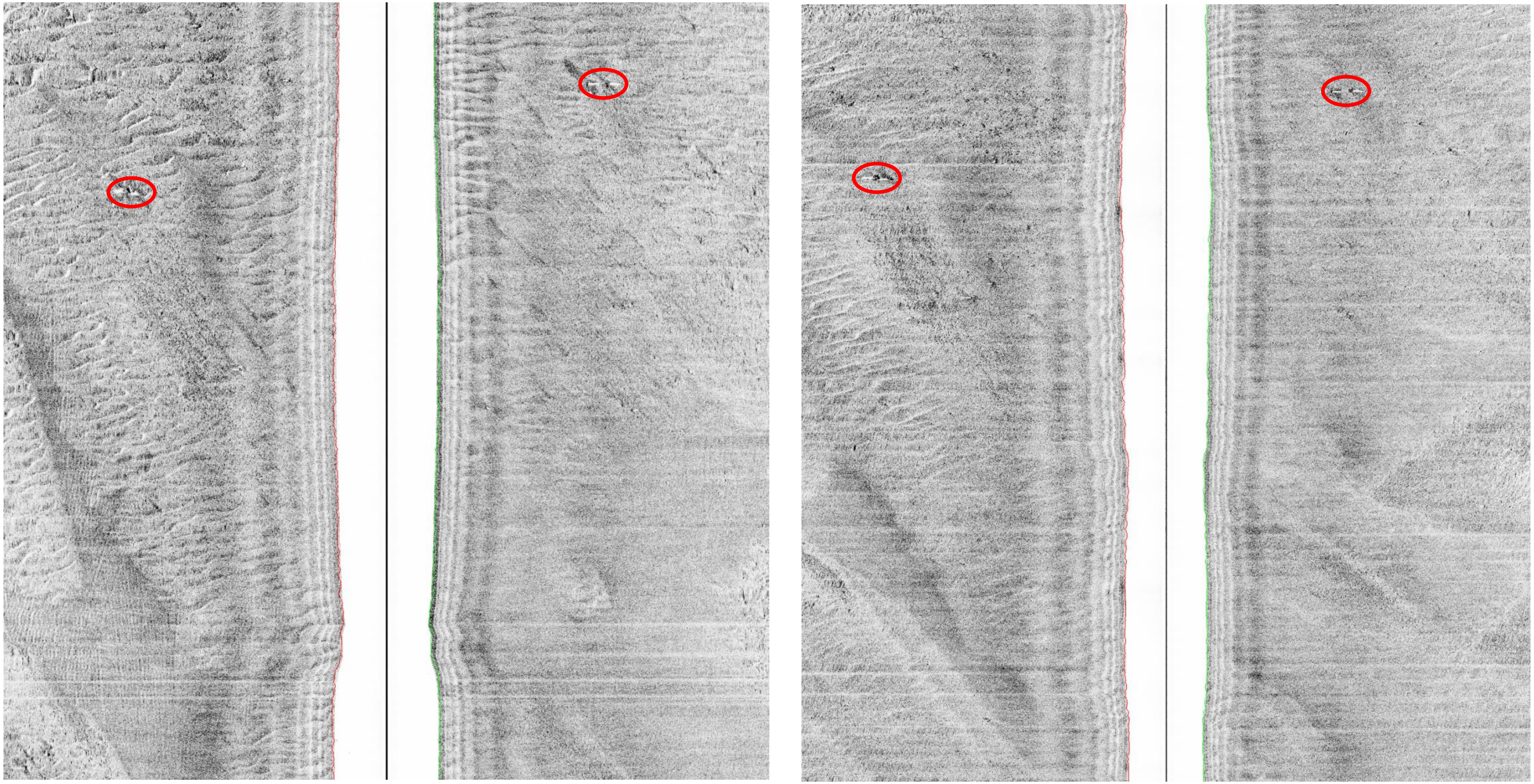

Figure 13. Section of side-scan sonar record from of Lane 12 (2.29 times swept) in September 2014 (left) and March 2015 (right). Red highlights indicate some common features in each image. Note the difference in geometry between images. Dredge marks are visible in September but not March.

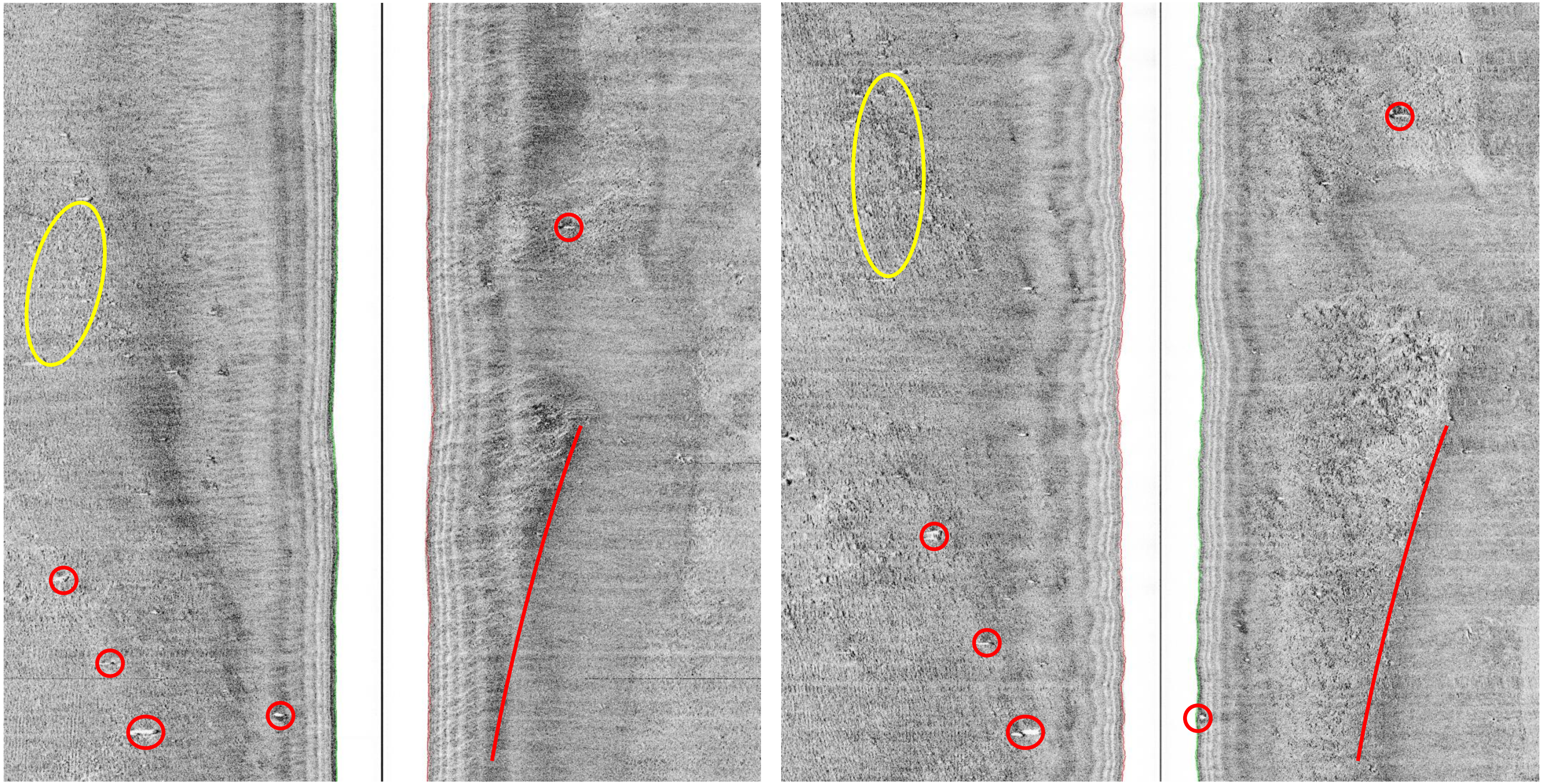

Figure 14. Section of side-scan sonar record from of Lane 3 (3.82 times swept) in September 2014 (left) and March 2015 (right). Red highlights indicate some common features in each image. Note the difference in geometry between images. Dredge scars are visible on the left side of both images. Yellow lines highlight some dredge marks.

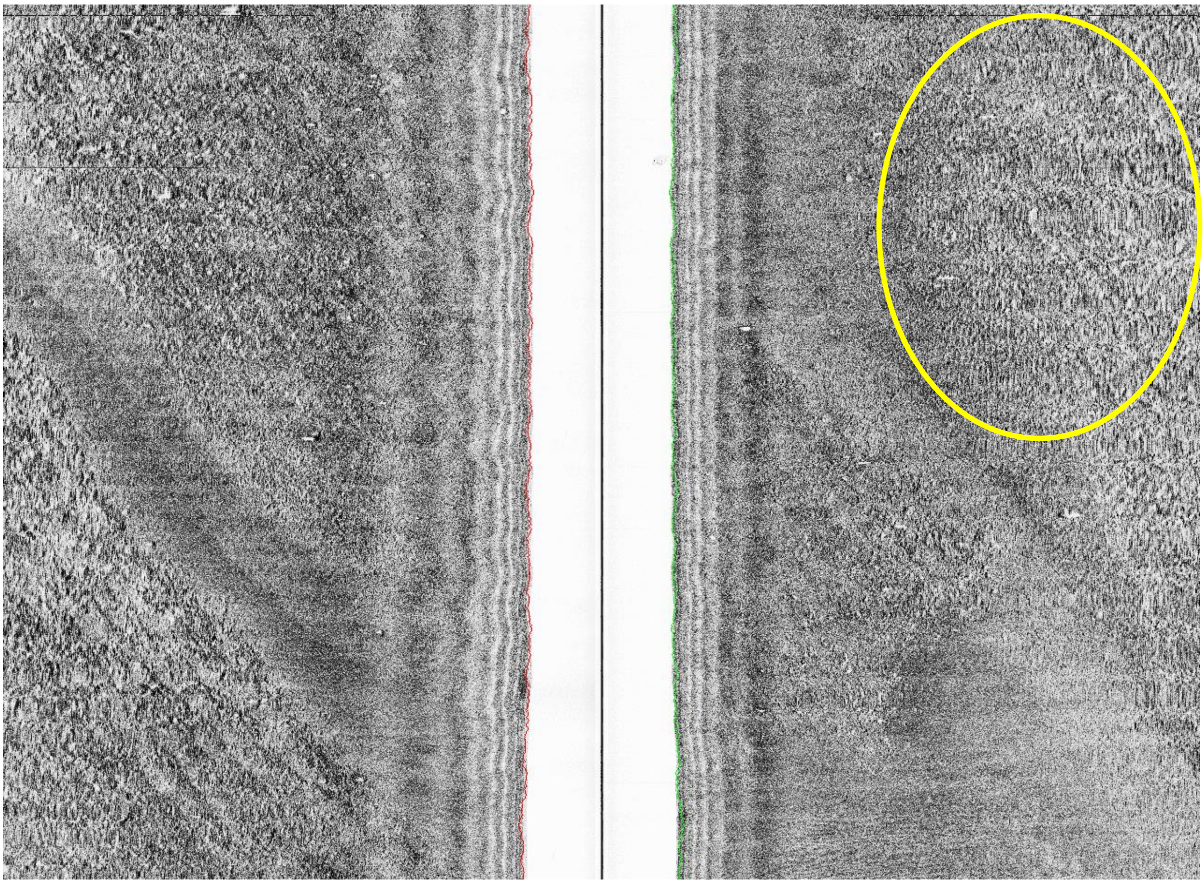

Figure 15. Section of side-scan sonar record from of Lane 16 (6.05 times swept) in March 2015. Yellow line highlights some dredge marks on coarser sediment.

4. Conclusions

The substrate in the experimental area of Cardigan Bay SAC was highly variable and patchy. Most lanes contained a mixture of fine and coarse sediment. Despite some loss of fine sediments, overall there was no significant change in sediment composition due to fishing, although scallop dredging was found to leave troughs in most areas where it occurred, on a range of sediments from sand through to gravel and cobble. In most cases these marks remained four months after fishing. However, in all but two cases the fishing marks were no longer visible 10 months after fishing. The physical impact of fishing were not consistent across substrate types. Dredge tracks tended not to be visible where sand waves were prominent. The sand waves, which were usually perpendicular to the direction of fishing, are indicative of mobile sand, which is probably less susceptible to the effects of dredging. In areas of smoother substrate (perhaps compacted sand) or coarser sediment, dredge marks were more prominent and remained for longer.

To allow the effects of most dredging to dissipate following the open fishing season it will be necessary to allow more than four months without fishing. If fished at higher intensities (>3.8 times swept) then more than 10 months may be required to allow recovery of the physical environment. Nevertheless, it is important to note that these physical changes do not necessarily impact the fauna inhabiting an area. The impact on infauna was detectable at fishing intensities of >2 times fished, but infauna had mostly recovered after four months, particularly where fished <4 times (Lambert *et al.* 2015b). Negative effects on epifauna were apparent in areas fished over two times for some species including stalked species, suspension feeders and species living attached to the substratum. Suspension feeder biomass and cushion-shaped species biomass decreased in response to fishing in gravel habitats (Lambert *et al.* 2015a). This corresponds with dredge scars being more persistent on coarser sediments, as observed in sidescan sonar records.

Therefore, in this area, restricting the number of times the seabed is impacted and ensuring an adequate recovery period should minimise the negative impacts of scallop dredging while allowing scallops to be harvested.

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