Lugworm Surveys – July 2022

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Summary

The impacts of bait digging on lugworm populations in the NIFCA district are not well known, and need to be better understood to complete assessments of marine protected areas. This study used methodology from PhD which collected baseline data in 2014 at Boulmer and Newton, adding another location with high levels of collection, Berwick. Lugworm casts were counted in randomly placed quadrats on the lower shore where bait digging occurs, using faecal casts as a proxy for the number of lugworms. Cast diameter was also measured to compare average lugworm sizes. Finally, an Unmanned Aerial Vehicle (UAV) was also used to assess its accuracy compared to ground-based surveys, to determine whether this could be useful in future surveys.

The study found:

- Boulmer had the highest lugworm density at 38 per m^2, compared to Berwick (6.5m^{-2}) and Newton (10.9m^{-2}).
- Average faecal diameter size showed the opposite trend, with the largest size at Berwick and smallest at Boulmer.
- Compared to the 2014, lugworm density increased significantly at Boulmer and decreased significantly at Newton. The reasons for this are unknown but surveys were conducted at different times of year (March 2014 and July 2022) therefore are not directly comparable due to possible annual changes in lugworm populations. Lugworm densities should also therefore be measured in March of next year for a better comparison.
- Images taken from a height of greater than 5m were not suitable to detect lugworm casts, and even at 5m only detected 85% of the casts identified by eye in the field. This factor could be applied to future estimates, however the ease of counting by eye and the ability to measure faecal string diameter mean we recommend continuing ground-based surveys.

Introduction

The long-term impacts of bait digging on lugworm populations are not known in the NIFCA district, including in the Berwickshire and North Northumberland Coast SAC and Coquet to St Mary's MCZ. The impacts of bait digging on the protected features (intertidal mud, and intertidal sand and muddy sand) is being assessed, which includes impacts on invertebrate communities.

A PhD (Tinlin-Mackenzie, 2018) conducted a comparative study and baseline surveys of lugworm densities at Boulmer, Newton and Fenham Flats at Holy Island (high, medium and low collection intensity respectively) in 2014, finding lugworm densities and species richness were not related to collection pressure. However, Boulmer had less than half the average infaunal abundance of the other sites despite it being muddier and expected to have higher abundance. Their experimental

study found a reduction in lugworm abundance in dug plots compared to controls, with incomplete recovery in the more intensely dug plots. Moreover, there was no baseline data to compare with, so they recommended continued monitoring of the lugworm densities over time.

This study used methods in Tinlin-Mackenzie (2018) to measure lugworm densities at Boulmer, Newton and an additional site, Berwick, which has similarly high levels of collection to Boulmer and has been highlighted as a potential area of concern in protected area assessments. NIFCA patrols record intertidal activities along the coast, and recorded an average of 2.65 bait diggers per patrol at Berwick, 1.95 at Boulmer and 0.21 at Newton. Fenham Flats was not included due to it being an uncollected site and not in need of assessment.

The study also used an Unmanned Aerial Vehicle (UAV/'drone') to compare accuracy with counts of lugworm casts by eye (as in original methods) and from ground-based photos, to assess the possibility of surveying larger areas or increasing efficiency in the future.

Methods

Three sites were selected (Boulmer, Berwick and Newton) within the NIFCA district to survey lugworm population densities. Surveys were conducted in July 2022 using both ground-based, and UAV based monitoring. The ground-based surveys used ten 1x1m quadrats randomly placed on the lower shore from which four photos were taken at each quarter and GPS waypoint marked at each location. In each quadrat, five casts were randomly selected, and individual diameter measured to the closest mm using a ruler. Counts of lugworm casts were taken by eye in each quadrat quarter and later compared to counts taken by photos to compare accuracy. The aerial UAV survey was conducted at the same time as the ground surveys at Boulmer. Photos by the UAV were taken at different heights: 5, 10, 15 and 20m, to count lugworms in each quadrat. Counts of the lugworms were conducted using a computer programme 'DotDotGoose' (American Museum of Natural History) and compared between these survey techniques to find the most accurate method for future surveys.

Results

Comparison between sites

There was a statistically significant difference in the mean number of lugworms per quadrat (m^2) between the three sites (Figure 1; ANOVA, F=98.53, df=2, p<0.0001). Boulmer had significantly higher lugworm numbers (mean of 38.3m^{-2}) than Berwick and Newton, and though there were slightly higher numbers at Newton than Berwick this was not significant.

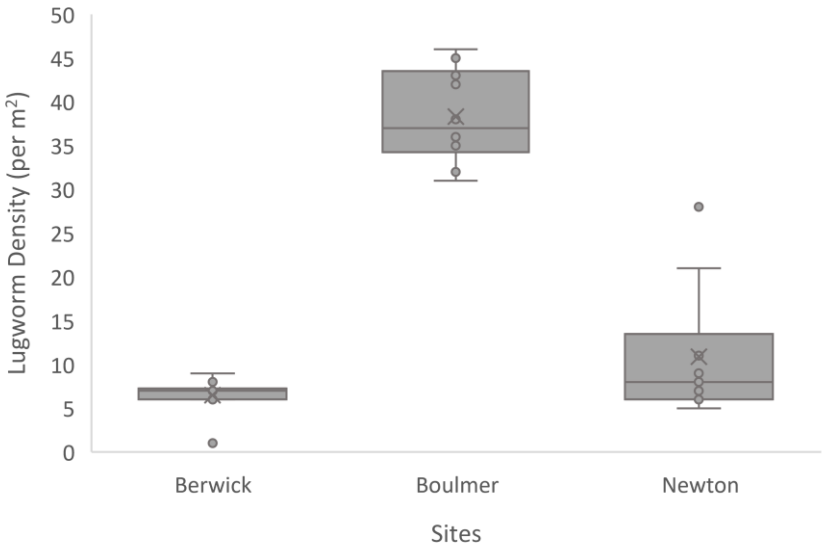

Figure 1. Lugworm density (per m^2) from three sites of varying collection pressure, sampled in July 2022; n=10 for all sites.

There was a significant difference between the median cast sizes in different locations (Figure 2; ANOVA, F= 17.76, df=2, p<0.0001). The largest was at Berwick (4.70mm mean size) and the smallest at Boulmer (3.52mm). The proportion of juvenile casts (2mm and under) was highest at Boulmer (14%) compared to Berwick (2%) and Newton (6%) which explains the smaller average cast size at Boulmer.

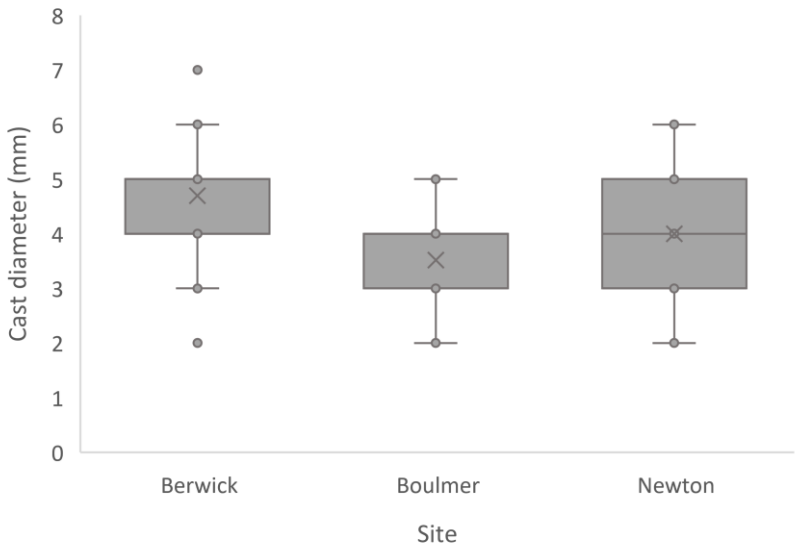

Figure 2. Lugworm cast diameter (mm) from three sites of varying collection pressure, sampled in July 2022 with a maximum of 5 casts per m^2 quadrat; n=50 at Boulmer and Newton, n=46 at Berwick.

Comparison over time

There were significant differences in the mean lugworm densities (m^{-2}) over time at Boulmer and Newton, from a study in March 2014 (Tinlin-Mackenzie, 2018) to July 2022 (Figure 3). Boulmer and Newton had opposite trends. There was a statistically significant difference in the mean lugworm population density in Boulmer, with a mean increase from 21.7m^{-2} in 2014 to 38.3m^{-2} in 2022 (t-test, t= -4.91, df=18, p<0.001). There was a significant decrease in mean lugworm density from 28.4-10.9m^{-2} at Newton over the same time period (t-test, t=4.46, df=18, p<0.0015).

In terms of cast size, there was no significant difference in the mean sizes over time at Boulmer (t-test, t=-0.86, df=94, p>0.05) however mean cast size increased at Newton from 3.4 – 4mm (t-test, t=-2.93, df=95, p<0.01) (Figure 4).

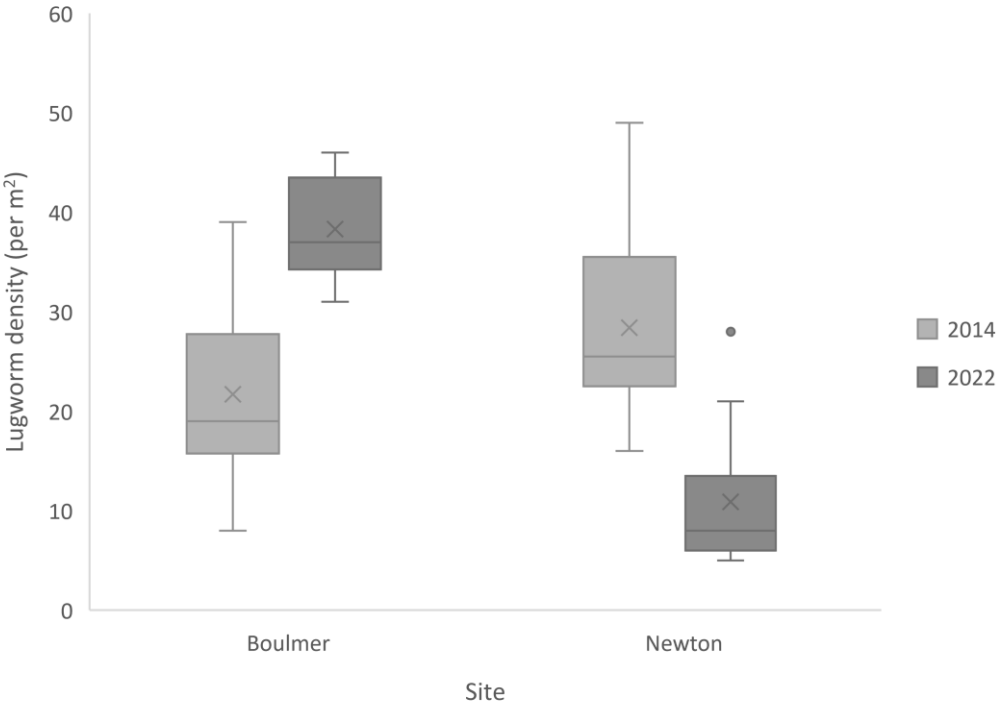

Figure 3. Lugworm density per m^2 over time at Boulmer and Newton, sampled in March,2014 and July,2022 using quadrats ($1m^2$); n=10 for all sites.

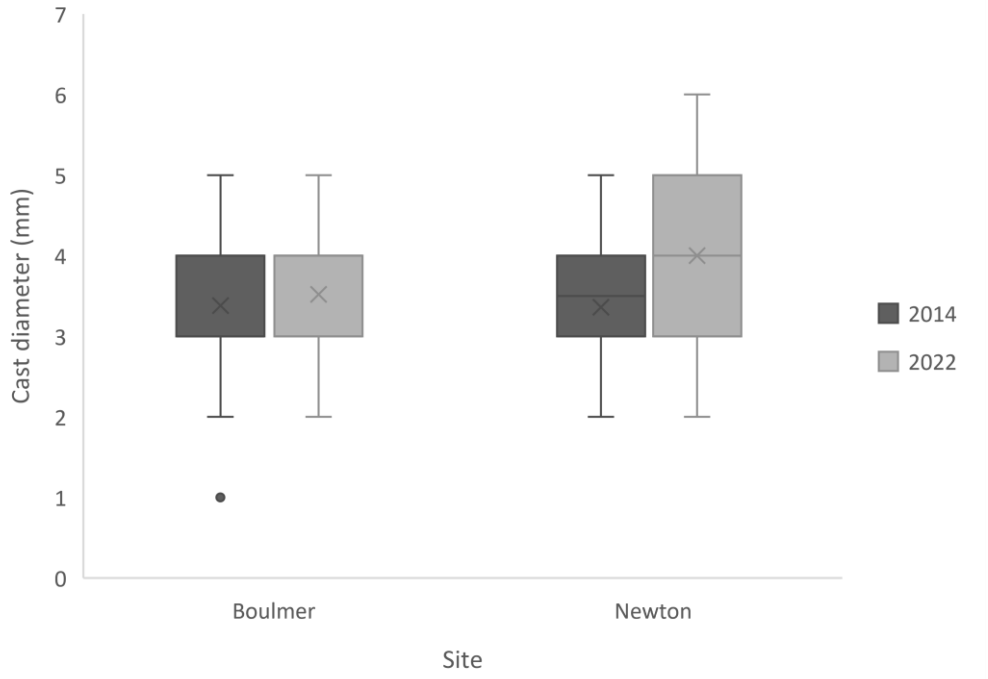

Figure 4. Cast diameter (mm) of lugworms at Boulmer and Newton, from March 2014 to July 2022; n=10 for all sites.

Survey methods

Different survey methods (counting lugworm casts by eye, counts from photos at ground level and counts from the UAV at different heights) were compared at Boulmer. Overall, compared to counting by eye, photos taken at ground level counted 94% of lugworm casts, UAV 5m counts 85% and at 10m only 54%, with accuracy decreasing with lower photo resolutions (Figure 5).

There was a statistically significant difference between the survey methods (ANOVA, $F=3.01$, $df=3$, $p<0.0001$). Post-hoc tests found no statistically significant differences between either counts by eye and from photos ($t= 0.98$, $p=0.35$), or between photo counts and UAV images taken at 5m ($t=1.31$, $p=0.22$) However, the t-test between counts by eye and counts from UAV photos at 5m showed a statistically significant difference ($t=2.07$, $df=11$, $p<0.05$) and the difference between counts by eye and by the UAV at 10m was highly significant ($t=4.32$, $p<0.01$).

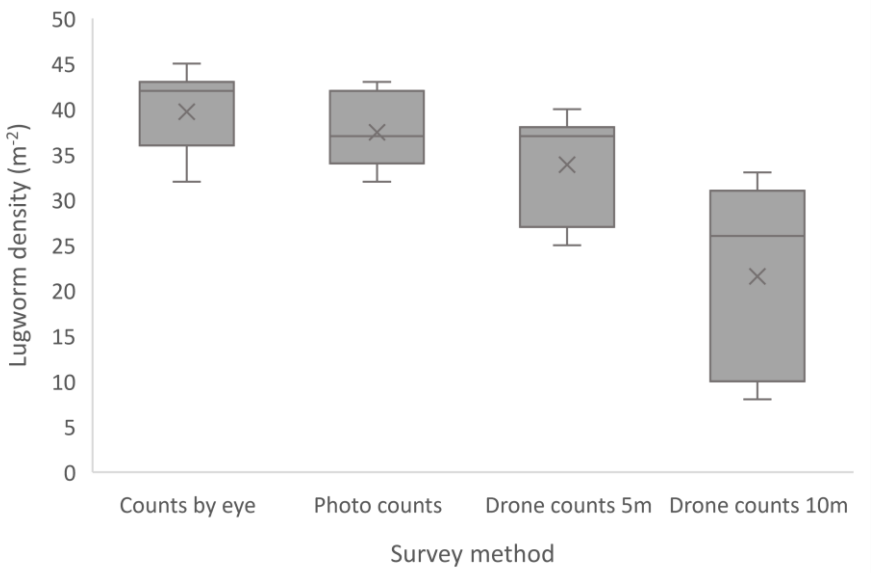

Figure 5. A comparison of the average counts of lugworms surveyed in Boulmer, counting by eye and from photos at ground level as well as at heights of 5m and 10m taken using a UAV.

A comparison of the percentage differences between drone and photo survey methods in relation to counts by eye for every quadrat are recorded in Figure 6. Counts from photos show less variability than counts from UAV images, ranging from 88-106% of those counted by eye, per quadrat. Counts from the UAV were more variable ranging from 64-118% difference.

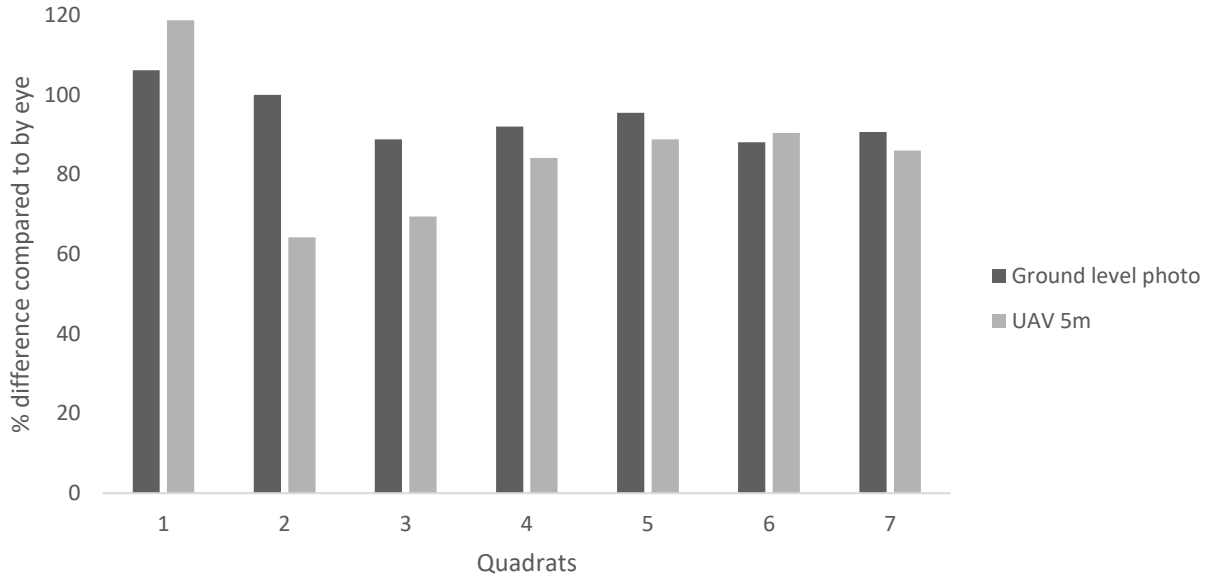

Figure 6. A comparison of the % difference between counts from drone and photo taken in relation to the counts by eye taken in Boulmer, in each surveyed quadrat.

Discussion

Comparison between sites

Lugworm density at Boulmer is significantly higher than at Berwick or Newton. Though both Berwick and Boulmer are targeted by collectors they have very different densities, while Newton has lower collection pressure but has similar lugworm density to Berwick. There is therefore no relationship overall between lugworm densities and collection pressure at these sites, which supports the findings of Tinlin-Mackenzie (2018). Boulmer has maintained the high abundance and large average size of lugworm despite continued collection.

The lowest density at Berwick could indicate an overcollected population, although it had the highest cast diameters indicating larger sizes of lugworm, which may mean it is still a valuable location to dig for bait compared to other locations, as larger lugworms are favoured by collectors. Larger worms also have a greater reproductive output per individual (Watson et al. 1998), so although Berwick has fewer lugworms recoverability through recruitment may be higher than at the other sites.

The discrepancy between Boulmer and Berwick, despite similar collection pressures, could be due to Berwick having slightly higher collection pressure in addition to it being over a smaller area compared to Boulmer where the bay is much larger and lugworm populations perhaps less likely to decline. The larger area at Boulmer means collection is more spread out and that there is a larger population to recolonise from which could increase recovery rates.

Newton could either have lower densities because of being overcollected in the past – although this seems unlikely as the other locations have higher collection pressure – or there being a naturally lower abundance of lugworms which leads to less targeting by collectors. It is likely that the different conditions at each of these sites is influencing the densities of lugworms over and above and collection pressure impacts. In general, densities observed in lugworm populations are determined by food availability (e.g. organic matter content) and environmental factors such as sediment characteristics (Longbottom, 1970) more than collection pressure.

Comparison of lugworm densities over time

There is no baseline information on lugworm densities at Berwick, though both Boulmer and Newton were surveyed in 2014 by Tinlin-Mackenzie (2018) therefore results can be compared, to see if there were any changes in lugworm population sizes and cast sizes between 2014 and 2022. While there were no changes (Boulmer), or small changes (Newton), to lugworm cast sizes over time, there were significant changes to lugworms densities at both sites. While Boulmer observed an increase in the lugworm population density, Newton saw a considerable decrease from 2014 to 2022.

Shore observations by Tinlin-Mackenzie (2018) in 2014 recorded an average of 2.38 collectors per observation at Boulmer, similar to the average number of 1.95 collectors per NIFCA patrol. At Newton there were 0.94 collectors per observation, higher than the 0.21 per NIFCA patrol. Tinlin-Mackenzie also carried out observations at night-time recording activity at Newton which NIFCA patrols would not include, therefore there has probably not been a significant change in collection activity from 2014-2022, though possibly a decrease at Newton or a slight increase at Boulmer. Therefore, changes in lugworm densities cannot be easily attributed to changing collection pressure.

Locations may differ in their resilience to activities such as bait digging, and lugworms are able to rapidly increase population numbers from migration and recruitment despite bait digging and collection pressures (Blake, 1979; Rees and Eleftheriou, 1989). Boulmer is a site with higher organic content compared to Newton which could explain the high population density (Tinlin-Mackenzie, 2018) although this does not explain the change in density at Newton over time. Newton could be a less resilient site to bait digging pressures than Boulmer. Lugworms also have a subtidal population which remains uncovered at low tide and therefore protected from collection pressure. Subtidal populations can recolonise collected intertidal areas. Tinlin-Mackenzie (2018) modelled the sensitivity of the sites to collection, based on characteristics such as sediment type, lugworm abundance and size, and importance to birds, finding low-moderate sensitivity at

Boulmer, Berwick and Newton which does not explain the differences seen over time at Boulmer and Newton.

One consideration/explanation is that the survey areas were not well-defined in the original study, therefore quadrats may have been placed in slightly different locations in 2022 compared to 2014, offering a different snapshot of the lugworm population. At Newton surveyors noticed that the majority of lugworm casts on the beach were higher up the shore than the survey area, which could explain the reduced lugworm densities if the previous survey was higher up the shore. The purpose of the original study however was to survey the 'lower shore where bait digging primarily occurs' which is what we aimed to do. The tides may have been slightly different enabling us to survey lower down the shore than Tinlin-Mackenzie (2018).

A final consideration is that the 2014 and 2022 surveys were not carried out at the same time of year, with original surveys carried out in March and 2022 surveys carried out in July. There are changes in lugworm breeding or migratory behaviour in response to seasonal changes, with the number of lugworm casts changing throughout the year (M. Southerton, pers. comms) which might explain the differences in lugworm densities compared to the previous survey. This however does not explain the different trends in the two locations. To enable a better comparison over time, surveys will be carried out in March 2023. Additionally, further survey work will continue in 2022 every four months to assess annual changes in lugworm populations.

Comparison among survey methods

Quadrats at Boulmer were experimentally surveyed by a drone at varying heights to ascertain its accuracy when compared to counting by eye or taking ground-based photos. If sufficiently accurate it could be used to efficiently survey large areas in shorter periods of time. However, we found the accuracy of the species count was reduced. This survey method was tested at varying heights, 5 and 10m respectively, and revealed that with higher altitude, the more inaccurate the species count in each quadrat. Surveys using drones could be used if it's maintained at a lower altitude such as 5m and an accuracy difference in the species count be factored in when conducting data analysis. As seen in Figure 7, there is no significant difference in the count data between counts from photos and from drone at an altitude of 5m. However, there was a difference between counts by eye which is the most accurate method. Ground-based surveys also enable measuring of faecal cast diameter which is not possible using the UAV. Furthermore, surveying larger areas by drone would still require identification of lugworm casts in the images by eye as there is not an automatic way of doing this, which would be very time consuming and the survey area would have to be subdivided anyway. The UAV could possibly be used to identify and monitor the extent of the lugworm bed, or to conduct a transect from low to high water to see how

lugworm size and density changed over this area. However, for the current purposes of monitoring low-water lugworm populations impacted by bait digging, and comparing data to previous surveys, we recommend ground-based methods which are quick and easy, and counting lugworms by eye in the field.

Conclusions

Lugworm densities varied between sites. Boulmer, a highly collected site, had much greater lugworm density than Newton or Berwick, another highly collected site although from a much smaller area. It is possible these variations are natural, defined by environment and food availability; further studies over time are required to determine whether bait digging levels at Berwick are sustainable as there is no baseline information. Compared to March 2014, lugworm density increased at Boulmer and decreased at Newton, the causes of which are unknown. Since lugworm populations may vary throughout the year and surveys were conducted at different times of year, future surveys will be conducted in March next year for a better comparison. While different survey methods were trialled, neither ground-based photos nor using a UAV were as accurate or quick as counting lugworms by eye in the field, therefore this method is recommended for future surveys.

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