LUNDY FIELD SOCIETY

Journal of the Lundy Field Society

Volume 8, 2023

ISSN 1758-3276

Journal of the Lundy Field Society

Volume 8

2023

Editor: Keith Hiscock

Journal of the Lundy Field Society

Volume 8, 2023

First published 2023

www.lundy.org.uk

Printed by Hobbs the Printers Ltd

ISSN 1758-3276

Cover: Flowers and young fruits of the Lundy cabbage, *Coincya wrightii*, above Miller's Cake. 28th May 2012. Image: R.S. Key.

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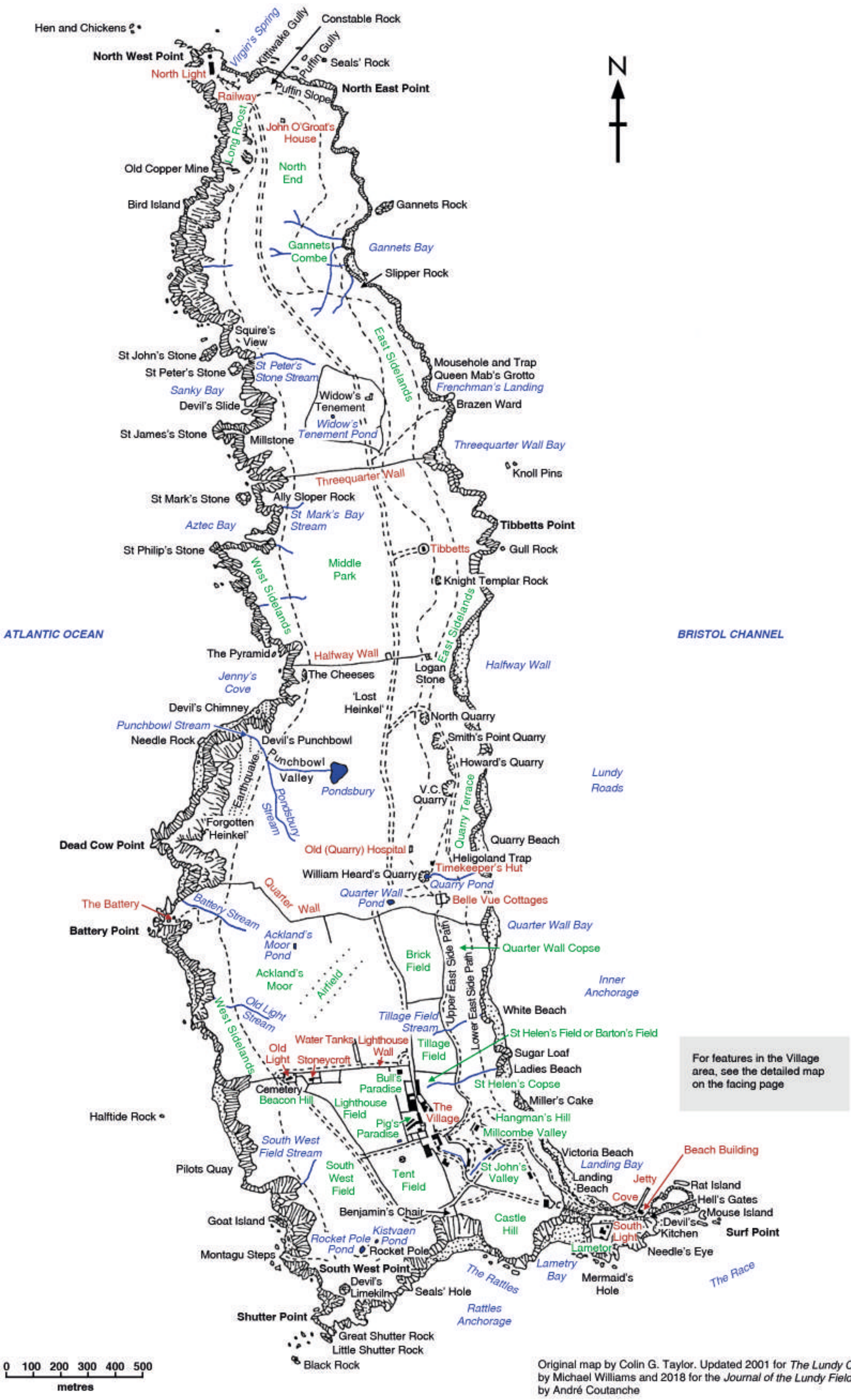
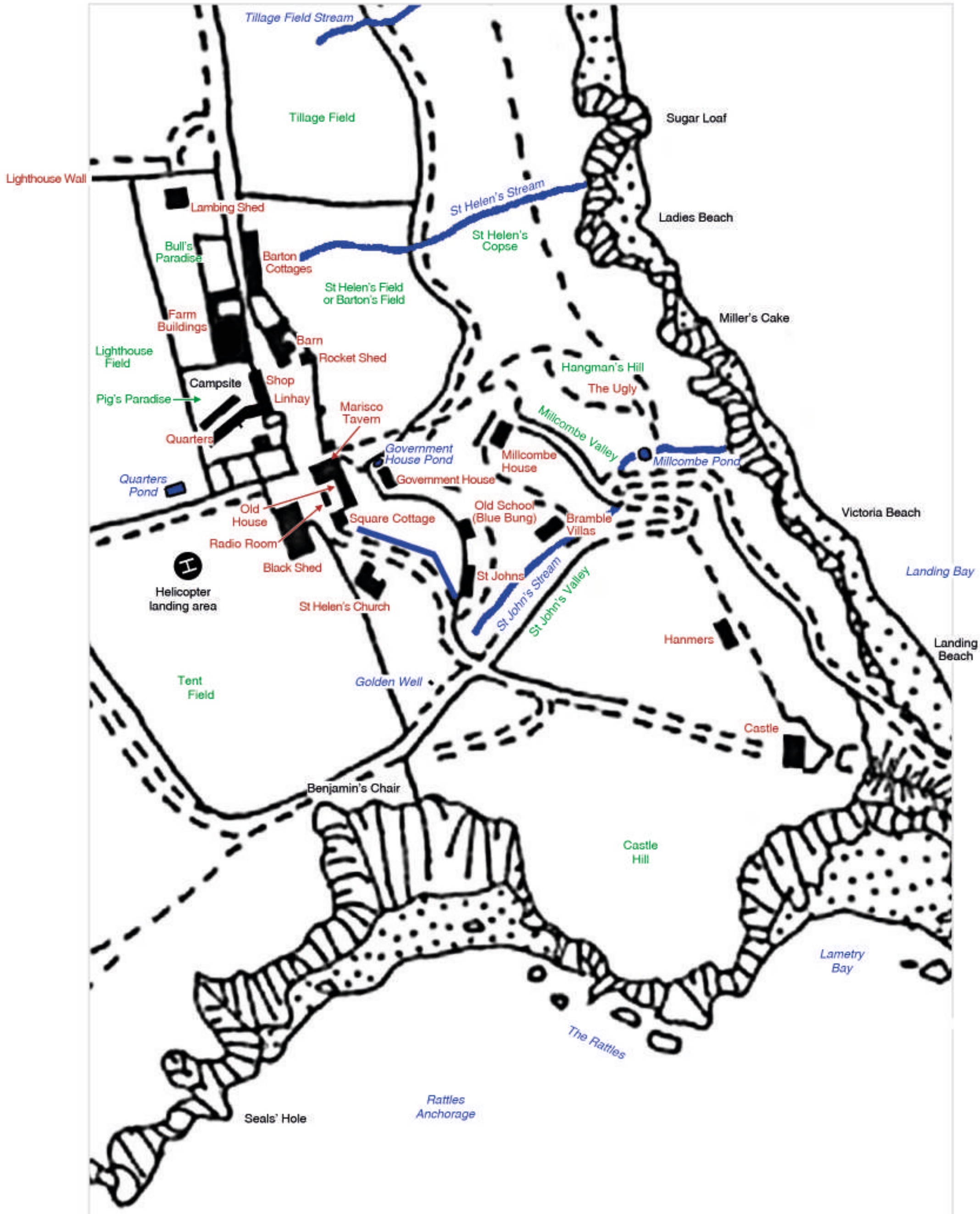
MAP OF THE ISLAND OF LUNDY



Original map by Colin G. Taylor. Updated 2001 for *The Lundy Companion* by Michael Williams and 2018 for the *Journal of the Lundy Field Society* by André Coutanche

MAP OF THE LUNDY VILLAGE AREA



Colour key:
Brown: built features
Green: named areas of land
Blue: water features
Black: everything else

EDITORIAL

Lundy attracts a wide range of studies generating information that visitors and academics find fascinating. This Journal provides a 'platform' for those academic studies whilst the Annual Report gives an account of observations and activities for a particular year and the Bulletin ('Discovering Lundy') a more informal account of what staff and visitors 'do' on Lundy. All of these publications and the activities that the LFS organise and run contribute to *the study and conservation of a unique island*.

I took on the role of Editor of this issue of the Journal from Jenny George who had edited the publication since its first volume in 2008. Jenny, working with André Coutanche, provided a very professional and systematic approach to producing an attractive and well-structured publication. I simply had to 'follow'.

In this volume, we learn about the continued recovery of seabird populations and that the island's breeding seabird population is now starting to regularly exceed the qualifying figure for a Special Protection Area. Streams, ponds and wells on Lundy are catalogued in a gazetteer. The little studied group of fungi that occur in those streams is a topic that will surprise some who will never look at the foam in running water in the same light again. The summary of work over 25 years on the populations of the unique Lundy cabbage population provides a baseline of what sort of change to expect from year-to-year and what factors influence that change. Fossils in Lundy slates are something not expected by many but are now demonstrated and described. Sibling conflict in kittiwake chicks is something to observe and we learn how to do that in a systematic way. Then there are very valuable short communications on maternal behaviour in soay sheep and in goats and more detail on the Clayton manuscript, described as 'A Particuler of Lundy Island'.

All of the work undertaken on Lundy depends on the facilities provided by the Landmark Trust and often the help of Landmark Trust staff and equipment. Researchers and students can now benefit from the facilities provided in the newly restored St Helen's Centre in the church making Lundy a welcoming and well-equipped but still often challenging place to do research.

Dr Keith Hiscock MBE
Editor
April 2023

LUNDY NOW INTERNATIONALLY IMPORTANT FOR SEABIRDS: CLIFF NESTING SEABIRD SURVEY 2021

by

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ABSTRACT

The upward trend for most seabirds on Lundy continues, with huge increases in auks, and more modest increases for a range of other species, masking an overall decline in gull numbers. The overall increase in the assemblage highlights how the importance of Lundy has increased significantly in recent years. The island's breeding seabird population is now starting to regularly exceed the qualifying figure for Special Protection Area status and a repeat of the Manx shearwater survey planned for 2023 will determine if this remains the case.

The overall increase in cliff-nesting seabirds continues to be driven by the significant gains shown by auks on Lundy, outstripping changes recorded nationally for these three species (JNCC, 2021). Jenny's Cove remains the single most important site for cliff nesters on Lundy, although availability of suitable habitat elsewhere does not appear to be a limiting factor, particularly for razorbill and puffin which are expanding around the northern half of the island.

With 40,000 pairs (80,000 birds) of seabirds recorded in 1939 (Perry, 1940) there is historical evidence that there is still potentially suitable habitat for seabirds to occupy. It will be interesting to see whether the overall seabird population will return to this level or indeed exceed it.

Keywords: *Lundy*, *guillemot*, *razorbill*, *puffin*, *rats*, *international importance*.

INTRODUCTION

Lundy's seabird populations have been regularly surveyed, enabling us to track the fortunes of each species over recent decades. The most recent combined population totals of cliff nesting seabirds (surveyed in 2017) and Manx shearwaters (surveyed in 2017/2018) was estimated at over 21,000 birds.

In 2021, 40 years after the first census in the current series was conducted in 1981, we returned to Lundy to reassess the numbers and distribution of the cliff nesting seabirds. This report presents the results of the 2021 survey and the overall importance of Lundy as a seabird colony.

There has been considerable effort to conserve the seabirds on Lundy including the removal of rats which has provided safer nesting sites for a number of species. However, our understanding of other important factors that can drive population changes is more poorly understood, especially those at sea. Long term monitoring remains an important conservation tool in providing information on how seabirds are faring and, along with other research help identify where conservation action should be targeted.

Plate 1. Paul St Pierre surveying in Section G on the north-west coast. Image: Helen Booker.

METHODS

In June 2021, a repeat survey of the cliff nesting seabirds was undertaken for guillemots *Uria aalge*, razorbills *Alca torda*, puffins *Fratercula arctica*, kittiwakes *Rissa tridactyle*, fulmars *Fulmarus glacialis*, shags *Phalacrocorax aristotelis*, lesser black-backed gulls *Larus fuscus*, herring gulls *Larus argentatus* and great black-backed gulls *Larus marinus*.

The survey was conducted between 1st and 10th June 2021, using a direct repeat of methods from previous surveys, the most recent conducted in 2017 and reported in detail in the Lundy Field Society Journal (Booker *et al.*, 2018). This and all previous surveys were based on the published standard methods for surveying each species (Walsh *et al.*, 1995) and we therefore have not included full details here. The purpose of the survey is to provide a population estimate and does not provide information on the success of breeding attempts which is provided by the study plots surveyed by the Lundy wardening team for the species they cover.

Every section of coastal cliff was monitored from the same vantage points as used in previous surveys, using a register to record numbers of all breeding seabirds at each site. In line with national methods, puffin, razorbill and guillemot were recorded as individuals (I), for all gulls and shag apparently occupied nests (AONs) were recorded and for fulmar apparently occupied sites (AOSs). For *Larus* gulls and shag the timing of the survey, which was later than ideal for these species, meant that it was difficult to determine all nesting attempts, as some sites had been abandoned or chicks had moved. The gull data has been included in this report, but a further survey is planned in 2022 to gain a more accurate estimate of numbers.

The full set of survey sections is depicted in Figure 1. Weather conditions during the 2021 survey were favourable allowing for the completion of two visits to the busier colonies around Jenny's Cove and further north on the west coast in sections E, F and G. Where two visits were undertaken, the higher recorded figure was used.

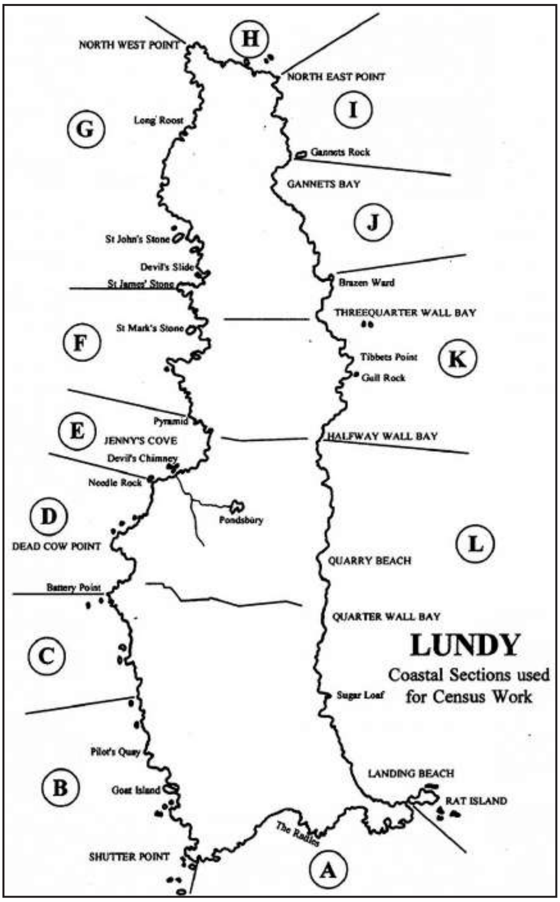

Figure 1. Section map for Lundy cliff-nesting seabird survey.

RESULTS

Overview of species totals and trends

The total all-island counts for 2021 for each species are presented in Table 1 along with the count totals from the previous nine surveys, providing an indication of species trends over the past 40 years. All the data has been submitted to the Joint Nature Conservation Committee (JNCC) to contribute to the latest national survey 'Seabirds Count'.

For the three auk species (guillemot, razorbill, puffin) there has been a significant increase in numbers, building on previous increases observed in the 2017 survey (Booker, 2018). Their populations far exceed the figures for the last national seabird census, Seabird 2000. Kittiwake, fulmar and shag have shown more modest increases since Seabird 2000, but overall gull populations have declined. Kittiwakes have shown mixed fortunes, with increases recorded by the 2017 and 2021 censuses being insufficient to offset the significant long-term decline since 1981. The removal of rats from Lundy was a major piece of seabird conservation work and the date has been added to species where this action could explain the changes in their populations.

Table 1. Numbers of cliff-nesting seabirds between 1981 and 2021. (Note: The count unit for auks is individual birds. For other species AON=Apparently Occupied Nests and AOS=Apparently Occupied Sites.)

Year	Guillemot (ind)	Razorbill (ind)	Puffin (ind)	Kittiwake (AON)	Fulmar (AOS)	Shag (AON)	Herring gull (AON)	Lesser black-backed gull (AON)	Great black-backed gull (AON)
1981	2,197	991	129	933	109	29	-	-	-
1982	1,979	861	87	911	117	43	573	75	27
1986	2,096	761	39	718	185	35	392	62	22
1992	2,628	791	37	407	174	22	497	166	28
1996	1,914	951	15	392	202	37	753	328	23
2000	2,348	950	13	237	190	56	762	443	35
2004	2,321	841	5	148	178	63	708	444	58
2008	3,302	1,045	14	151	170	63	534	263	57
2013	4,114	1,324	80	127	209	112	437	242	50
2017	6,198	1,735	375	238	227	55	229	132	46
2021	9,880	3,533	848	284	265	96	248	91	21
% Change 2017-2021	+59%	+104%	+126%	+19%	+17%	+75%	+8%	-31%	-54%
% Change 2000-2021	+320%	+272%	+6,423%	+20%	+40%	+71%	-68%	-80%	-40%

Species accounts

Guillemot and razorbill. Guillemots are the second most numerous seabird species breeding on Lundy (after Manx shearwater) with an estimated 9,880 individuals in 2021, which represents a staggering 59% increase on the 2017 figure. Lundy now supports almost four times the number of guillemots recorded in 2004, and the population is currently at a level not seen since the late 1940s. This increase for these species, although in line with wider UK trends (JNCC 2021), is greater here on Lundy.

Razorbills are the most widely distributed cliff nesting seabird on Lundy occupying all sections. They have also increased considerably since 2004 with 3,533 individuals recorded in 2021 representing an incredible 104% increase on the previous survey.

Both species have shown significant population growth since the absence of rats on Lundy.

The populations of guillemots and razorbills are illustrated in Figure 2 below, showing the relatively stable populations until 2004, followed by marked increases.

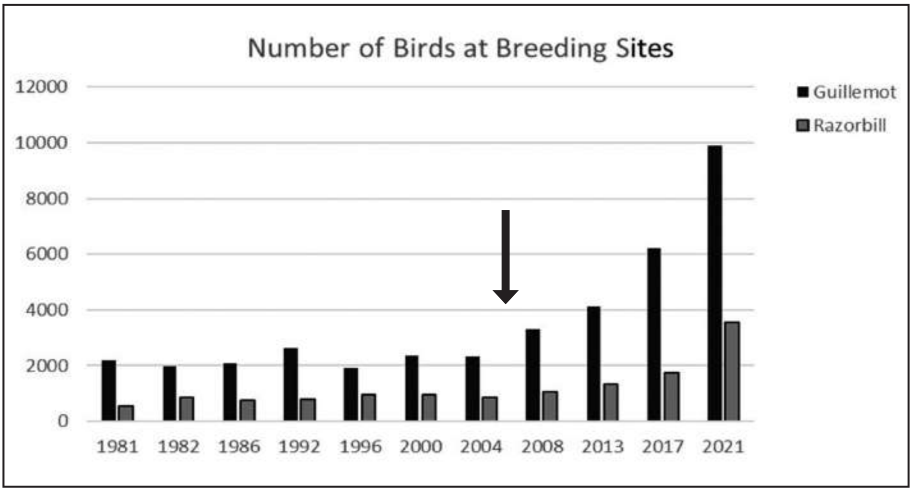

Figure 2. Guillemot and razorbill population change since 1981 (individuals). The arrow indicates the eradication of rats from Lundy, which was completed in March 2004 (Appleton *et al.*, 2006).

Puffin. The continued growth in puffin numbers since 2004 (just five birds) to 848 individuals in 2021 is extremely stark (Figure 3). It is recognised within the methodology used for assessing puffin populations (Walsh *et al.*, 1995) that obtaining absolute numbers is not possible (as many birds are out of sight in burrows). The counts, which are of all individual birds visible on the land and sea at a specific point in time, therefore represent an index of the population. However, as counts have been conducted on the same basis for all of the surveys since 1981, they are likely to provide actual trends for Lundy. Although not used in the results, information from intensive monitoring of individual study plots carried out by the Lundy conservation team over the whole breeding season (Davis & Jones, 2021) could potentially be used to extrapolate our figures that would calculate a population figure that would be significantly bigger than ours. This species is considered one of the key beneficiaries of the rat removal on Lundy.

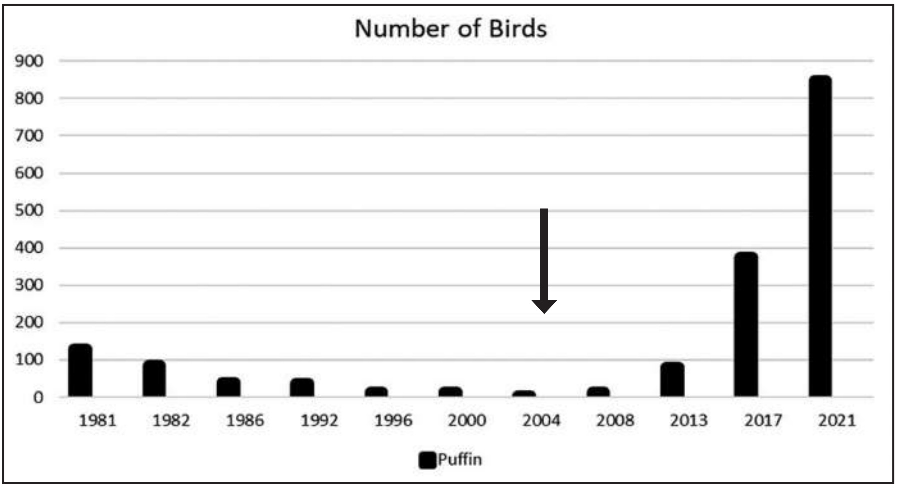

Figure 3. Puffin population change since 1981 (individuals). The arrow indicates the eradication of rats from Lundy.

Kittiwake. Kittiwakes declined consistently from 1981 through to 2013. The welcomed modest upturn in 2017 has continued to 2021, with a 19% increase to 284 AONs, restoring the population to its pre-2000 levels. However, in spite of the encouraging sign in this survey of AONs, more intensive study plots used by the wardening team have shown productivity to remain poor (Jones, 2018 & 2019) so maybe indicating that the population growth maybe a result of birds moving in from other colonies. There are wider regional and UK declines (JNCC, 2021) and this is thought to be linked to food availability, as a result of climatic factors or fisheries management (Mitchell *et al.*, 2004) which could also potentially be affecting some of the other surface or plunge feeding seabirds (e.g. Larid gulls) on Lundy.

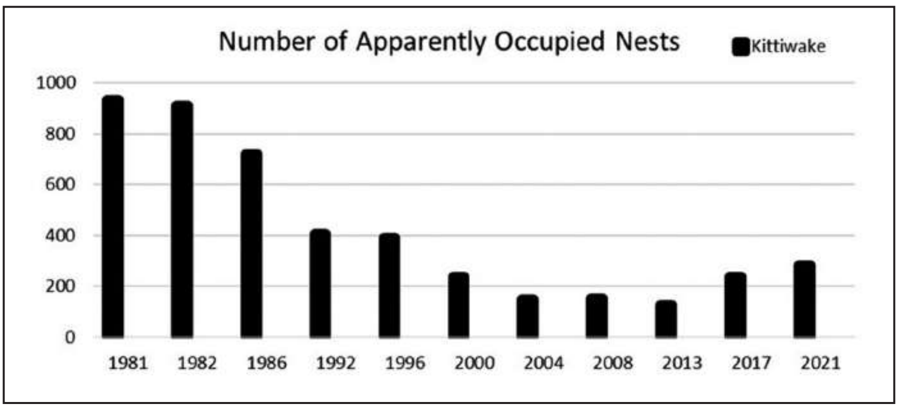

Figure 4. Kittiwake population on Lundy from 1981 to 2021 (AONs).

Fulmar. The 2021 survey produced an encouraging further increase in fulmars to 265 AONs, the highest count over the 40 years of the survey.

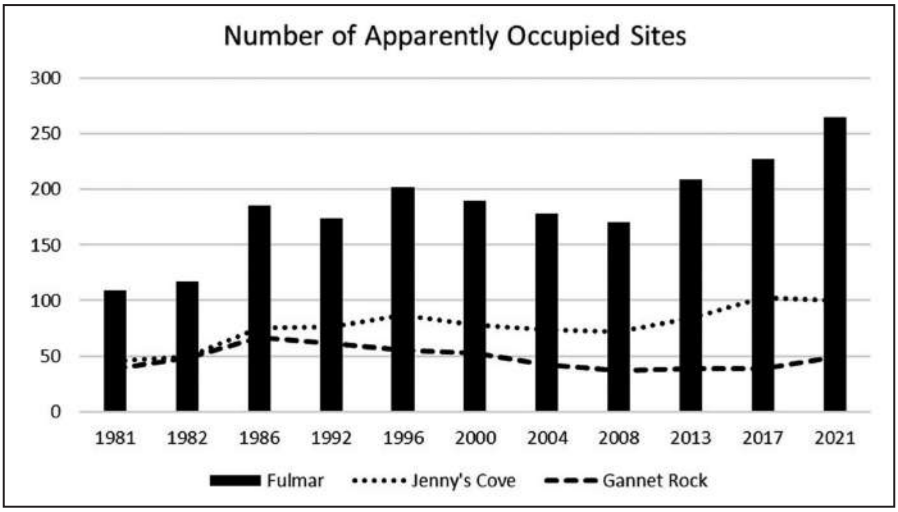

Figure 5. Fulmar breeding numbers from 1981 to 2021 (AOS).

Shag. The timing of seabird surveys on Lundy (which are chosen to optimise auk counts) is generally after the peak breeding period for shags. Consequently, results need to be interpreted with some caution. The 96 AONs in 2021 is a welcome increase over the 2017 figure of 55 AONs and much closer to the 112 AONs recorded in 2013.

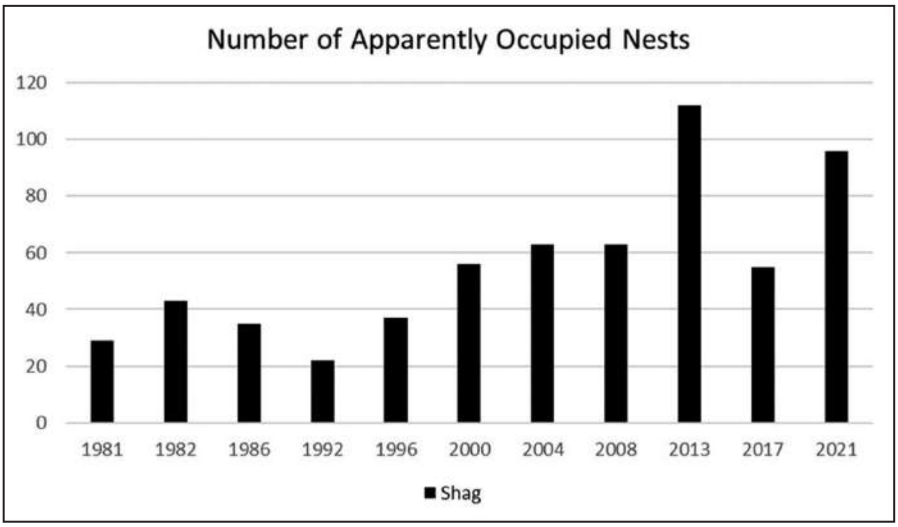

Figure 6. Change in the number of shag nests recorded since 1981.

***Larus* gulls**. The current timing of the survey is not optimal for censusing Lundy's three breeding *Larus* gull species (herring, lesser black-backed and great black-backed) as some pairs may have abandoned sites by the time survey work is carried out. As with shags, some caution is therefore needed in interpreting results. Nevertheless, for these three species, the timing of field surveys has been consistent over the 40-year history of the census on Lundy and so results should be broadly comparable. As shown in Figure 7, the overall trend for gulls is downwards with the outlook for lesser black-backed gulls looking bleak and great black-backed gulls at their lowest level since 1996. However, herring gulls have shown a slight upturn and future surveys will seek to determine if this is the start of a more positive trend.

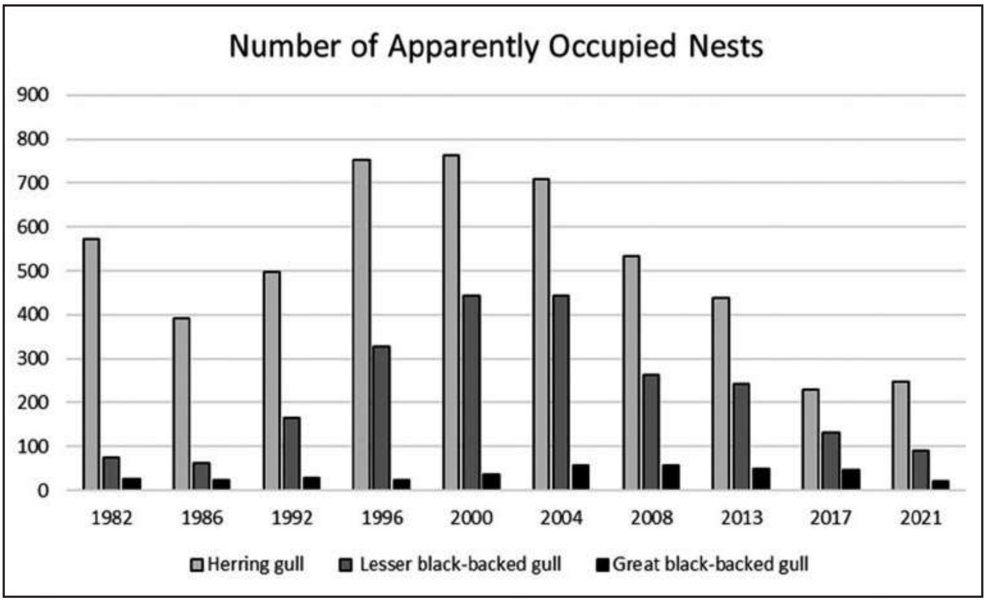

Figure 7. Change in number of *Larus* gull nests recorded since 1982.

Changes in the distribution of seabirds on Lundy

As populations increase, it is interesting to see how species' distributions change over time. The 2021 survey results show that over 90% of cliff-nesting seabirds are found on the west side of the island between Jenny's Cove and North West Point (sections E, F, G – Figure 1 and Table 2). This concentration on the west coast has always been the case, even back in 1939 (Perry, 1940), but there has nevertheless been considerable change within this area. Jenny's Cove (Section E) remains the most important site on the island, but numbers have increased considerably during the last decade such that it currently supports nearly half of all the island's cliff-nesting seabirds (Table 2). It now looks and sounds like a true 'seabird city'.

Since the last survey in 2017, the area from Jenny's Cove northwards to North West Point, continues to support growing numbers of auks, particularly guillemots, where the extensive sheer cliffs and ledges provide ample habitat for this species to occupy. Numbers in Jenny's Cove alone have increased by a staggering 2,761 birds (101%) in just this four-year period, while just to the north of Jenny's Cove, in Section F (Pyramid to St James Stone) there has been an increase of 551 birds.

Plate 2. Guillemots on St Mark's Stone. Image: Paul St Pierre.

Jenny's Cove also remains the most important site for puffins and survey counts for section E have swelled from 198 in 2017 to 536 in 2021, an increase of 338 in just four years (Table 3). As noted above, this is considerably lower than the total numbers present as the Lundy Conservation Team's monitoring of puffin burrows in their study plot in Jenny's Cove found 347 apparently occupied burrows (AOBs).

Puffins and razorbills have also spread north along the coast occupying suitable available habitat (holes and crevices respectively). This range expansion has extended around the northeast of the island and south to Brazen Ward.

Razorbills, occupying all count sections, have seen numbers between Needle Rock on the west coast and Halfway Wall on the east coast (sections E to K, inclusive, representing the northern half of the island), double since the last survey. Whether the increase in distribution reflects a greater availability of rat free habitat for this species compared to guillemot and accounts for the greater increase in this species since the last survey is unknown. Other factors such as differing feeding preferences or foraging areas could also play a role but would be something worthy of further investigation.

Table 2. Overview of results for cliff-nesting species in 2021 by survey count section.

Section	Guillemot (ind)	Razorbill (ind)	Puffin (ind)	Kittiwake (AON)	Fulmar (AOS)	Shag (AON)
A: South Light to Shutter Rock	8	119	0	0	1	0
B: Shutter Rock to Old Light	9	145	0	0	2	9
C: Old Light to Battery Point	0	15	0	0	0	0
D: Battery Point to Needle Rock	130	100	40	0	47	1
E: Needle Rock to Pyramid (Jenny's Cove)	5488	1037	536	125	100	7
F: Pyramid to St James Stone	2579	725	116	159	13	9
G: St James Stone to NW Point	1589	1071	132	0	42	32
H: NW Point to NE Point	38	65	4	0	0	0
I: NE Point to Gannets Rock	33	112	17	0	49	9
J: Gannets rock to Brazen Ward	0	76	0	0	0	1
K: Brazen Ward to Halfway Wall	6	26	3	0	11	11
L: Halfway Wall to South Light	0	42	0	0	0	17
TOTALS	**9880**	**3533**	**848**	**284**	**265**	**96**

Table 3 gives more detail of puffin numbers and distribution, and clearly shows the expansion into seven sections from just five birds at St Philips Stone in section E in 2004. It is also encouraging that since 2017 puffins have occupied their first new site on the east coast between Brazen Ward and Halfway Wall.

Whilst both kittiwake and fulmar numbers seem to be increasing again, the changes in occupancy of sites since the last survey are different for the two species. Kittiwakes, which do sometimes totally relocate colony sites between years, have increased from 59 AONs in Jenny's Cove in 2017 to 125 in 2021, but the numbers at the two Section F colonies declined from 179 to 159 AONs.

For Fulmars, the long-term increase along the west coast continues (numbers in Jenny's Cove seem to have stabilised) and numbers on the east coast have bounced back. There have been increases of 11 AOSs between Battery Point and Needle Rock (section D), 13 AOSs between St James' Stone and North West Point (section G) on the west coast, 10 AOSs at Gannets' Rock (section I) and 7 AOSs between Brazen Ward and Halfway Wall (section K) on the east coast (Figure 5).

Table 3. Puffin population change since 2004 by survey count section.

Section	**2004**	**2008**	**2013**	**2017**	**2021**
A: South Light to Shutter Rock					
B: Shutter Rock to Old Light					
C: Old Light to Battery Point					
D: Battery Point to Needle Rock			1	31	4
E: Needle Rock to Pyramid (Jenny's Cove)		6	61	198	536
F: Pyramid to St James Stone	5	8	15	57	116
G: St James Stone to NW Point			3	58	132
H: NW Point to NE Point				20	4
I: NE Point to Gannets Rock				11	17
J: Gannets Rock to Brazen Ward					
K: Brazen Ward to Halfway Wall					3
L: Halfway Wall to South Light					
Total	**5**	**14**	**80**	**375**	**848**

Seabird assemblage and importance of Lundy

Lundy supports 11 species of regularly breeding seabird, with the latest addition being storm petrel in 2014 (Taylor, 2014). The total number of cliff-nesting seabirds recorded during the 2021 survey was 16,271 individuals. This is presented in Figure 8 against previous population totals and in combination with the latest Manx shearwater numbers (and a storm petrel estimate) shows the trend in Lundy's seabird population over the last four decades and highlights the remarkable rise in numbers since 2004.

The 2021 survey indicates that the population of cliff nesting seabirds has continued to increase dramatically since 2004 with particularly large population gains shown for breeding auks and Manx shearwater.

Combining the figures from this survey and the last census of Manx shearwater in 2017/18 (Booker *et al.*, 2019) which estimated 5,504 pairs (or occupied burrows) – representing 11,008 individual birds and adding 100 storm petrels (based on a minimum estimate of 50 AOBs in 2021 (Davis & Jones, 2021) the overall seabird assemblage for Lundy now stands at a minimum of 27,329 individuals.

This total population of Lundy's seabirds meets the qualifying criteria for international importance. International importance for birds is often recognised by an increased level of statutory protection within the UK and notified as Special Protection Areas (SPAs). To qualify as an SPA, a seabird colony needs to regularly support an assemblage of over 20,000 birds, and/or more than 1% of the biogeographical population of a species listed on Annex 1 of the EU Birds Directive. This is the second survey of Lundy's cliff-nesting seabirds where the island has exceeded the SPA qualification threshold (20,000 individuals) for a seabird assemblage. The future for UK conservation designations is uncertain post Brexit, but the importance of Lundy as a seabird breeding site is clear and growing. Of particular note is that – in terms of overall numbers – Lundy is now likely to be the third largest cliff-nesting seabird colony in England, with only Flamborough SPA (412,000) and the Northumberland Coast SPA (over 200,000) supporting higher numbers.

The dramatic increase of auk species on Lundy follows the eradication of rats in 2004. Changes in spatial distribution, already observed in 2017, continues, with increasing expansion of birds into the broken ground where the cliff tops meet the steep grassy coastal slopes.

However, other factors are also likely to be playing a role in the growth of the seabird population on Lundy. Tracking information indicates that foraging ranges of some of Lundy's seabirds are smaller than expected (Thaxter *et al.*, 2012) and a recent study of forage fish (Campanella & van der Kooij, 2021) has highlighted the seas around Lundy as a hotspot for spawning and nursery grounds for a range of key seabird fish prey. However, our understanding of how and where Lundy's breeding seabirds use the Celtic Sea is still poorly understood, along with the status of their food prey items and this warrants further study.

Whilst the Lundy seabird population is showing encouraging signs of recovery there are still a range of threats that could affect their fortunes. A future incursion of rats

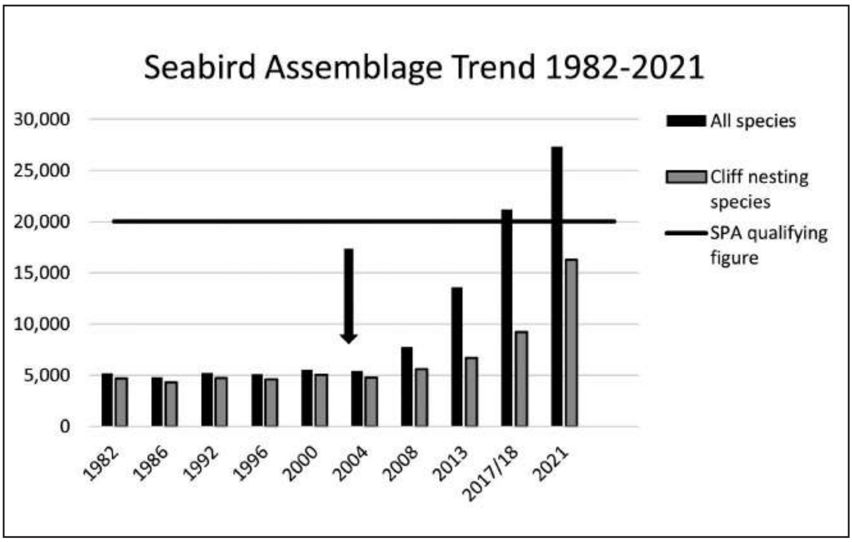

Figure 8. The change in the Lundy seabird population between 1982-2021 (the first year when gulls were also surveyed with other cliff nesting seabirds). The arrow signifies the eradication of rats from Lundy. Prior to 2000 the all-species total is given as an estimate (the cliff-nesting total plus a contribution of 500 birds for Manx shearwater) due to lack of data on Manx shearwater. Note that the Manx shearwater were surveyed over two years in 2017/18 whilst the cliff nesting seabirds were only surveyed in 2017. The horizontal bar signifies the qualifying figure for Special Protection Areas (SPAs).

onto the island could undermine the current recovery and therefore it is important to maintain good biosecurity measures. Diseases such as avian influenza which has devastated some UK seabird colonies has been recorded on Lundy so it will be important to monitor the situation. Also, the potential impact of badly placed floating wind farms could result in birds being excluded from key foraging areas. It will therefore be important to identify and protect the most important areas for Lundy's seabirds at sea as well as improving the level of protection of Lundy's seabird colony to SPA status to reflect it's true importance, so it is considered in the same way as the seabird colonies off Pembrokeshire and on Scilly.

ACKNOWLEDGEMENTS

Thanks to Voluntary Assistant Wardens Eleanor Grover & Ben Arkless for fieldwork assistance.

Thanks also to Derek Green, Lundy General Manager, for supporting the survey through the providing the RSPB with tickets and accommodation free of charge and to Dean Jones, Lundy Warden, for support and survey help and Rosie Ellis, Assistant Warden, for sharing the study plot information.

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THE STREAMS, PONDS AND WELLS OF LUNDY

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ABSTRACT
A gazetteer of the more permanent, streams, ponds and wells of Lundy giving locations, historic and suggested contemporary names and brief descriptions. Each water body is fully referenced to all known descriptive and survey literature.

Keywords: *Lundy*, *lentic*, *lotic*, *stream*, *pond*, *well*

INTRODUCTION

In a wet winter, almost every dip in the ground on Lundy will form a pool of some size. These can range from hoof marks and ruts in a track to any large low-lying hollow. Some of the ponds formed on the central track can be up to 10 m in length and 2 m in width.

At the other extreme, in a dry summer, even the most permanent of ponds, ranging from the Pondsbury basin through deep quarry excavations and water courses can dry up. In the drought of 1976 Pondsbury was reduced to a small pool, in 2006 Quarter Wall Pond was so reduced that fish had to be moved to Rocket Pole Pond and in 2022 all watercourses and ponds with the exception of Rocket Pole Pond, Pondsbury and Quarry Pond were dry.

The Freshwater Habitats Trust defines a pond as being at least one metre square and holds water for at least four months of the year.

This paper will list and identify the more permanent of water courses, pools and ponds. At the same time, names that have been in common use will be given or a descriptive and acceptable name suggested, along with grid references.

Some ponds, wells and reservoirs have been described or surveyed before permanently drying up or otherwise becoming lost. An attempt will be made to identify their original location and to tie together the disparate names, references and locations.

The following list is compiled from various (mainly Lundy Field Society) sources but omits covered reservoirs and wells and those waters that have either proved unidentifiable, ephemeral or otherwise inaccessible. All water bodies have been visited and surveyed by the author.

The list aims to provide a standardised description, confirm locations and attempts to make future surveys easier to compare both lotic (flowing) and lentic (still) waters with a degree of consistency and accuracy. Grid references given for streams are generally located where the standard access pathway crosses the watercourse, and where possible, the source and, for ponds an actual or estimated central point.

References immediately following each feature, briefly identify the source and year together with any name or reference number used that is different from the suggested or adopted name.

There are three typical types of pond on Lundy both natural and man-made. Natural ponds are where water collects in a hollow such as at Pondsbury, but such hollows can be augmented by extraction by human agency or by damming of streams. Others are the cause of excavations such as quarries, archaeological digs or an attempt to provide stock watering holes. Wells are of two types. One meaning of well is "hole or shaft that is excavated, drilled, bored, or cut into the earth so as to tap a supply of water… ", the other is "a natural pool where ground water comes to the surface" (Collins, 2014). Both feature on Lundy.

EARLY MAPS

The earliest map of Lundy is that of 1765 drawn by Benjamin Donne. (Ternstrom, 2006) The only recognisable body of water is in the centre of the island labelled "A well". The location is that of Pondsbury and should not be confused with a traditional well, a shaft sunk to the water table. Although named as a "well" we can be reasonably sure this is Pondsbury (Collins, 2014). This description can also be applied to other wells viz: St John's, St Helen's and Golden wells.

The next usable map is that produced by Trinity House at the time of the construction of the Old Light in 1819. (Ternstrom, 2006). Again, Pondsbury features but this time labelled as "Pond". In addition, there are indicated two wells and a spring. Locations are a little difficult to determine, but the south-westernmost well would appear to be Golden Well, with St John's spring to the northeast of it. The well adjacent to the Barn is where Bull's Paradise well is located.

The Ordnance Survey produced their first one inch to the mile map of Lundy in 1820 (Ternstrom, 2006). The south of the island has many features which may obscure any water bodies, but moving northwards, we come to a depiction of Pondsbury which is shown as a pond with a complicated stream system. The present two streams that converge at Punchbowl Valley can be seen but the other streams are no doubt now submerged by a much larger body of water now known as Pondsbury.

Moving further north, past Tibbets Hill a pond is shown which may be Widow's Tenement Pond flowing northwest to empty at St Peter's Stone. It is joined by a tributary no longer in existence which appears to rise north of Widow's Tenement adjacent to the central track. The stream system at Gannets' Combe can also be seen although labelled as Gallows Comb.

The next map was produced in 1822 to accompany an attempt to sell the island by De Vere Hunt (Ternstrom, 2006). This is a very detailed map giving many forgotten field names but also locating, if not always naming, other water bodies. The well adjacent to number 21 on this map would appear to be St John's Well.

Parson's Well is located in Parson's Field but may be what is known as Bull's Paradise Well.

Pondsbury and its streams are similar to the depiction on the Trinity House map with a small pond for Pondsbury and three streams converging into Punchbowl Valley. The system at Widow's Tenement seems to be further south but does appear to flow down by St Peter's Stone. Gannets' Combe stream system is also shown.

A map was also produced in an attempt to sell the island by the Heaven family in 1840 (Ternstrom, 2006). St John's Stream and Millcombe Stream both appear by the Mansion (Millcombe) and converge at the bend in the "New Road". A pond and stream are shown just north of the Old Lighthouse and is probably the spring and stream now known as Lighthouse Stream and Lighthouse Pond.

Again, Pondsbury is shown to be quite small and with two other streams one of which is now submerged by an enlarged Pondsbury. The others are Pondsbury Stream South and Punchbowl Stream. Further north, Widow's Tenement pond and St Peter's Stone Stream can be identified as well as the Gannet's Coombe system.

The 1877 map included in Chanter (1877) adds more streams whilst omitting others none of which are named.

CONTEMPORARY SURVEYS

Various attempts to name and classify streams have been made in the last 50 years commencing with Langham's (1969) reference sketch map of *Water courses and reservoirs on Lundy* which complements his Annual Report paper. (Figure 1 Water bodies of Lundy – after Langham). Langham frequently used the location of the telegraph poles which ran from the North Light to the Old Light as reference points. I have included them in his quoted descriptions although they no longer exist.

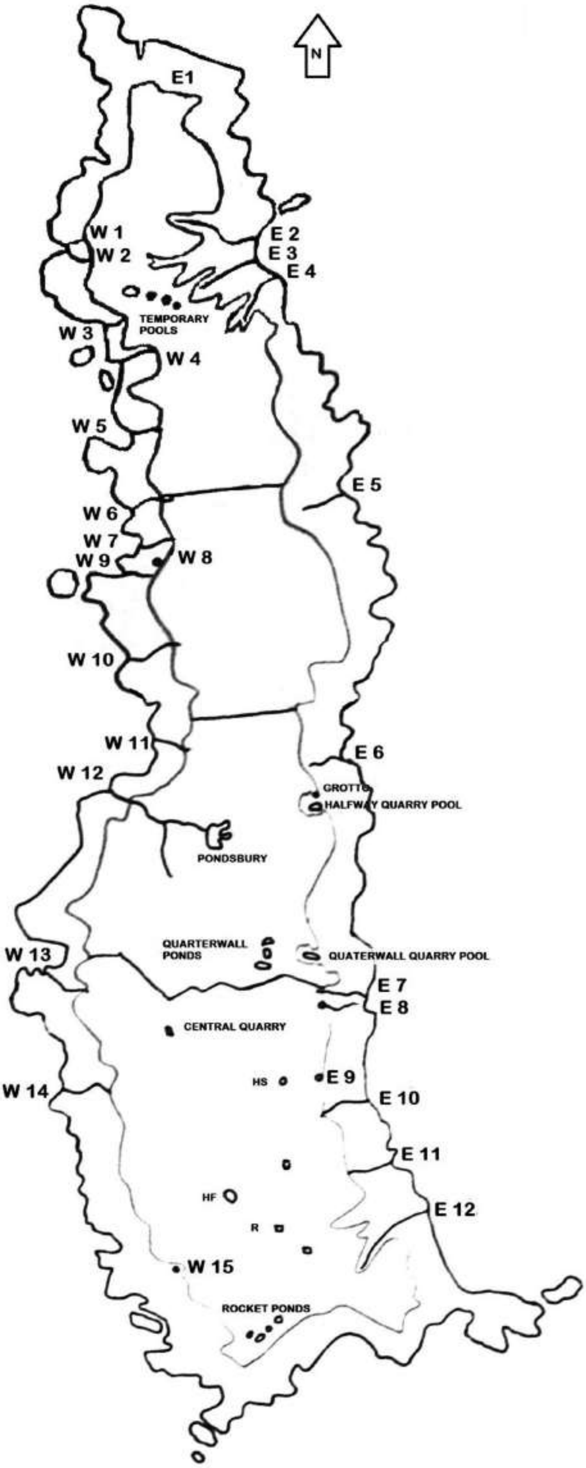
Richardson, Compton and Whitely (1997) in their Fertilizer Nitrate study arbitrarily numbered streams from the north-east as Number 1 then moved clockwise around the island to Number 16 on the north-west. The location of the sources on the plateau of these streams is used to loosely locate them which results in the same name being used for more than one stream. The four selected ponds are numbered from the south to the north. Four ponds were identified at Rocket Pole, P1a, P1b, P1c, P1d. The nitrate results indicate P1c as being the pond with highest nitrate levels suggesting that this is Rocket Pole Pond and that P1a and P1b were to the west of this location and that P1d is Kistvaen Pond (Richardson, Compton & Whiteley, 1997).

Long's (1993) sketch map which accompanies his, *A study into the micro-invertebrate fauna and water quality of Lundy's lotic habitats,* numbers six streams (Long, 1993).

STREAMS – LOTIC WATERS

Wherever possible, grid references are given of the source and where any paths cross the stream. West coast streams generally cross the west coast path; east coast streams mainly cross both the Upper and Lower East Coast paths although in the northern half of the island they cross only the Lower East Coast Path.

Battery Stream – SS 1296 4492
Stream with pool (see **Battery Reservoir**) beside the path leading to Battery Point.



W1 } Ephemeral
W2 } No longer
W3 } Identifiable
W4 St Peter's Stone Stream
W5 Ephemeral
W6 Threequarter Wall Stream
W7 Ephemeral
W8 } St Mark's Bay
W9 } Stream
W10 Pyramid Stream
W11 Butler's Pantry Stream
W12 Punchbowl Stream
W13 Battery Stream
W14 Lighthouse Field Stream
W15 South West or Pilot's Quay Stream

E1 Constable Rock Stream
E2 } Gannet's Bay
E3 } Stream
E4 } System
E5 Threequarter Wall Stream
E6 Halfway Wall Stream
E7 } Quarter Wall Streams
E8 } Either side of wall
E9 Brick Field Stream
E10 Tillage Field Stream
E11 St Helen's Spring
E12 St John's/Millcombe streams

Sketch map key to Lagham's gazetteer in the LFS Annual Report Volume 19 (Langham, 1969)

Figure 1. Reference sketch map of *Water courses and reservoirs on Lundy.* After: Langham (1969).

References: Galliford (1953) 15; Langham (1968) W13, Richardson, Compton & Whitely (1997) 12 Ackland's Moor Stream.

Brick Field Stream – SS 13674 44561, 13808 44570
Stream originating in Brick Field Well (see entry). It flows on the northern side of the south wall of Brick Field before flowing down the eastern sidelands through Quarter Wall Copse and into the sea.
Reference: Langham (1968) W9.

Butler's Pantry Stream – SS 1338 4576
This is the stream which pools under the "Cheeses" south of Quarter Wall and before quickly disappearing over the cliff.
Reference: Langham (1968) W11.

Constable Rock Stream – Path SS 1326 4799 Source SS 13408 45750
This is the overflow from Constable Rock Pond (see entry) and only flows when this pond is full. Its course is almost vertical from source to sea.
Reference: Langham (1968) E1.

Gannets' Combe Stream system – SS 1332 4749 and SS 1329 4723
There are at least three distinct streams, heavily overgrown with bracken, flowing eastward from around the central footpath into Gannets' Bay where they converge before falling over the cliff edge at SS 1353 4744.

Another separate stream emerges from the plateau at SS 1352 4713 and runs towards Slipper Rock before tumbling over the cliff at SS13560 47227.

Langham's and Richards (*et al.*) source grid references are E1 1326 4799; E3 1343 4730; E4 1353 4750; East 1 1332 4750.
Reference: Langham (1968) E2, E3, E4; Long (1993) East 1, Richardson, Compton & Whitely (1997) 1, 2, 3.

Halfway Wall Stream – SS 13802 45676
This is a very short stream hidden by vegetation for most of the year. Early in the year when there is no bracken and little other vegetation, it can be seen to emerge far down the cliff slope and runs for about 10 m before emptying over the cliff.
Reference: Langham (1968) E6, Richardson, Compton & Whitely (1997) 5 Halfway Wall.

Millcombe Stream – SS 1386 4405
This stream emerges some 100 m downhill from Government House. It flows past the Casbah before disappearing underground at the side of Millcombe House. Fluorescein tracing confirmed that the stream that emerges from the ground in the Secret Garden is the same stream. It then flows through Millcombe Gardens where it merges with St John's Stream and flows via Millcombe Pond into the sea via Smelly Gully. Originally a natural stream, it was canalised through the gardens sometime between 2006 and 2012.
Reference: Langham (1968) E12, Richardson, Compton & Whitely (1997) 9 Millcombe.

Old Light Stream – SS 1325 4446
Stream north of the Old Light which develops from a spring at the western end of the airfield at OS grid reference SS 13259 44464. The spring appears after wet weather and is absent for most of the year. It flows west into the marshy pool north of the Old Light then down the cliffs into the Western Sidings. It consists of alternating areas of rapids, pools and small waterfalls interspersed with larger boulders and smaller rocks. (See also **Old Light Pond**.)
Reference: George & Sheridan (1986), Richardson, Compton & Whitely (1997) 11 Ackland's Moor Stream.

Pilot's Quay Stream (see **South West Stream**)

Pondsbury Stream – SS 1326 4520
The southern of a pair of streams which join together to form Punchbowl Stream before flowing westward over the cliff. Confluence at SS 1317 4548.

Punchbowl Stream – Source SS 1341 4545 (Pondsbury) Confluence SS 1317 4548
A fairly short stream flowing from Pondsbury down Punchbowl valley via the adjacent small David's Pool (see entry). It consists of alternating areas of rapids, pools and small waterfalls interspersed with larger boulders and smaller rocks with rapid flow throughout and eventually flowing over the cliff. A tributary, Pondsbury Stream (see entry) joins it from the south halfway above Punchbowl valley at the confluence.
Reference: Hemsley in Fraser-Bastow (1949), Pondsbury West Side; Galliford (1953) 17; Langham (1968), W12; George & Sheridan (1986), Punchbowl Valley; Long (1993), West 4, Richardson, Compton & Whitely (1997) 13 Pondsbury Stream.

Pyramid Stream – Source SS1348 4610 Bridge SS1335 4612
This stream is up to 1m in width and widens into two pools beside the path. There is no vegetation in either and the lower pool is practically silted up (Langham, 1968). It passes between where telegraph poles No 53 and No 54 stood and curving north of pole No 54. The source is in Middle Park but separate from Middle Park Pond (see entry) where it rises amidst *Sphagnum* and *Juncus* ssp. Rushes at SS 13488 46112.
Reference: Galliford (1953) 7; Langham (1968) W10; Long (1993) West 3, Richardson, Compton & Whitely (1997) 14 Middle Park Stream.

Quarry Leat – SS 1374 4500
A short artificial stream created to divert surface water from the quarry workings. It drains Quarter Wall Pond North (q.v.) and is most apparent from a position adjacent to the former Quarry Company Smithy. It runs in a narrow granite lined channel, which is occasionally bridged with granite blocks before being lost in a granite spoil heap above Quarter Wall Copse on the east coast at SS 1387 4493.
Reference: Rothwell & Ternstrom (2008) The Quarry Leat.

Quarter Wall Stream – SS 1356 4488
This rises on the north side of the wall bounding Brick Field by Quarter Wall gate. It

then flows east to the Upper East Side Path before flowing down through Quarter Wall Copse and falling into the sea.
Reference: Langham (1968) E7, Richardson, Compton & Whitely (1997) 6.

St Helen's Stream – SS 1377 4488
A stream rising near St Helen's Well (see entry) in Barton's (or St Helen's) Field and flowing down to Ladies Beach.
Reference: Langham (1968) E11 Long (1993) East 2, Richardson, Compton & Whitely (1997) 7 St Helena's Copse (sic).

St John's Stream – SS 1377 4399
A stream rising in the corner of Stoneycroft and running underground across Lighthouse Field. It is piped near Quarters Pond via the Helipad to re-surface north of the Church where it runs overland to the head of St John's Valley. It receives runoff from the Golden Well area then flows down St John's Valley via Brambles Pond and thence through Millcombe gardens where it is joined by Millcombe Stream. This combined stream then empties into Millcombe Pond before falling to the sea through Smelly Gully. It is stated never to dry up (Gade, 1978; Fursdon pers. comm.). Langham (1968) described it as "Leat running across the field below the Church starting by the Hotel and ultimately ending in St John's Valley. It is however liable to, and does, dry up."
Reference: Langham (1968) E12, P24; Long (1993) East 2, Richardson, Compton & Whitely (1997).

Plate 1. St Peter's Stone Stream.

St Mark's Bay Stream – SS 1346 4647
A small stream dammed to produce a moderate sized pool with muddy bottom. Between where telegraph poles No 57 and No 58 were located. [Pole 58 originally gave a line eastwards to Tibbetts.]
Reference: Langham (1968) W8/9, Long (1993) West 2, Richardson, Compton & Whitely (1997) 15 Middle Park Stream.

St Peter's Stone Stream – SS 1345 4696
This drains the northern edge of Widow's Tenement. Rising in marshy ground, it runs westwards via two dammed pools, one each side of the path and full of Marsh St John's Wort *Hypericum perforatum* where it is crossed by stepping stones before quickly running over the cliff into the sea.

This is north of where telegraph pole No 69 stood. Grid reference is given for where the west side path crosses the stream via the stepping stones.

The upper pool has much floating vegetation (*Potomageton* and *Hypericum*) merging into *Sphagnum* marsh at the eastern end. The lower pool is shallow with less vegetation. The stream progresses along SS 13274 47002 and SS 13247 47004 (pics1669-72) before falling over the cliff edge at SS 13204 47011.
Reference: Galliford (1953) 6; Langham (1968) W4; Long (1993) West 1, Richardson, Compton & Whitely (1997) 16 North End Stream.

South West or **Pilot's Quay Stream** – Source SS 1329 4400 pool SS 1324 4397
A stream which rises in marshy ground in the field south of the Old Light which is dammed by a very substantial dam near the cliff top.
Reference: Langham (1968) W15, Richardson, Compton & Whitely (1997) 10 South West Field Stream.

Three Quarter Wall Stream – SS 13752 46528
This insignificant stream drains from the north side of Tibbetts Hill and crosses the Lower East Side Path at the above grid reference from where it flows north-eastwards into the bay south of Brazen Ward. It is less than 100 m in length and consists of pools and marshy areas.
Reference: Langham (1968) E5, Richardson, Compton & Whitely (1997) 4.

Tillage Field Stream – SS 1380 4445
A stream rising from the pond in Tillage Field (q.v.) above the Upper East Side Path halfway along the wall of the Tillage Field and flowing east over the Eastern Sidings.
Reference: Langham (1968) E10, Richardson, Compton & Whitely (1997) 8 Broad Coombe.

PONDS – LENTIC WATERS

A grid reference is given at either the actual or estimated central point of the pond. Plate 2 shows Quarry Pond formed in a man-made excavation, Plate 3 Long Roost is a pond in a naturally occurring hollow. Plate 4, South-West Field pond shows an example of a dammed waterway forming a pond. Plate 5, Middle Park Pond is an example of a man-made scrape which forms a pond.

Plate 2. Quarry Pond.

Plate 3. Long Roost Pond.

Plate 4. South-west Field Pond.

Plate 5. Middle Park Pond.

Ackland's Moor Pond – SS 1325 4476
A pool in an old clean sided excavation in the granite about a quarter of a mile north of the Old Light on the old Golf Course close to trig point 466 and just south of a pronounced bend in Quarter Wall. Water very green with algae and muddy bottom. Langham's map names it Central Quarry but refers to it as the High Pond Quarry when originally excavated by the Granite Company.
Reference: Galliford (1953) 4; Langham (1968) P10, Langham (1994) Rowland (2014), George & Rowland (2016).

Airfield Pond – SS 1325 4464
Identified on an early map from where it is shown as the source of either Battery or Old Light Stream. It is an occasional pool which floods in very wet weather to the south of, and distinct from, Ackland's Moor Pond.
Reference: NDRO (1840).

Barton Cottages Pond – SS 1372 4423
Pool excavated by the tenant farmer, Kevin Welsh in 2010 (pers. comm. 2010), a pond in Barton's Field for watering stock.

Barton's Field Pond – SS 13725 44176
Pool excavated by the tenant farmer, Kevin Welsh in 2010 (pers. comm.). Another Pond in Barton's Field, a scrape quickly filled with water to create a stock watering hole. It is fenced to allow geese to use it but not larger stock. It relieves a 'blister' of water trapped between strata flowing from higher on the plateau towards Lighthouse Field (Roger Fursdon, pers. comm.).

Battery Reservoir – SS 12964 44934
A small pool which is very marshy and the source of Battery Stream water course. Even in very wet weather there is no open water merely a marshy area of *Juncus* sp. rushes.
Reference: Galliford (1953) 16; Langham (1968) P8.

Brambles Pond – SS 1397 4397
Although shown on the 1967 OS map, this does not feature in Langham's (1968) otherwise complete listing. Pictures exist from the time of the rebuilding of Brambles as Colonel Gilliat's residence around 1970 showing a landscaped terraced area either side of the St John's stream but with no pond. In 2019, the area was excavated by the Lundy Conservation Team to reform the pond and in November a baseline survey was undertaken by the author.

Brick Field Pond – SS 13706 44900
Located in Brick Field immediately south of Quarter Wall in a rush and boggy area. It was created by Kevin Welsh, the tenant farmer in 2009, by scraping out the area to conserve pumped water thus creating a stock watering hole. (Welsh, pers. comm.). A low bank of excavated earth is located on the west bank of the pond. It receives much surface water from the stream which runs along both sides of Quarter Wall and reveals the high water table in the area. It has quickly been adopted by flying insects and aquatic plants.

Constable Rock Pool – SS 1326 4799
Small deep *Sphagnum* pool on cliffs above Constable Rock. When full it overflows to become Constable Rock Stream (see entry).
Reference: Langham (1968) E1.

David's Pool – SS 13846 44228
A small pool adjacent to and on the western edge of Pondsbury from whence flows Punchbowl Stream (see entry).
Reference: George (2006).

Government House Pond – SS 1380 4406
A sheltered area excavated from the rocks on the north side of the path near Government House and protected by trees. First referred to as "the pond in the Quarry" Heaven Archive 1870, a later unpublished document Langham (1993) suggests it was the quarry from where stone was quarried to build The Old House of Sir John Borlase Warren and later he refers to it as "Garden Quarry" (Langham, 1994). Ternstrom (1999) notes it in her Gazetteer as G343 Pond in the Quarry.
Reference: Heaven Archive (1870); Langham (1993, 1994); Ternstrom (1999); Rowland (2020).

Howard's Quarry Pond – SS 13868 45276
A very weedy, dark and murky pool immediately below the western wall of this quarry. It is overhung by *Salix* sp. (willow) and heavily covered in blanket weed. It dries up completely each summer leaving white shrouds of blanket weed and appears to be up to 2 m in depth.

Johnny's Pool – SS 13287 47237
Two adjacent pools, one on the central track the other to the west of the track, which contains water for the majority of the year and only occasionally dries. See also **Temporary Ponds at the North End**.
Reference: George (2006).

Kistvaen Pond (see **Rocket Pole Pond)**

Lighthouse Field Pond – SS 1345 4415
Originally, this was a large cattle pond in the field south east of the Old Light. It was fenced and had a rich fauna and flora. Illustrated in Galliford, it is now a complete hydrosere revealed only by thicker vegetation of *Eleocharis palustris*, Common Spike Rush and *Juncus effusus* soft rush in an otherwise complete pasture.
Reference: Galliford (1953) 3; Langham (1968) P19.

Long Roost Pond – SS 13176 47565 (Plate 3)
Not reported until it was found in May 2014 – it may prove to be temporary.

Approximately 6 x 2 m and probably 30 cm in depth.

It is a natural hollow formed in granite with a granite gravel bottom showing some signs of vegetation. Lying northeast-southwest almost at the north eastern tip of the island.

A hand grab of gravel revealed three *Lumbriculus variegatus* Black Worm, and observation of three Chironomidae Non-biting midge larvae in vegetative cases on the surface. A small diving beetle Dytiscid was seen disappearing into the bottom gravel.

Water is clear but tinged yellow-brown by peat.

Subsequently a reference was found in Moulton (1974). The route to the climb 'Rock Pool Buttress' (MR13174787) refers to the "rock pool on its summit".

Middle Park Pond – SS 13523 46172 (Plate 2

It is a scrape to contain groundwater in a natural depression but has neither inlet nor outlet. It is fairly close to, but separate from, the source of Pyramid Stream (see entry) but does not appear to contribute to it.

The eastern edge has been defined by granite boulders and some attempt has been made to form a small separate enclosure. An old copper washing boiler placed adjacent to the scrape provides a small deep and more permanent water collection. To the south and west, there is a bank apparently formed from the original scrape. The body of the pond is flat and shallow on the bedrock but has accumulated organic matter and silt. It was certainly formed before the 1970s (Richard Campey, pers. comm.).

Millcombe Pond – SS 1404 4403

Before the 1980s this was a watercress bed located halfway between the beach and plateau at 125 m above sea level. The pond was excavated in 1984/5 by David Rosser a building contractor with help from the island workforce as a sewage treatment and disposal facility. The bottom was lined with polythene sheeting before being covered with puddling clay.

It is fed by St John's stream which is visible at Lodore below Brambles and reappears in the gardens and is joined by the flow through the Secret Garden from Millcombe Valley.

There are two outflows from the pond. The original is via a 12 cm diameter concrete pipe in the south-east corner of the pond, 18 cm deep with a controlled sluice. This is fed from a submerged pipe 70 cm below the top of the pipe. In the bottom of the concrete pipe there is a gulley running east west. Water can be heard running, but not seen in this gulley. The second outflow is at the centre of the eastern bund. This feeds under the concrete sewage tank into Smelly Gulley. This sewage tank is serviced via five manhole covers. A further pair of manhole covers adjacent to the road gives access to the outflow from the sewage treatment works.

In 2021, a channel was dug across the pond from the stream to the leaky outflow which has, so far, not reverted to a pond.

Reference: Dave Rosser (pers. comm.); Harvey (1950).

North Quarry Pools (Smith's Point Quarry Pools) – SS 1383 4557

Two pools in the North Quarry which are shallow and covered in *Lemna sp*. Duckweed.

Pool 1 – nearest the quarry entrance on the south side varies from 0.73 m (October 2003) to 0.57 m (April 2005) and is approximately 6 x 3.5 m in area.

Pool 2 – adjacent to the steep quarry wall, on the south side is completely surrounded by large rocks. It varies from 0.9 m (October 2003) to 1.25 m (April 2005) and is

approximately 2.9 x 1.7 m in area Langham's map references these as Halfway Quarry Pond.
Reference: Langham (1968), George, McHardy (Stone) & George (2003); George (2006).

Old Light Pond – SS 1306 4456
Pool north of the Old Light. This small shallow pool forms part of the stream system flowing down Western sidings (see also **Old Light Stream**). In August 1979 there was a small through flow of water, and a fairly dense cover of vegetation had been established. In 2010, this is an almost permanently silted up hydrosphere which only has any depth of water in very wet conditions.
Reference: George and Stone (1980).

Pondsbury – SS 1345 4545
The largest body of freshwater on the island, it is surrounded by *Sphagnum* bog, heathland and rough grazing pasture. It is probably of natural origin although the damming on the west side has increased its size and depth. Its margins are marshy and the water at the edge is fairly shallow and threatened by encroaching vegetation and peat formation. It receives surface run-off from the surrounding land and has an outlet stream that flows down Punchbowl Valley (see entry) and into the sea at Jenny's Cove. During dry periods the pond becomes reduced in size and very occasionally can dry up altogether, as it did in 1976.
Reference: Galliford (1953) 9; Langham (1968) P4; Clabburn (1993; George (1997); George (2006) George & Stone (1979), Richardson, Compton & Whitely (1997) P3.

Quarters Pond (see **Reservoir Pond**)

Quarry Pond or **William Heard's Quarry Pond** – SS 1375 4503 (Plate 2).
This is a very sheltered body of water, 22 x 11 m. It is a true deep quarry pool overshadowed by steep rocky walls and some willow trees. It is fed by a small stream falling over granite boulders and has a shallow swampy outlet on its eastern side through a path of weeds and willows. It is used as a watering hole by horses, sheep, cattle and deer. Langham's Map references it as Quarterwall Quarry Pond
Reference: Hemsley in Fraser-Bastow (1949) Old Quarry; Galliford (1953) 8 Old Quarry Pond; Langham (1968) Quarterwall Quarry; George (1997); George, McHardy (Stone) & George (2003); George (2006) Quarry Pool

Quarter Wall Ponds
Originally there were four ponds marked on the 1906 Ordnance Survey map but currently there are three in existence.
Quarter Wall Pond 1 – SS 1361 4493 although classed as a permanent pond, it does dry out in exceptionally dry summers. It is the largest of the ponds formed from an excavation in the rock. It is an open body of water 19 x 12 m with steep rocky banks and only a few weed beds. Situated at a high level on the island's eastern side, it probably receives little surface drainage. It has no outlet.
Quarter Wall Pond 2 – SS 1359 4491 to the south of Pond 1 is a temporary shallow weedy pond with no open water. It is situated in a depression (3 x 6 m) in a marshy area

where there are stands of soft rush. Its edges are marshy with a few large rocks. Its depth varies according to weather conditions with a maximum recorded depth of .0.3m. In dry periods, for example the summer of 1995 and summer/autumn 2003, it dries up altogether. There is a small outlet on the eastern side which drains into a ditch on the north side of Quarter Wall. This drains over the eastern sidelands and is joined by the increasingly pond like boggy area to the south of the wall.

Quarter Wall Pond 3 – SS 1361 4498 to the north of Pond 2 is a weedy depression approximately 30 x 8 m in size. It is mainly overgrown with weed, but there is a small area of open water much used by Mallard in the breeding season. It eventually forms a small stream which drains over the eastern sidelands via a channel near to Belle Vue Cottages.

Reference: Galliford (1953) 5, 5a; Langham (1968) Quarterwall Ponds; George (1978) Quarterwall Ponds 1 and 2; George & Stone (1979); George, McHardy (Stone) & George (2003); George 1997; George 2006, Richardson, Compton & Whitely (1997) P2.

Ray's Pool (see **St Helen's Spring**)

Reservoir or **Quarters Pond** – SS 1364 4403

A large artificial pond in the south-eastern corner of Lighthouse Field. St John's Stream (see entry) flows into and out of it. It is part of the island's water supply system.

Reference: Langham (1968) P21.

Rocket Pole Ponds

There were four sites here numbered from west to east. Currently only two are to be seen:

Rocket Pole Pond 1 – SS 1348 4368, is a steep sided deep body of freshwater excavated in the granite near the South-West Point. It is 25 x 11.5 m in size and up to 2.2 m in depth with its western side stepped and much shallower. There is no through drainage. It is fully exposed to the prevailing westerly winds. It is frequently coloured green by an algal bloom.

Rocket Pole Pond 2 – **Kistvaen Pond** – SS 1355 4369 is the large depression to the east of Rocket Pole Pond. A temporary autumnal pond, it contains some water at some times of the year. At other times there is no water at all.

Reference: Galliford (1953) 1 Rocket Pond and Rocket Pole temporary 11; Langham (1968) Rocket Pole Ponds; George & Stone (1979); George (1997); George, McHardy (Stone) & George (2003); George (2006), Richardson, Compton & Whitely (1997) P1a, P1b, P1c, P1d; Rowland (2020).

St Helen's Spring – SS 1385 4422

Situated at the bottom of the field below Barton Cottages. It is a spring fed pool with a maximum depth, in January 2006, of 0.75m. It lies adjacent to the eastern wall above the sidelands where it sources St Helen's stream (see entry). Not to be confused with St Helen's Well which is now, lost.

Reference: Langham (1968) E11, George (2006) (Ray's Pool); (St Helen's Well).

Sheep Dip – SS 13705 44193
This stood in the farmyard between Barton Cottages and the Slaughterhouse and should not be confused with the original sheep dip now lying disused in the corner of Brick Field (see **Brick Field Well**). In May 2010, it lay disused with the surface covered in *Lemna* sp. Duckweed. By 2020, following a visit by the island's Health and Safety Officer, it had been filled in.

South-West Field Pond – SS 1324 4397 (Plate 4)
A man-made dam created on the western cliff edge of the South West Field across Southwest Field Stream (see entry) forms a square pool used for watering stock. It consists of several courses of field stone with an overflow pipe in its centre.
Reference: Langham (1968).

Temporary Pools at the North End
A series of shallow ponds marked on the Ordnance Survey map on the area that was burnt in a major heathland fire in 1933. They are shallow depressions in the solid granite with a bottom of loose quartz and, increasingly, more flora. A series of four were seen in February 2010. Up to 25 such temporary pools can be identified in very wet years. (e.g. June 2012).
Temporary North End Pond 1 – SS 13163 47275 – approximately 32 x 10m.
Temporary North End Ponds 2, 3, and 4 – centred on no 3 – SS 13223 47236 10 x 2, 19 x 5 and 10 x 3 respectively north to south. See also **Johnny's Pool**.
Reference: Galliford (1953) 10; Langham (1968) P1, Richardson, Compton & Whitely (1997) P4 North End Pond.

Tillage Field Pond – SS13805 44460
A depression at the extreme eastern edge of Tillage Field much used by domestic stock. There is an outflow under the fence which forms Tillage Stream (see entry).

Widow's Tenement Pond – SS 1346 4682
In a boggy area due east of the location of telegraph pole No 66 is a cattle pond about 12 m in diameter with a muddy bottom. In February 2010 this was measured at 10 m (N–S) x 14 m (E–W) partially encircled by *Juncus articulatus* (jointed rush) and containing *Potomageton* sp. pond weed and other water plants.
Reference: Galliford (1953) 12; Langham (1968) P2; Rowland (2014); George & Rowland (2016).

WELLS – LENTIC WATERS

Many of these wells are listed by Langham (1968) with the prefix "P" indicating them as ponds. I have separated out the obvious wells. Plate 6 illustrates two examples of wells on Lundy, the Old Hospital and Airfield wells.

Airfield Well – SS 13241 44399 (Plate 6 lower)
An otherwise unidentified and un-investigated well covered in rusting corrugated iron measuring 0.9 m square with a depth of 1.75 m of which 1.07 m was water.

Plate 6. Old Hospital Cottages (upper) and Airfield (lower) Wells.

Battery Cottage Tank – SS 1279 4491
Stone reservoir immediately adjacent to the easternmost cottage and the side of the path.
Reference: Langham (1968) P9.

Belle Vue Cottages Pump house – SS 1375 4495
Well-marked by a granite square filled with rubble. 2.5 x 2m.
Reference: Rothwell & Ternstrom (2006).

Benson's Borehole –SS1351 4388
A small concrete depression about three feet square, being a concrete cover to borehole made in search of reputed treasure to a depth of 500 ft.
Reference: Langham (1968) P28, Langham (1991), Gade (1978).

Brick Field Well – SS 13674 44561
In the south-west corner of Brick Field, a two metre square, shallow well. This is the original Sheep Dip. It is situated at a blocked gateway which led into the Airfield, the north bank being defined by a fallen gatepost. It is the source of Brick Field Stream, the outflow is piped under the gateway to Tillage Field from where it runs the length of Brick Field before flowing down the eastern sidelands.
Since 2020/21, the area was enclosed as a pig run and the site may not now be visible.
Reference: Gade (1978).

Bull's Paradise or **Fowl Run Well** – SS 13671 44237
10 x 10 x 5 m deep. A covered reservoir and open well 6 x 4 x 2 m deep built by the Granite Company. Although listed separately by Langham, they are probably the same structure.
Reference: Langham (1968) P15 or 16.

Church Pond – SS 1368 4396
Overgrown pond in the field due west of the Church. In February 2010 this was a 1 m concrete well with rusting corrugated iron covering showing an abundance of *Lemna sp*. Duckweed.
Reference: Langham (1968) P25.

Golden Well – SS 1385 4384
Originally a large, fenced pool on the reputed site of Golden Well, a source of St John's Stream between the Church and Castle Hill and named for the colour the silt gives to its water. Golden Well was concreted, cleaned out, and a filter-bed added so that Bramble Villa would have a better supply and quality of water (Gade, 1978). The outflow runs down towards the crenelated wall at the top of St John's Valley where it runs under the road at SS 13895 43875.
Reference: Galliford (1953) 2; Langham (1968) P29.

Greensward Cistern – SS 13743 44080
Collects surface water from farm area, which is carried across the main path by pipe. This is now disused but is located beneath the seats in 'the Nook'.
Reference: Langham (1968) P20.

Millcombe Well – SS 1401 4402
Dipping well beside the main track by the entrance to Millcombe House drive, taking the flow from stream St John's Stream and adjacent to the freshwater pump house. This is also known as Lodore, possibly from the colour of the water (Golden Water) with reference to the poem *The Cataract of Lodore* by Robert Southey 1820.
Reference: Langham (1968) P23.

Old Hospital Cottages Well – SS 13629 45051 (Plate 6 upper)
A well at the eastern side of the central path constructed for the cottages, the foundations of which are still apparent. 0.4 x 0.4 m, 1.25 m in depth of which 0.5 m is water.
Reference: Langham (1968) P5 Quarter Wall cistern.

Old Light Wells – SS 13216 44281
Two adjacent covered wells within compound of the Old Lighthouse.
Reference: Langham (1968) P12 & 13.

Parson's Well – SS 1333 4415
South-West Field – in the area close to the Friar's Garden but not currently visible.
Reference: Galliford (1953) Spring in Friar's Garden Field, 13; Langham (1968) P18.

Quarter Wall Cottages Well – SS 13552 44929
West of the track behind the foundations of Quarter Wall Cottages which it served. 0.55 x 0.75 m and 1.75 m deep of which 1.35 m is water.

St Helen's Well – SS 1338 4418
Although recorded by Langham this can no longer be located but is marked on the Ordnance Survey map by the symbol for a Site of Antiquity in St Helen's or Barton Field.
Reference: Langham (1968) P17.

St John's Well – SS 13913 43898
There are three candidates for this well.
1. St John's Well is located on all Ordnance Survey maps just below the beach road on the south side of St John's Valley. Water wells up from there before joining the stream at SS 13913 43898. Smith (1959) reports it as being "close to the road, but some feet below its level, about 200 yards above the bungalow (Brambles)". He gives further information on the valley "In St John's Valley, mid-way between the top wall and the bungalow, can be seen the remains of a dam which once stood there."
2. At the junction of this road and the road between the Castle and Village there is a square structure which once was roofed and contained water which fed into a drinking trough at the side of the Beach Road. Covered well at junction of roads at top of St. John's valley SS 1390 4386.
3. At the head of the valley is a stone and brick structure located immediately adjacent to the boundary wall. It is heavily overgrown with *Rubus* sp Brambles. Water feeds the well from the road into the square structure forming a heavily vegetated but shallow pool about 5-6 cm in depth.

It takes run-off from the road which collects in the shallow 2 m square well before overflowing down St John's Valley. SS 13878 43909.
Reference: Langham (1968) P27, Smith (1959).

Stoneycroft Well – SS 13283 44271
Located in the south-west corner of the front garden at Stoneycroft. It is a Trinity House construction. Covered well approx. 3' x 3' and 11 ' deep. "A true well- never known to run dry."
Reference: Langham (1968) p. 14.

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A PRELIMINARY SURVEY OF AQUATIC HYPHOMYCETES IN LUNDY STREAMS

by

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ABSTRACT

Aquatic hyphomycetes are fungi which colonise and decompose detritus in freshwater, especially material from terrestrial plants, and are known to be important components of the food web, particularly as a food source for freshwater invertebrates. Microscopy was used to make counts of conidia (spores) of these fungi, which are often trapped in clots of foam, by removing foam samples from selected streams on Lundy to compare the species present and their approximate abundance. A total of 25 taxa were found, most of which are illustrated by micrographs. Many were new records for Lundy. Tentative interpretations of conidium numbers/ species diversity of samples are made and conclude they may be related to three factors: the relative length of the streams; the differences in the quality of the plant litter entering the streams; the time of year the samples were taken.

Keywords: *Lundy*, *fungi*, *aquatic hyphomycetes*, *freshwater streams*, *ecology*, *lotic*

INTRODUCTION

Aquatic hyphomycetes are fungi found in fresh or brackish water, although they may not be exclusively aquatic and can occur on plant remains away from water bodies. Many form spores with arms, often four in number, termed tetra-radiate, but also less frequently with more branches. Another shape is also common, sigmoid (S-shaped) also termed anguilliform, since it resembles nematode worms. The English mycologist Terence Ingold is credited as the founder of studies of these fungi, which he found growing on decaying alder (*Alnus glutinosa*) leaves in a stream (Ingold, 1942), since when many more 'Ingoldian hyphomycetes' have been described, with several hundred known to date. Plate 1 is a micrograph of a foam sample from the Quarter Wall Copse North Stream showing a mixture of branched and s-shaped spores.

The term hyphomycete is now somewhat redundant and referred to species which produce spores, often termed conidia (singular, conidium), without any 'sexual' process involving meiosis. Many are now known to be forms (anamorphs) of Ascomycota fungi whose 'sexually' produced fruit bodies are termed the teleomorph. In some cases

Plate 1. A group of Aquatic Hyphomycete conidia (and a pollen grain) in a foam sample from Quarter Wall Copse North Stream, collected in November 2021.

aquatic hyphomycetes species have been linked to teleomorphs which are species in the Ascomycota, by both observation e.g. Webster (1992) and molecular phylogenetics e.g. Baschien (2006), Johnston & Baschien (2020). Some species are in the order Helotiales (especially family Helotiaceae), forming minute cup or button-shaped fruit bodies (apothecia)on woody debris in or near freshwater, but other taxa are linked to different Ascomycota families and a few have Basidiomycota affinities (Webster, 1992).The relative roles of anamorph and teleomorph spore types in the biology of these fungi may include a differential dispersal strategy, the anamorph conidia being adapted to dispersal in the stream environment, as discussed below, whereas the teleomorph ascospores are air-dispersed and could provide a means of returning the fungi to the headwaters of the stream. The population structure of these fungi is now known to be much more complex than being entirely aquatic and they have now been found in a range of terrestrial environments, both as saprotrophs on plant remains (Bärlocher & Boddy, 2016) but also as endophytes within living roots and leaves (Sokolski *et al.,* 2006, Lazar *et al.,* 2022).

Both the branched and s-shaped conidia were shown in 'water tunnel' experiments in the 1970's by Webster and his colleagues at the University of Exeter to impact with greater efficiency onto surfaces as compared to rounded spores (Iqbal & Webster, 1973). This gives good retention on debris in streams and the conidia respond quickly to contact by forming appressoria which stick them in place with mucilage, followed by penetration and colonization of the plant materials, including leaves twigs and larger woody debris, that have fallen into the stream or pond (Read *et al.*, 1992) as well as to aquatic plants like *Potamageton* (Bärlocher, 2016).

These fungi are found throughout the world in streams but also in still bodies of water such as ponds and lakes and in very small volumes of water in temporary pools, including ones in tree boles (Bärlocher, 1992) and in cryoconite holes, water-filled depressions on glaciers (Edwards *et al.,* 2013). They also occur and disperse in terrestrial habitats (Bärlocher & Boddy, 2016). In freshwater they are part of a food web largely based on terrestrial plant remains entering the water, including leaves, fruits, seeds, twigs and wood (termed allochthonous) rather than on the primary production within the water body by algae and aquatic plants (termed autochthonous). As such they act as 'energy intermediates' for stream invertebrates (Bärlocher, 1985 & 2016; Koehn, 2016) by processing the low-quality food resources into a higher quality, at least for a time, by digesting the cellulose and hemicellulose in the material and converting it to fungal mycelium. Experiments have shown that many detritus-feeding invertebrates, especially shredders such as caddis and mayfly larvae, prefer feeding on leaves colonized by these fungi (Suberkropp, 1992) and some can even thrive on pure cultures. However, these experiments show that not all species of these fungi are equally palatable. There are also differences in preferences amongst the fungi: leaves of some broad-leaved tree species like Alder have a more diverse community of hyphomycetes than others such as oak (*Quercus* sp.). Communities on leaves of grasses and sedges are depauperate compared to broad-leaved tree leaves, and streams arising on moorland are thus species-poor compared to those running through deciduous woodland (Shearer & Webster, 1985a).

These fungi are found throughout the world in streams and still bodies of water such as ponds and lakes or even in very small volumes of water in temporary pools (Bärlocher, 1992) but can also occur and disperse in terrestrial habitats (Bärlocher & Boddy, 2016). They are part of a food web largely based on terrestrial plant remains entering the water, including leaves, fruits, seeds, twigs and wood (termed allochthonous) rather than on the primary production within the water body by algae and aquatic plants (termed autochthonous). As such they act as 'energy intermediates' for stream invertebrates (Bärlocher, 1985 & 2016) by processing the low-quality food resources into a higher quality, at least for a time, by digesting the cellulose and hemicellulose in the material and converting it to fungal mycelium. Experiments have shown that many detritus-feeding invertebrates, especially shredders such as caddis and mayfly larvae, prefer feeding on leaves colonized by these fungi (Suberkropp, 1992) and some can even thrive on pure cultures. However, these experiments show that not all species of these fungi are equally palatable. There are also differences in preferences amongst the fungi: leaves of some broad-leaved tree species like alder have a more diverse community of hyphomycetes than others such as oak (*Quercus* sp.). Communities of fungi on leaves of grasses and sedges are depauperate compared to broad-leaved tree leaves, and streams arising on moorland are thus species-poor compared to those running through deciduous woodland (Shearer & Webster, 1985a).

AIMS OF THE STUDY

The identification of these fungi in streams stems from the appreciation by Ingold in the 1940s that their conidia are trapped on small bubbles of air in water and then accumulate in clots of foam, leading him to publish in 1975 a Freshwater Biological Association guide to identification of conidia within foam samples (Ingold, 1975). Microscopy of samples thus gives an idea of species diversity and this has been the approach used in our own study of Lundy streams. Hedger & George (2018) listed four species in their account of the fungi of Lundy, all of them from foam collected from Pondsbury in October 2003 (Hedger & George, 2004). The current database of Lundy fungi to be found on the Lundy Field Society website (www.lundy.org.uk/index.php/about-lundy/wildlife-on-the-island/fungi) includes these four records. The opportunity to extend the study to Lundy streams came in November 2021 and March 2022 when visits to the island by the authors coincided with many being swollen by recent rains and as a result forming foam clots which could be sampled for conidia.

METHODS

Foam from the streams was scooped up with a petri dish bottom and dropped into to a 5 ml plastic vial using a teaspoon. Plate 2 shows sampling in progress next to the Millcombe Pond stream in March 2022. Plate 3 shows a foam raft on the stream in Quarter Wall Copse, also in March 2022. Denatured 100% Ethanol was then gently added with a pipette to dissolve the foam bubbles and fix the conidia, giving a volume of 1-2 ml per tube. Tubes were labelled with site and date and stored at room temperature. To identify the conidia present, the sediment from the bottom of the tube was carefully removed with a needle-pointed 1 ml syringe graduated to 0.01 ml and syringed out into a vial then withdrawn again to mix it. A drop of 0.1 ml was added to a microscope slide and a 2 x 2 cm coverslip dropped onto it. A preliminary examination was made using the x 10 objective (x 100 magnification) of the microscope. If there were many conidia present, then counting/identification was carried out in 10 random microscope fields of the x 40 objective. These counts were converted to approximate numbers in 0.1 ml suspension by measuring the field diameter using a calibration slide and using πr^2 to calculate the area of the field. The ratio of the field area to the area under the coverslip (400 mm^2) was used to calculate numbers of conidia per 0.1 ml of suspension. If there

Plate 2. Field sampling of foam.

Plate 3. Foam in Quarter Wall Copse North Stream.

were few conidia found in the preliminary scan of the preparation, then the whole of the coverslip area was counted by longitudinal traverses using the x 10 objective, using the x 40 or x 60 objective to identify the conidia, and this was considered to be the approximate number in 0.1 ml.

These counting procedures were only semi-quantitative, one error being the distribution of the conidia under the coverslip, which was not random in spite of attempts to break up clumps. In addition, the field sampling itself was also not standardized since some foam masses were large, others small and the volume removed differed somewhat at each site. Nevertheless, we feel the data do give some indication of relative abundance and diversity of aquatic hyphomycetes in Lundy streams.

RESULTS

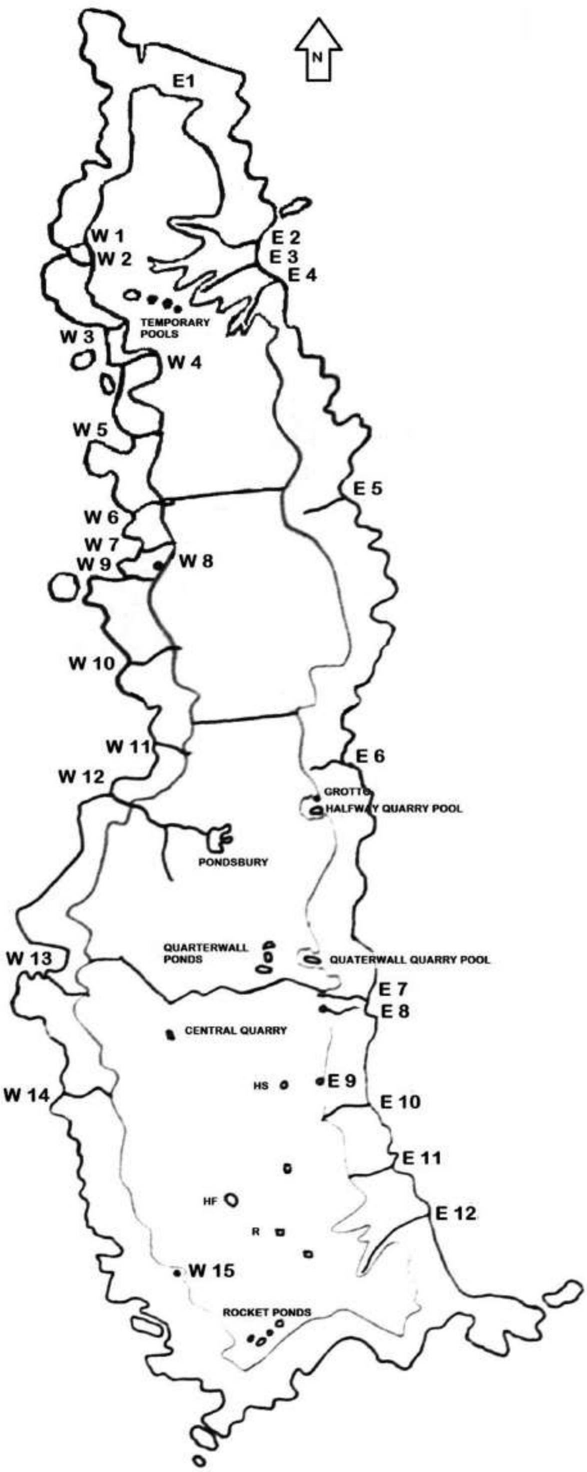
Location of the streams sampled and their characteristics

East Side The streams on the east side have a varied flora of herbaceous and woody plants, except for those which rise and flow north of Halfway Wall which run through unimproved grassland and waved heath. From north to south the streams sampled were:

Gannets' Combe Complex (Sample Date: 15 March 2022)
Gannets' Combe North comprises at least three distinct streams, heavily overgrown with bracken and grasses, flowing from around the central footpath eastwards into Gannets' Bay where some converge before falling over the cliff edge into Gannets' Bay.

The northern branch of the main stream rises in the waved heath at SS 13324 47492 and runs for 169 m. The southern branch rises near the central track as SS 13290 47238 and runs for 262 m. They converge at SS 13437 47422 before flowing a further 83 m to the cliff edge at SS 13537 47442 where samples were taken. The vegetation through which they flow is mainly unimproved grassland, bracken (*Pteridium aquilinum*). and tussock sedge (*Carex paniculata*). Longest length is 345 m.
Gannets' Combe South a stream 175 m south of the North Stream rises at SS 13526 47131 within a short grassy valley between two granite outcrops. It flows eastwards for 182 m to the cliff edge where it was sampled at SS 13560 47227. The vegetation through which it flows is also unimproved grassland, bracken and tussock sedge.

Quarter Wall Stream (Sample Date: 04 November 2021)
This stream rises on the north side of Quarter Wall which forms the northern boundary of Brick Field by Quarter Wall gate SS 13565 44885. It then flows east to the Upper East Side Path where it is joined by a stream on the south side of Quarter Wall at SS 13788 44887 which drains from Brick Field Pond SS 13706 44900. Quarter Wall is a typical Devon hedge hosting many herbaceous plants and woody plants including bramble *Rubus* sp., bracken and gorse *Ulex* sp. From the Upper East Side Path, they form a braided stream which flows down the steep sidelands through Quarter Wall Copse comprising turkey oak (*Quercus cerris*), alder (*Alnus glutinosa*), birch (*Betula* sp.) and rowan (*Sorbus aucuparia*) before flowing under the Lower East Side Path then over the cliff edge in Quarter Wall Bay SS 13969 44825, a total of 457 m. Samples were taken



Taken from two sketch maps by A.L. Langham (1969) 'Water courses and reservoirs on Lundy' located in Western Studies Library (*Bho sxB/LUN/LAN/836 Box 55*). Streams which were sampled during the survey are in bold.

West Side

W1-3 unnamed
W4 **St Peter's Stone Stream**
W5 unnamed
W6 Threequarter Wall Stream (west side)
W7 unnamed
W8, 9 **St Mark's Bay Stream**
W10 **Pyramid Stream**
W11 Butler's Pantry Stream
W12 **Pondsbury / Punchbowl Stream**
W13 Battery Stream
W14 **Old Light Stream**
W15 **Southwest Field or Pilots Quay Stream**

East Side

E1 Constable Rock Stream
E2–4 **Gannets' Combe Complex**
E5 Threequarter Wall Stream (east side)
E6 Halfway Wall Stream
E7, 8 **Quarter Wall Stream (either side of wall)**
E9 Brickfield Stream
E10 Tillage Field Stream
E11 St Helen's Spring
E12 **St John's & Millcombe Streams**

Figure 1. Locations of the streams sampled during the survey.

in the copse from the northern (= **Quarter Wall Copse North)** and southern braids (= **Quarter Wall Copse Central**) at SS 13922 44835.

St John's Stream (Sample Dates: 02 & 06 November 2021)
This stream rises in boggy areas in Lighthouse Field SS 1355 4409 which is improved and heavily cropped grassland with outcrops of soft rush (*Juncus effusus*). It then flows through Quarters Pond SS 1364 4403 which is surrounded by dense rushes then via the staff vegetable gardens where the first sample was taken, and under the helipad before emerging at the side of Square Cottage. The stream has been canalised to the top of St John's Valley but has pond water-starwort (*Callitriche stagnalis*) and hemlock water dropwort (*Oenanthe crocata*) in its bed. At the head of St John's Valley SS 1388 4391, it receives runoff from the Golden Well area then flows through unimproved grassland with tussock sedge, soft rush, bracken, bramble and a small, stunted copse of willow (*Salix* sp.) before reaching Brambles Villas SS 1397 4397 where it is culverted under the access road and emerges in a sycamore (*Acer pseudoplatanus*) copse with ground cover of common nettle (*Urtica dioica*). Emerging from this at Lodore, an animal drinking trough, it runs under the road into Millcombe Gardens where it is joined by Millcombe Stream the bed of which hosts hemlock water dropwort and has been canalised and lined with shale blocks. The combined flow then cascades into Millcombe Pond SS 1404 4403 which is heavily covered with yellow iris (*Iris pseudacorus)* and hemlock water dropwort before emptying into the sea through Smelly Gully a total length of 750 m.

Samples were taken at four locations, below Quarters Pond SS 1364 4403, at the head of St John's Valley SS 1388 4391, adjacent to Brambles Villas SS 1397 4397and below the cascade at Millcombe Pond SS 1404 4403.

West Side Most of the streams on the west side flow through unimproved grassland and/or heath with no trees or shrubs on their banks. The exceptions are two streams, one arising from Pondsbury and flowing down the Punchbowl Valley, the other draining the south side of the valley. Both run through the edges of the creeping willow (*Salix repens)* forest. The remainder of the streams contain a limited flora, typically of soft rush, common spike rush (*Eleocharis palustris*), *Potamogeton* sp. and in some cases bog St John's-wort (*Hypericum elodes*) and various *Sphagnum* species. From north to south, the streams sampled were:

St Peter's Stone Stream (Sample Date: 15 March 2022)
This stream drains the northern western edge of Widow's Tenement. Rising in marshy ground SS 1345 4696, the stream runs westwards via two dammed pools, one each side of the path crossed by stepping stones SS 1333 4697 with an abundance of bog St John's-wort, *Potamogeton* species and soft rush before flowing through a broad grassy valley between granite outcrops where the sample was taken SS 1324 4700 then over the cliff into the Atlantic, a total of 338 m.

St Mark's Bay Stream (Sample Dates: 10 November 2021 & 14 March 2022)
This is a short stream rising south of Threequarter Wall SS 1346 4647 and draining the western side of Middle Park near where the telephone spur ran from the west side of

Lundy to the signal station at Tibbetts. It has been dammed to produce a moderate sized pool with muddy bottom where it was sampled at SS 1332 4643 and hosts sphagnum and bog St John's wort in its 265 m length.

Pyramid Stream (Sample Date:10. November 2021 & 15 March 2022)
This is a fair-sized stream which rises in the unimproved grassland and rushes of Middle Park at SS1348 4610. It flows due west and widens into two pools beside the path. There is little vegetation in the stream other than sphagnum and rushes, and the lower pool is practically silted up. It is a short stream of 400 m. Samples were taken at SS1329 4609 west of the western footpath.

Pondsbury / Punchbowl Stream (Sample Date: 03 November 2021 & 15 March 2022)
The outflow of Pondsbury SS 1341 4545, and named Pondsbury Stream, is 250m in length and flows down the shallow upper Punchbowl Valley through heathland with tall purple moor grass (*Molinia caerulea)* and large patches of creeping willow (*Salix repens*); the Punchbowl Stream drains the low hills south of Pondsbury, originating in the purple moor grass-dominated heathland at SS 1326 4520 and flows 283 m to their confluence at SS 1317 4548 near the Punchbowl, above which the two streams were separately sampled. The flow below this point consists of rapids, pools and small waterfalls interspersed with larger boulders and smaller rocks down Punchbowl Valley into the Atlantic Ocean. The maximum length is 479 m.

Old Light Stream (Sample Date: 03 November 2021 & 23 March 2022)
This stream is north of the Old Light and develops from a spring at the western end of the airfield at SS 1325 4446. The spring appears after wet weather and is absent for most of the year. It flows west into Old Light Pond, the marshy pool north of the Old Light below which it was sampled SS 1306 4456. Vegetation consists of unimproved grassland, bracken, sphagnum and rushes. From there it flows steeply down the cliffs into the Western Sidings as alternating areas of rapids, pools and small waterfalls interspersed with larger boulders and smaller rocks, a total of 450 m in length.

South West Field or **Pilot's Quay Stream** (Sample Dates: 02 November 2021 & 20 March 2022)
This short stream of 227 m rises in marshy ground in the field south of the Old Light SS 1329 4400 amidst unimproved grassland and rushes. It is dammed by a very substantial wall near the cliff top from where it falls almost vertically into the Atlantic Ocean. There can be much vegetation, mostly water starwort, *Potamogetan* and rushes in the resulting pool, which is near the footpath leading to Montagu Steps. It was sampled where the stream enters the pool at SS 13246 43937.

Appearance of the foam samples
The foam samples varied considerably in their size and colour: some were large clots, brown with trapped detritus; others were small and white. The colour was not an indication of spore loading in the foam. Some large brown clots on the west side streams contained very few conidia. The Quarter Wall Copse foam was white and clear (see

Plate 3) but microscopy showed it contained many conidia. The browner clots were always rich in cells of diatoms, including *Tabellaria* and *Navicula* species, probably released from the epiphytic algal communities on the aquatic plants and rocks.

Identities of conidia found in the foam samples

Identification of the conidia present was made using Ingold (1975): admittedly out of date but still the best review of the common species of these fungi. In the descriptions below we include some reference to more recent interpretations of the taxonomy and any relationships to ascomycete teleomorphs. Plates 4a–d shows micrographs of some, but not all, of the aquatic hyphomycete conidium-types we found. Spores of terrestrial species of fungi also occurred, the most obvious being the purple ascospores of the dung fungus *Ascobolus* c.f. *immersus.* Multiseptated ascospores of *Pleospora* species and dematiaceous conidia of *Articulospora tetracladia*, *Alternaria*, *Pestalatiopsis* and *Stemphylium* were common in a few samples and were probably from streamside vegetation.

Alatospora acuminata Ingold (Plate 4a top left)

A. acuminata was identified as small (5-15 µm long) tetra-radiate conidia with the two curved bluntly-pointed arms arising in the middle of a non-septate, also curved, axis. They resembled a butterfly or bird in form. It is very common in the UK and throughout the world in freshwater habitats and conidia were found in many of the foam samples but were most abundant in those from the Quarter Wall Copse streams. No teleomorph appears to be presently known, though DNA cladistics place the fungus in the Ascomycota Family Leotiaceae**.**

Anguillospora crassa Ingold (Plate 4a top right)

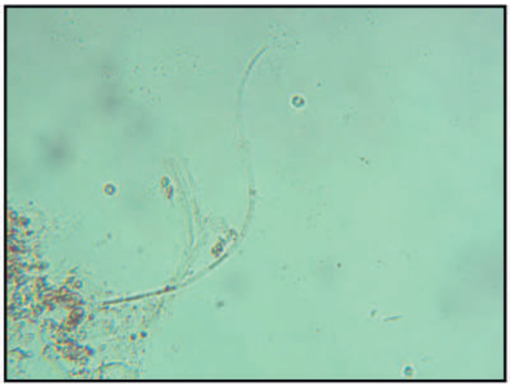
The s-shaped conidia of this species were easy to spot in samples due to their large size (around 75-100 µm long by 5-15 µm wide) and division into cells by 10-12septae. The example in Plate 4a has been stained with Methylene Blue. Most conidia had 10-15 cells, more than quoted in the literature (3-7). *A.crassa* is commonly found in foam samples throughout the UK. Webster (1961) considered its teleomorph was in the Ascomycota genus *Mollisia* (Order Helotiales), characterised by disc-shaped apothecia but more recent interpretations (Baschien, 2006) place it in the Order Pleosporales which have perithecial fruit bodies. On Lundy the conidia were widely distributed but most abundant in the Quarter Wall Copse samples. It was recorded on Lundy in 2003, from Pondsbury (Hedger & George, 2004).

Anguillospora longissima (De Wild) Ingold (Plate 4a middle right)

The very long (100-200 µm) S-shaped conidia of this species were often tangled within clumps of branched conidia of other Hyphomycetes and one can be seen in such a clump in Plate 1. Conidia were much narrower than conidia of *A. crassa* and also differed in the acutely pointed end, although the number of septae was about the same (10-20). *A. longissima* is commonly found in freshwater foam samples in the UK and like *A. crassa* has been placed by cladistics in the Ascomycota order Pleosporales, possibly in the genus *Massarina*. On Lundy it was widely distributed but it was most abundant in the

Alatospora acuminata

Anguillospora crassa



Anguillospora longissima

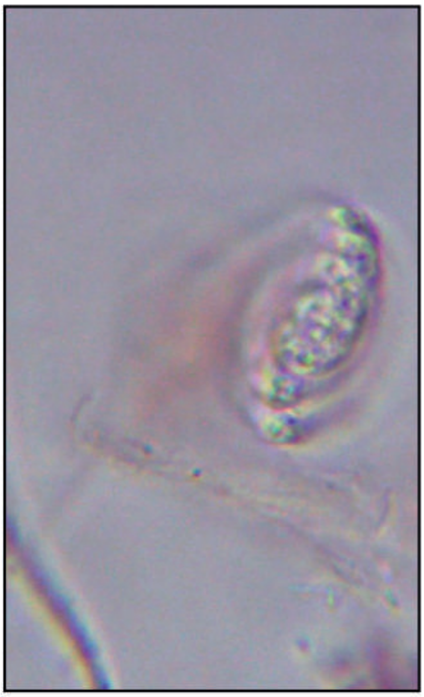
Articulospora tetracladia

Clavariopsis aquatica

Plate 4a. Spore micrographs.

Dactylella appendiculata

Heliscus lugdunensis

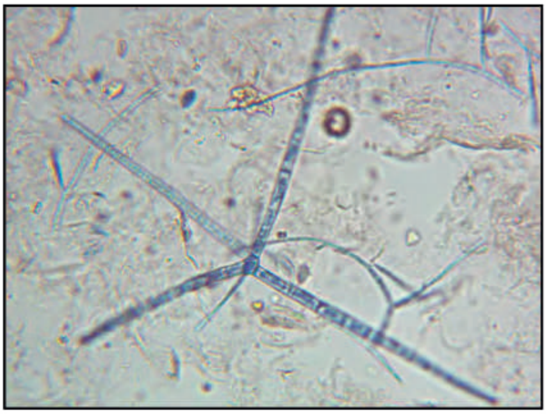


Gyoeffyella speciosa

Dendrospora erecta

Plate 4b. Spore micrographs.

Lateriramulosa uni-inflata



Lemonniera aquatica

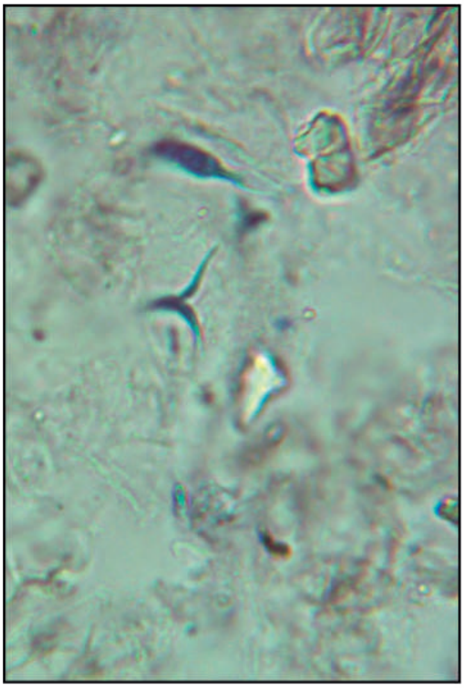
Tetracladium setigerum

Tetracladium marchalianum

Plate 4c. Spore micrographs.

Varicosporium elodeae

Tetrachaetum elegans



Volucrispa aurantiaca

Tricladium splendens

Plate 4d. Spore micrographs.

November sample of St John's Stream below Quarters Pond where it made up well over half the total count of conidia.

Two other conidia with elongated shapes were also found in the foam samples, *Flagellospora curvula* Ingold and *Lunulospora curvula* Ingold. The S-shaped conidia of *F. curvula* could be mis-identified as *Anguillospora longissima* but were separated by their lack of septae and a narrower diameter. Cladistics have now placed it in the Ascomycota family Nectriaceae. It has a wide distribution in the UK with a cluster of unconfirmed records for Devon (NBN Atlas). On Lundy it was only found in large numbers in the Quarter Wall Copse Streams.

L. curvula has a distinctively shaped conidium with a strongly curved crescent moon shape, lacking any septae and around 20-40 µm in length. NBN Atlas does not show it is as widespread in the UK as Ingold's 1975 statement that it is common. There is however a cluster of unconfirmed records for Devon. All of the Lundy records were for November 2021, when it occurred, though not abundantly, in half of the foam samples. No conidia were found in March 2022, perhaps confirming Ingold's view that the fungus prefers warmer conditions, so that the population declines in the winter months. Cladistics place it in the Ascomycotina subdivision Pezizomycotina. *L. curvula* has been previously recorded on Lundy by Hedger & George (2004), from Pondsbury.

Articulospora tetracladia Ingold (Plate 4a bottom left)
The conidia of this species have a distinct main axis with three once septate 'arms' at one end (Plate 2). A clear constriction at the junction of each arm and axis helped identification of this species in the samples, together with the length of the conidia - up to 200µm. The fungus is currently placed by cladistics in the Ascomycota order Helotiales though the teleomorph is not known. It has been widely recorded in the UK. Conidia were most abundant in the Pondsbury and Quarter Wall Copse North stream samples. Conidia of *A.tetracladia* had been previously found in foam samples from Pondsbury lake (Hedger & George, 2004).

Clavariopsis aquatica De Wild (Plate 4a bottom right)
The distinctive shape of this spore type made it easy to identify in samples, with one short wide septate arm with a narrow base and with three long (40-60 µm) non-septate narrow arms attached to the rounded top. The species has been found throughout the UK in freshwater foam. On Lundy conidia seemed to be restricted to the Quarter Wall Copse samples except for one record for Millcombe Pond in March 2022. It was described as early as 1895 by De Wild. Cladistics indicate it is within the Pleosporales order of the Ascomycota though no teleomorph appears to have been found.

Clavatospora longibrachiata (Ingold) Nilsson *and* ***Clavatospora stellata*** (Ingold & Cox) Nilsson
These conidium types were only found a few times, mostly in the Quarter Wall Copse North Stream but also in the St John's Stream at Brambles and in Millcombe Pond. No good images were obtained. The conidia were small, with a tapering main axis about 10 µm in length subtending three branches, around 8 µm long in *C. longibrachiata*. The

conidia attributed to *C. stellata* had a very short main axis and three very short branches, giving a stellate shape. They were very similar in appearance to those of *Heliscus lugdunensis* (described below) which however had a longer septated subtending branch. Both species seem to be placed in the Ascomycota order Sordariales by cladistics.

Dactylella appendiculata Anastasiou (Plate 4b top left)
The large size (60-80 µm long) and odd shape of the conidia of this fungus (Plate 4b) made it easy to identify though it was found infrequently, in the Quarter Wall Copse and the Pondsbury streams. The central part of the conidium consisted of two swollen cells, with a tapering tail cell at one end (the lower part in Plate 4b) and a narrower cell at the other from which three long straight appendages are directed backwards, though in the figure they appear folded (by damage). Ingold (1975) felt that the species should be removed from *Dactylella*, and it is now known as *Monacrosporium tentaculum* Rubner & Gams and placed in the Ascomycota Family Orbiliaceae.

Dendrospora erecta Ingold (Plate 4b lower right)
Large size (2-300 µm in length) and complex branching of the conidia of this species made it easy to identify. The conidia had a straight main axis, projecting to the right in Plate 4b with a cluster of branches arising from the base (to the left in the figure). Both axis and branches were divided into cells by numerous cross walls. It was only found once, in March 2022 in the Old Light Stream. However, in a more recent survey in November 2022 a sample of foam from St John's Stream in Millcombe was found to contain many conidia of the fungus, which is widespread in the UK. A member of the Ascomycota its classification beyond the Pezizomycotina sub-division remains unclear.

Gyoerffyella speciosa (Ingold) Miura (Plate 4b bottom left)
The curious spiral conidia of this species were once thought to be an alga. There is a central axis with a long tail which coils back on itself and encloses two or three tightly curved branches from the central axis which also have long tapering tails. The result is a tight flattened spiral surrounded by long projecting filaments. Lundy conidia were smaller than the description in Ingold (1975), around 20-30µm in diameter. *G. speciosa* is widely distributed in the UK but not common according to the NBN Atlas. Cladistics place it in the Ascomycota Family Discinellaceae. On Lundy we have only found it in the north branch of the Quarter Wall stream, so it seems to need, as it does elsewhere, woodland detritus.

Heliscus lugdunensis Sacc. & Therry (Plate 4b top right)
Ingold (1975) correctly describes the small (10 µm long) conidia of this species as clove-shaped, with a tapering basal cell and three short arms projecting from the sides of the broader apical cell. We only found it to be abundant in one foam sample (Quarter Wall Copse Central Stream in March 2022). The NBN Atlas shows it is widespread in the UK and it is known to be the anamorph of a *Nectria* teleomorph described as *N. lugdunensis* by Webster (1959), now considered to be *Neonectria lugdunensis* (Sacc. & Therry) L. Lombard & Crous. In Quarter Wall Copse the fungus probably colonises twigs of alder forming the conidia (*Heliscus* state) when it flows, but the teleomorph, a minute

rounded reddish perithecium, the *Neonectria* state, may occur on the same twigs when the stream dries out in the summer, a strategy proposed for this wood decomposing fungus by Shearer (1992).

Lateriramulosa uni-inflata Matsushima (Plate 4c top left)
The conidia of this species are very distinctive, with three sharply pointed arms subtended on a round central cell by a narrow neck. The micrograph shows an example from St John's stream at the valley top which was the only site where it was found during the survey. Cladistics place it in the Ascomycota as far as the Pezizomycotina subdivision and no teleomorph seems to be known. The NBN atlas shows very few records for the UK though there is one (unconfirmed) for Devon. The conidia are small (ours measured 5-10 μm) so may well be overlooked in foam samples.

Lemonniera aquatica De Wild (Plate 4c top right)
This species was easily identified in samples due to the length (50-100 μm) of the four straight arms of the tetra-radiate conidia. In the micrograph a conidium stained with Methylene Blue shows how the three arms radiate from a central point from which a fourth projects at 90 degrees. Cladistics show *L. aquatica* is in the Family Discinellaceae of the Ascomycota but no teleomorph has yet been found. Conidia were found the St John's Valley stream, a number of the West Coast streams and in the Quarter Wall Copse North Stream. The NBN Atlas shows it as widely recorded in the UK, including Devon.

Tetracladium species (Plate 4c bottom left and right)
The distinctive conidia of this genus have a main axis up to 20 μm long ending in rounded or finger-like projections and branches. *T. marchalianum* De Wild has one or two rounded central knobs plus two to four longer branches on either side, easily seen in the micrograph. In *T. setigerum* (Grove) Ingold there is a central group of three finger-like lobes bordered by two or three longer branches. Both conidium types were found in foam samples from seven out of the ten streams sampled in November 2021 but *T. setigerum* was much the commoner of the two and it was the only species found in the March 2022 survey. Both are widely distributed in the UK. Some smaller conidia were found in samples from the St. John's Stream at the valley top which corresponded to a third species, *T. maxilliforme* (Rostrup) Ingold, which resemble *T. setigerum* but only have two central lobes and two longer arms. The NBN Atlas shows this has been recorded much less frequently in the UK than the other two *Tetracladium* species. All three have been placed in the Ascomycota, Order Helotiales.

Tetrachaetum elegans Ingold (Plate 4d top right)
The tetra-radiate conidia of this species have a central curved axis with two curved side branches in the middle, making the structure bird-like in shape, clearly seen in the micrograph. Ingold (1975) correctly points out that the narrowness of the curved arms and axis and the length (up to 150 μm) make this species easy to separate from similar conidia such as *Lemonniera aquatica*. The NBN Atlas shows that *T elegans* is widespread in the UK and there are a number of unconfirmed records from S. Devon. Conidia were

not found in the November 2021 survey but were present in the Quarter Wall Copse, Pondsbury and Pyramid stream samples in the March 2022 survey. Cladistics have yet to assign it further than Ascomycota but it is likely to be in the order Helotiales.

Triscelophorus monosporus Ingold
The structure of the conidia of this species is similar to that of *Lemonniera aquatica* with three straight arms radiating from a central cell with another slightly longer arm at 90 degrees to them. However they are much smaller in size (10-20 μm length for each arm). It was found only once, in a sample from the SW Field Stream in November 2021. NBN Atlas data show it to be found infrequently in the UK and Ireland.

Varicosporium elodeae Kegel (Plate 4d top right)
Conidia corresponding to this species were easy to identify due to their large size (100-250 μm in length) and complex but irregular pattern of branching of arms arising from a central axis, sometimes with additional branches arising from the arms. They were often tangled together in small clumps in the foam. The conidium illustrated is relatively simple with one pair of arms and one solitary arm. Cladistics have placed the genus in the Ascomycota Family Helotiaceae. NBN Atlas records show it to be common in the UK. We found it widely in the November 2021 survey, sometimes abundantly, as in St John's stream below Quarters Pond, but conidia were much less frequent in the March 2022 samples. As the name implies, *V. elodeae* was first described on dead shoots of the waterweed *Elodea canadensis* by Kegel in 1906 but most records are from terrestrial plant litter and wood in water, as well as soil and litter well away from water (Bärlocher, 1992). There is one existing record of it for Lundy, from Pondsbury in 2003 (Hedger & George, 2004).

Varicosporium delicatum Iqbal
We identified this species on the basis of branched conidia which were in structure and size like *V. elodeae* but with much narrower axes and branches, which were also curved. Ingold (1975) remarks that the conidia often break up and we often found curved sections, as well as intact structures, making for possible confusion with *Anguillospora longissima*. It seems to have a similar UK wide distribution to *V. elodeae* and NBN lists 69 records. Only one foam sample contained conidia of this species, from the Pondsbury Stream in November 2021.

Volucrispora aurantiaca Haskins (=*Tricellula aurantiaca* (Haskins) Von Arx.) (Plate 4d lower left)
The minute (5-8 μm long) conidia of this species had two short curved and pointed arms in the middle, correctly likened to birds' wings by Ingold 1975. They showed up best in foam samples when the preparation had been stained with Methylene Blue. In practice it was difficult to separate conidia of this species from those of the similar *Volucrispora graminea* Ingold which differed in having only one branch on the main axis, creating a Y shaped structure. The NBN Atlas shows neither species as being widely recorded in the UK. Both species were infrequent in the Lundy stream samples, except for the St John's Stream below Quarters Pond in November 2021.

Tricladium splendens *Ingold* (Plate 4d lower right)
The tetra-radiate conidia of this species were relatively easy to distinguish due to the length of the pointed curved main axis (80-100 μm) and its division into wide (up to 10 μm) cells. Two septate branches were attached to the blunt basal cell and penultimate cell, shown clearly in the micrograph and can arise on either side of the axis or on the same side. A range of morphologies and sizes of conidia were found in the samples, some of which could have been assigned to other species of *Tricladium* described in Ingold (1975) such as *T. attenuatum* Iqbal but were all recorded as *T. splendens*.

The genus *Tricladium* is included in the Ascomycota, Order Helotiales and the NBN Atlas shows *T. splendens* occurring widely in the UK, including a number of localities in Devon. On Lundy it occurred in four out of ten stream samples from November 2021 and six out of the twelve March 2022 samples and was most abundant in the Quarter Wall Copse North Stream in November sample, though absent in March 2022.

A number of *Tricladium*-like conidia were found in the Pondsbury Stream foam samples in which a side branch, usually from the basal cell, subtended a further branch, corresponding to the description of *Pleuropedium tricladoides* Maranova & Iqbal in Ingold (1975) and have been recorded as such, though without complete confidence.

Abundance of aquatic hyphomycete conidia in the foam samples
Numbers of species in stream samples The data for the numbers of species of Hyphomycete found in each stream in the November 2021 and March 2022 surveys are summarized in Figure 2.

The highest species count in both years was in foam from the Quarter Wall Copse streams. Fourteen taxa were found in November 2021 in the North Stream sample. The March samples of the North Stream were also the most diverse though with a lower species total (nine). The Central Stream foam, only sampled in March 2022, had eight taxa, most being the same as in the North stream. Some of the conidia in the Quarter Wall Copse streams were not found elsewhere on Lundy, such as *Clavatospora longibranchiata*, *C. stellata* and *Gyoerffyella speciosa*. *Tricladium splendens*, *Articulospora tetracladia* and *Alatospora acuminata* had the highest conidium counts.

The other high species counts were from the St John's stream sites in November 2021 (at 750 m the longest stream by far). The greatest numbers of conidia were in the foam below Quarters Pond and there were a lower number downstream at the valley top and at Brambles. A feature of the foam below Quarters Pond was the abundance of two of the conidium-types: *Varicosporium elodeae* and *Anguillospora crassa*. These species were almost absent from foam at the valley top and at Brambles. The count was 960 conidia/ 0.2ml suspension for *Varicosporium elodeae* below Quarters Pond but a zero score at the valley top and just one conidium at Brambles. Although present in foam in some of the other streams conidia of these two species were always in very much lower numbers.

The Pondsbury stream samples were the only ones which approached the diversity of the Quarter Wall Copse and St John's streams with 11 taxa found in November and five in March. There were even a few taxa in common with the Quarter Wall Copse streams, including *Dactylella appendiculata* in November 2021. The Punchbowl stream,

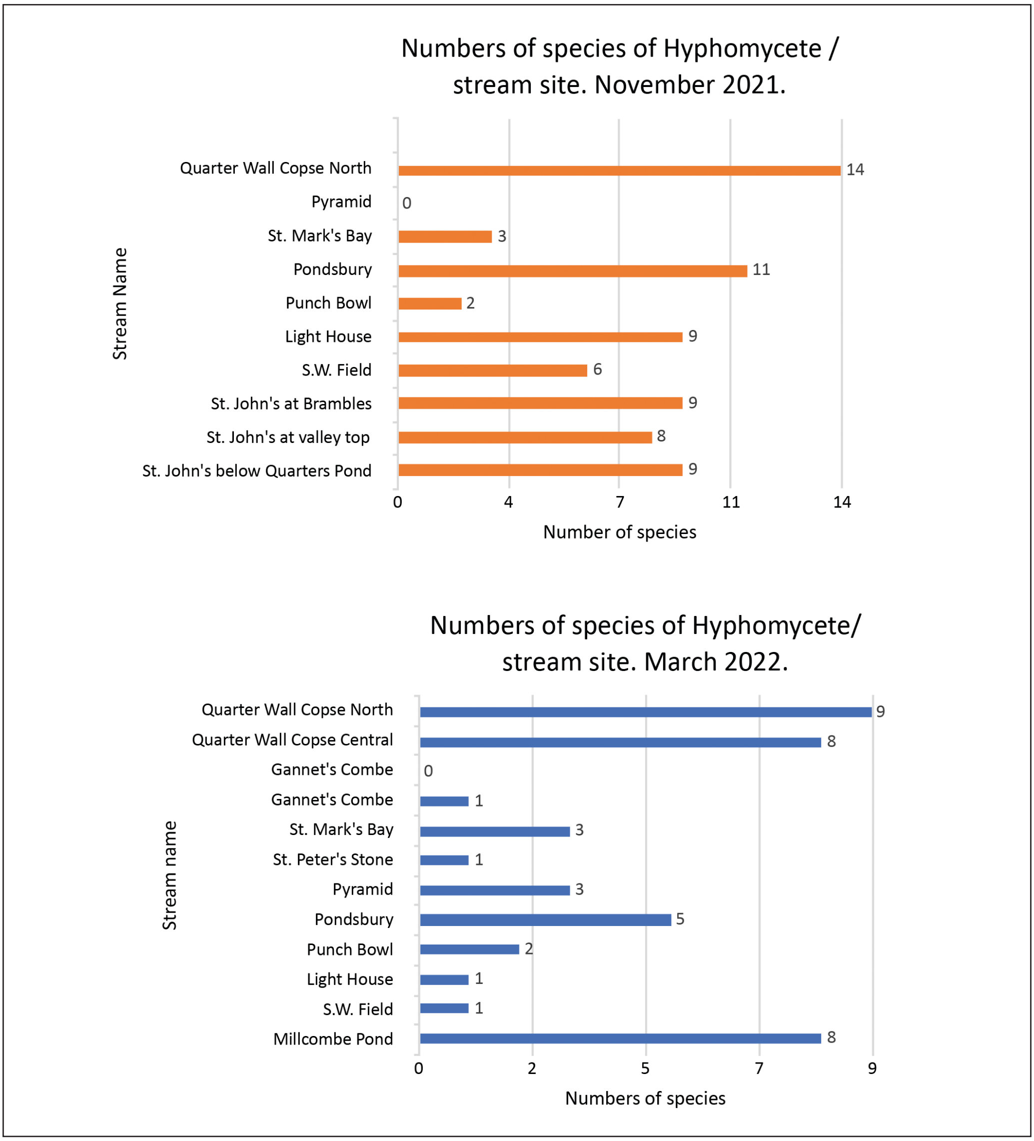


Figure 2. Number of Hyphomycete species found in foam samples from Lundy streams. November 2021 (left) and March 2022 (right).

which joins the Pondsbury stream and is about the same length, had, in contrast, very low numbers of just three taxa (*Anguillospora crassa* in the November 2021 sample, *Articulospora tetracladia* and *Varicosporium elodeae* in March 2022). The foam from the other west side streams (St Mark's Bay, St Peter's Stone, Pyramid, South West Field and Old Light) contained more taxa but Pyramid Stream was odd, with no conidia found in the November 2021 sample, though three taxa and 28 conidia were found in the March 2022 sample. The Gannet's Combe streams were only sampled in March 2022 and were really depauperate, no conidia in one sample and one (a *Tricladium splendens* conidium) in the other.

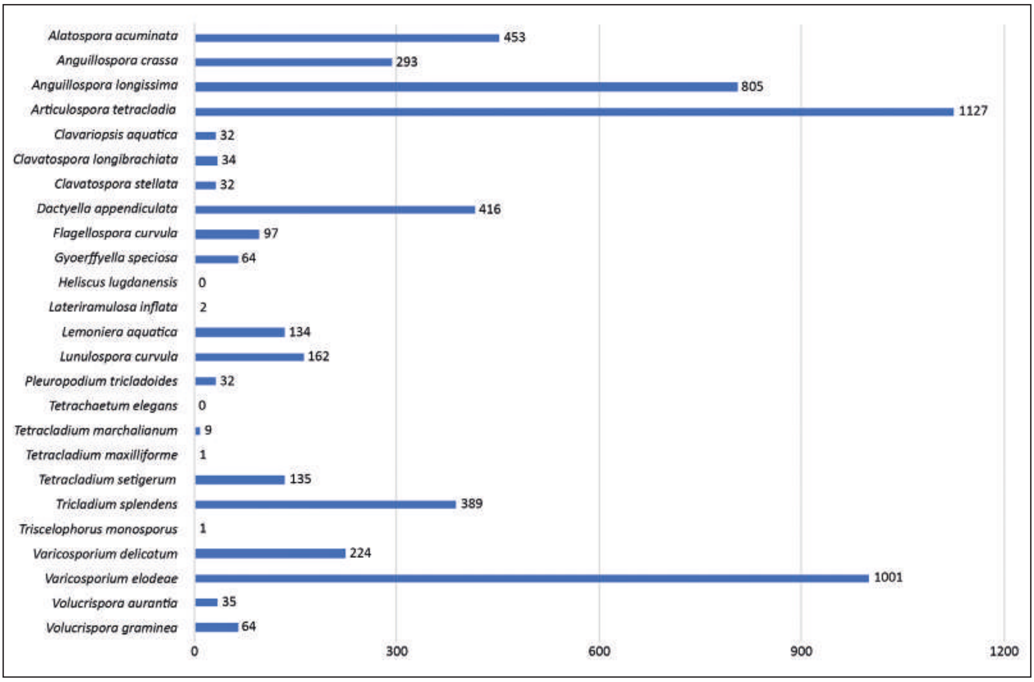


Figure 3. Totals counts of conidia of Hyphomycete species in foam samples from all sites (November 2021).

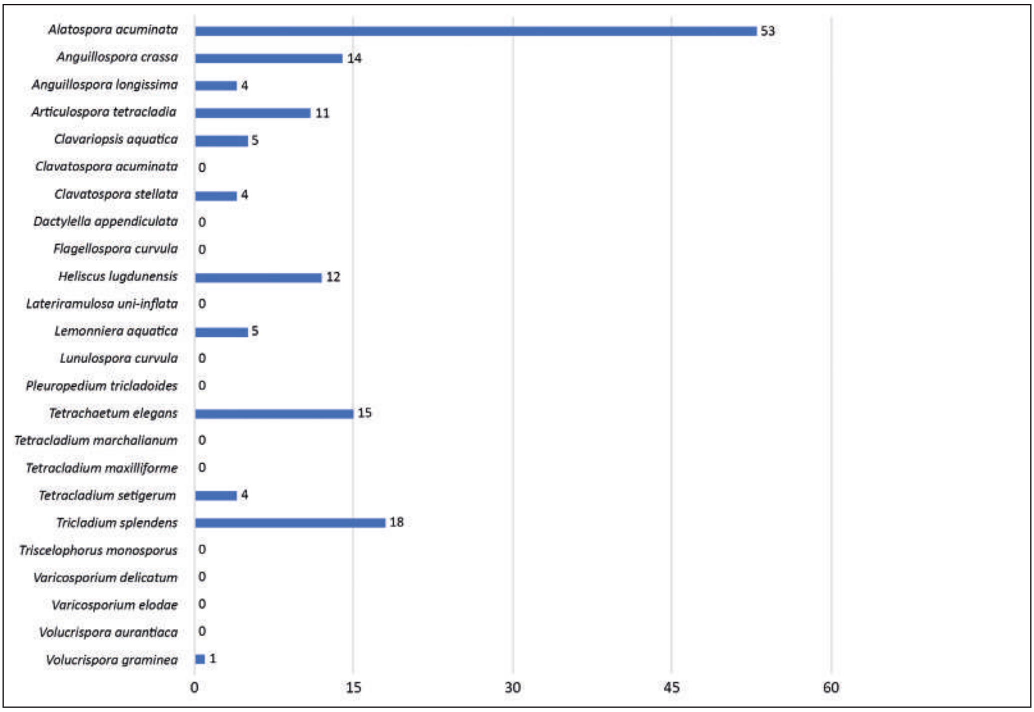


Figure 4. Totals counts of conidia of Hyphomycete species in foam samples from all sites (March 2022).

Numbers of conidia of each species Counts of the conidia of each species in the samples are shown in Figure 3 (November 2021 survey) and 4 (March 2022 survey). The combined total was much higher in November 2021 (5,542) compared to March 2022 (146) and the bar charts show that most taxa were much more abundant in the November samples. Only a few showed the reverse trend and in one case (*Heliscus lugdunensis*) this was an artifact since the one site where it was found (Quarter Wall Copse Central Stream) was only sampled in March 2022. In both November and March samples the two *Anguillospora* species, *Alatospora acumunita*, *Articulospora tetracladia, Varicosporium elodeae* and *Tricladium splendens* made up a high proportion of the conidium totals.

DISCUSSION

Our studies were very limited in scope so any conclusions must be tentative. There do seem to be differences in the numbers of aquatic hyphomycete conidia, and by extrapolation populations of the fungi, between Lundy streams. One explanation could be the length of the stream above the point where the foam sample was taken, giving a greater surface area over which conidia can be released into the flow. A second is that they differed in the quality of plant litter they received, which would determine the diversity of fungi which can colonize it. Both aspects of stream dynamics have been shown to influence conidium diversity (Shearer & Webster, 1985b; Bärlocher, 1992; Bärloche, 2016).

Taking the first explanation, the Pondsbury stream is the second longest on the island second only to St John's stream. The stream at Quarter Wall Copse is also comparatively long and partially rises from springs in Brick Field well above the wood. All three had the highest diversity of Hyphomycete species in the foam samples in both November 2021 and March 2022. In contrast the streams with short lengths tended to have lower species diversity and lower conidium counts, especially the very short west side streams: South-West Field, Old Light, Pyramid, St Mark's Bay and St Peter's Stone.

The second explanation reflects the results of many studies of streams and rivers, i.e. that the quality of the plant debris which enter the water body can determine the diversity of aquatic hyphomycetes. Leaves of broad-leaved trees like alder, birch and oak have been shown to support more species than conifer litter or grass litter, which are of poorer quality or contain inhibitory chemicals (Bärlocher & Oertli, 1978). The two Quarter Wall streams had the highest diversity, flowing in their lower sections through alder, turkey oak and other deciduous trees and received higher quality litter, especially in the autumn. St John's stream also passes through stands of Willow in the valley and has an input of sycamore leaves below Brambles.

The relatively high hyphomycete diversity in the Pondsbury stream may be connected to its length. It could also be related to the quality of the resources entering it, including leaves of creeping willow (*Salix repens*) in the Upper Punchbowl valley and to aquatic plants like *Potamageton*. In this respect the difference in numbers and diversity of Hyphomycete conidia counted in November 2021 and March 2022 in foam samples collected from the Pondsbury Stream and the Punchbowl Stream, which join in the Lower Punchbowl Valley, is striking; the Punchbowl Stream samples had much lower numbers of species and conidia. Both streams are about the same length, but the Punchbowl stream largely flows through dense tussocks of the very silicaceous purple moor grass (*Molinia caerulea*), a difficult substrate for any decomposer fungus. So, the poorer resource quality in the Punchbowl Stream catchment could be the explanation of the difference in Hyphomycete communities. Likewise, the foam samples taken in March 2022 from the two streams in Gannets' Combe were also species-poor (one and zero) and ran though tussocks of the highly silicaceous Tussock Sedge. Past studies, such as those of Iqbal & Webster (1977) on Dartmoor also found low Hyphomycete diversity in streams with moorland catchments.

The species diversity in the foam samples from some of the other West Side streams (South West Field, Old Light, Pyramid (in March 2022), St Mark's Bay, St Peter's Stone) were low but not as low as the Punchbowl Stream Their catchments were mostly grazed grassland but the vegetation was more diverse than on the Punchbowl Stream catchment, perhaps promoting a higher Hyphomycete diversity, in spite of their short lengths.

Finally, the fact that far more Hyphomycete conidia, both in totals and species diversity, were found in the November 2021 than in the March 2022 foam samples of the same streams may be compared to much more detailed studies of streams and rivers throughout the year in Europe. Most have also found that there is an Autumn /early Winter maximum number of conidia in the water bodies and lower populations in the spring. A Devon example, and so climatically similar, is the work of Shearer & Webster (1985b) who in a study of the River Teign catchment found maximum conidium numbers from November to January. Explanations offered include more opportunities for growth of the fungi on the autumnal input of plant debris, especially leaves, which will be progressively removed during the winter and not replenished until late Spring and Summer.

Aquatic hyphomycetes are of importance in the food web in Lundy streams. Future work could include more detailed surveys of Lundy streams by sampling foam, with better replication. Concentrating on the species-rich hyphomycete communities in the Quarter Wall Copse Streams could be a priority and brief sampling of foam from the north stream in November 2022 has already yielded a new record for Lundy, (*Camposporium pellucidum* (Grove) S. Hughes). A closer look at the invertebrate ecology of the streams, especially the shredder communities, is also needed.

ACKNOWLEDGEMENTS

We thank Sandra Rowland and Mandy Dee for assistance with sampling in the field on Lundy. Rosie Ellis, Lundy Warden, is thanked for permission to carry out the field work. We are indebted to André Coutanche for assistance in preparing the text figures and plates. We thank Jenny George for the gift of her copy of Terence Ingold's *Guide to Aquatic Hyphomycetes*.

One of us (JNH) wishes to thank Dr Harry Hudson for introducing him to the world of aquatic hyphomycetes many years ago. The other (AR) wishes to thank JNH for requesting his assistance and introducing him to aquatic hyphomycetes. We both thank the referees for their very useful suggestions for the improvement of the manuscript.

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THE UPS AND DOWNS OF LUNDY CABBAGE, A 25-YEAR STUDY

by

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ABSTRACT

Uniquely in Britain, *Coincya wrightii* is an endemic plant and the only foodplant of two endemic insects. Between 1994 and 2016, we monitored all the plants in flower each year across its entire range. Both the total number and proportion of plants in flower varied greatly between years. In earlier years the number in flower was clearly correlated with fluctuating rabbit numbers driven by the cycle of myxomatosis outbreaks. In recent years rabbit numbers have remained low and flowering has varied more erratically between years and the threat to the cabbage from rhododendron was eliminated by its almost complete clearance.

INTRODUCTION

Lundy cabbage (*Coincya wrightii*) (Plate 1) is a short-lived perennial crucifer known only from Lundy. Its taxonomy and ecology is summarised by Compton *et al.* (2000). It is unique in Britain because it is an endemic plant that is also the only host of an endemic plant-feeding insect, the leaf beetle *Psylliodes luridipennis*, and is the major host of a second beetle known only from Lundy, a weevil currently named *Ceutorhynchus contractus* '*var. pallipes*' but which is likely to be recognised as a distinct species in the near future (Compton *et al*., 2002; Key *et al*., 2021). Lundy cabbage is probably a neo-endemic that diverged post-glacially on Lundy from Isle of Man cabbage (*Coincya monensis monensis*) after its original sand dune habitat disappeared (Compton *et al*., 2007). Associated with this change in habitat it adapted to life on steep coastal slopes and cliffs and switched from an annual to a perennial life-style. Lundy cabbage is a 'weedy' plant that likes the bare, disturbed ground found naturally on the cliffs, inland buttresses, and steep, clifftop slopes ('sidelands') on the more sheltered east side of Lundy (Plates 2, 3 and 4). Its range is restricted to about a 3.2 km length of the island's south-east coastline (Figure 1).

POPULATION MONITORING – METHODS AND LIMITATIONS

We began systematic monitoring of the entire population of Lundy cabbage in 1994 after an initial scoping visit in 1993. A census of the number of plants in flower was then carried out in late May/early June each year, at the time of year when most plants were in flower. Flowering by Lundy cabbage peaks towards the end of May, though the overall flowering period starts as early as February and can extend into the Autumn for plants

Plate 1. Flowers and young fruits of the Lundy cabbage, *Coincya wrightii*, above Miller's Cake. 28 May 2012. Image: R.S. Key.

Plate 2. Lundy cabbage occupying cliffs just to the south of Quarry Bay on 5 June 2013. Image: R.S. Key.

Plate 3. A familiar view of Lundy cabbage on the sidelands on the north side of Millcombe Valley viewed from the beach road. 3 June 2013. Image: R.S. Key.

that have been damaged by grazing. The counts therefore represent an estimate of the likely maximum number of plants in flower each year, rather than the total number of plants that flowered. We only counted the numbers of plants in flower, rather than all the plants, as most grow on inaccessible sea cliffs which meant that most counts had to be made from a distance using binoculars. Where dense, continuous stands were present, numbers of plants had to be estimated. To standardise as far as we could, the same observers counted the same areas each year, standing in the same place. This methodology is more appropriate for recording changes in the number of plants in flower each year rather than the number of plants *per se*.

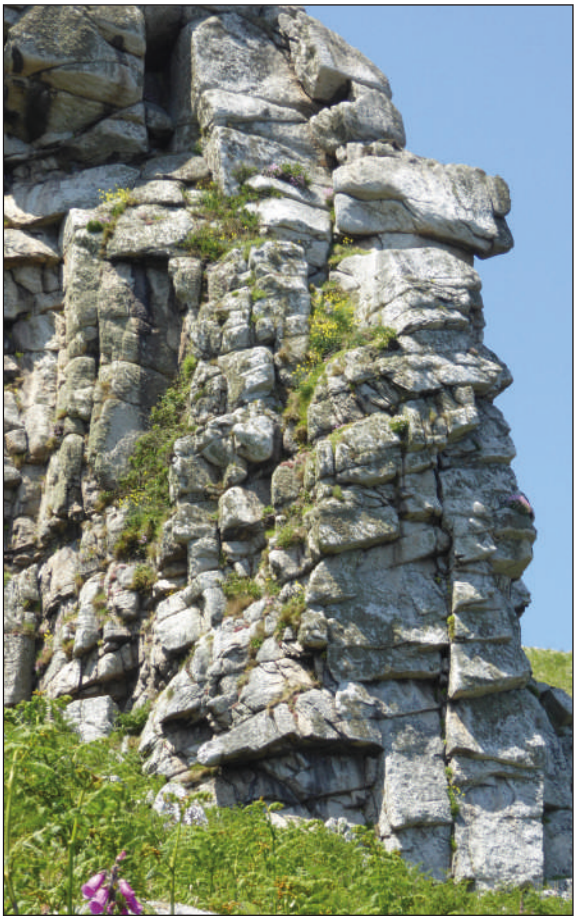

Plate 4. Lundy cabbage on the granite buttress of Knights' Templar Rock on 3 June 2016. Image: R.S. Key.

The overall population was split into convenient count areas, the number of which eventually reached 89 as Lundy cabbage occasionally colonised new areas (usually temporarily). Count areas where plants were present, but none were in flower, were included in our distribution summaries but did not contribute to the flower counts. Sub-populations of Lundy cabbage at some cliff-side and cliff-top sites could not be viewed every year, especially in the earlier years when they were screened from the land by dense blocks of rhododendron. Whenever possible, counts of these and other populations on the cliffs were made from a boat cruising parallel to the east coast of the island. More plants are visible from the sea than from the top of the cliff at any one site and, where cliff-side counts were possible from both land and sea in one year, we accepted whichever count was the higher.

The annual census of the total number of plants was extrapolated from counts of *all* the plants (not just those in flower, but including seedlings, young rosettes, mature plants yet to flower and those decapitated by grazers) present in three small areas where close access was possible (in Millcombe, at the buttress above Halfway Wall and in Quarry Bay). Cabbage populations were much larger in one of the three areas (Millcombe, Plate 3), so our extrapolations are inevitably biased towards what was happening there.

RESULTS

The distribution of Lundy cabbage

The geographical limits of Lundy cabbage's distribution along the East coast of Lundy hardly changed during the 25-year survey period. This probably reflects environmental constraints that limit the northern and southern boundaries – possibly accessibility to grazing animals on the gentler northern cliffs and slopes, and the northerly aspect of the cliffs in the far south east. In most years a few plants were also recorded at the eastern edge of the south facing cliffs on the west side of the Castle and hence on the west side of the island. However, these plants were only a few metres over a saddle from a large population facing eastwards below Lundy Castle. A small extension in range or colonisation event was detected in 2009 when two flowering individuals were present just above sea level on the north (i.e. south-facing) side of the bay immediately south of Gull Rock, approximately 150 m beyond what had been the plant's northern border for at least the previous 20 years. The plants were not seen to flower there again in subsequent years.

Within its overall range, the distribution of Lundy cabbage can be divided into core areas where it was present during every or almost every year of our surveys, and satellite, usually smaller count areas where plants were only recorded intermittently. Temporarily-occupied count areas were often slightly inland on gentler slopes, whereas the permanently occupied areas were on the buttresses, sea cliffs and steeper sidelands. Occupation of the temporary sites probably resulted from either colonisation events (usually within a few tens of metres from where plants had flowered in earlier years) or local disturbance that enabled seeds to germinate from the soil seed bank (Compton *et al.*, 2010).

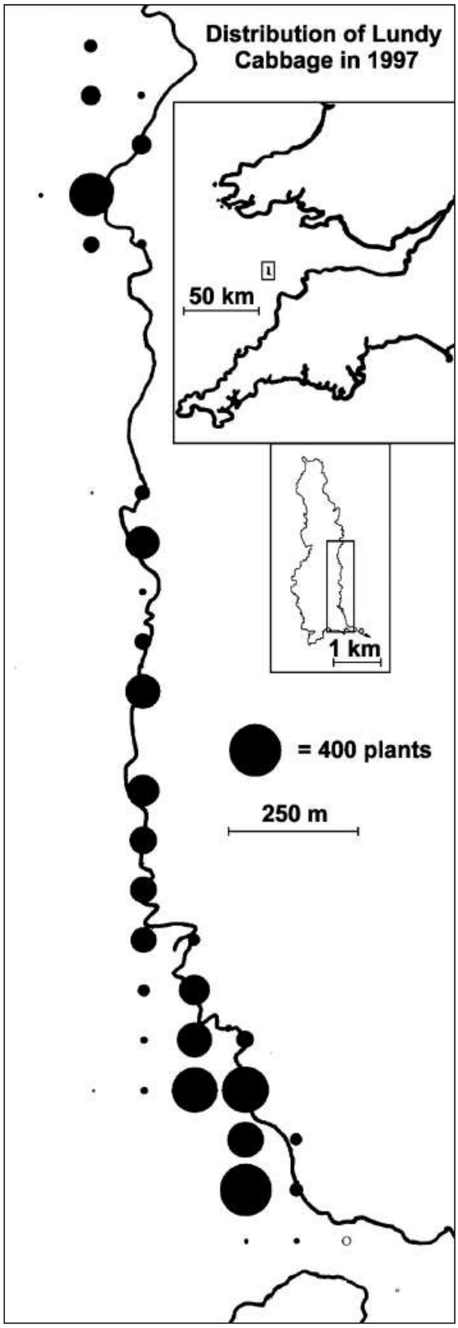

Figure 1. The total distribution and relative numbers of Lundy cabbage in flower on Lundy by hectare grid squares in 1997, when about 3,000 individuals were flowering. Open circles depict subpopulations where the cabbage was present but no plants were in flower.

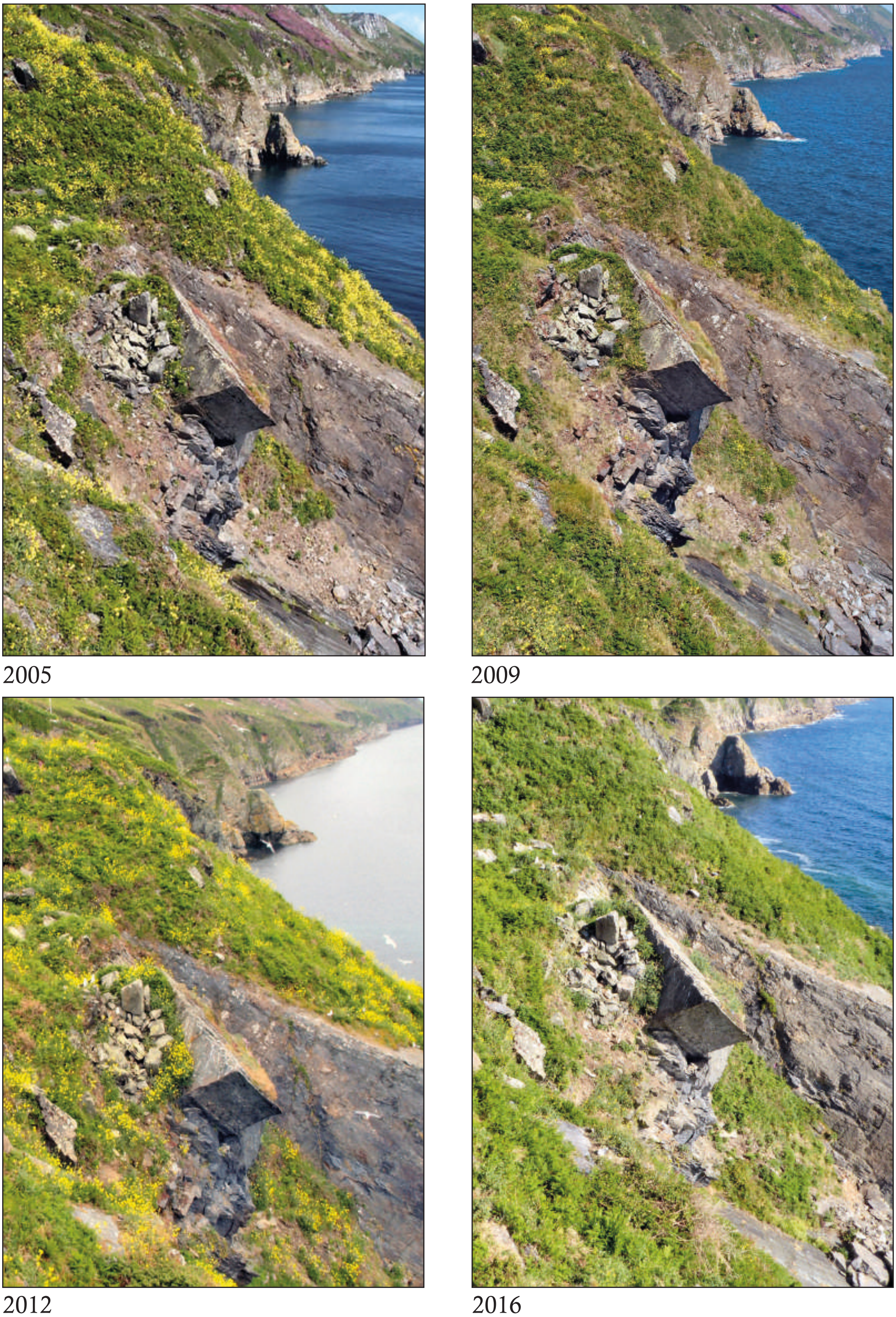

Plate 5. Examples of variation in the extent of flowering of Lundy cabbage in different years. Looking northwards to Miller's Cake. Images: R.S. Key.

Plate 6. Examples of variation in the extent of flowering of Lundy cabbage in different years. Looking northwards along the Eastern Sidelands. Images: R.S. Key.

The largest Lundy cabbage populations were usually on the cliffs in the central part of the plant's range, followed by Millcombe and its nearby sidelands and cliffs (Figure 1). Fixed point photographs illustrate the extent of between-year variation in Lundy cabbage flowering intensity (Plate 5). Our lowest total plants-in-flower count was about 880 (in 2002) and our highest was about 13000 (in 2013), a roughly 15-fold difference (Figure 2). Changes in numbers between years were often well synchronised across count sites, but there were usually exceptional sub-populations that bucked general trends in any one year.

Drivers of annual variation flowering intensity

Larger Mammals The larger mammals on Lundy, in particular the wild goats and domestic sheep but also Sika Deer, ponies and (probably) cattle will all eat Lundy cabbage if they are allowed access to it and are very likely to limit the distribution of Lundy cabbage in areas where they have access, goats particularly so in the north of the island. Over the years improvements to fences, good stock control and the targeted culling of excess goats and deer has had a positive impact on overall numbers of Lundy cabbages in particular areas, especially in the south.

Rabbits In the earlier part of the study period the numbers of Lundy cabbage in flower showed a cyclic pattern (Figure 3) that was closely linked to the numbers of rabbits on the island, with short-lived but dramatic flowering peaks two years or so after

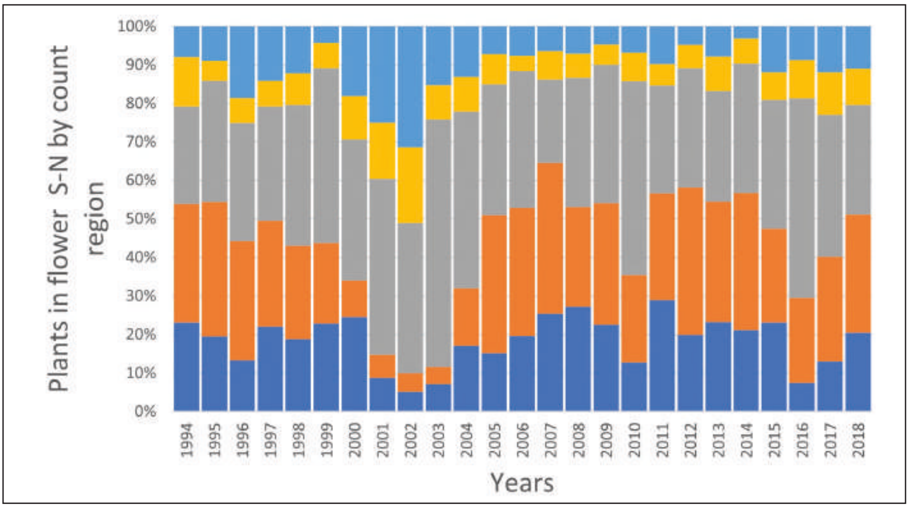

Figure 2. Annual variation in the relative numbers of Lundy cabbage in flower in different parts of the island. Place names follow maps of Lundy. The count regions (from south to north) were (1) South of Millcombe (dark blue), (2) Millcombe to Miller's Cake (orange), (3) Miller's Cake to Quarter Wall (grey), (4) The quarries and cliffs below, including Quarry Beach (yellow) and (5) North of the quarries (pale blue).

myxomatosis outbreaks (Compton *et al.*, 2004). This was a feature of the first two major disease outbreaks we monitored and Lundy warden's reports suggest the same pattern had occurred earlier, around 1983. Peak rabbit populations depressed Lundy cabbage numbers as a result of their very high grazing pressure. In other years, temporary sub-populations often appeared during years when rabbit populations were low, after they had previously created bare soil and reduced competition from grasses. The eventual collapse of rabbit numbers due to myxomatosis then released the plant from grazing at a time when there are many micro-sites suitable for colonisation. If this scenario is correct then the spectacular numbers of Lundy cabbage recorded in 1998 and 2013 would not have been seen on Lundy in the centuries prior to the introduction of myxomatosis about thirty years ago.

By combining information from National Trust standardised mammal counts, Lundy warden's annual reports and our own observations it is possible to produce a rough estimate of changes in rabbit numbers on Lundy since 1994 (Figure 4). They are calibrated by estimates produced by Leeds University students using pellet counts and decay rate estimates (Taylor & Williams, 1956) for 1996, 2000 and 2005. The three counts illustrate the dramatic swings in rabbit numbers that were occurring on the island, with an estimated 20,000 rabbits recorded in January 1996, 1,800 in 2000 and 15,000 in early 2005. Regular winter rabbit culls may have had some effect on their numbers (at least 7000 rabbits were removed in 2004/2005), but disease appears to have been a more important mortality factor.

In a previous publication (Compton *et al.*, 2004) we hypothesised that if rabbit numbers remained low for a long period, then Lundy cabbage abundance would stabilise

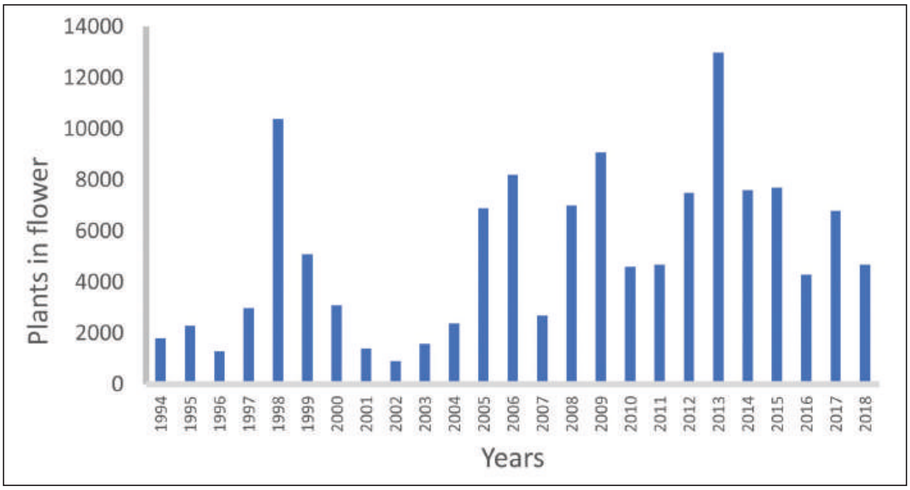

Figure 3. Estimates of total numbers of Lundy cabbage in flower in late May/Early June in the years 1994 to 2018.

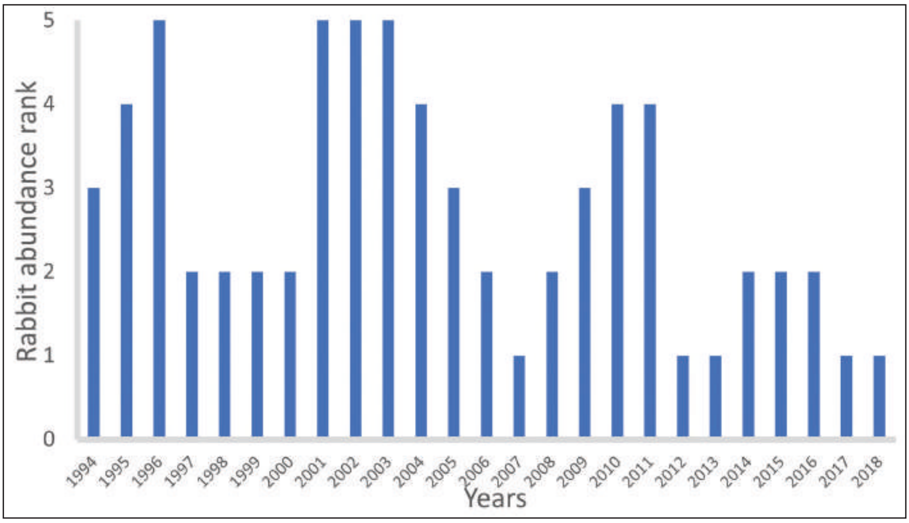

Figure 4. Estimated annual variation in estimated abundance of rabbits on Lundy. 1 = 'very low', 2 = 'low', 3 = 'medium', 4 = 'high' and 5 = 'very high'. Numbers estimates based on late winter pellet counts were 20,000 in 1996, 1800 in 2000 and 14,500 in 2005.

at a level somewhere between the extremes were had been recording. Coincidentally, rabbit numbers remained low or very low since 2011, following the arrival of Rabbit Haemorrhagic Disease (RHD) on the island. It initially seemed to have a limited effect on the rabbit population, but Kevin Welsh, the island's farmer reported (personal communication) over 1000 had died from the disease in 2003/2004. If the change in rabbit numbers is attributable to RHD then the dynamics of this disease seem very different to Myxomatosis, with none of the 'boom-and-bust' in rabbit numbers seen in earlier years. In this later period of our study there were no extremely low Lundy cabbage flowering counts, because rabbit numbers never exploded again, and a baseline of at least 4000 flowering plants each year seems to have become established. However, above this value, the total number of plants in flower has been unstable, unpredictable, and highly variable between years.

Pollen Beetles Flower counts during 2007 were exceptionally low despite there being only small numbers of rabbits present that year. Adult flower beetles (*Meligethes*, Nitidulidae) feeding on the flowers and flower buds of Lundy cabbage were common in every year of our study, but were remarkably abundant in 2007 (Key *et al*., 2018). When they were identified, they were not the usual *Meligethes* species present on the island *Meligethes viridescens*, but *Meligethes aeneus*, which is a major pest of oilseed rape on mainland Britain. A guide for farmers suggests a density threshold of *M. aeneus* beyond which chemical sprays are advised (Key *et al*., 2018). Mean densities per Lundy cabbage *flower* that year were higher than the number suggested as an economic spray threshold per whole plant of oilseed rape.

Other Factors Other factors may also have had a more localised influence on flower numbers. Since 1994 the most significant change in the vegetation of the East side of the island has been the clearance and near-eradication of *Rhododendron ponticum* from the sidelands and cliffs. In the local areas where rhododendron was cleared, the bare ground this created initially favoured Lundy cabbage, along with other early successional plants such as foxgloves (*Digitalis purpurea*) (Plate 7). These local booms in Lundy cabbage numbers were short lived due to rapid increases in competition from grasses and bracken. Clearance of Rhododendron on the cliffs themselves has had a very positive, more long-lasting effect in removing what was considered to be the biggest threat effecting the long-term survival of the Lundy Cabbage. (Compton *et al*., 1999; Compton *et al*., 2016).

The relationship between plants in flower and overall population size

There were only three areas where we were confident of counting all the Lundy cabbage, not just those in flower. In every year, the majority of plants were not flowering. Some

Plate 7. Growth of Lundy cabbage and foxgloves after rhododendron clearance on the sidelands. 1 June 2008. Image: R.S. Key.

of the non-flowering individuals were seedlings or small immature rosette plants, others had been damaged by grazing mammals to varying extent, some of which are likely to have come into flower later in the year if grazing pressure was relaxed. The ratio of non-flowering to flowering plants in different years was highly variable, from about 2:1 to 24:1 (Figure 5). In years with high flowering counts almost half the plants may have been in flower, whereas in years with low flowering counts there was often a majority of individuals that had not flowered by early June. These included seedlings and many plants that would never manage to flower because of repeated grazing or competition. Clearly our counts of plants in flower were underestimating the size of the total population of Lundy cabbage and perhaps also overemphasising the extent of year to year variation in overall population numbers, because in years when flowering counts were very low there was usually a higher proportion of additional plants that were not flowering. Counts of plants in flower are nonetheless the only option for routine monitoring of population trends and for informing management decisions. Counts of Lundy cabbage in flower are continuing thanks to members of the Lundy Field Society.

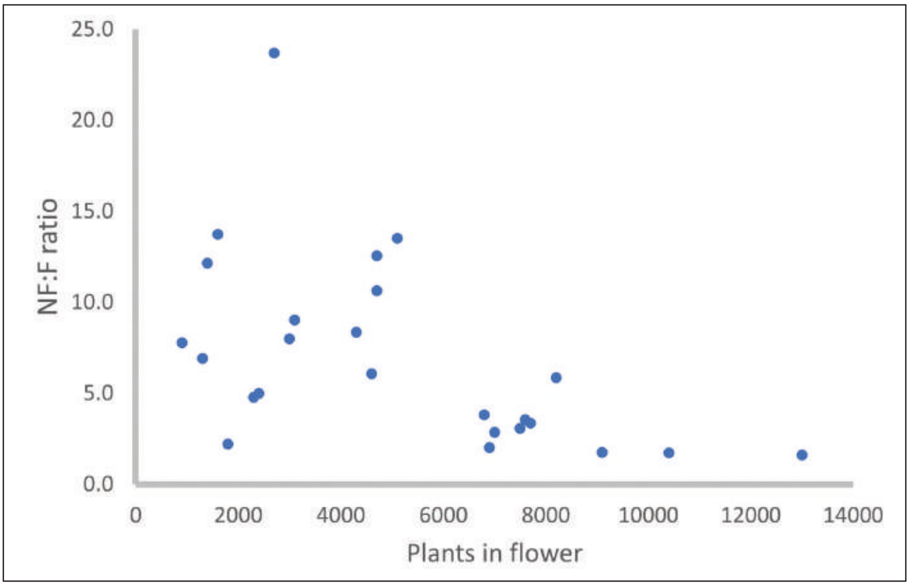

Figure 5. The relationship between the proportion of flowering Lundy cabbage in early June and the total number of flowering plants recorded at that time in the years 1994 to 2018. NF = Non-flowering, F = flowering.

CONCLUSIONS

Over the 25-year period the year-to-year variation in the numbers of flowering Lundy cabbage at first followed an almost regular series of peaks and trough and subsequently became more chaotic. This was linked to grazing by mammalian herbivores, mainly, though not exclusively linked to the large annual variation in grazing intensity by rabbits. In the first few years, cycles in rabbit abundance that were driven by myxomatosis outbreaks and recovery were reflected in delayed peaks and troughs in the flowering success of the Lundy Cabbage, but the dynamics changed in later years, apparently due to the arrival on Lundy of a second rabbit disease. For the rest of our study period rabbit numbers remained relatively low and Lundy cabbage flowering became less predictable. Our results emphasise the value of long-term autecological studies, both on Lundy and elsewhere.

ACKNOWLEDGEMENTS

English Nature/Natural England gave us financial support in most years. The Landmark Trust provided a boat whenever it was available and supported us in other ways. Funding gaps were filled by support from the University of Leeds and our personal funds. Genetic studies were funded by NERC and the Marie Curie Foundation. Numerous University of Leeds students helped with field work. The wardens and other Landmark Trust staff made our annual visits to Lundy a continuing pleasure.

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A PRELIMINARY NOTE ON THE RE-DISCOVERY OF MARINE FOSSILS IN THE LUNDY SLATES

by

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ABSTRACT

Although fossils were first reported from the slates on Lundy Island more than eighty years ago, the rocks are widely, and erroneously, considered to be unfossiliferous. This paper documents recent discoveries that confirm an abundant fossil marine fauna is preserved in thin, shelly limestone beds within the Lundy Slates. Assemblages include brachiopods, gastropods, ostracods and echinoderms; all of which have been previously reported from Lundy. Bellerophont molluscs, orthocone nautiloids, fish and conodonts are reported for the first time. Conodonts have the potential to provide a definitive age for the Lundy Slates and better correlation to formations elsewhere.

Keywords: *fossil, invertebrate, palaeoecology, Devonian, Carboniferous*

INTRODUCTION

Lundy mostly comprises intrusive igneous rocks (granites and dykes) of Paleocene age that represent the most southerly known outcrop of the North Atlantic Igneous Province (Charles *et al*., 2017), and which have been studied since at least the 1830s (De la Beche, 1839). These igneous rocks were emplaced into much older, grey, metasedimentary mudstones with well-developed cleavage (i.e., slates) that crop out in the southeast part of the island. Termed the 'Lundy Slate Series' by Dollar (1941), these metasedimentary rocks have hitherto received far less study. Almost all studies that have discussed the Lundy Slates, since Etheridge (1867) and including the most recent British Geological Survey memoir to cover Lundy (Edmonds *et al*. 1979), have stated that they are non-fossiliferous.

Owing to this supposed lack of fossils, the slates on Lundy have been correlated to the Upper Devonian Morte Slates Formation of northern Devon by means of lithological similarity alone (e.g. Etheridge, 1867; Dollar, 1941; Edmonds *et al*., 1979). This correlation has been questioned a number of times over the past 150 years (e.g. Hall, 1871; Dollar, 1941), but in the absence of new (palaeontological) evidence it has remained untested. Although the rocks are currently mapped as belonging to the Morte Slates Formation, given the lack of firm evidence in support of that correlation Dollar's (1941) informal designation of 'Lundy Slates' is preferred.

Despite the prevailing orthodoxy that the Lundy Slates are unfossiliferous, possible fossils have been reported on at least two occasions. Hall (1871, p. 619) mentions a "very indefinite marking, which may possibly belong to a vegetable impression", but the most convincing and extensive record is that described in Dollar's (1935) PhD thesis and subsequent publication (Dollar 1941). Dollar records the presence of several fossil groups including brachiopods, echinoderms and gastropods, although he notes that some of the identifications are equivocal and none are identified to genus or species level.

This paper documents the recent discovery of unequivocal fossils from the Lundy Slates, and provides preliminary notes on the taxa present, including a number of groups recorded from Lundy for the first time. The importance of this fossil assemblage for understanding the age and correlation of the Lundy Slates is briefly discussed.

METHODS

Following the authors' initial chance discovery in 2019 of fossiliferous pebbles on the small beach between Rat Island and the main island, permission was obtained to conduct a more thorough search of the slate outcrops of Lundy with the aim of finding and sampling *in situ* fossiliferous beds. Fieldwork took place in 2021, and also included a survey of the Landing Beach and the rocky outcrops around the Devil's Kitchen to identify and collect additional fossiliferous *ex situ* pebbles.

Thin-sections were made of all samples, in order to determine their lithology and their fossil content. In addition, selected samples were dissolved in buffered 10% acetic acid, following the methods of Jeppsson *et al*. (1999), in order to release any phosphatic (micro)fossils present. Residues were then sieved into smaller size fractions using mesh sizes of 1 mm, 500 µm, 250 µm, 125 µm and 63 µm, and then picked under a binocular microscope. All samples, residues and specimens are housed in the collections of the Natural History Museum, London (NHMUK).

RESULTS

In total, two *in situ* and 20 *ex situ* samples which have been collected thus far, including the initial discoveries in 2019, have yielded fossils. Importantly, these fossiliferous *in situ* samples have extremely similar lithology, preservation and fossil content to the *ex situ* ones, indicating that the fossiliferous pebbles found loose on the beaches do indeed derive from the local slate outcrops on Lundy and have not been transported in from elsewhere. The two *in situ* fossiliferous samples were collected from the foreshore outcrops of the Landing Beach at N51° 09.804', W004° 39.444' (NHMUK PEI 5537) and N51° 09.782', W004° 39.404' (NHMUK PEI 5538).

The fossils are preserved in thin, shelly limestone beds, between 5 mm and ca. 5 cm thick. Both of the *in situ* samples were lens-shaped scours with erosive bases (Plate 1A). In thin section, samples are predominantly composed of densely packed calcareous bioclasts, with subordinate phosphatic bioclasts and lithoclasts, and have been substantially recrystallized during burial and diagenesis (Plate 2). Although recrystallization partly obscures the original fabric, these rocks may be classified as bioclastic packstones; i.e. they are clast-supported with an infill of mud between the clasts. A range of different fossil marine invertebrate groups can be identified in thin section, albeit only at a very coarse taxonomic level. Almost all of the fossil bioclasts are disarticulated and fragmented and none are in life position.

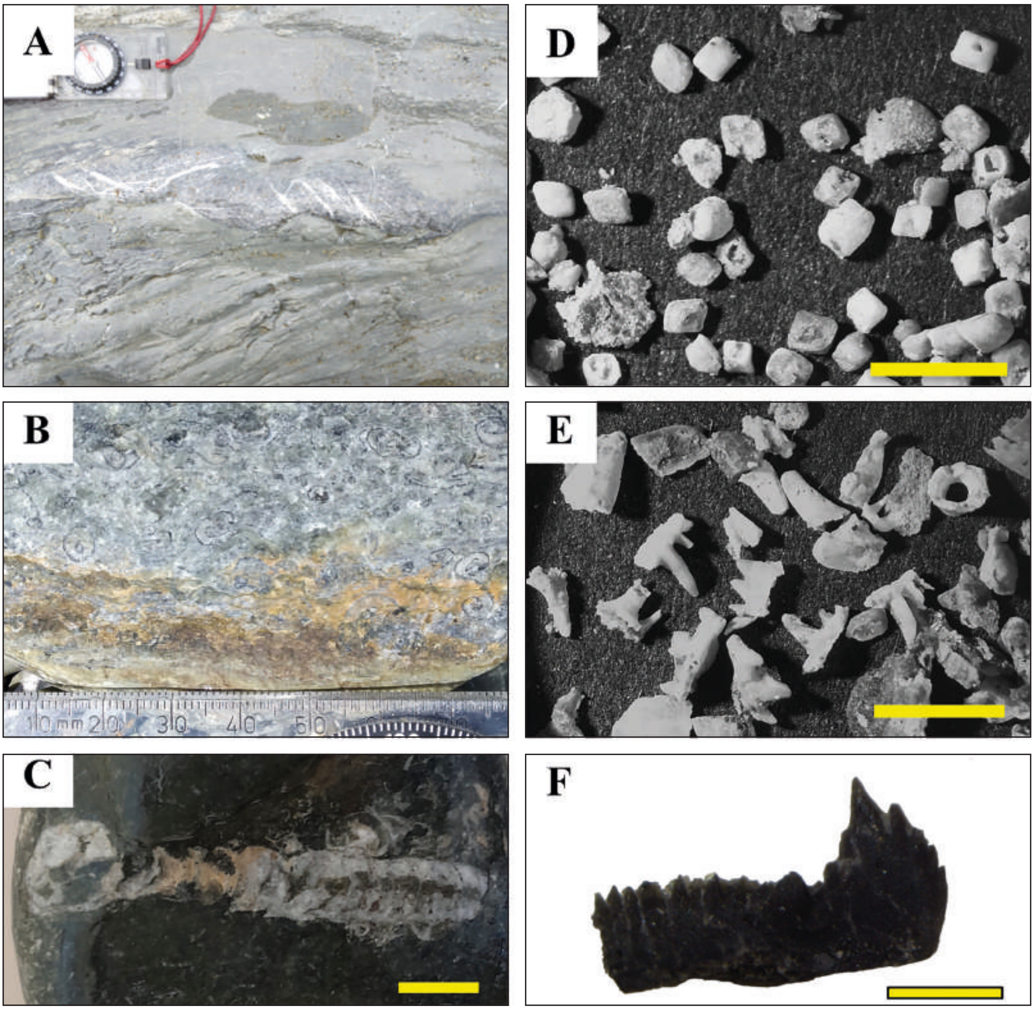

Plate 1. A selection of fossils collected from the Lundy Slates: A) an *in situ* fossiliferous limestone lens from the Landing Beach foreshore [N51° 09.804', W004° 39.444'], NHMUK PEI 5537; B) an *ex situ* hand specimen containing abundant bellerophont molluscs, NHMUK PEI 5558; C) an orthocone nautiloid in an *ex situ* pebble, scale bar = 1 cm, NHMUK PI CN 215; D) acanthodian scales from the sample shown in A, scale bar = 1 mm; E) chondrichthyan teeth from the sample shown in A, scale bar = 1 mm; F) a conodont element (cf. *Bispathodus*) from the sample shown in A, scale bar = 500 μm.

Brachiopods

Brachiopods are common in most samples, mainly represented by fragments of disarticulated valves (Plates 2, 3). Some specimens still preserve hints of original shell microstructure, comprising a thin outer layer and thicker inner layer typical of many brachiopod groups, but most have been recrystallized. It is possible that some recrystallized valves may also be from bivalve molluscs, but owing to their preservation a positive identification cannot be made from the materials examined thus far.

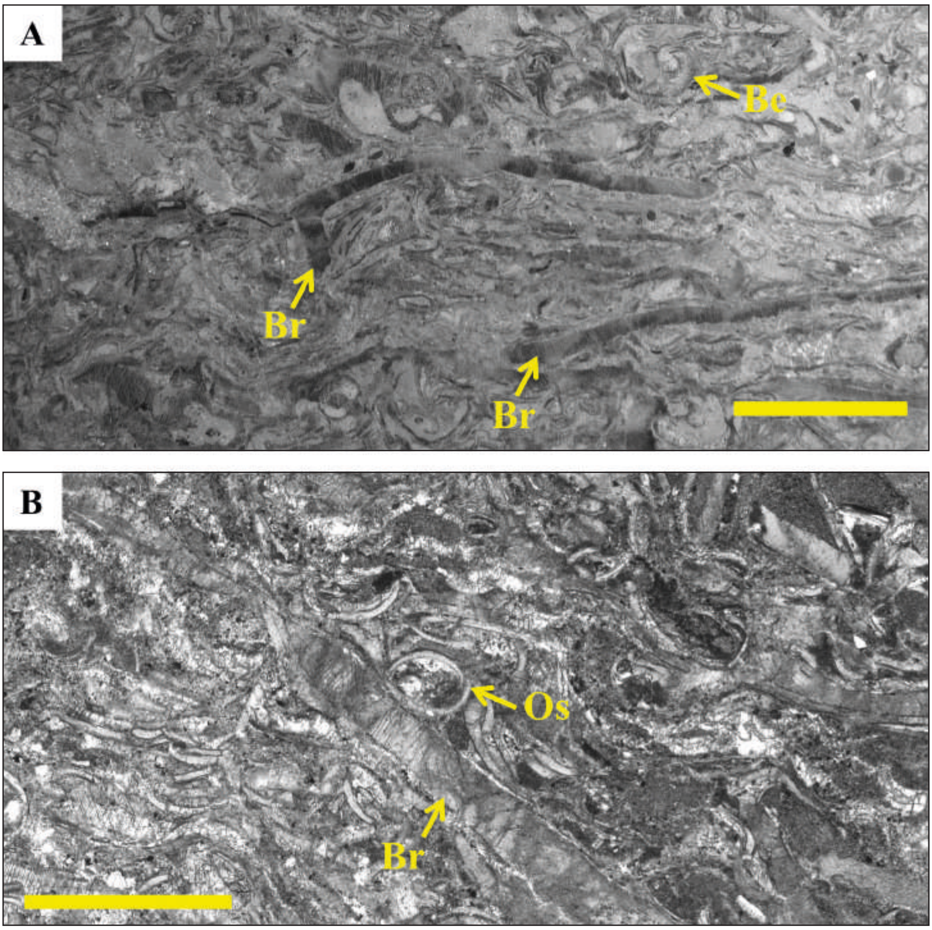

Plate 2. Two thin section views of a typical fossiliferous *ex situ* limestone event bed of the Lundy Slates, NHMUK PEI 5544. The sample can be classified as a densely packed, poorly sorted bioclastic packstone, with an assemblage dominated by brachiopods (Br) and ostracods (Os), and with a few bellerophont molluscs (Be). A) reflected light, scale bar = 2.5 mm; B) plane polarised transmitted light, scale bar = 1 mm.

Molluscs

Molluscs are not present in all of the samples, but are very common in some samples and may even be visible in hand specimen too. Several classes are represented. The most common are relatively thick-shelled, involute and planispirally coiled specimens that are referable to the Superfamily Bellerophontoidea (Plate 3). Bellerophonts are an unusual group of extinct molluscs, ranging from the Cambrian to Lower Triassic, with uncertain taxonomic affinities, and are classified within the Gastropoda or Monoplacophora (e.g. Wagner 2001). The Lundy Slate bellerophonts reach 5 mm in size and may be visible in hand specimen (Plate 1B). True gastropods are also present in the assemblages, although these are rare. Morphologies include a high-spired form and a globose form. Compared to the bellerophonts, these gastropods are relatively thin-shelled.

Two cephalopod specimens have also been found to date. Both are orthocone (straight-

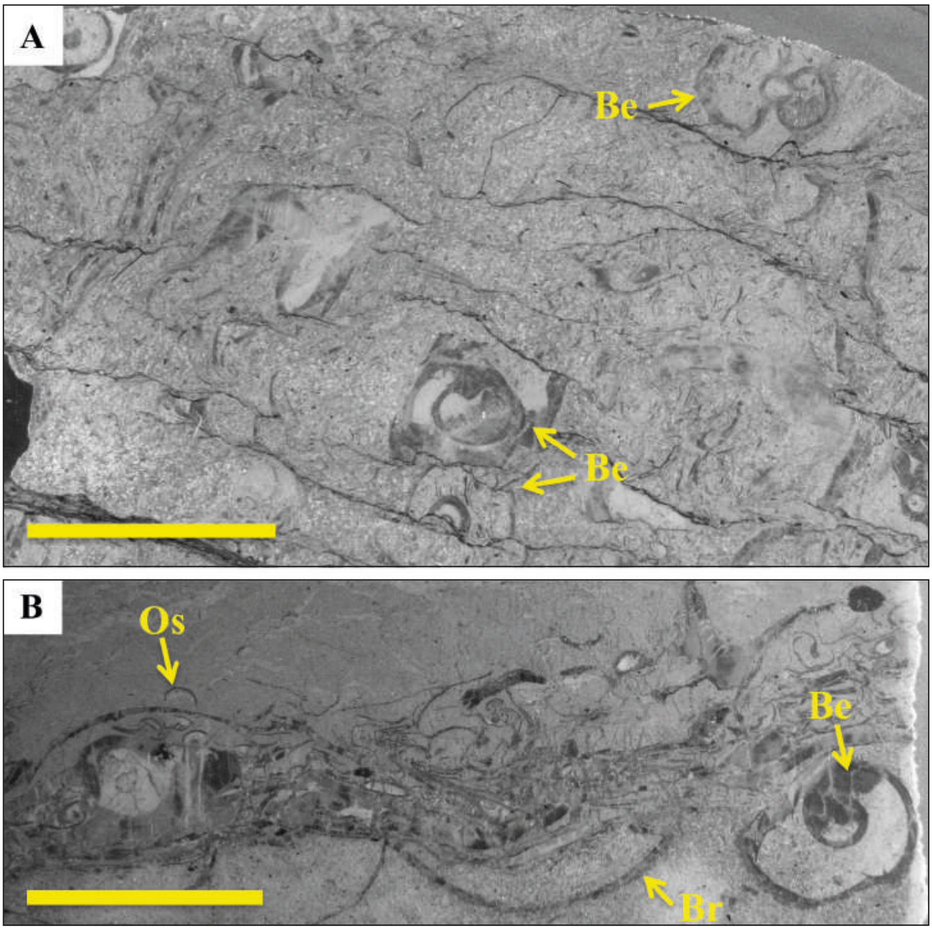

Plate 3. Thin section views of fossiliferous *ex situ* event beds of the Lundy Slates with a silty matrix. A) sample NHMUK PEI 5558 under reflected light; B) a thin lag of bioclasts on the base of a metasiltstone, NHMUK PEI 5542, under reflected light. Br = brachiopod, Be = bellerophont, Os = ostracod. Scale bars = 5mm.

shelled) nautiloids, and may represent the same species although taxonomic work is ongoing. Unlike the other (benthic) molluscs recorded in the assemblage, orthocone nautiloids were nektic or nektobenthic predators that inhabited the water column. The largest specimen is 5 cm in size, and was the first fossil specimen to be found in this study (Plate 1C).

Arthropods

Ostracods are common components of most samples, and dominate the thinnest shell beds. Disarticulated valves are most common (Plates 2B, 3B), but articulated specimens are present too (Plate 2B). To date, no unequivocal trilobite bioclasts have been observed.

Fish

The most common fossils in the acid-prepared residues are the teeth and scales of fish.

Taxonomic work is ongoing but preliminary observations suggest that a number of extinct groups are represented (C. Duffin, pers. comm.). Rhomboid-shaped scales of acanthodians are very abundant in all samples, possibly belonging to the genus *Acanthodes* (Plate 1D). Acanthodians are an extinct class of jawed fish and are sometimes referred to as 'spiny sharks', but they are not true sharks. Teeth belonging to extinct members of the Class Chondrichthyes are, however, also present. For example, common, small 'cladodont' teeth with multiple cusps, used to clutch or grab prey, are recorded in most samples and are identified as belonging to extinct holocephalians from the Order Symmoriiformes (Plate 1E). Some are similar to the Carboniferous genus *Denaea.*

Conodonts

Conodont elements are the tooth-like mouthparts of extinct, jawless marine chordates related to living lampreys and hagfish. They range from the Cambrian to the end of the Triassic, and are extremely useful for biostratigraphy and for correlating marine rocks of that age worldwide. Conodonts are present in every sample residue examined to date, and are reported from the Lundy Slates for the first time. Preliminary identifications suggest that the genera *Polygnathus* and *Bispathodus* (Plate 1F) are present, consistent with an Upper Devonian to Lower Carboniferous age (Corradini *et al.*, 2017).

DISCUSSION

The fossils documented in this study demonstrate without doubt that the Lundy Slates contain an abundant and diverse fossil fauna of marine invertebrates and vertebrates, adding significantly to the geodiversity of Lundy and of southwest England. Fossils are confined to thin, shelly limestone beds within the Lundy Slates, and do not appear to be present in the surrounding mudstones. Most fossils are disarticulated, with the exception of some of the ostracods (Plate 2B), and none are in life position, indicating that the assemblage underwent post-mortem decay and transport prior to final burial. These limestones are interpreted as 'event beds', recording the sudden downslope transportation of dead shells, teeth and scales into a deeper water setting, rather than the *in situ* accumulation or concentration of bioclasts. The two *in situ* beds sampled in this study likely represent scours or gutters that were emplaced during large storms. Transportation and rapid deposition during single storm events is consistent with the dense packing, poor grading and poor sorting of the bioclasts (Kidwell, 1991). Differences in thickness between the fossiliferous beds, and in the relative proportions of the fossil groups preserved in those beds (e.g. the dominance of ostracods in some beds; Plate 2B), demonstrate that multiple events have been sampled. Event beds with slightly coarser, siltier matrix, generally contain fewer ostracods and more thick-shelled bellerophont gastropods (Plate 3A). Such differences probably reflect hydrodynamic sorting and winnowing downslope, with the thinner beds containing a greater proportion of smaller bioclasts being deposited further offshore and/or from weaker flows.

Our re-discovery of marine invertebrate fossils in the Lundy Slates also confirms, after more than eighty years, the observations of Dollar (1935, 1941). Although Dollar did not figure any of his fossil specimens in his 1941 publication, a single photomicrograph in his PhD thesis purports to show a crinoid ossicle (Dollar, 1935, plate 6.3). The senior author has examined Dollar's thesis in the library of Cambridge University, and the image is, unfortunately, somewhat unconvincing. In contrast, however, Dollar's detailed written descriptions of the 'organic remains' he observed in his samples clearly demonstrate that he had undoubtedly discovered fossils in five of his eight Lundy Slate samples, including brachiopods, gastropods and echinoderms, and possibly bivalves and ostracods (Dollar 1935, p. 50-55). The latter group, ostracods, was never specifically named by Dollar (1935, 1941) amongst the fossils that he described, but his descriptions of 'ovoid bodies, with major axes 0.5mm long and minor axes 0.4mm long' are very suggestive of this group. Unfortunately, despite extensive enquiries, the whereabouts of his PhD sample collection is currently unknown and it may have been lost.

It is perhaps worth speculating why Dollar's (1941) discovery of fossils in the Lundy Slates was not followed up at any time in the intervening decades before our chance re-discovery. The timing almost certainly did not help: although Dollar first read his thesis paper at the Geological Society of London on 1st December 1937, it was not published until 1941, in the midst of an ongoing world war. Furthermore, his study was mainly concerned with the mineralogy and age of the granites and dykes of Lundy, and the comments he received at the time also focussed on the same aspects (Dollar, 1941, p. 76-77). One of his main conclusions – that the granites of Lundy were the same age as those of the mainland – was queried at the time (Dollar, 1941, p. 76) and later shown to be false (e.g. Dodson & Long, 1962), so perhaps that error may have affected acceptance of some of the rest of his work too.

Most damaging, however, were probably the less-than-supportive comments he received (and published!) from two palaeontologists he consulted about his apparent discovery of a crinoid ossicle: one thought it may be a calcareous alga whilst the other was "disinclined to express an opinion" (Dollar 1941, p. 45). Unfortunately, he chose not to publish the more supportive comments he evidently received; for example, regarding one of his thin sections, he notes in his thesis that 'there is general agreement among palaeontologists to whom this section has been submitted that many of its calcareous structures are of organic initiation' (Dollar, 1935, p. 54). Had Dollar chosen to figure these other fossil specimens, such as the 'recrystallized shell fragments', 'brachiopods with their loops preserved' or the 'slightly arcuate platy bodies of calcite' that he identified as 'brachiopod-valves or the shells of allied creatures' (Dollar, 1935, p. 51-54), the outcome may have been different.

Age assignment and correlation

As Dollar (1941) and others before and since have lamented, in the absence of fossil evidence it is not possible to confidently determine the age of the Lundy Slates. They have long been assumed to correlate with the Morte Slates Formation (e.g. Etheridge, 1867), and are currently mapped as such by the British Geological Survey (Edmonds *et al.*, 1979), but this correlation is based on scant evidence such as a similarity in colour and grain size, and on the presence of diagenetic quartz veins. As first noted by Hall (1871), the Lundy Slates may instead correlate to the Devonian-Carboniferous Pilton

Mudstone Formation or to overlying Carboniferous units of the mainland. Although detailed systematic work has yet to be completed, it is interesting that the fossil fish fauna, with abundant *Acanthodes*-type scales and *Denaea*-like symmoriiform teeth, seems to be similar to Carboniferous fish assemblages described from elsewhere in the British Isles and Europe (e.g. Ginter, 2022; Ginter *et al.*, 2015; Duffin, pers. comm.).

It is also important to consider the wider geological setting too. The major Sticklepath-Lustleigh fault system runs NW-SE through Devon and the Bristol Channel to the east of Lundy, and the direction of offset and displacement of Palaeozoic rocks recorded along this fault suggests that the Lundy Slates should perhaps correlate with the Pilton Mudstone Formation (Evans & Thompson, 1979, p.5). The widely accepted correlation with the Morte Slates Formation should therefore be regarded as tentative at best; an untested hypothesis.

On present evidence, the fossil assemblage of the Lundy Slates is certainly different to that recorded from the Morte Slates Formation. In their review of the Devonian successions of North Devon, Whittaker and Leveridge (2011, p.734-5) document the fossils that have been recorded historically from the 'Morte Mudstone Formation' (= Morte Slates Formation) of the key locality at Barricane Beach. The assemblage is reported as comprising poorly preserved brachiopods, including the spiriferid *Cyrtospirifer* and unidentified rhynchonellids, possible fragmentary crustaceans, bivalves and crinoid ossicles (Whittaker and Leveridge, 2011). Invertebrate macrofossil groups present in the Lundy Slates, such as orthocone nautiloids, gastropods or bellerophontids, are seemingly absent from Barricane Beach. Although this may reflect real differences between the assemblages, either because of age or environment, it might simply be the result of collection failure. Likewise, the apparent absence of conodonts, fish teeth and scales from the Morte Slates Formation is probably because the fossiliferous horizons at Barricane Beach comprise sandstone lenses (Whittaker & Leveridge, 2011) rather than carbonate-rich lithologies, as on Lundy, that are amenable to acid dissolution.

The discovery of identifiable fossils, in particular conodonts, from acid-dissolution of *in situ* samples means that a much more secure age assignment and correlation is achievable. Detailed taxonomic analysis of the conodont fauna has yet to be completed, but given their importance in biostratigraphy, especially through the Devonian-Carboniferous transition (e.g. Corradini *et al.,* 2017), it is anticipated that they will yield an accurate and precise age for the Lundy Slates. Knowing the correct age of the Lundy Slates will improve our understanding of the evolution of marine ecosystems through the Devonian-Carboniferous transition, an interval of major mass extinction and biotic change (e.g. Caplan & Bustin, 1999), and will also assist in deciphering the geological structure and history of the region.

Thermal history

Conodonts are also useful indicators of the thermal history of the rocks in which they are found, as they have been shown experimentally to undergo a predictable and irreversible colour change with increasing temperature (Epstein *et al.*, 1977). All conodonts recovered from the Lundy samples are black in colour (Plate 1F), which equates to a Colour Alteration Index (CAI) value of 5 on the Epstein *et al*. (1977) scale, and indicates that the conodonts have experienced temperatures of 300-480°C. This is consistent with the mineralogy of the slates themselves, which indicates a low level of metamorphism equivalent to greenschist facies (Edmonds *et al*., 1979). Greenschists typically form during regional metamorphism at temperatures of 300-450°C.

CONCLUSIONS

The Lundy Slates are fossiliferous, and yield a marine assemblage of brachiopods, ostracods, bellerophontid molluscs, gastropods, orthocone nautiloids, fish (chondrichthyans and acanthodians) and conodonts. Fossils are concentrated in thin, bioclastic 'event' beds that record the transport and subsequent deposition of biological remains from shallower to deeper water settings during individual storms. Many of the fossil groups are documented from Lundy for the first time, and detailed taxonomic work is still ongoing. Identifiable fossils, in particular the conodonts, are reported for the first time from Lundy and with further study should provide a definitive age estimate for the Lundy Slates. The currently accepted Upper Devonian age for the Lundy Slates and current correlation with the Morte Slates Formation are not based on any fossil evidence, and should be considered tentative at best. Conodonts are black in colour (CAI = 5), indicating that they have experienced temperatures of 300 to 480°C, consistent with mineralogical evidence that the slates have undergone regional metamorphism to greenschist facies. Given that the authors have only surveyed a fraction of the available outcrop of the Lundy Slates, it is highly likely that future work will reveal additional fossiliferous horizons and an even greater richness and diversity of fossil remains.

ACKNOWLEDGEMENTS

We thank the current and previous Lundy wardens, Rosie Ellis and Dean Woodfin Jones, for their enthusiastic support for this study. Permission to sample the Lundy Slates was kindly granted from Natural England. The following are thanked for spending their time searching the geological collections in their care in an effort to locate Dollar's PhD samples: Ben Winpenny (The Sedgwick Museum, Cambridge), Erika Anderson (The Hunterian Museum, Glasgow), Margaret Collinson (Royal Holloway, University of London) and Louise Neep (British Geological Survey). Louise Clarke and staff of Cambridge University Library are thanked for kindly granting access to Dollar's PhD thesis. The following colleagues are thanked for discussions of the Lundy fossil fauna, and for preliminary identifications of the conodonts and fossil fish specimens: Giles Miller, Chris Duffin and Charlie Underwood. The authors thank Prof. Malcolm Hart and an anonymous reviewer for their constructive comments.

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SIBLING AGGRESSION BETWEEN BLACK-LEGGED KITTIWAKE (*RISSA TRIDACTYLA*) CHICKS

by

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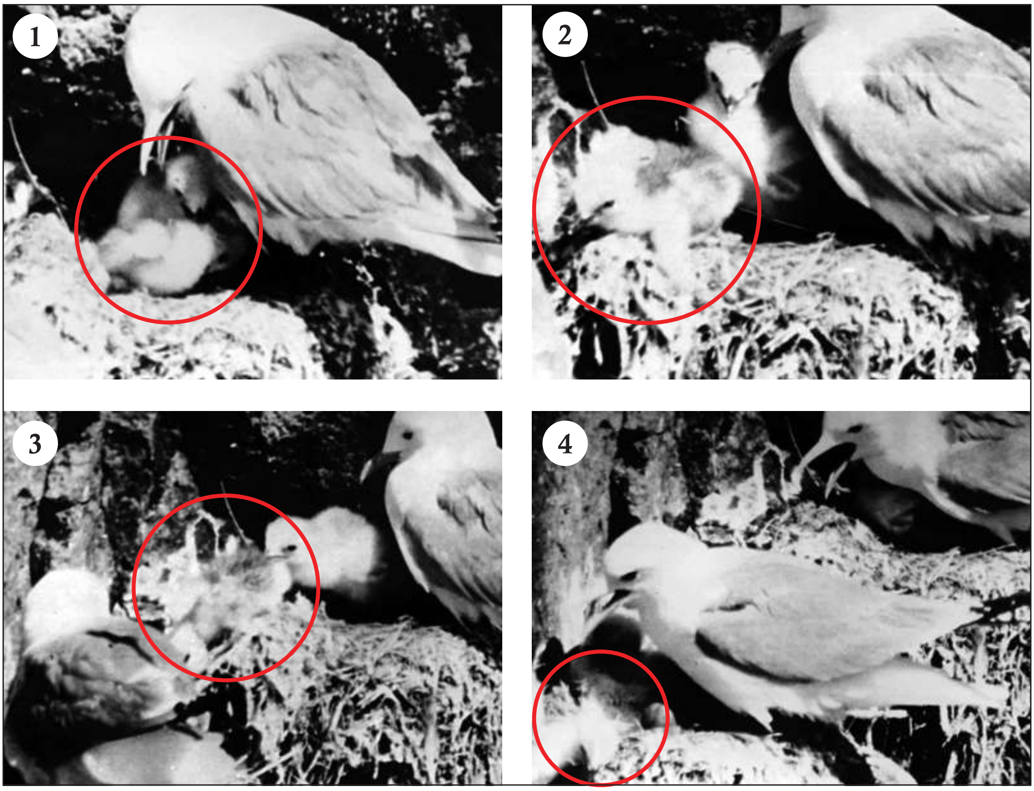
ABSTRACT
Siblicidal aggression has been documented in black-legged kittiwakes (*Rissa tridactyla*) by many researchers. First hatched (alpha) chicks attack and evict beta chicks, leading to the death of the younger bird. The infrequent nature of siblicide makes collecting consistent data difficult, but aggressive interactions between chicks are more readily captured. It is possible that patterns in aggressive behaviour will provide insight into the antecedents of siblicide. In this study, we used film footage collected during the breeding seasons from 2018-2021 to analyse aggressive interactions. First, we explored frequency differences in key behaviours between alpha and beta chicks. We then looked at the behavioural sequences within nests to describe aggressive interactions. Alpha chicks were consistently the aggressor in all samples, and beta chicks acted defensively. We comment on these findings and their relation to siblicidal aggression.

Keywords: *siblicide*, *aggression*, *sequential analyses*, *black-legged kittiwakes*

INTRODUCTION

Black-legged kittiwake, hereafter kittiwake (*Rissa tridactyla*) chicks engage in physical attacks against their siblings (Braun & Hunt, 1983; Dickins, 2021, Morandini & Ferrer, 2015; White *et al*., 2010). Attacks are characterised by pecking behaviour (White *et al*., 2010) in which one chick, almost exclusively the alpha (older) chick (Braun & Hunt, 1983; Dickins, 2021), delivers swift and often repeated directional beak jabs onto the head, body, or neck of the beta (younger) sibling. Attacks can cause the death of the beta chick (Dickins, 2021; Morandini & Ferrer, 2015). Siblicidal deaths do not usually occur on the nest (Maunder & Threlfall, 1972; Braun & Hunt, 1983) but are caused by the beta chick being forcibly evicted and falling from the nest.

Plates 1-4 show a sequence of photographs taken of a reported siblicide (D.W. Dickins, pers. comm.). In Plate 1, the alpha chick engages in a pecking attack against the beta sibling. The attacked chick faces away and tucks its beak down, an appeasement posture discussed at length by Cullen (1957) (Plate 2). As the alpha chick continues to attack, the beta chick exits the nest cup, falling into the nest below (Plate 3) where it is attacked



Plates 1-4. A sequence of images showing a siblicide event in progress. The beta chick is circled in red. The event occurred in a colony at Puffin Gully, Lundy. Images: David W. Dickins.

by the adult in that nest and forcefully ejected to its death (Plate 4). The images do not appear to show any instances of *pushes* as reported by Braun & Hunt (1983).

Siblicide is widely attributed to increased competition under food stress but has also been observed outside of feeding events. Research has primarily focused on rates of siblicide and aggression.

Studies of animal conflict increasingly use sequential analysis methods (Egge *et al.*, 2011; Trigos-Peral *et al.*, 2021) but this has not been extended to the interactions of kittiwake chicks during conflict situations. Sequential analysis enables patterns to be determined such that the likelihood of a target behaviour can be calculated from the occurrence of prior behaviours.

In the present study we used observational data collected from a population of kittiwake chicks on Lundy, to examine the behaviours of siblings immediately preceding and following pecking attacks with a view to better understanding the responses of beta chicks to attacks.

AGGRESSION

The beak is a key instrument in kittiwake encounters (Cullen, 1957). In adult kittiwakes, an attacker attempts to grasp the opponent's beak. An attacked bird may counter this by engaging in a *beak hiding* movement, tucking its beak into its body, denying the attacker access to the beak. During feeding bouts, Cullen observed that beta chicks turn their head away until the older sibling is satiated, at which point the beta chick would attempt to gain food.

According to Cullen, the beak hiding strategy is an adaptation to cliff-nesting. The behaviour serves as a method of appeasement in conflicts since there is no option to retreat given the precarious position of the nest ledge. This behavioural response suggests that beta chicks can control some aspects of aggressive encounters with their alpha siblings and avoid potential siblicide.

Research Aims

To assess differences in the frequency of key behaviours between alpha and beta chicks.
To examine conflict sequences for patterns of activity.

METHODS

We used film footage collected during the breeding seasons of 2018-2021 as a part of a long-term project studying the kittiwakes of Lundy (Dickins *et al.,* 2018). In Phase 1, we identified and selected 18 films containing two-chick nests and instances of conflict. These films were watched, and a behavioural catalogue was produced (Bateson & Martin, 2021). In Phase 2, we formally coded the behaviours on each of the 18 films.

Permissions

Ethics permission for the project was granted by Middlesex University Psychology Research Ethics Committee (Application 1114). Research and site work conformed to the Association for the Study of Animal Behaviour code of conduct and was in accordance with recommended seabird monitoring and survey methods (Walsh *et al.*, 1995). Permission was granted to collect data from the site, which is protected with restricted access. Lundy has a long history of scientific observations, established with successive wardens and is included in the Seabird Monitoring Programme (JNCC, 2021). The Warden, Dean Woodfin Jones, granted permissions for the study.

Field Site

All data were collected at the Aztec Bay inlet located on the northwest of Lundy, U.K. (51.186185, -4.674085). The site consists of steep exposed cliff faces with little vegetation which descend into the sea below. kittiwake population numbers at this colony are known to fluctuate (Jones, 2020). Kittiwakes share the site with neighbouring razorbills (*Alca torda*), guillemots (*Uria aalge*), and puffins (*Fratercula arctica*). The birds are not physically accessible to the public or researchers and suffer from no disturbance in this respect. During breeding seasons, the site experiences mild but changeable weather and can be exposed to strong winds, storms, mist, and strong sun within the range of a few hours. Average temperatures for June and July are 17°C and 19°C respectively. Plate 5 shows the site as viewed from the observation point.

Plate 5. Aztec Bay, June 2021. Image: Amanda Mead.

Data Collection

The main source of data was film footage which had been collected at the site during June and July of the breeding seasons of 2018-2021 (Dickins *et al.*, 2018). Films were created by randomly selecting nest sites to record, with a view to building an archive for future analyses. Footage had therefore not been collected directly for the present study and there was assumed to be no selection bias. All film and field data had been captured during daylight hours from 8am to 5pm. Film footage had been recorded using tripod-mounted digital video cameras with x30 and x60 digital zoom at approximately 100 metres from the nests.

Phase 1 Procedure

We developed a behavioural catalogue for chicks within the Behavioural Research Interactive Software package (BORIS version 7.10.2; Friard *et al.*, 2016; Table 1). We chose *Pecks* (Braun & Hunt, 1983; White *et al.*, 2010) and *Pushes* (Braun & Hunt, 1983) as measures of conflict behaviour. *Beak Grabs* and *Eating* were used to measure food gaining. *Facing Away* and *Beak to the Ground* were included as functions of appeasement, following Cullen (1957). *Defecation* was included as a proxy measure of satiety. A *Fall* and *Outside Nest Cup* category were each included for use in the event of an eviction or exit from the nest. Table 1 gives the behaviours with motor descriptions. We randomly sampled four films to pilot test the behavioural categories. Where behaviours occurred multiple times in succession, we coded each as a *point* event. For example, where a chick pecked repeatedly, every peck was recorded.

Table 1. Behavioural catalogue.

	Behaviour	**Description**
1	Peck	Focal animal jabs beak into sibling nestmate
2	Eating	Focal animal ingests food from adult
3	Beak Grab	Focal animal grasps adult's beak with own beak
4	Push	Focal animal moves sibling nestmate with force
5	Fall	Focal animal exits nest cup and ledge permanently
6	Facing away	Focal animal turns head and body so that the back is directed towards nestmates
7	Defecation	Focal animal visibly defecates
8	Outside nest cup	Focal animal exits nest cup onto surrounding ledge
9	Beak to the ground	Chick directs beak towards the nest floor

The film archive yielded 22 two-chick films with a mean duration of 22 minutes (median & mode=32 minutes, standard deviation=13 minutes). Films were selected if they contained physical conflict between siblings in the form of a peck or a push. Nests with no activity were omitted. As a result, 18 film samples were coded for the study.

Chicks sharing a nest were assumed to be siblings because most nest ledges sampled were positioned such that movement of chicks between nests was unlikely. Due to hatching asynchrony, alpha chicks start to grow sooner than beta chicks, and maintain a size advantage before the fledging phase. Therefore, the larger of two siblings in a nest was classified as the alpha chick. In all nests, identification of alpha and beta was clear with no ambiguity. We were able to identify individual nests from mapping conducted by the long-term research team. In this way we could assure the independence of our data points.

Phase 2 Procedure

We coded the 18 sampled films using our catalogue within the BORIS software. Observations commenced at the start of a film and used continuous observation concluding at the end of the film with every instance of a behaviour being recorded as an event.

RESULTS

Inferential statistics

We first conducted a series of Mann Whitney U tests to determine whether the distribution of core behaviours was the same across alpha (n=9) and beta (n=9) chicks. Each category was recorded as a percentage of overall behaviour emitted. As our sample size is low, we would urge caution in terms of interpreting the p-values associated with test statistics. But even when adopting a conservative $p=0.005$ to account for sample size, Table 2 clearly shows that only Pecks were unevenly distributed, and this because only the alpha chicks pecked in our sample. We can retain the null hypotheses for all other categories. The distribution of eating and defecation suggests that both chicks were equally provisioned in each nest. The distribution of facing away suggests that this behaviour is not only adopted in defence.

Table 2. Mann Whitney tests for asymmetries in the distribution of behaviour between alpha and beta chicks.

Null Hypothesis	p=
The distribution of Beak Grab is the same across categories of Chick	.258
The distribution of Pecks is the same across categories of Chick	.004
The distribution of Defecation is the same across categories of Chick	.666
The distribution of Eating is the same across categories of Chick	.489
The distribution of Facing Away is the same across categories of Chick	.113

Sequential Analysis

For each of the 18 films we generated a behavioural string using BORIS (version 7.10.2; Friard & Gamba, 2016). These strings were then used for sequential analysis in Behatrix, an additional program within the BORIS suite (Behatrix version 0.9.11; Friard & Gamba, 2021). Sequential analysis is an appropriate tool for examining interactions between a small number of focal animals (Drerup *et al.*, 2020; Cordoni *et al.*, 2022; Maglieri *et al.*, 2022). Behatrix enabled us to group all the strings together to explore the overall patterns of behavioural sequences within the 18 sampled nests (Trigos-Peral *et al.*, 2021; Drerup *et al.*, 2020). This was achieved by allocating an alpha or beta mark to each behaviour produced. In this way, for example, an *[Alpha] Beak Grab* and a *[Beta] Beak Grab* are treated as two separate begging behaviours that might occur next to one another in a string, or not. There were no *push* or *fall* events during the observations, and only one instance of leaving the nest cup. This last behaviour was therefore excluded from the analysis.

Table 3. Transition matrix for alpha and beta behaviours. The left hand column provides the first behaviour, whilst the remaining columns show the number of times that behaviour followed. For example, [Alpha] Beak Grab was followed 37 times by an [Alpha] Peck.

First Behaviour	[Alpha] Beak Grab	[Alpha] Defecation	[Alpha] Eating	[Alpha] Peck	[Beta] Beak Grab	[Beta] Beak to the ground	[Beta] Defecation	[Beta] Eating	[Beta] Facing away
[Alpha] Beak Grab	0	3	9	37	23	0	1	7	1
[Alpha] Defecation	3	0	0	0	1	0	1	0	0
[Alpha] Eating	7	0	0	3	1	0	0	5	0
[Alpha] Peck	41	0	1	0	0	4	0	3	8
[Beta] Beak Grab	17	1	0	4	0	0	2	5	1
[Beta] Beak to the ground	3	1	0	0	0	0	0	0	0
[Beta] Defecation	2	1	0	0	1	0	0	0	0
[Beta] Eating	6	0	3	8	2	0	1	0	5
[Beta] Facing away	4	1	2	6	1	0	0	5	0

Table 3 presents the transitions matrix for the entire data set representing all 18 nests. Repeated behaviours were excluded from this analysis, leaving just the one event to represent them. For example, repeated pecks would be represented as just one peck in the transition matrix. Repeated behaviours are regarded as bouts, which can indicate intensity of response, but for this analysis we were interested only in transitions between behavioural types.

Using these transitions, we then ran a permutations analysis with 102 permutations. Permutation analyses compare the actual sequence of behaviours observed with possible sequences, randomly drawn from the data set. These random draws are referred to as permutations. As we had a small data set, we ran a small number of these permutations (Knijnenburg *et al.*, 2009) to determine whether the transitions in the observed data were due to chance or not. Permutation analysis returns empirical *p-values* (alphas) for these probabilities, calculated from the actual data and not dependent upon any assumed distribution. Table 4 contains p-values after 102 permutations. Where a p-value is significant (at a conservative $p=0.005$ due to sample size) we can determine that at no point during the 102 permutations was a value equal to or higher than the number of observed transitions achieved. For example, we can see that was a significant transition at p<0.0001. If we refer to Table 3, we can see that this happened four times within the observations. Thus, no permutation returned a transition frequency .

Table 4. Permutation matrix for 100 permutations drawn from the original data. The table should be read as Table 3, but each cell contains a p value. Where p is significant then the transition is not considered random. Where p=0.000 it should be read as p<0.0001. The sample size is small, and we would recommend a conservative alpha threshold of p=0.005.

First Behaviour	[Alpha] Beak Grab	[Alpha] Defecation	[Alpha] Eating	[Alpha] Peck	[Beta] Beak Grab	[Beta] Beak to the ground	[Beta] Defecation	[Beta] Eating	[Beta] Facing away
[Alpha] Beak Grab	1.000	0.500	0.059	0.000	0.000	1.000	0.922	0.716	1.000
[Alpha] Defecation	0.363	1.000	1.000	1.000	0.559	1.000	0.137	1.000	1.000
[Alpha] Eating	0.196	1.000	1.000	0.696	0.882	1.000	1.000	0.000	1.000
[Alpha] Peck	0.000	1.000	0.980	1.000	1.000	0.000	1.000	0.951	0.049
[Beta] Beak Grab	0.010	0.500	1.000	0.931	1.000	1.000	0.186	0.196	0.912
[Beta] Beak to the ground	0.059	0.147	1.000	1.000	1.000	1.000	1.000	1.000	1.000
[Beta] Defecation	0.618	0.176	1.000	1.000	0.520	1.000	1.000	1.000	1.000
[Beta] Eating	0.843	1.000	0.157	0.137	0.863	1.000	0.422	1.000	0.000
[Beta] Facing away	0.902	0.402	0.324	0.186	0.951	1.000	1.000	0.020	1.000

From the transitions we created a schematic representation of the behavioural sequences in the form of a kinematic graph (Figure 1). The graph shows which behaviours preceded and followed one another and the transition frequencies, that is, the percentage of times a behaviour followed another (Egge *et al.*, 2011). The graph makes behavioural transition more easily understood, whilst containing all the data found in Table 3.

Alpha pecks were reliably followed by alpha beak grabs and beta beak to the ground. What is more, alpha beak grabs were reliably followed by alpha pecks and beta beak grabs, and alpha eating by beta eating (Figure 2). Combining these permutation results with the raw transition data in Table 3, it appears that Alpha chicks peck Beta chicks mostly in the context of feeding. Alphas peck the Beta, then beg whilst the Beta puts its beak to the ground in defence, and the Alpha pecks again after begging, whilst the Beta begs also. Beta chicks eat after Alpha chicks.

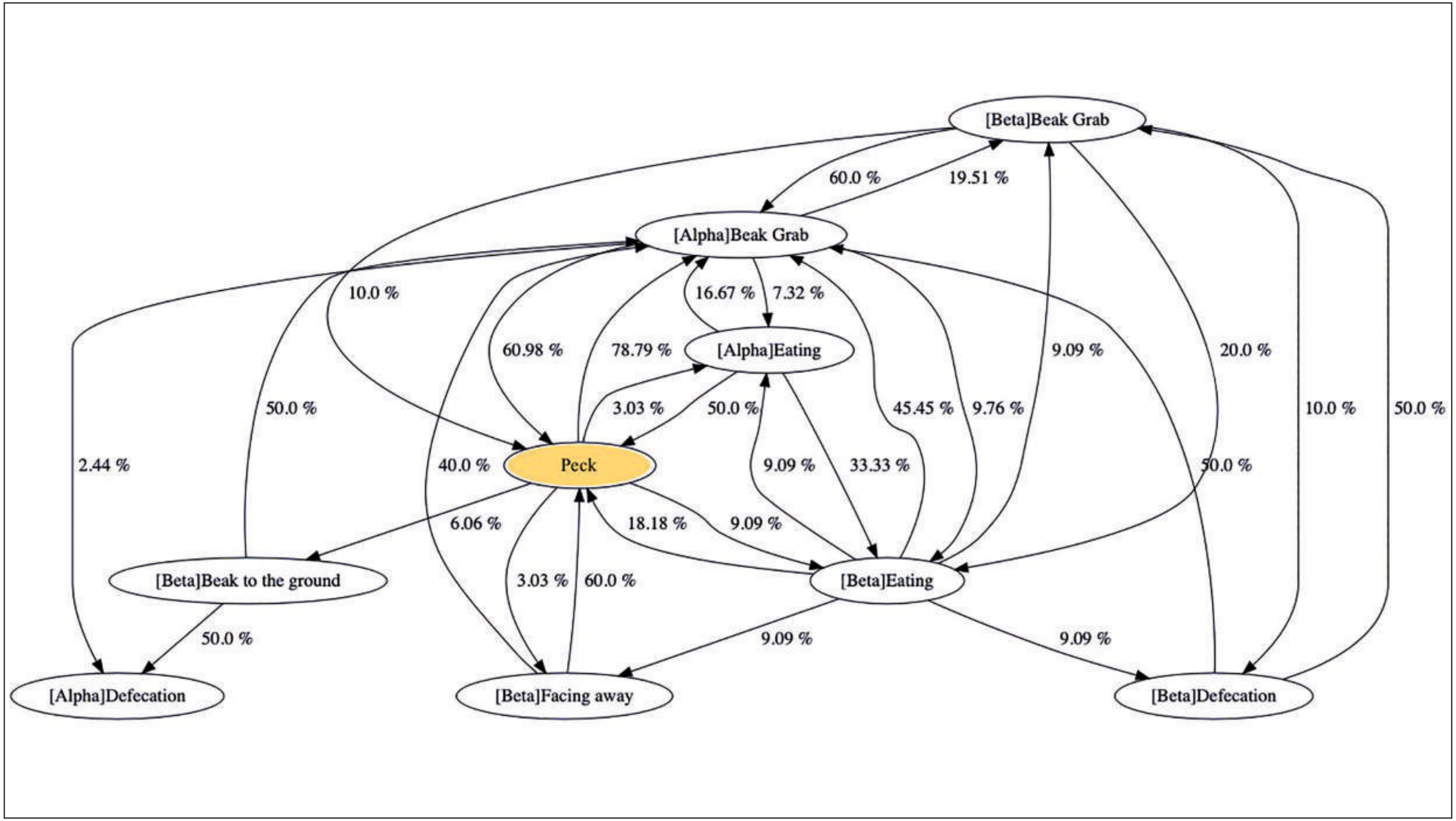


Figure 1. Kinematic diagram showing the behavioural transitions of alpha and beta chicks. Arrow direction indicates which behaviour occurs prior to a behaviour (arrow in) and which follows (arrow out). Transition frequencies are displayed as a percentage to the left of their respective arrow. See Table 3 for transition frequencies.

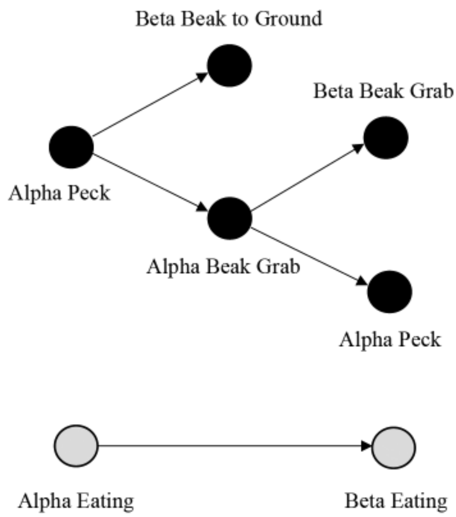


Figure 2. The main transitions in behaviour between alpha and beta chicks. As can be seen two distinct clusters of relationship emerged from the analysis.

DISCUSSION

Pecks were only delivered by alpha chicks. The behaviours of this population are therefore consistent with the literature (Cullen, 1957; Braun & Hunt, 1983). Differences in the frequencies of all other measured behaviours between the sibling groups were not significant (Table 2). As noted above, we had a small sample size, and it is possible that these null results are a consequence of this. Sequential analysis revealed that beak to the ground was performed by beta chicks in response to alpha aggression. This suggests that although chicks use the behaviour for appeasement, it is not used preventatively.

With due caution around sample size, eating was evenly distributed between alpha and beta chicks across the study suggesting that parents were provisioning their chicks equally. Kittiwakes are known to provision selectively and will allocate a greater proportion to the beta chick in the later stages of the nesting period, should the beta survive (Robertson *et al*, 2015). This study did not generate data which would allow us to test whether chicks were fed to satiation, but non-selective provisioning by parents would suggest that either there was no food stress in the colony and/or that parents were managing to find enough food. It is possible that parents of two-chick nests are of higher quality and experience than those producing one chick clutches and are therefore able to find ways to provision two chicks even where conditions are unfavourable.

To further explore these relationships a larger sample of behaviour across more nests would be desirable. It is our hope that more footage will be produced as a part of the long-term work on the island. With more data we can deploy the same analyses, but we can also begin to look to other forms of dependencies within the data. Currently we have only inspected one-step, or one-lag, transitions, asking what behaviour occurs next. It is entirely possible that a focal behaviour will in fact reliably predict behaviours further along in the sequence. To do this we would employ Markov procedures to look for dependencies, and then lag-sequential analyses to inspect them. These approaches, combined with those in this paper, would provide sophisticated association data from which to develop causal hypotheses.

Presently our transition data implies that much of the behaviour is at random, with behaviours associated with feeding providing the only clear signal. It is possible that this pattern will persist even with increased data and analyses. Kittiwakes have a small array of behaviours when chicks and producing them at random may be a part of a developmental trajectory that enables chicks to learn specific stimulus-response patterns under food reward and punishment (Dickins, 2021). From Figure 2 we can see that alpha pecking leads to beta appeasement, but also to alpha begging and then more alpha pecking. However, it also appears that beta chicks beg after alphas do. This presents the possibility that both alphas and betas will pair alpha pecking with beta begging – something that would be picked up by a lag sequential analysis. Under food stress begging should increase, in both chicks, and as a result alpha pecking may increase in intensity. What would need inspecting is whether beta appeasement reduces or has no effect upon alphas under these conditions. If this is so, then the transition to siblicide, by forcing the beta chick to shift away and fall from the nest, possibly to avoid intense pecking, becomes a quantitative matter. In other words, siblicide would not be a qualitatively different behaviour, but rather the sorry outcome of intense pecking under reduced or ineffective appeasement.

ACKNOWLEDGEMENTS

A-RM and TD should like to thank Alex Banks and one other anonymous reviewer for useful comments on the initial submission. Keith Hiscock, the editor, has also provided useful input and advice. More generally, this project and the longer-term project on Lundy kittiwakes would not be possible without the continued support of the Lundy Wardens and their teams. A-RM and TD are also grateful to Kirsty Neller for her work on the kittiwake film archive.

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A PRELIMINARY INVESTIGATION INTO ENVIRONMENTAL FACTORS IMPACTING THE MATERNAL BEHAVIOUR OF FERAL GOATS (*CAPRA AEGAGRUS HIRCUS*) AND SOAY SHEEP (*OVIS ARIES*) ON LUNDY

by

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INTRODUCTION

This short communication presents the preliminary findings of mother-offspring interactions in feral goats (*Capra aegagrus hircus*) and Soay sheep (*Ovis aries*) obtained between the hours of 09:00 and 17:00 during a week-long study on Lundy in late April – early May 2021. It should be noted that while this study was short in duration and limited in the time of day that observations were made, it still contributes to general understanding of the behaviour of two species of ungulates on Lundy.

METHODS

Feral goats and Soay sheep were found at Halfway Wall on the east side of the island (Figure 1). Soay sheep were found between Quarter Wall and Threequarter Wall. Subjects were nine feral goat pairs (mother and kid), and 46 Soay sheep pairs (mother and lamb).

An ethogram was used to capture behaviours observed during mother-offspring interactions (Table 1). Four researchers collected 36 10-minute continuous focal observations, which involved the behaviour of one pair being recorded continuously during each observational period.

Table 1. Ethogram of behaviours observed during mother-offspring interactions of feral goat (*Capra aegagrus hircus*) and Soay sheep (*Ovis aries*) pairs on Lundy.

BEHAVIOUR	TYPE	DESCRIPTION
Allogrooming	State	Any act of social grooming strictly between individuals in the maternal pair bond.
Suckling	State	The individual either receives or gives milk upon contact with the udder.
Calling between mother and offspring	Event	The individual calls for another individual strictly within their maternal pair bond.

At the start of each 10-minute observation, the following information was recorded:

- Percentage cover of vegetation, using a randomly placed 1 x 1 m quadrat.
- Terrain type, categorised as grassy plateau, grassy slope, rock, or cliff face.
- Wind speed, obtained from the Met Office.

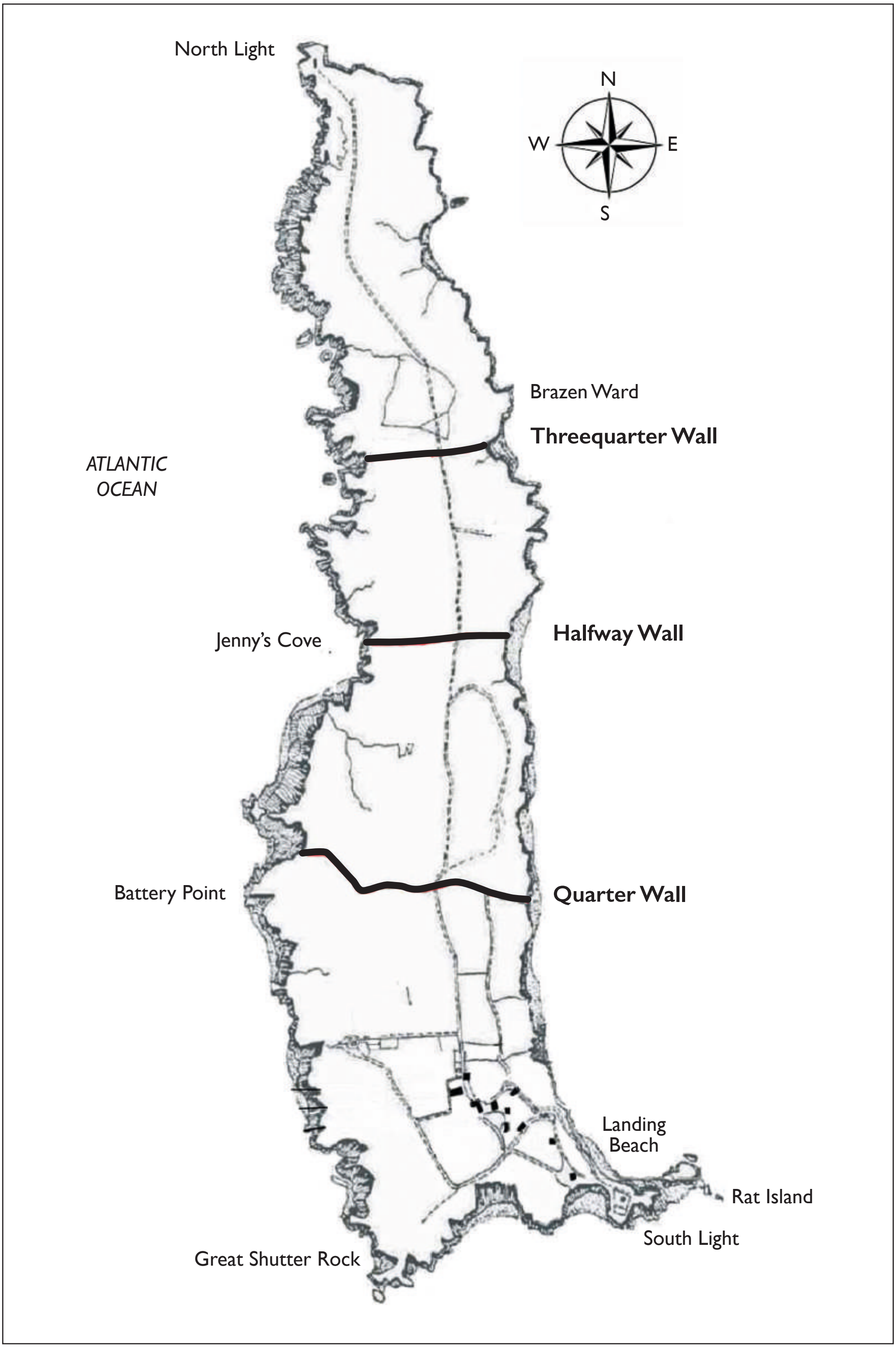

Figure 1. Map of Lundy indicating Halfway Wall, Quarter Wall, and Threequarter Wall.

- Weather type, categorised as sun, cloud, or rain.
- Time of day, categorised as morning (09:00-11:55), early afternoon (12:00-13:55) or late afternoon (14:00-17:00).

RESULTS

Three maternal behaviours were recorded (Table 2). Allogrooming and suckling were recorded in seconds, and calling was recorded in frequencies.

Table 2. Descriptive statistics including the minimum, maximum, mean, and standard deviation of the duration or frequency of observed maternal behaviours between feral goat (*Capra aegagrus hircus*) and Soay sheep (*Ovis aries*) pairs on Lundy. Behaviours were recorded within 10-minute observational periods.

BEHAVIOUR	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
Allogrooming	0.000	19.000	1.667	4.523
Suckling	0.000	68.000	13.639	17.437
Calling	0.000	6.000	0.4167	1.3174

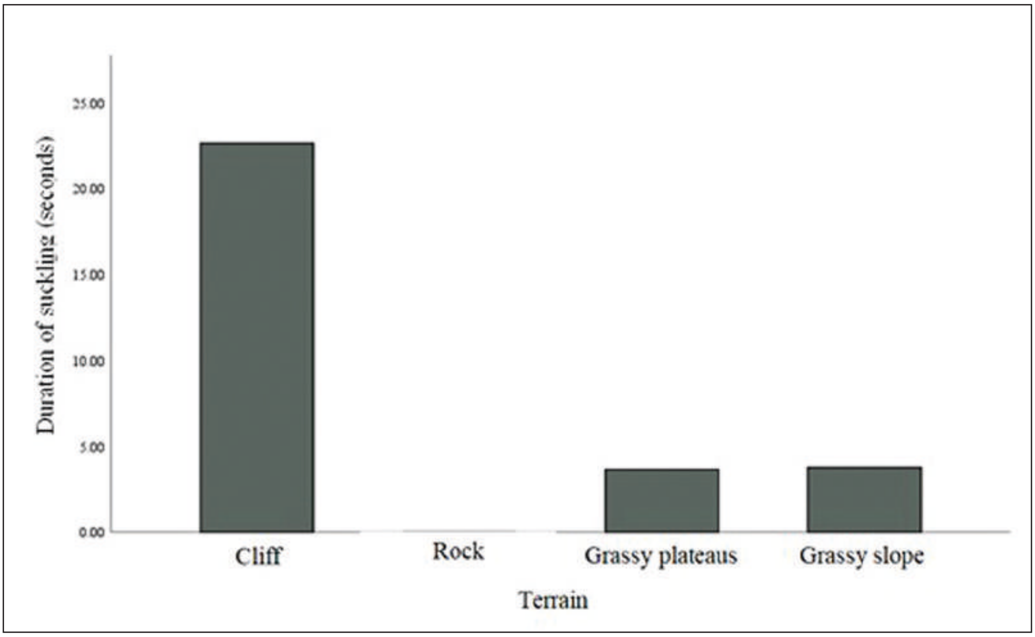

Figure 2. Relationship between terrain type and mean duration of suckling, between mother-offspring pairs of feral goats (*Capra aegagrus hircus*) and Soay sheep (*Ovis aries*) on Lundy. Suckling occurred most often on cliffs, in comparison to rock, grassy plateaus, and grassy slope terrains.

A significant relationship between terrain type and suckling was found ($P < 0.001$). Suckling occurred most often when the ungulates were on cliffs, in comparison to rocks ($P = 0.001$), grassy plateaus ($P <0.001$), and grassy slopes ($P <0.001$) (Figure 2). Allogrooming also had a significant relationship with terrain type ($P = 0.001$). Allogrooming occurred significantly more often when the ungulates were on grassy slopes, in comparison to cliffs ($P = 0.006$), rocks ($P = 0.027$) and grassy plateaus ($P < 0.001$).

CONCLUSION

The behaviours recorded in this study were allogrooming, sucking, and calling between mother and offspring. Significant relationships were found between terrain type and suckling, and terrain type and allogrooming. This study presents the preliminary findings of mother-offspring interactions in feral goats (*Capra aegagrus hircus*) and Soay sheep (*Ovis aries*), which can act as a starting point for further research.

ACKNOWLEDGMENTS

We are grateful to Dr Lisa Leaver and the University of Exeter for providing the opportunity to visit Lundy and conduct this study, and to Dr Andy Higginson for his assistance with the analysis of our data. We would like to thank The Landmark Trust for allowing us access to the island despite the restrictions posed by COVID-19, and for their excellent upkeep of the island throughout this strenuous year. We are also grateful to Dr Keith Hiscock for his thorough guidance and feedback on this short communication, as well as to the anonymous reviewers who provided us with invaluable feedback.

A PARTICULER OF LUNDY ISLAND: THE CLAYTON MANUSCRIPT

by
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INTRODUCTION

This note provides further information and dating of the paper on which the Clayton Manuscript was written (Rowland *et al.,* 2018). The 2018 paper makes a connection between the Clayton manuscript and the 17th Century owners of Lundy, the Grenville/Granville family (hereinafter Grenville) of Stowe House in Kilkhampton.

In the section of the 2018 paper devoted to the medium on which the 'Particuler' was written, the size and form of the paper was described. This description includes the paper size; 14¾ x 11¾ inches (375 x 297 mm), the lines from the paper-making process and its watermark.

Purely serendipitously, during transcription of Bishop's Transcripts for Kilkhampton in Cornwall, an identical piece of paper was identified.

BISHOPS' TRANSCRIPTS (BTs)

BTs were supposed to be verbatim copies of original entries of births, marriages and deaths as entered into Parish Registers although not all are exact copies nor have they survived. The earliest existing examples date from 1561 but with new regulations introduced by an archiepiscopal order in 1598, more examples date from 1598. There was a hiatus in the Commonwealth Period of 1649-1660. (Fitzhugh 1985).

Archdeacons were expected to travel to each parish in the diocese at Easter to collect the BTs, but in practice the local clergyman would bring his copies to a more central location in the diocese where they were collected and taken back to the Bishop's palace. Copies were most often made on any scrap of paper or parchment that could be acquired. Some of them were on scraps cut from blank areas of documents others were submitted on the back of old records.

Nowadays we are used to paper being freely available. Most households probably have a ream of printer paper ready for use. Until the middle of the last century, paper was not so common. Use was made of envelopes and the empty pages at the backs of books for shopping lists, recording card game scores or for immediate similar uses either due to this lack of paper or for good economic reasons.

VICARS OF KILKHAMPTON 1661-1672

Denis Grenville DD, was the youngest son of Sir Bevill Grenville. He was born in 1636/7. He was ordained deacon in March 1661 and in July 1662 instituted to the Rectory of Kilkhampton. He remained there until May 1664 when he became Dean of Durham.

From 1664, Daniel Bollen MA was presented to the living of Kilkhampton by John, Earl of Bath, the eldest surviving son of Sir Bevill Grenville. Bollen died, aged 67, in 1672. He was succeeded by Joseph Coryndon MA, again presented by John, Earl of Bath, and remained vicar up to 1711 (Dew 1926).

These appointments and places of worship and residence show the connection and continuity that the Grenvilles and Stowe House had with the vicars of Kilkhampton either with a direct relative or where the vicar was instituted, or recommended by a Grenville.

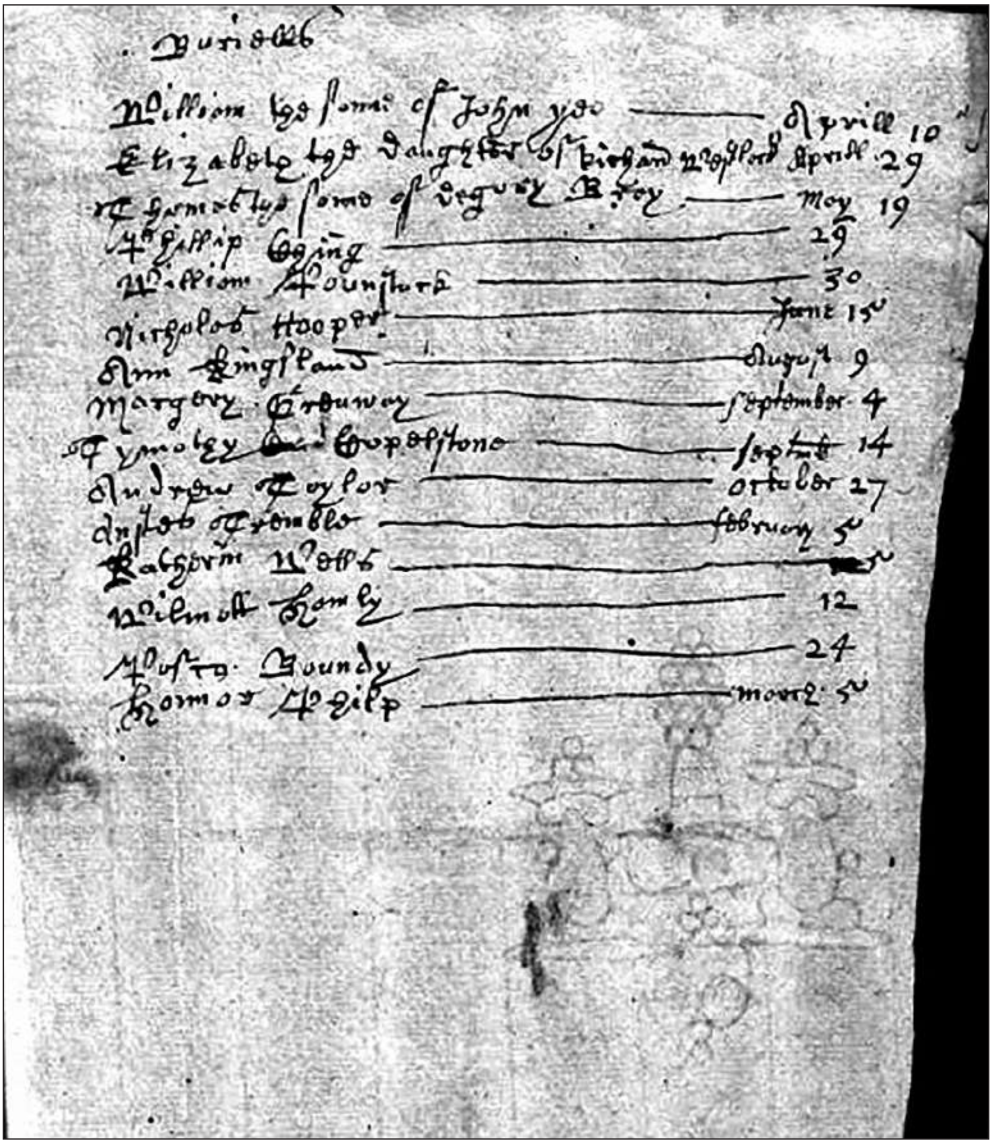

Plate 1: The Bishop's Transcript (BT) from Kilkhampton. Reproduced by kind permission of Devon Archives & Local Studies, DHC Early Bishop's Transcripts, Cornwall, Kilkhampton.

THE RETURN

Plate 1 shows a BT from Kilkhampton, discovered by the first author, of one side of the folio of returns for the year and is headed "*Kilkhampton the 17th of Aprill 1672 A True Coppy taken out of the Regester Booke of all the Christnings + Maraiges and Buriels of the last yeare 1671 as followeth …*". This title (reproduced in italics above) and the Baptisms and Marriages are on the reverse of the illustrated page of Burials and cover the period 9th April 1671 to 5th March 1672.

The BT is on a sheet of paper 14¾ x 11¾ inches (375 x 297 mm) folded lengthwise in half of the same size and form as that used in the Clayton paper and bearing the identical watermark which appears to be a three element candlestick supporting stacked circular elements. The marks created during the paper-making process are easily discernible and match the Clayton manuscript.

It is not unreasonable to assume that Coryndon, the vicar, would have asked for any paper that could be spared from the manor of Stowe House. Stowe had been in the possession of the Grenville family since 1620 and they still lived there at the time of this return and it could be reasonably assumed that he was given this folio for his use. Other BT returns around this entry in the archives look similar, but only this example has the distinctive watermark.

That there were many papers at Stowe is evidenced by Baring Gould (1899) who quotes the wife of Rev. R.S. Hawker. She noticed a document at Stowe signed by Sir Bevill Grenville wrapped around a mutton bone. This led Hawker to the discovery of a large chest full of letters dating from the 16th and 17th centuries. Dew (1926) then records that, a mass of original documents and letters from Stowe, relating to the Grenville family, were sent to Baron Carteret in London in 1854, where they were "committed to the flames".

Given that paper was not commonly available at this time and the fact that the vicar of Kilkhampton had to find something on which to write his returns to the Bishop, it is possible that his source of paper was from the local landed gentry. The family of his patrons, at Stowe, would have been disposed to support a request for spare paper from the vicar they had recommended who had a need for paper to make his returns and for which they apparently had little need.

Baring-Gould (1899) and Dew (1926) record that a large volume of paper was stored at Stowe throughout the 18th and 19th centuries and that no great value was attached to it. The size and appearance of the paper together with the distinctive watermark suggests that the BT and the Clayton manuscript originated from the same source. The date of the BT supports the origin of the paper as being 17th Century and that the Clayton manuscript dates quite possibly around the late 17th Century.

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LUNDY FIELD SOCIETY

for the study and conservation of a unique island

Established 1946
Registered Charity 258294
www.lundy.org.uk

THE LUNDY FIELD SOCIETY is a registered charity for the study of the history, natural history and archaeology of Lundy, and the conservation of its wildlife and antiquities.

Lundy is unique in many ways. It is home to an unusual range of plants, birds and other wildlife and, having suffered little disturbance, it offers special opportunities for study and research.

The island has a long and interesting history, with Bronze Age settlements, rare early Christian grave stones, a medieval castle and the remains of Victorian granite quarries. There is also a lot more architecture than you might expect!

There are 41 scheduled sites and monuments and 14 listed buildings. Much of the island is a Site of Special Scientific Interest (SSSI). The surrounding seas are the UK's first Marine Nature Reserve and a Special Area of Conservation. In 2003, part of the Reserve became the first No-Take Zone where removal of marine life is banned, and in 2010 the Reserve was rebranded as the UK's first Marine Conservation Zone.

The Society is part of the Lundy Management Forum, a partnership between the National Trust, which owns Lundy, the Landmark Trust, which manages the island, and other organisations with particular roles and expertise. They include the Devon and Severn Inshore Fisheries and Conservation Authority, English Heritage, the Environment Agency, Natural England, the Royal Society for the Protection of Birds and the Lundy Marine Conservation Zone Advisory Group. The LFS provides the secretariat for this last body.

The Lundy Field Society works with the island management. As well as providing volunteers for working holidays two or three times a year to assist the Lundy Conservation Team, we organise occasional events on the island which are open to our members, to islanders and to visitors.

As well as helping to study and improve Lundy, the LFS has a strong social side. For many of our members the Society is a way of keeping in touch with fellow enthusiasts and extending their knowledge and enjoyment of this special place. Nothing shows this better than the Annual General Meeting, held in Crediton in March, where members enjoy reports from the Island Manager and Warden and other talks by experts; renew acquaintances; often join in an auction of Lundy items; and enjoy a drink together afterwards.

The LFS produces many publications, both regular ones for members, and books and leaflets for the general public. The Annual Report details the work carried out on the island each year; the Journal of the Lundy Field Society contains peer-reviewed research papers; and the annual Bulletin has articles on a variety of Lundy topics and updates on island and LFS news. The Society also maintains a library on the island for the use of members and islanders.

For more information about the Society, including information about LFS publications, visit the the main website at www.lundy.org.uk and the Facebook page at www.facebook.com/DiscoverLundy.

To join the LFS, download a membership leaflet from www.lundy.org.uk/lfs/join.html. Whether you have just discovered Lundy or have known it for years, you will be welcomed as a member, and you will be making an important contribution to the study and conservation of the island through your membership.

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