A COMPARATIVE INVESTIGATION OF THE PLANKTON COMMUNITIES OF THREE LUNDY PONDS

by

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ABSTRACT

Three Lundy ponds were selected to study the composition and seasonal changes in the plankton community over a whole year. Two ponds result from excavations in the granite, Rocket Pole and Ackland's Moor, and the third is a shallow weedy pond at Widow's Tenement in the north of the island. Physical and chemical measurements were taken and plankton collected from April 2012 to March 2013. Results showed that the plankton communities have remained remarkably stable over the last 60 years since Galliford first studied them in the 1950s. Persistent algal blooms still occur in Rocket Pole Pond but plankton diversity and that of Ackland's Moor Pond is good. Lower diversity is seen in the shallow acidic Widow's Tenement Pond which has considerable plant life. Seasonal changes in species composition and numbers were also demonstrated.

Keywords: *Lundy, ponds, plankton, species diversity, seasonal changes*

INTRODUCTION

This field work study resulted from a statement: 'The composition of the plankton community changes very quickly in a small pond throughout the year and monthly samples are required to fully understand these changes.' (George, 2012).

The baseline for all freshwater plankton surveys on Lundy is Galliford (1954) who surveyed all Lundy ponds for the months of July 1952 and March, May, August and November 1953. This survey may show continuity of species, loss of species or previously unrecorded species. Nonetheless it will, after 60 years, provide a new baseline for future surveys and give data for those months in which there had been no surveys.

Three ponds were selected: Ackland's Moor Pond, a flooded quarry pond set in semi-improved grassland; Rocket Pole Pond, a larger quarry pond set in acid grassland and known for its algal blooms and Mirror Carp population; and Widow's Tenement Pond, a weedy shallow pond set at the boundary of maritime and acid grassland.

The main aim of the investigation was to examine the composition of the flora and fauna of the plankton of the three ponds each month for a whole year to determine seasonal changes that regularly occur in small water bodies.

ORIGIN OF PONDS AND GENERAL CHARACTERISTICS

The origins and characteristics of two of the ponds, Ackland's Moor Pond and Widow's Tenement Pond, have recently been described in detail by Rowland (2014).

Rocket Pole Pond - RPP (OS Grid reference SS1348 4368)
The pond is a deep, steep-sided water body cut into granite. Granite from this excavation provided building material for the construction of the South Lighthouse in 1897. At this time, during the excavation, it was reported to contain a spring (Lewis, 1918). There is no through drainage and it is fully exposed to the westerly winds that commonly blow across the island.

There is little vegetation apart from the rush *Eleocharis palustris* in the few shallower areas, stands of the Soft Rush, *Juncus effusus,* at the edges and occasionally some patches of Water Pennywort, *Hydrocotyle vulgaris*. It often displays a green or brown algal bloom and has a population of Mirror Carp. It has never been reported as drying out but during drought periods water is extracted to aid the water demands of the island. Further details of the characteristics and the flora and fauna can be found in earlier papers e.g. George (2007), George *et al*. (2004a, b).

Ackland's (sometimes Acland's) Moor Pond - AMP (OS Grid reference SS13262 44748)
The pond is a square cut granite quarry on the third highest point of the island and is cut into a cairn. It is fairly shallow and set in semi-improved grassland (Barker, 2012). The pond has neither inflow nor outflow and relies totally on surface runoff and rainfall for its existence. It dries out during drought periods (e.g. 2006, 2011, 2014).

Widow's Tenement Pond - WTP (OS Grid reference SS1346 4682)
This is a roughly circular, naturally formed, shallow weedy pond lying within the mediaeval enclosure of Widow's Tenement. The pond sits in a bowl of earth, the eastern edge of which is distinguished by *Sphagnum* moss and the rush *Juncus articulatus* and the western edge by the Soft Rush*, Juncus effusus.* It dries out during periods of drought.

Sketch maps of the three ponds showing vegetation and areas of plankton sampling are shown in Figure 1 and Plates 1-6 show the ponds in summer and winter.

METHODS

The three ponds were visited every month from April 2012 to March 2013 by Alan Rowland when abiotic measurements and plankton samples were taken. This included a very cold spell in March 2013 when ice had to be broken on WTP and negotiated around on AMP. The ponds were also photographed on each monthly visit.

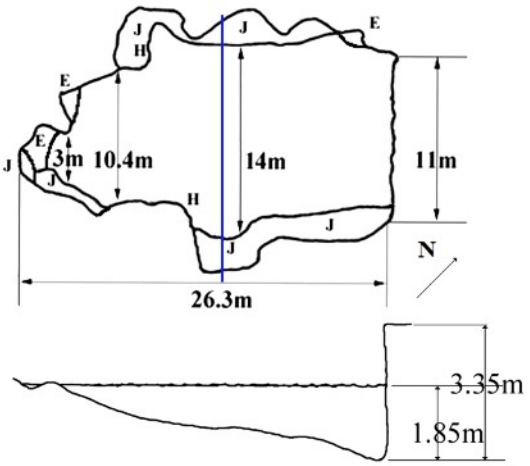
Abiotic

Six parameters were measured at each visit: air and water temperatures, dissolved oxygen, pH, light penetration and maximum depth of pond.

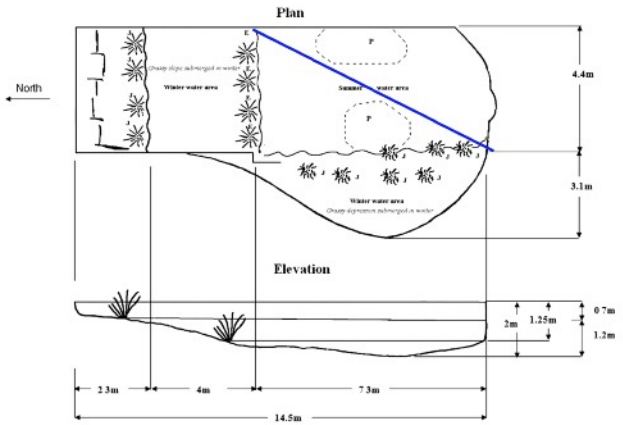
Air and water temperatures

Ambient temperatures were recorded at the beginning of the survey, but opportunity arose later on to use data loggers with associated deep water containers. These consisted of three separate Gemini TK-4014 Tinytag Talk2 temperature loggers each enclosed in a

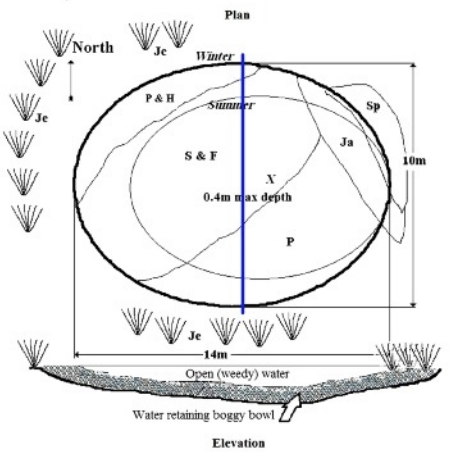
Rocket Pole Pond



Ackland's Moor Pond



Widow's Tenement Pond



Key

C = *Callitriche stagnalis*
E = *Eleocharis palustris*
F = *Fontinalis antipyretica*
H = *Hydrocotyle vulgaris*
Ja = *Juncus articulatus*
Je = *Juncus effusus*
P = *Peplis portula*
Po = *Potomageton polygonifolius*
S = *Scirpus fluitans*
Sp = *Sphagnum cuspidatum*

Figure 1: Plan and elevation of all three ponds with depths and flora. The blue line indicates the plankton trawl

Plate 1: Rocket Pole Pond in summer (July 2012). © Alan Rowland

Plate 2: Rocket Pole Pond in winter (December 2012). © Alan Rowland

Plate 3: Ackland's Moor Pond in summer (September 2012). © Alan Rowland

Plate 4: Ackland's Moor Pond in winter (February 2013). © Alan Rowland

Plate 5: Widow's Tenement Pond in summer (May 2012). © Alan Rowland

Plate 6: Widow's Tenement Pond in winter (December 2012). © Alan Rowland

GeminiACS-00-1(IP68) stainless steel deep water container for temperature monitoring. One was placed on the bottom of the pond, a second just below the water surface and the third placed on dry land near the edge of the pond. By the end of the surveys it was possible to collect data for a month at a time. The resulting data were analysed using the proprietary software kindly supplied by Gemini Tinytag Explorer (V.7) (Gemini 2011).

Dissolved Oxygen and pH

At the start of the surveys a digital meter Reed YK2001 Intelligent meter with two probes was used. For pH the probe is a PE-03 general purpose 0.0-14.0 pH and for oxygen, a PDO polarographic (Clark oxygen electrode) dissolved oxygen probe with integrated temperature sensor. After pH sensor problems a Pen type pH tester was acquired and substituted. Dissolved oxygen was measured only just below the water surface in each pond.

Light Penetration

A Secchi disc was used to measure the light penetration into the ponds. This disc, 20cm in diameter with a black and white pattern, was lowered into the water (at the same selected place for each water body) to the depth at which it just disappeared from sight. It was then raised to the depth at which it just came into sight. Transparency is the mean of the two depths. Light transmission is affected by the turbidity of the water which is the amount of suspended particulate material (inorganic, organic, plankton) in the water.

Depth

A line weighted with a 140g lead fishing weight was used to measure the maximum depth of each pond at each monthly visit. The line is marked at 250mm intervals but additionally the line is measured using a tape measure accurately to record the depth. The location of the deepest part was ascertained by repeated soundings in the three ponds early on in the survey.

Plankton

Plankton was collected using an EFE-GB phytoplankton net, 53µm mesh 24cm wide and 0.5m in length with a 53µm detachable terminal filter. Two hauls were made across each pond in the same position every month (Figure 1) and the resultant plankton was collected in two separate pots for later study. Samples were fixed in 4% formaldehyde solution and then transferred to 70% Isopropyl alcohol (IPA) for microscopic examination. An estimate of relative abundance of each taxon was made on a scale of 1-6:

1	1 or 2 only of the taxon
2	3-25 of the taxon
3	26-100 of the taxon
4	101-500 of the taxon
5	over 500 of the taxon
6	over 1000 of the taxon

In months when phytoplankton blooms occurred, e.g. in Rocket Pole Pond, sub-sampling was required for the identification and estimation of abundance.

RESULTS

Temperature

Figure 2 shows a combined graph of air and water temperatures for each month that the survey was undertaken. Simultaneous surveying was not possible. On day visits, two or three hours separated them and on longer visits as much as a day or two separated surveys. Air and surface water temperatures were measured on each visit, but due to this time difference the graph shows a range of air temperatures depicted as a varying light blue band. It can be seen that water temperature is usually lower than that of the air with the single exception of Widow's Tenement Pond, which is the shallowest pond, in June when the water was warmer that the air. The deepest pond, Rocket Pole, was the coolest but the temperature of the water followed that of the ambient air. There was a greater variation of temperatures in the warmer periods but in winter temperatures were much more uniform. Species that inhabit the ponds with a greater range of temperatures have to be able to cope with such changes.

Diurnal temperatures were logged for all three ponds. Temperatures from Ackland's Moor and Widow's Tenement ponds using Tinytag temperature monitors for a month are shown in Rowland (2014).

Figure 3 shows temperature recorded using these monitors, initially for four days in May, and later for a whole month over late December 2012 and January 2013 for Rocket Pole Pond. It is informative to compare summer and winter as well as diurnal variations of air, water and pond bottom temperatures.

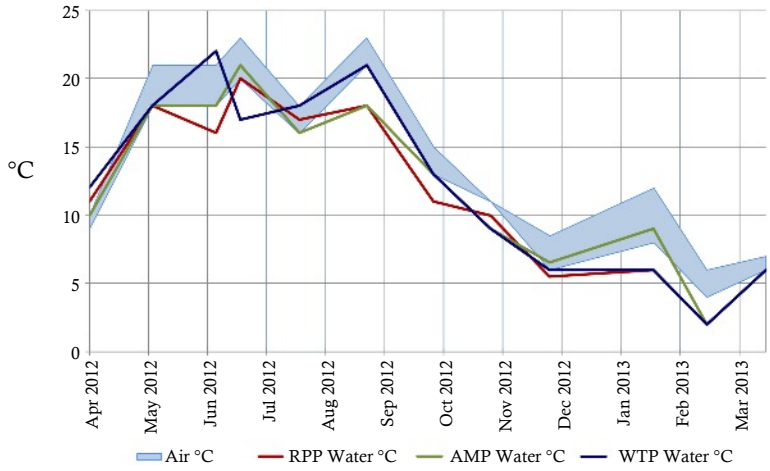


Figure 2: Combined air (light blue band) and water temperatures for Rocket Pole (red), Ackland's Moor (green) and Widow's Tenement (dark blue) Ponds for the period of the survey

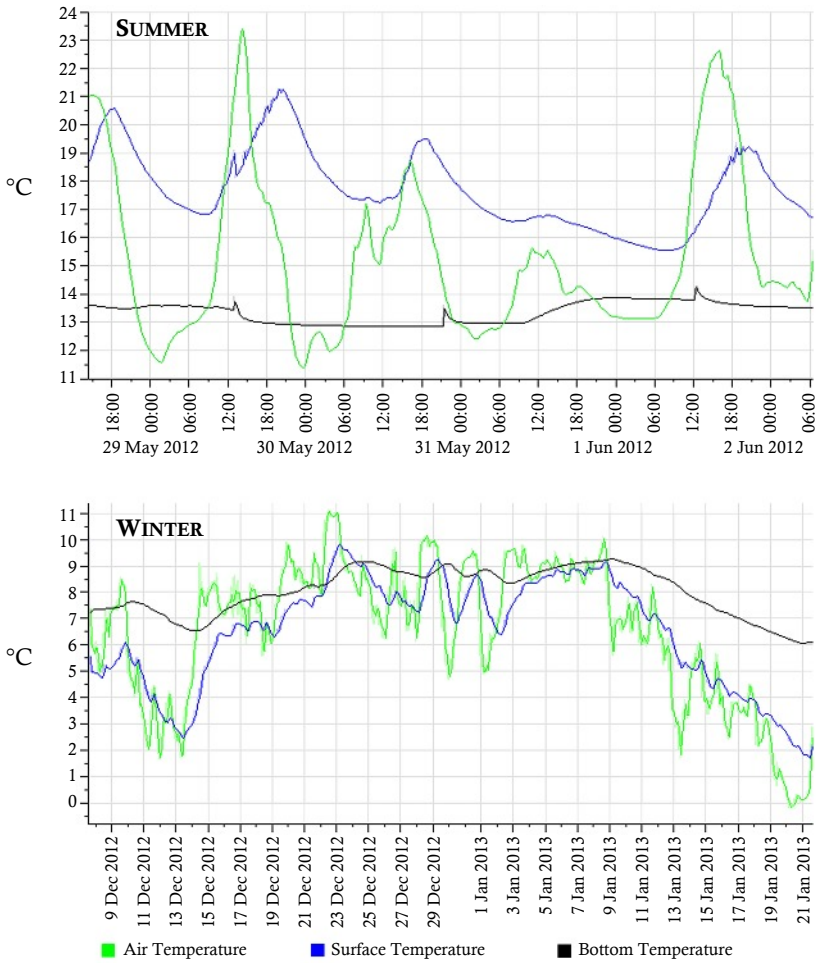


Figure 3: Comparison of air (green), water surface (blue) and pond bottom (black) temperature in Rocket Pole Pond in summer (top) and winter (bottom)

The upper graph shows air temperature alternating between around a high of 23°C at midday to a low of around 11°C at night (green trace). The blue trace records the surface temperature of the water which also shows a diurnal cycle but with a six hour lag – air peaks at midday whilst water peaks at 6pm. However, the minimum and maximum water temperatures are smoother with only a 5°C difference as compared with 20°C air temperature variation. The sensor on the bottom of the ponds (black trace) shows only a 1°C variation throughout.

The winter temperatures, taken over a six week period, show similar diurnal variations but within a much narrower range. Air temperature varied around 9°C and surface water a similar amount, but the deep water varied only by a few degrees.

This illustrates the damping effect of water on temperature variations – the deeper water varying much less than that in direct contact with the air. There is an inverse relationship between the amount of oxygen in water and its temperature which is exacerbated by any lack of flow. This has a major effect on the species that inhabit freshwater which depend on oxygen for respiration. Warmer water holds less oxygen and high temperatures can have fatal effects on organisms. The steady temperature of deeper water allows sensitive organisms to survive.

Depth and Light Penetration

Table 1 shows the depth and the depth of light penetration into the three ponds.

Rocket Pole Pond is the deepest pond, typically around 2 metres at maximum, but it consistently has a thick opaque algal bloom that restricts light transmission. Light penetration was between 0.15 and 0.38 metres throughout the survey whereas the total depth varied from a maximum of 2.23 to a minimum of 1.85 metres.

Ackland's Moor Pond is much shallower, rarely being more than one metre in depth, and often considerably clearer. During the survey its depth varied from a maximum of 1.1 to a minimum of 0.5 metres. On occasion, in June, July and September, the water was completely transparent giving views to the bottom mud. For the rest of the year, light penetration varied between 0.32 and 0.75 metres.

Widow's Tenement Pond is shallower than the other two ponds, being only 0.4 metres at maximum depth and 0.15 at its minimum during the survey. It is a weedy pond where light transmission is restricted and it was never clear to the bottom, with light penetration varying between 0.08 and 0.25 metres throughout the year.

pH and Dissolved Oxygen

The pH of all three ponds varied from month to month but averaged values over the year showed that Rocket Pole Pond is an alkaline body of water (pH 8), Ackland's Moor Pond is near neutral (pH 6.5) and Widow's Tenement Pond is an acidic body of water (pH 4.7).

Dissolved oxygen was measured only just below the water surface and surface waters in all ponds showed them to be well oxygenated (over 80% saturation) throughout the year, partly due to the strong winds that often blow across the island which keep the waters well mixed. Oxygen content in the deeper water was not measured, but previous research in the deeper Rocket Pole Pond has shown that oxygen content rarely fell below 65 % saturation in the bottom water layers (George, 2007).

Table 1: Depth in metres (m) of the three ponds and the extent of the light penetration (m) into the ponds from April 2012 to March 2013

Pond	Rocket Pole		Ackland's Moor		Widow's Tenement	
Date	Depth m	Light Penetration m	Depth m	Light Penetration m	Depth m	Light Penetration m
Apr 2012	1.85	0.28	0.50	0.32	0.35	0.08
May 2012	1.85	0.29	0.60	0.48	0.15	0.10
Jun 2012	1.86	0.15	0.60	0.60	0.32	0.20
Jul 2012	1.85	0.38	0.75	0.75	0.27	0.13
Aug 2012	1.85	0.31	0.62	0.52	0.28	0.21
Sep 2012	1.85	0.34	0.50	0.50	0.30	0.18
Oct 2012	2.10	0.30	0.75	0.70	0.40	0.20
Nov 2012	1.92	0.30	0.80	0.60	0.37	0.13
Dec 2012	2.13	0.28	1.07	0.54	0.33	0.08
Jan 2013	2.23	0.30	1.10	0.48	0.37	0.25
Feb 2013	2.21	0.29	1.04	0.68	0.31	0.20
Mar 2013	2.21	0.26	0.87	0.59	0.35	0.25

Both pH and oxygen can be affected by input from animals which use the ponds (e.g. sheep and goats in RPP, domestic and Soay sheep, Sika deer and goats in AMP and Soay sheep and goats in WTP). In addition the fish population and the frequent algal blooms can affect both pH and dissolved oxygen in Rocket Pole Pond.

Plankton

The two plankton samples collected each month from the three ponds did not show any significant differences in the allocated scores (1-6) so results were combined in the Tables 2 to 4.

Rocket Pole Pond (Table 2)

Rocket Pole Pond is dominated by green algae throughout the year with *Pediastrum boryanum* and *Desmdesmus magnus* the main species that are particularly abundant in the summer months. Another green alga, *Ankistrodesmus falcatus*, reached bloom proportions in November and December. *Botryococcus braunei*, another green alga but which appears brown due to the presence of oil capsules, appeared in the spring (March/April) as it had done previously in 2005. The Blue/green alga, *Microcystis*, occurred in the summer months but was not so abundant as it had been in earlier years (George & Sheridan, 1987).

Two species of Crustacea were dominant in the zooplankton, the cladoceran, *Bosmina longirostris*, and the copepod, *Cyclops. Bosmina*, was recorded by Galliford in 1952 and 1953 as being common in the plankton during his six months of sampling. In 2012-13 it occurred every month with young forms present in June and July. In December, January and February adults with overwintering resistant eggs in the brood pouch were found. Cladocerans (water fleas) occur as females for most of the year which reproduce parthenogenetically but as water conditions deteriorate (low temperatures, drought etc),

Table 2: Plankton organisms in Rocket Pole Pond

Species	2012									2013		
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
PHYTOPLANKTON												
Cyanophyta												
Microcystis sp.			2	2	2	2	5					
Chlorophyta												
Botryoccus braunei	6											4
Pediastrum boryanum	5	5	5	5	6	6	4	5	5	4	4	4
Demodesmus magnus	4	4	4	4	5	6	5	5	4	4	3	3
Ankistrodemus falcatus	2			2		4	5	6	6	3	3	3
Oedogonium sp.	3	2	2	2	2					2	2	3
Ulothrix sp.	3											2
ZOOPLANKTON												
Cladocera												
Daphnia obtusa	3	2				2	2	2	2		1	1
Bosmina longirostris	3	3	4	6	2	3	3	3	4	3	4	3
Chydorus sphaericus	2					2						
Copepoda												
Cyclops sp. adults	4	4	4	5*	3*	3*	2	3	3	3	4*	3
Immature cyclopids	2	3	3	4	2	3	2	2	2	2	4	2
Cyclopid nauplius L.	2	2	2	3	2	3	2	1	2	2	3	2
Canthocamptus sp.	3	2	2	2	2	3*	2	2	2	3	3	2
Rotifera												
Brachionus rubens		2	2	2	1							3
Keratella quadrata		2	3	2	2							
Keratella cochlearis	2	2	3	3	3	3	3	2	2	2	2	3
Keratella valga	2	2	2	3				2	3	3	3	4
Filinia longiseta	2		2	2	2	2	2	3	3	3	4	4
Cephalodella sp.	3	3	3	2	2				2	3	2	3
Trichocerca sp.						2		2				
Annelida												
Nais sp.												1
Insecta - Hemiptera												
Corixa sp.		1										
Insecta - Diptera												
Chironominae L.				1	2					1		
Chaoborus crystallinus L.						1						
Tardigrada												
Macrobiotus sp.											1	

Key: L.=larva. 1=one or two of taxon; 2=3-25; 3=26-100; 4=101-500; 5=Over 500; 6=Over 1000
* several females with egg sacs and males with modified antennules

some eggs develop into males. Females are fertilized and they produce special resistant eggs. These are released from the brood pouch when the females moult and they develop thickened walls. Such resistant eggs can remain dormant in the bottom mud often for considerable periods. When favourable conditions return they develop into females which reproduce again parthenogenetically.

Cyclops adults occurred throughout the year and females with egg sacs and males with modified antennules for grasping the female were present during the summer months. *Cyclops* larvae (nauplii) and immature stages were found in the plankton throughout the year. The harpacticoid copepod, *Canthocamptus* sp., occurred in reasonable numbers throughout the year, but the other free-living copepod group, the calanoids, are apparently absent from Lundy although found on the mainland.

Seven species of the Rotifera were present in the pond, six of which had been recorded by Galliford in 1953. *Keratella cochlearis* was found in every month of the survey, *Filinia longiseta* in 11 months and *Keratella valga* in 9 months but not in late summer and early autumn. *Cephalodella* sp. also occurred in 9 months but appeared to be absent in early and late autumn. All four species were fairly numerous during the winter months when several were observed with resting eggs attached. As in the water fleas these eggs are very resistant to extremes of temperature and desiccation and can remain dormant for long periods. *Keratella valga* was not recorded by Galliford (1954) but he did find it in several other Lundy ponds, including Ackland's. He found *Keratella quadrata* in Rocket Pole Pond as our survey identified in late spring and summer.

Very few other organisms occurred in the plankton, usually just one or two of a species in one month only e.g. the Naid oligochaete in March, the Lesser Water Boatman, *Corixa* sp., in May and the Phantom midge larva, *Chaoborus crystallinus*, in September; this latter species is abundant in other Lundy ponds in the autumn e.g. Pondsbury, Quarry Pool and the larger pond at Quarterwall. Chironomid larvae which are common in the three ponds named above, were occasionally found in Rocket Pole in summer and winter.

Ackland's Moor Pond (Table 3)

Ackland's Moor Pond has six species of green algae, with the filamentous *Oedogonium* sp. present for most of the year. None reached 'bloom' proportions as was seen in Rocket Pole Pond.

Chydorus sphaericus and *Simocephalus vetulus* were the most dominant of the cladocerans with *Daphnia obtusa* present in the autumn and winter months. The dominant Cladoceran, *Bosmina longicornis*, in Rocket Pole Pond was found in Ackland's Moor Pond but only in July and December. Galliford (1954) only found this *Bosmina* in Rocket Pole Pond and nowhere else on the island, but now it is appearing in other ponds – Ackland's as we have seen and also in the larger Quarterwall Pond (George, 2012), but in small numbers.

The cyclopoid copepod, *Cyclops* sp., was fairly abundant occurring in every month of the year, being particularly prevalent in the spring and winter months. Females with egg sacs and males with modified antennules appeared in spring, summer and late winter. The harpacticoid copepod, *Canthocamptus*, was found mainly in the spring and summer.

Table 3: Plankton organisms in Ackland's Moor Pond

Species	2012									2013		
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
PHYTOPLANKTON												
Chlorophyta												
Pediastrum boryanum				2								
Desmodesmus magnus		2	2	2								
Chlorella sp. 'group'	3	3	4	2	1							2
Oedogonium sp.	2	3	4	2	2	2	2	3	2	2		
Spirogyra sp.			2		2							
Microspora sp.												4
ZOOPLANKTON												
Cnidaria - Hydrozoa												
Hydra viridissima								1		3		
Cladocera												
Daphnia obtusa						2	2	2	3			
Bosmina longirostris				2					2			
Chydorus sphaericus	4	2	2	5	2	2	3			2	4	3
Simocephalus vetulus			3	3	2	2	2	3	3	3	3	4
Copepoda												
Cyclops sp.	4	4*	3*	3*	1	3	3	3	4	4	5*	3*
Cyclopid nauplius L.			2	2	1			1			2	3
Canthocamptus sp.		2	2	3	1						2	
Rotifera												
Brachionus rubens				3	3				1		1	
Brachionus angularis					4		1				1	
Keratella cochlearis						5	1	1	1	2		
Keratella serrulata				1							2	2
Keratella valga	2	4	2	3	4	1	2		2	1		
Filinia longiseta					1	1						
Trichocerca sp.				1								
Annelida												
Nais sp.				1							1	
Insecta - Hemiptera												
Corixid juvenile					1							
Insecta - Coleoptera												
Fam. Dytiscidae L.				2								
Insecta - Diptera												
Chironominae L.				2	2	1	1	2	2	3	2	1
Arachnida												
Hydracarina (water mites)				2	2	2	1	1	1	1		1
Tardigrada												
Unidentified species			1	1	1	1			1	1	2	

Key: L.=larva. 1=one or two of taxon; 2=3-25; 3=26-100; 4=101-500; 5=Over 500; 6=Over 1000
* several females with egg sacs and males with modified antennules

Seven species of Rotifer were present in the pond, six of which had been recorded by Galliford in 1952 and 1953. As in Rocket Pole Pond, *Keratella valga* occurred in most months of the year, with *Keratella cochlearis* appearing in the autumn and winter months. Other species, *Brachionus rubens*, *Brachionus angularis*, *Filinia longiseta*, *Keratella serrulata*, *Trichocerca* sp., were only occasionally found during the year.

Other organisms found in the plankton samples included the green Hydra*, H. viridis*, which had been recorded by Rowland (2014) before and after the pond dried up in 2011. Chironomid (midge) larvae and different species of water mites appeared in the plankton in several months but in very small numbers.

Widow's Tenement Pond (Table 4)

Widow's Tenement pond is a shallow acidic, weedy pond with very little open water compared with the other two ponds. Green algae are represented by the filamentous forms, *Oedogonium,* which occurs mainly in the summer, and *Ulothrix* in autumn and winter. The diatom, *Pinnularia,* occurred in 10 months of the sampling but not in large numbers. A spherical blue-green alga, *Chroococcus*, was found in May and June.

The zooplankton was dominated by the cladoceran water flea, *Chydorus sphaericus,* which occurred throughout the year often in large numbers, particularly in the summer months. This cladoceran was also noted by Galliford (1954) in his three months of sampling (March, May April) in 1953, when he observed that this was the most common cladoceran in the ponds on the island. As in the other two ponds, the copepods, *Cyclops* and *Canthocamptus*, were present. Fairly small numbers occurred, mainly throughout the year with females with egg sacs and males with modified antennules for grasping the female being present in the summer months.

Three species of rotifer were found in the pond, the most abundant being *Keratella serrulata* that also occurred in Ackland's Moor pond*. Lecane*, a littoral species occurring amongst plants, was present in small numbers, and a bdelloid rotifer, *Philodina*, that crawls mainly on *Sphagnum* moss, was found in November 2012. Both *K. serrulata* and *Lecan*e (two species) were found by Galliford in 1953.

Other organisms in the plankton included the oligochaete worm, *Nais* sp., and beetle larvae of the Family Dytiscidae. Two sub-families were represented, Dytiscinae and the more abundant Hydroporinae. Adults and larvae of *Hydroporus erythrocephalus* were found by Rowland in all seasons of the year in his surveys of this pond since 2009 (Rowland, 2014). The dipteran Chironominae larvae also frequented this pond and mosquito larvae, *Culex* sp., were found in the autumn.

A beetle mite, *Hydrozetes*, occurred in most samples except in the coldest months of January and February 2013. These mites crawl and feed on plants, and occur in shallow waters containing *Sphagnum* moss.

The organisms in this pond differ considerably from those in the more open water of Rocket Pole and Ackland's Moor ponds. It is obvious that organisms such as beetle larvae and beetle mites that live amongst the plants will be collected by the plankton net as it is pulled across this weedy shallow pond.

Examples of plankton organisms occurring in the ponds are shown in Plates 7 and 8.

Table 4: Plankton organisms in Widow's Tenement Pond

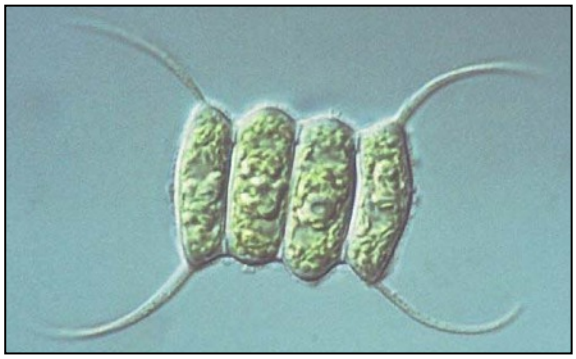
Species	2012									2013		
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
PHYTOPLANKTON												
Cyanophyta												
Chroococcus minimus		2	3									
Chlorophyta												
Oedogonium sp.		2	3	5	2							
Ulothrix sp.								2	2	2		2
Bacillariophyta												
Pinnularia sp.	2	2	2		2	2	2		2	2	3	3
ZOOPLANKTON												
Cladocera												
Chydorus sphaericus	4	3	6	5	5	4	3	4	4	3	2	3
Ostracoda												
Cypris sp.						2	2					
Copepoda												
Cyclops sp.	2	2	2	3*	2	3*	2	2	2	2	2	2*
Cyclopid nauplius L.			1		2	2		1	1			
Canthocamptus sp.	2	2	2	3*	2	2*	2	2	2	2		2
Rotifera												
Keratella serrulata	2	2	3	3	3	2	2	2	2	2	2	2
Lecane sp.		2	2	2		2	2	2		2	1	1
Philodina sp.								1				
Annelida												
Nais sp.		1		2	2	2	2	2		1	2	1
Insecta - Coleoptera												
SF Hydroporinae L.	2	1	1	2	2		2	2	2	2	1	2
SF Dytiscinae L.	1	1						1		1		
Insecta - Diptera												
Chironominae L.				2	2	2	1	2	2	2	2	1
Corynoneura L.								1	2	2		
Culex sp. L.			1			3						
Arachnida (Mites)												
Hydrozetes sp.	2	2	2	2	3	3	3	2	2			2

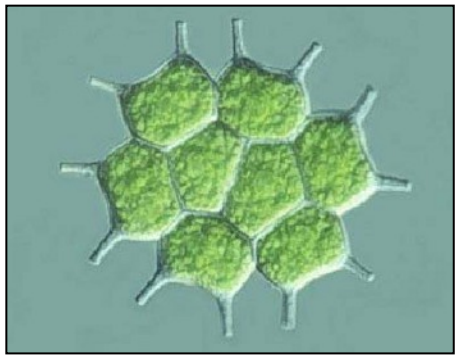
Key: L.= larva. 1=one or two of taxon; 2=3-25; 3=26-100; 4=101-500; 5=Over 500; 6=Over 1000
* several females with egg sacs and males with modified antennules

DISCUSSION

Abiotic factors

The majority of ponds and streams on Lundy are acidic (Long, 1994, Clabburn, 1994, Richardson *et al.*, 1998) and Widow's Tenement is a typical acidic weedy pond. Ackland's Moor Pond varied from acidic to near neutral over the year whereas Rocket Pole Pond has become more alkaline since surveys began in 1979. This probably results from the large frequent algal blooms that occur as their active photosynthesis removes the carbon dioxide causing the pH to increase.





Top left: *Desmodesmus magnus*. Green alga. Cells up to 20µm long. © Peter V. York

Top right: *Pediastrum boryanum*. Green alga. Colonies up to 50µm across. © Peter V. York

Right: *Microcystis sp*. Blue-green alga. Cells 5µm in diameter, closely packed in irregular masses of mucilage. © John Clegg

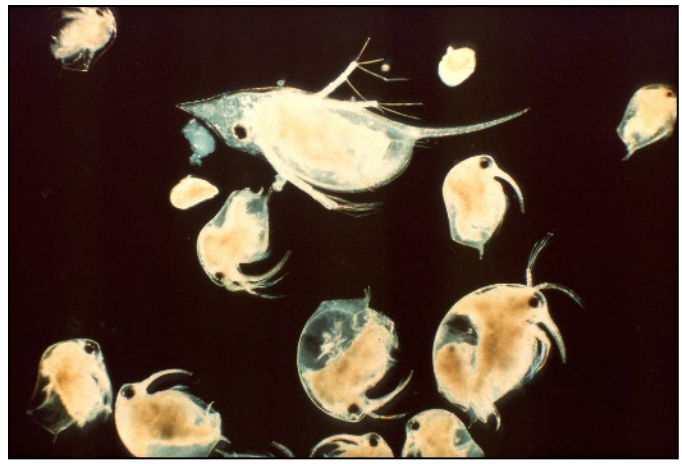
Left: *Cyclops sp.* Female with two egg sacs. Crustacean copepod. Body length 1.0-1.8mm. © Oxford Scientific Films

Right: *Daphnia obtusa.* Crustacean Water flea. Body length 2.5mm. © Oxford Scientific Films

Plate 7: Plankton organisms in the three ponds

Left: *Chydorus sphaericus.* Crustacean Water flea. Body length 0.5mm. © Oxford Scientific Films

Right: *Bosmina longirostris* (and one *Daphnia*). Small Water flea. Body length 0.5mm. © John Clegg



Above: *Brachionus rubens.* Rotifer. Body length 280µm. © B. Bracegirdle

Right: *Keratella valga.* Rotifer. Body length 250µm

Plate 8: Plankton organisms in the three ponds

Two of the ponds, Rocket Pole and Ackland's Moor, have similar origins (rock excavations) and are situated at a high level on the island Neither pond has an outlet and consequently organic input from plants and animals will tend to build up in the ponds. However Ackland's Moor pond is much shallower and is prone to drying out during drought conditions whereas the deeper Rocket Pole Pond has never been known to dry out.

The dense algal blooms that occur in Rocket Pole restrict the penetration of light into the deeper layers. Although several species of algae occur in Ackland's Moor Pond they never reach 'bloom' proportions and the pond appears much clearer with light able to penetrate to the bottom of the pond. The much shallower Widow's Tenement Pond is very different with its considerable plant life and it is often turbid with suspended silt and light rarely penetrates to the bottom sediments. It dries out completely in very dry weather.

In all three ponds the water temperatures follow ambient air temperature, but usually water temperature was much lower. Diurnal water temperatures show considerable differences between those of midday and night temperatures, but these were considerably less in the winter months and in the deeper water of Rocket Pole Pond.

Plankton

Considering the main plankton groups, Algae, Crustacea (Cladocera and Copepoda) and Rotifera, the greatest diversity was found in Rocket Pole Pond and Ackland's Moor Pond, although there were far greater number of organisms in Rocket Pole Pond, particularly in the algal species. The much shallower weedy Widow's Tenement Pond had fewer truly plankton species.

Fifteen of the species recorded in 1952 and 1953 by Galliford (1954) were still present in the ponds 60 years later, demonstrating that the isolation and lack of interference on Lundy helped to maintain the original diversity.

Table 5 shows the main zooplankton organisms in the three ponds and their presence or absence noted by Galliford.

Four algal species were mentioned by Galliford occurring in Rocket Pole and Ackland's Moor ponds, but especially abundant in Rocket Pole Pond – *Microcystis* (Blue-green) and the green algae*, Pediastrum*, *Arthrodesmus* and *Scenedesmus. Microcystis*, *Pediastrum* and a *Desmodesmus* were found in our survey and the *Arthrodesmu*s and *Scenedesmus* may have been a *Desmodesmu*s as there have been several revisions of these genera in recent years (John *et al.* 2011).

Our survey found the harpacticoid copepod, *Canthocamptus*, in all three ponds, but it was more abundant in Rocket Pole Pond where it occurred for all months of the year. This copepod was not recorded by Galliford in the three ponds but he did find it in Pondsbury, the largest freshwater body on the island.

Another species not found by Galliford is the rotifer, *Keratella cochlearis*, which now occurs in reasonable numbers in Rocket Pole and Ackland's Moor ponds. *Bosmina longirostris,* a small cladoceran, which occurred in large numbers in Rocket Pole Pond and to a lesser extent in Ackland's Moor Pond, was recorded by Galliford as only present in Rocket Pole Pond and nowhere else on the island. It also is found in the larger pond at Quarterwall (George, 2012) and now seems to be spreading into other Lundy ponds. Resistant eggs of this species often lie dormant in the bottom mud and they can be picked up by animals using these ponds and transferred from pond to pond in this way.

Table 5: Comparison of species in the three main zooplankton groups in 2012-13 and in 1952-53

Species	RPP	AMP	WTP
Cladocera			
Daphnia obtusa Kurz	P G	P G	- -
Bosmina longirostris (Müller)	P G	P -	- -
Chydorus sphaericus (Müller)	P G	P G	P G
Simocephalus vetulus (Müller)	- -	P G	- -
Copepoda			
Cyclops sp.	P G	P G	P G
Canthocamptus sp.	P -	P -	P -
Rotifera			
Brachionus rubens Ehrb.	P G	P G	- -
Brachionus angularis Gosse	- G	P G	- -
Keratella quadrata (Müller)	P G	- -	- -
Keratella cochlearis (Gosse)	P -	P -	- -
Keratella valga (Ehrb.)	P -	P G	- -
Keratella serrulata (Ehrb.)	- -	P G	P G
Filinia longiseta (Ehrb.)	P G	P G	- -
Cephalodella sp.	P G	- -	- -
Trichocerca sp.	P G	P G	- -
Lecane sp.	- -	- -	P G
Philodina sp. (Bdelloid)	- -	- -	P G

Key: P = present 2012-2013. G = found by Galliford 1952-53

Seasonal changes are noticeable in several of the plankton organisms. In Rocket Pole Pond, although the green algae *Pediastrum boryanum* and *Desmodesmus magnus* occurred throughout the year, *Botryococcus braunei* appeared in the spring as it did in earlier years. The blue-green alga, *Microcystis*, was present in the summer and early autumn but never in such bloom proportions as it had been in the late 1970s and 1980s. The Ackland's Moor Pond species of the '*Chlorella* group' of green algae was found in the spring and early summer.

Six members of the zooplankton were found in all months of the year: the copepod, *Cyclops* in all three ponds; the cladocerans *Bosmina longirostris* in Rocket Pole Pond and *Chydorus sphaericus* in Widow's Tenement Pond; and the rotifers *Keratella serrulata* in Widow's Tenement Pond, and *Keratella cochlearis* and *Filinia longiseta* in Rocket Pole Pond. *Cyclops* are able to breed throughout the year as immature forms and nauplius larvae were found in all months. *Chydorus sphaericus* is regarded as the commonest and most widely distributed of all cladocerans especially in shallow weedy waters (Scourfield & Harding, 1994) and it is not surprising that it was abundant in the shallow weedy Widow's Tenement Pond.

The rotifer *Keratella serrulata* is commonly found in *Sphagnum* bogs and other acid waters and conditions in Widow's Tenement Pond were obviously favourable to this species, but it never occurred in large numbers. Other rotifers appeared for a few months e.g. *Keratella valga*

in Rocket Pole and Ackland's Moor ponds, *Keratella quadrata* and *Cephalodella* sp. in Rocket Pole Pond. Reproduction and periodicity in rotifers have been the subject of much research over the years, and water temperature, diet and pH have all been considered (Pontin,1978).

Desiccation is a major threat to aquatic organisms, and rotifers and cladocerans with their resting eggs can overcome ponds drying out completely for considerable periods. *Cyclops* is also able to survive by encystment and it seems to be the younger copepodid stages rather than the adult with the ability to encyst (Pennak, 1953).

CONCLUSIONS

The plankton communities in the three ponds have remained remarkably stable over the last 60 years with plankton species recorded by Galliford in the 1950s still present today. The persistent algal blooms in Rocket Pole Pond were also occurring at that time with the same green and blue-green algae dominating the pond. There is now evidence that some species, e.g. *Bosmina longirostris*, are spreading from Rocket Pole Pond into other ponds on the island and also a few new species, e.g. *Keratella cochlearis*, are appearing that were not recorded by Galliford.

Plankton diversity in Rocket Pole and Ackland's Moor ponds is similar, but far greater numbers of organisms occur in the much deeper Rocket Pole Pond which has never been known to dry out as happens in Ackland's Moor Pond in very dry weather. Widow's Tenement Pond has a very different plankton community with only a few truly plankton organisms present, e.g. *Cyclops* and *Chydorus sphaericus*. This shallow pond has considerable plant life and many of the organisms found there are those that occur on plants, e.g. rotifers *Lecane* and *Philodina* sp. Tolerance to acid pH is important in the colonization of this pond.

Monthly sampling throughout a year has shown seasonal changes in both species composition and numbers of organisms. Several species, e.g. *Cyclops* and *Chydorus sphaericus,* are found all year round whilst others appear for short periods, e.g. alga *Botryococcus* and various rotifer species.

Water temperature is an important factor in determining the changes in species populations and the data-loggers have established that there are considerable differences in diurnal temperatures, particularly in the summer months.

The Lundy ponds, apart from the animals drinking from them, have little disturbance and pollution from the human species and it is likely that the plankton communities will remain stable for the next 60 years unless extreme weather events occur.

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