THE STATUS OF THE SUNSET CUP CORAL *LEPTOPSAMMIA PRUVOTI* AT LUNDY

by

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ABSTRACT

The findings of a survey of the numbers of the nationally rare sunset cup coral *Leptopsammia pruvoti* at Lundy in September 2007 are presented together with more recent observations. Counts of individuals were undertaken using divers and *in situ* photography. An estimate is given of the overall size of the coral's population at Lundy, its extent and its condition, and the proportion of new recruits within the population. The findings are compared with other studies undertaken at Lundy since the early 1980s. These comparisons show dramatic declines in numbers in some areas but increases in others.

Keywords: *Lundy, Leptopsammia pruvoti, decline, underwater photography, SAC, MNR*

INTRODUCTION

Within British waters, the small but eye-catching sunset cup coral *Leptopsammia pruvoti* (Lacaze-Duthiers, 1897) (Plate 1) is a species of particular marine natural heritage importance. It is nationally rare (i.e. it occurs in eight or fewer 10 km by 10 km Ordnance Survey grid squares containing sea within the 3 mile limit of territorial seas around Great Britain), and, since 1999, it has had its own Biodiversity Species Action Plan (UK Biodiversity Action Group, 1999).

Lundy is a small island, approximately 5 km long by 1 km wide, which lies at the mouth of the Bristol Channel some 18 km from the nearest point of the north-west Devon mainland. The island's dramatic cliff scenery continues into the sublittoral around much of its coast, extending to depths of over 40 m within 100 m of the North-East point. It is around the northern half of the east coast in particular that most *Leptopsammia pruvoti* corals are concentrated (Figure 1), being present within the biotope 'sponges, cup corals and anthozoans on shaded or overhanging circalittoral rock' (Connor *et al*., 2004). Furthermore, Lundy was the site where *Leptopsammia pruvoti* was first discovered in British waters in 1969 by Keith Hiscock (Hiscock, 2008).

Leptopsammia pruvoti is a Mediterranean-Atlantic species at the northern limits of its range at Lundy. It is only found at a handful of other sites in south-west Britain including the Isles of Scilly, off Plymouth Sound and in Lyme Bay. It is also present at Sark in the Channel Islands and at a few other locations off the Brittany coast. These

isolated populations may be 'relict' populations, the remains of much larger populations that once flourished in our coastal waters some 700+ years ago, when sea water temperatures were higher than they are today. Alternatively, it might be that recruitment only occurs extremely rarely (on a scale of hundreds of years) to new specific locations where isolated colonies develop and become self-sustaining within very small areas (i.e. just a few square metres).

Earlier studies of the populations at Lundy and the Isles of Scilly (undertaken during the 1980s) have shown there to have been very little new recruitment in evidence (Hiscock, 2003) and consequently, as the populations age, the overall number of individuals has been declining. The conclusion that populations are in decline has been reinforced by comparing photographic images of one discrete colony over time and counting visible individuals. This has been undertaken at Lundy using images taken from 1981 to 2009 by Keith Hiscock at the site known as 'Knoll Pins Cave'.

In order to be able to quantify the apparent decline, Natural England, as managers of the Marine Nature Reserve and the Special Area of Conservation at Lundy, were keen to obtain a reliable assessment of *Leptopsammia pruvoti* numbers at Lundy. This assessment would also provide a baseline figure with which other counts in the future could be compared. Three other closely related tasks were also undertaken. The first was to compare the counts with previous studies; the second was to assess the overall 'condition' of the corals by inspecting a selection for the presence of potentially damaging associated species: the barnacle *Megatrema anglicum*, the phoronid worm *Phoronis hippocrepia* and of any other externally conspicuous boring organisms such as the polychaete worm *Pseudopotamilla reniformis*; and the third was to determine if any new recruits to the population could be found.

A similar survey of *Leptopsammia pruvoti* at Lundy had been undertaken by volunteer divers from the Marine Conservation Society in 1999 and 2000 (Irving & Northen 2004), which had provided an estimate of the overall population size at the island, as well as more detailed records from two sites (the Knoll Pins and Gannets' Rock Pinnacle) off the north-east coast. The purpose of the current survey (undertaken in September 2007) was to build upon this earlier study, repeating counts from the same sites and extending the survey to new search areas.

Leptopsammia pruvoti has quite particular habitat preferences: it favours shaded vertical or slightly overhanging bedrock or stable boulders in the circalittoral, and it is often found in caves and gullies or under overhangs. Typically, it is located on open coast sites, mainly facing away from prevailing winds and sheltered from local currents. However, a small population has also been reported from off the exposed west coast of Lundy (Keith Hiscock, own observations). In general, its preferred habitat tends to be quite silty.

METHODS

Fieldwork was carried out over three days (4-6 September 2007) and involved a team of five SCUBA divers. A full account of the recording methods used is given in Irving (2008). Dives were concentrated at three main locations off the island's north-east coast (Figure 1): the Knoll Pins, three conjoined pinnacles which lie approximately 250 m to the north-east of Tibbetts Point; Gannets' Rock Pinnacle, a dramatic underwater cliff

just 30 m east of Gannets' Rock; and Anchor Pinnacle, an isolated rock pinnacle some 150 m to the north of Gannets' Rock Pinnacle, which rises as a steep cliff from 30 m depth (below chart datum) to 4 m below the surface. A search was also undertaken at Brazen Ward where suitable habitats occur and where a colony of *Leptopsammia pruvoti* was present in 2001 (Robert Irving, own observations), but this colony could not be relocated in 2007. Another site, Pete's Pinnacle, where *Leptopsammia pruvoti* has been found in the past (Irving & Northen 2004), was briefly visited, but no *Leptopsammia pruvoti* corals were found. Each of the three main locations were divided into a number of search sectors, within defined depth bands and easy-to-relocate stop/start points. This had to be done prior to the commencement of diving operations, so familiarity with the layout of the sites was invaluable (Figure 2). A pair of divers would then be instructed to undertake counts within a particular search sector. Two main methods of counting were employed, as described in the following paragraphs.

Diver counts

The first method of counting utilised pairs of divers searching along adjacent horizontal belt transects which varied in width from 2 to 5 m, depending on the terrain. The length of the transects was also determined by the type of terrain and the topography of the site, but typically they were from 10 to 25 m long. Each transect began at a re-identifiable starting point (i.e. a particular rocky feature or a boulder which stood out because of its shape) and ended at a known finishing point which could either be easily re-identified or was temporarily marked in some way, such as by using a fluorescent ribbon. For the shorter transects, adjacent 'belts' were divided by a temporary line (Figure 3), while a pre-determined depth was agreed upon by the two divers to mark the division between the longer 'belts'. This method was used in areas where the individual corals were known to be spread out.

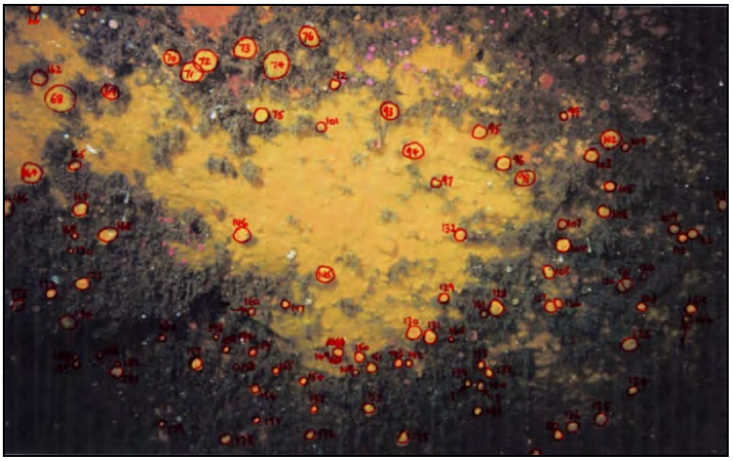
Photographic counts

In areas where there were known to be high concentrations of individual corals, a second recording method was used. This method relied upon taking a series of overlapping close-up photographs of the rock face using a housed digital SLR stills camera (Nikon D70 camera equipped with a Nikkor 12-24mm lens set at wide angle) with two flashguns attached. The photographs were taken as 'flat-on' to the rockface as possible, from a lens to subject distance of about 40 cm, giving a picture area of about 60 x 40 cm. The images were overlapping and no framer was used. Counts of corals were made from the photographs. This method was suitable for those areas where the higher concentration of corals meant that counting mistakes could have been made by using the first method.

Overlapping photographs were printed in colour on A4 sheets. A clear acetate sheet was then placed over the top of each photograph and individual corals were ringed and numbered using a fine marker pen (Plates 2a and b). By this means it was possible to identify every individual coral and to separate out smaller individuals of less than 5 mm in diameter. The total number of corals observed at any one site was then obtained by adding the totals from the *in situ* diver observations with the totals obtained from the photographs.

Plate 1 (top): A large solitary sunset cup coral *Leptopsammia pruvoti*, fully expanded and surrounded by dense bryozoan turf. Maximum diameter across its tentacles is approximately 60 mm. Photo: Keith Hiscock

Plates 2a (above) and **2b** (right): Photograph from the Knoll Pins East site, showing the original photograph (Plate 2a) and the same photograph with an acetate overlay with individual *Leptopsammia pruvoti* corals marked with a red circle and an ID number (Plate 2b). Photo: Keith Hiscock



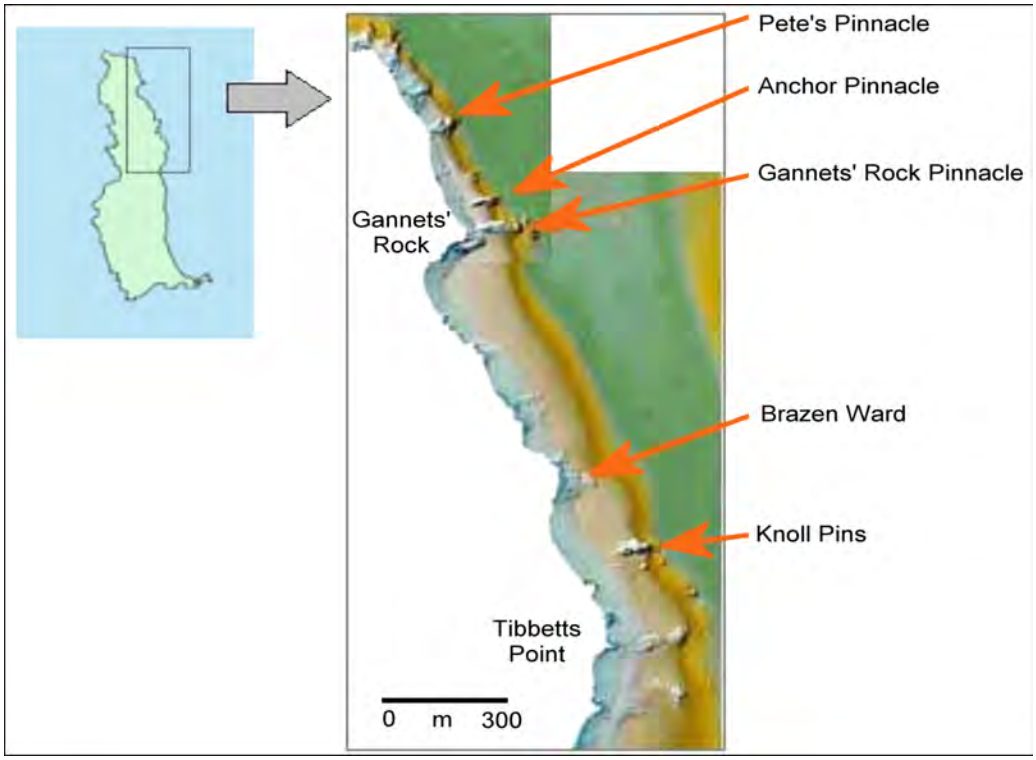


Figure 1: The north east coast of Lundy showing the location of sites visited. (The right hand figure is a colour-enhanced multibeam acoustic survey image from work undertaken by Hydrosurveys Ltd. in 2005). Colours indicate depth zones (below chart datum): grey (<10 m), pink (11-20 m), brown/yellow (20-30 m), and green (30-40 m).

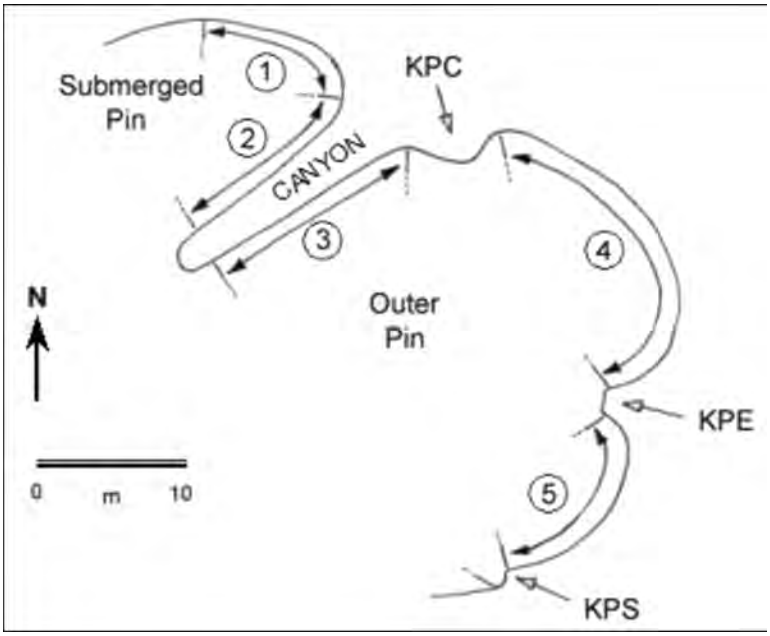


Figure 2. Plan view of part of the Knoll Pins showing the five *Leptopsammia* search sectors. The scale bar provides only an approximate indication of distance.
KPC: Knoll Pins Cave
KPE: Knoll Pins East
KPS: Knoll Pins South

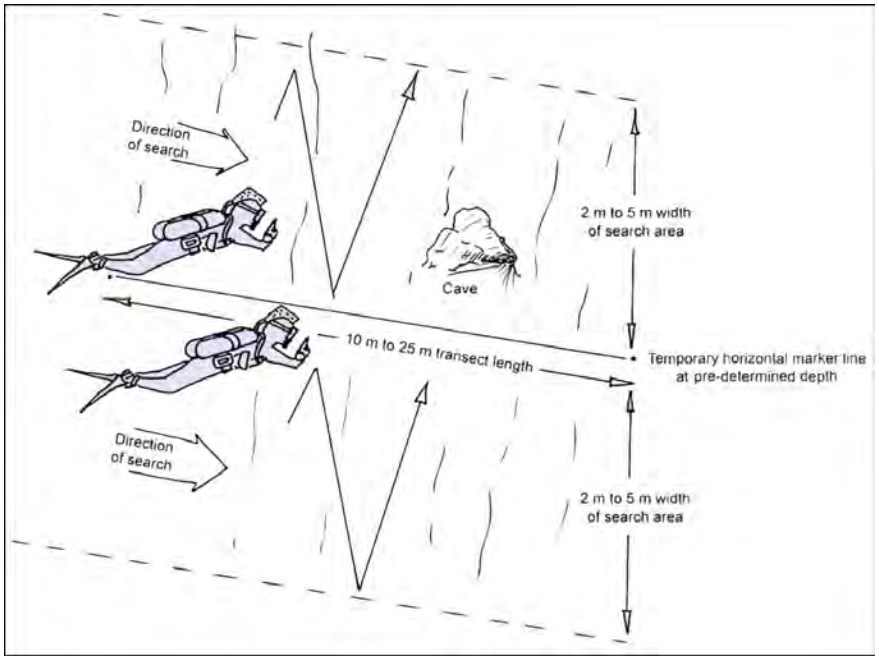


Figure 3: Diagrammatic representation of divers searching for *Leptopsammia pruvoti* cup corals on a vertical underwater cliff, using a 'zig-zag' method of search.

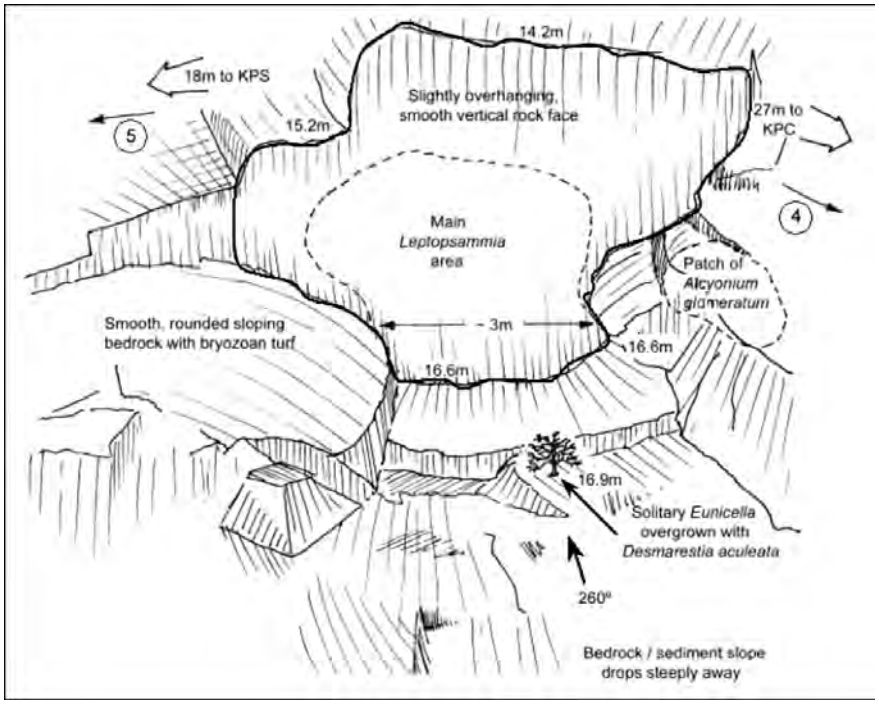


Figure 4: The Knoll Pins East site on the eastern side of the Outer Pin. Overlapping photographs were taken within the area marked by a thick black line. The start/end of search sectors 4 and 5 are marked by arrows. All marked depths are below chart datum (BCD). Scale is approximate. (Re-drawn from an *in situ* sketch by Robert Irving)

RESULTS

Counts of *Leptopsammia pruvoti* were completed at the Knoll Pins, Gannets' Rock Pinnacle and at Anchor Pinnacle. The results of the counts are set out in Table 1. Re-location sketches of the Knoll Pins East site (Figure 4) and of the Gannets' Rock Pinnacle site (Figure 5) are given, with search sectors and photographic count areas marked.

For both counting methods, individual corals were recorded as being either 'adults' (i.e. the diameter of their calyx was greater than 5 mm) or 'juveniles' (i.e. the diameter of the calyx being less than 5 mm) (Plate 3). These terms, however, do not reflect any indication of the individual's reproductive capacity - the terms were simply used to indicate size. 'Juveniles' are likely to be recent recruits to the population, but without any information on the species' growth rates, it is impossible to say when such recruitment may have taken place.

Table 1: Numbers of *Leptopsammia pruvoti* individuals (both 'juveniles' and 'adults') counted at the Knoll Pins, Gannets' Rock Pinnacle and at Anchor Pinnacle, 4-6 September 2007

Site name	Position of centre of site	Search sector (see diagram)	Method	Depth range (below chart datum)	No. of *Leptopsammia*		
					Juvenile (< 5 mm)	Adult (> 5 mm)	**Total**
Knoll Pins							
		1	Diver count	16.0 - 19.0 m	0	0	0
Knoll Pins Canyon	51° 11.306' N 004° 39.639'W3	2 (NW side)	Diver count	11.2 - 16.9 m	1	44	45
		(SE side)	Diver count	11.7 - 16.7 m	6	180	186
Knoll Pins Cave	51° 11.306' N 004° 39.622' W		Photography	15.5 m	7	121	128
		4	Diver count	12.9 - 18.2 m	2	32	34
Knoll Pins East	51° 11.302' N 004° 39.600' W		Photography	14.2 - 16.6 m	50	222	272
		5	Diver count	9.7 - 19.2 m	0	22	22
Knoll Pins South	51° 11.292' N 004° 39.617' W		Photography	13.2 - 14.2 m	4	12	16
Knoll Pins Totals					70	633	**703**
Gannets' Rock Pinnacle							
		6	Diver count	25.3 - 27.3 m	5	162	167
Vertical transect site	51° 11.865' N 004° 39.971' W		Photography	25.0 - 26.0 m	8	6	14
		7	Diver count	19.5 - 27.5 m	0	8	8
Gannets' Rock Pinnacle Totals					13	176	**189**
Anchor Pinnacle							
	51° 11.892' N 004° 40.013' W	8	Diver count	14.0 - 28.0 m	8	52	60
	51° 11.903' N 004° 40.008' W	9	Diver count	7.0 - 30.0 m	0	2	2
Anchor Pinnacle Totals					8	54	62
Overall Totals					**91**	**863**	**954**

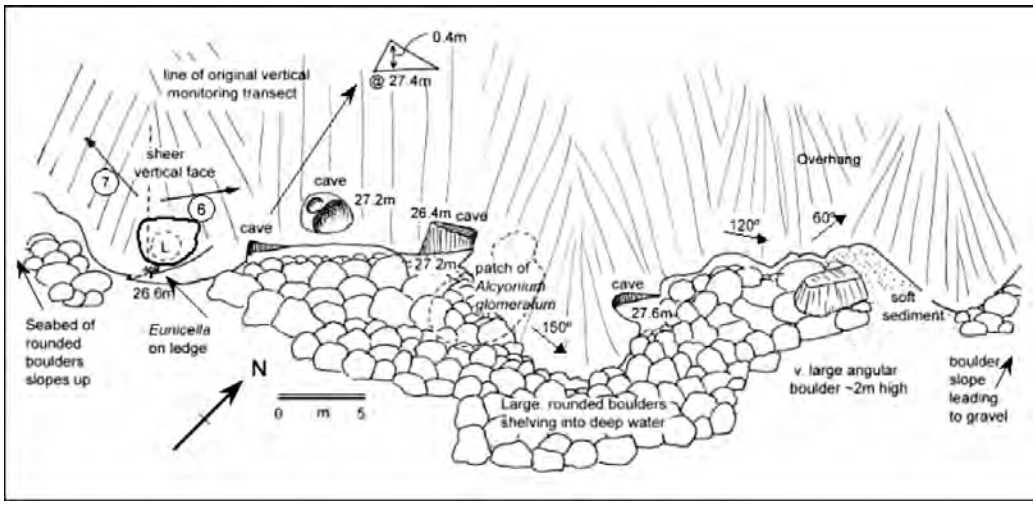


Figure 5: The Gannets' Rock Pinnacle site, with the location of search sectors 6 and 7. More detail is shown of the topography on the north side of the site, which produced more *Leptopsammia pruvoti* individuals, often found inside small caves. Overlapping photographs were taken within the area marked by a thick black line. All marked depths are below chart datum (BCD). Scale is approximate. (Re-drawn from an *in situ* sketch by Robert Irving)

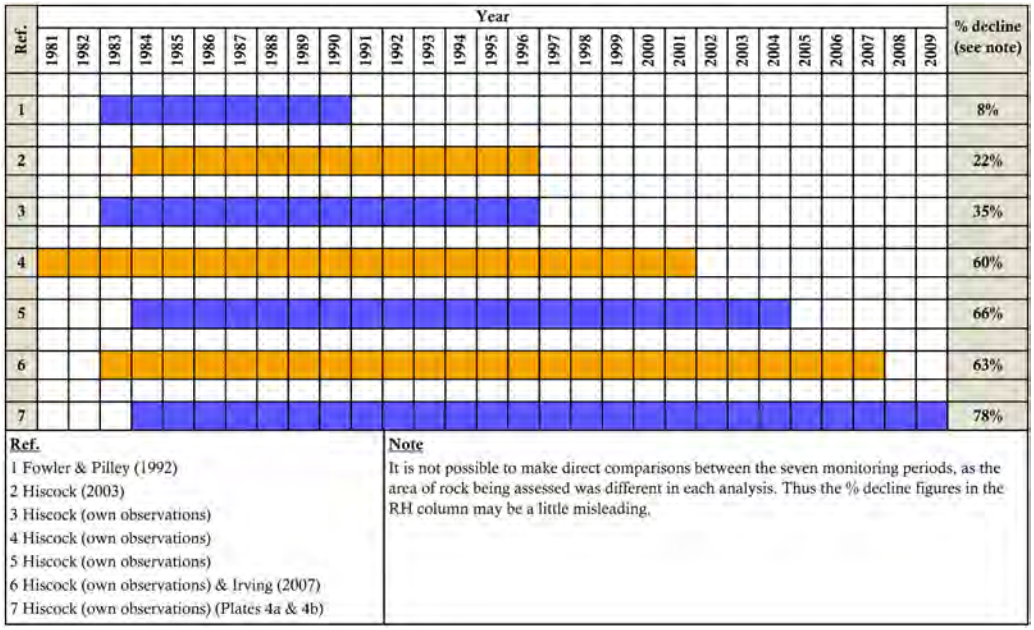
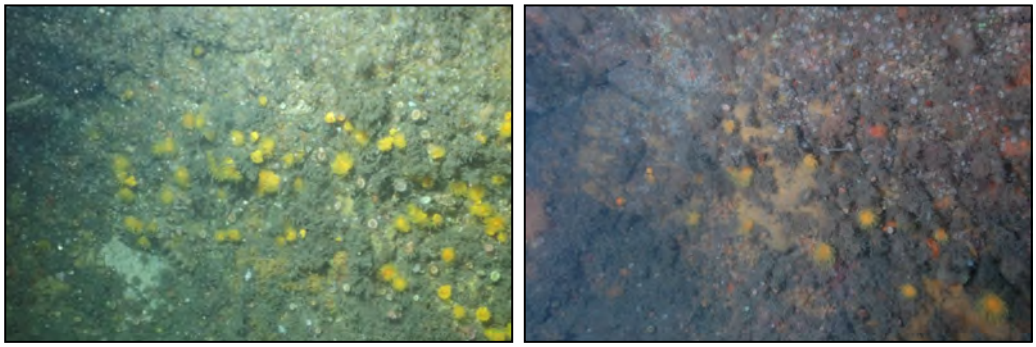


Figure 6: A visual representation of the time periods involved in various comparative studies and the associated percentage decline in *Leptopsammia pruvoti* numbers within those periods. All studies were undertaken in the Knoll Pins Cave area.

Plate 3: An area of vertical rock to the west of the Knoll Pins Cave site, showing both 'adult' and 'juvenile' *Leptopsammia pruvoti*, which stand out from the monochrome background of bryozoan turf. Picture taken 26 July 2008. Picture width approx. 40 cm. Photo: Keith Hiscock



Plates 4a & 4b: The same area of rock face photographed at the Knoll Pins Cave area in 1984 (3 August) and 2009 (20 June). Counts of *Leptopsammia pruvoti* individuals by Keith Hiscock give a reduction of 78%. Photos: Keith Hiscock

Plate 5: A *Leptopsammia pruvoti* individual with the lophophores of several *Phoronis hippocrepia* horseshoe worms emerging from tubes around its base. The small bulbous extrusion attached to the side of the coral and covered by the coral's yellow tissue is the inquilinistic barnacle *Megatrema anglicum*. Photo: Robert Irving (taken in 1998)

Table 1 shows that a total of 954 *Leptopsammia pruvoti* individuals were recorded from the three sites: the Knoll Pins (703), Gannets' Rock Pinnacle (189) and Anchor Pinnacle (62). It is estimated that this accounts for approximately two thirds of the total *Leptopsammia pruvoti* population at Lundy, based on an estimate given by Irving & Northen (2004) that the total population size in 2000 was in the region of 1,400-1,500 individuals. No evidence was found of the presence of the phoronid worm *Phoronis hippocrepia* nor of the fan worm *Pseudopotamilla reniformis*, but a small percentage of corals had the barnacle *Megatrema anglicum* growing on their corallites (Table 2).

Table 2: A comparative assessment of the numbers of *Megatrema anglicum* barnacles attached to individual *Leptopsammia pruvoti* corals from various locations

Search sector	Total no. of individual corals	No. of individuals with *Megatrema*	Mean no. of *Megatrema* per coral (range)	Percentage colonisation	Mean diameter of corals (mm) (range) / no. measured
Knoll Pins					
2: NW side of canyon	44	11	0.4 (1-3)	25%	10.7 (7-14) / 44
3: SE side of canyon	180	34	0.4 (1-4)	18%	11.3 (4-17) / 44
4: Outer Pin: from KPC to KPE	32	0	0	0%	8.6 (3-12) / 16
5: Outer Pin: from KPE to KPS	22	5	0.5 (1-3)	23%	9.5 (4-15) / 19
			Mean:	**16.5%**	
Gannets' Rock Pinnacle					
6: to the north of vertical transect site	162	10	1.0 (1-2)	**6%**	7.9 (3-14) / 23
7: to the south of vertical transect site	8	Not recorded			
Anchor Pinnacle					
8: the south-east quadrant	2	Not recorded			
9: the north-east quadrant	52	10	0.4 (1-3)	**19%**	9.6 (3-15) / 47

DISCUSSION

A number of discussion points are commented on below, relating to the 2007 study and to comparisons with previous studies.

The analysis of the photographs

The allocation of a number to each individual *Leptopsammia pruvoti* coral ensured no coral was counted twice and, in future analyses, should allow for absences of individuals (and the appearance of new individuals) to be more apparent. During the analysis of the photographs it became apparent that small individuals could easily be hidden by bushy growths of bryozoan turf. An individual may not have been noted at all in one photograph and yet in the next (overlapping) photograph, it was. This situation emphasised the importance of ensuring sufficient overlap with adjacent photographs, and consistent camera and flash angles.

The accuracy of the *in situ* counts

Despite taking great care over the diver counts, there are probably a few individual corals (possibly in the region of 1-2% or about 10-20) which would have been missed and therefore not included in the total number counted. However, this figure is purely

an estimate and is not based on any statistical method. As a means of checking the accuracy of the counts, and of introducing some level of quality control, a repeat count was made by a second pair of divers within search sector 2 on the north side of the Knoll Pins canyon. The reason why this particular sector was chosen was because of the considerable drop in the number of *Leptopsammia pruvoti* from the counts made from the same sector in 1999 (Irving & Northen 2004) - from 127 in 1999 to just 45 in 2007, a fall of 65%. The second pair of divers counted exactly the same number of corals, thus providing some reassurance that any inter-diver variability was likely to be very small.

Comparisons with previous studies

The earliest photographic record of *Leptopsammia pruvoti* populations at Lundy (from the Knoll Pins) dates from 1981 when Keith Hiscock took some 'viewpoint' photographs of the 'cave' area, with the intention of the same view being photographed on future occasions for comparative purposes. This pioneering work led, in 1984, to the start of the sublittoral monitoring programme run by the Nature Conservancy Council (NCC) which concentrated on communities featuring Mediterranean-Atlantic species, including *Leptopsammia pruvoti* (Hiscock 1984). As part of this programme, repeat sets of photographs were taken of the same area of rock face at the Knoll Pins Cave in 1985 (Hiscock, 1986a), 1986 (Hiscock, 1986b), 1987 (Howard, 1987), 1988 (Howard, 1988) and 1990 (Irving, 1990).

An analysis of the results of the photographic monitoring studies of *Leptopsammia pruvoti* (as well as other species) from 1983 to 1990 was undertaken by Fowler and Pilley (1992). They found the number of *Leptopsammia pruvoti* within the Knoll Pins study area (approximately 250/0.85 m^2) to have fallen by 8% over a seven year period from 1983 to 1990. This was the first 'in depth' analysis to have been undertaken of any of the NCC monitoring photographs and raised initial concerns about the decline in *Leptopsammia pruvoti* numbers. It is interesting to note that numbers of the Devonshire cup coral *Caryophyllia smithii*, which were also counted, declined at a similar rate over the same period.

The decline was confirmed and found to be happening to an even greater degree when Keith Hiscock undertook his own separate analysis of a part of this same population. He found numbers to have fallen by 22% over a 12- year period from 1984 to 1996 (Hiscock, 2003). If one takes into account more recent photographs of the population, i.e. up to 2001, to 2004 or to the study undertaken in 2007, the loss of individuals rises to between 60% and 66% (Figure 6). Most recently (Plates 4a & b), decline was measured as 78% over a 25-year period between 1984 and 2009, at the location photographed. The decline in numbers since 1981 is very alarming, particularly to those involved with the management of the Lundy Marine Nature Reserve / Special Area of Conservation, for which *Leptopsammia pruvoti* is of great importance.

The only other study involving systematic *in situ* counts of individual *Leptopsammia pruvoti* corals at Lundy (of which the authors are aware) was undertaken by volunteer divers from the Marine Conservation Society in 1999 and 2000 (Irving & Northen, 2004). Comparing counts from the present study with those from 1999 and 2000 they show a decline in numbers in certain areas (such as a loss of 65% on the north side of the Knoll Pins canyon), but an increase in numbers in others (such as a gain of 44%

between the Knoll Pins Cave site and the Knoll Pins South site). It is thought this gain of 44% is largely due to recent recruitment at the Knoll Pins East site, which lies between the two aforementioned sites.

Table 3: Comparisons of total counts ('adults' & 'juveniles') of *Leptopsammia pruvoti* undertaken by MCS volunteer divers in 1999 and 2000 (Irving & Northen, 2004) with those from the 2007 study

Search sector	Counts from 1999/2000	Counts from 2007	% change
Knoll Pins			
1: East & north side of Submerged Pin	16	0	- 100%
2: Submerged Pin/Outer Pin: NW side of canyon	127	45	- 65%
3: Outer Pin/Submerged Pin: SE side of canyon	220	186	30%
KPC (from photographs)		128	
4: Outer Pin: from KPC to KPE	193	34	+ 44%
KPE (from photographs)		272	
5: Outer Pin: from KPE to KPS		22	
KPS (from photographs)		16	
Sub-totals:	556	703	+ 21%
Gannets' Rock Pinnacle			
6: to the north of vertical transect site	(191)[1]	167	
GRP monitoring site	N/A	14	
7: to the south of vertical transect site	(68)[1]	8	
Sub-totals:	259	189	- 27%
TOTALS (for Knoll Pins & Gannets' Rock Pinnacle):	**815**	**892**	+ 9%
Anchor Pinnacle			
8: East & north (incomplete in 2007)	N/A	60	
9: East & south	N/A	2	
Sub-totals:	-	62	
Brazen Ward			
Vertical face on north side of 1 m wide gully	20	N/A	
Sub-totals:	20	-	
Gannets' Rock Pinnacle northwards (incomplete)	293	N/A	
'Bob's Bump' Sub-totals:	40	N/A	
	333	-	

Note: 1. It is uncertain where the Gannets' Rock Pinnacle 'start' position was for the searches undertaken by the volunteers. Hence a direct comparison with the 2007 figures for counts within sectors 6 and 7 is not possible.

The 1999/2000 figures quoted in Table 3 are believed to be as accurate as possible, though the figures were given a possible estimated error of ±4% (Irving & Northen, 2004). The 2007 figures have been given a possible estimated error of ± 1-2% (see above). The

difference between these two error ranges probably reflects the fact that the 2007 figures were obtained by a small 4-man team of professional surveyors dedicated to just this one task. In 1999 and 2000 there were larger teams of 8 volunteer surveyors who were also being asked to undertake other diving tasks during their time at Lundy (typically 4-5 days).

The accuracy of each set of data may also be affected by:

- Possible duplication of counts of particular individual corals when many are encountered in one patch, or when the diver is distracted and takes his mind off the task in hand.
- Possible confusion or simply forgetting the total number just counted in a 'batch' before the number is written down on a slate.
- Possible over-looking of individual corals obscured by surrounding organisms, particularly lush growths of bryozoan turf.
- Unintentional missing out of small areas of search.

It can be seen from the data presented in Table 3 that the number of *Leptopsammia pruvoti* has continued to decrease in some sectors (comparing the years 2007 and 1999), but in other sectors the number has actually increased, and increased significantly. The main points to make on these apparent discrepancies are:

- There now appear to be no *Leptopsammia pruvoti* occurring within search sector 1 (on the east and north side of the Submerged Pin at the Knoll Pins). In 1999, 16 individuals were counted from this sector.
- The number of *Leptopsammia pruvoti* present on the north side of the Knoll Pins canyon (search sector 2) has fallen dramatically: 127 in 1999 to 45 in 2007, a fall of 65%.
- There would appear to have been a significant increase (30% since 1999) in the number of *Leptopsammia pruvoti* present on the southern side of the Knoll Pins canyon (search sector 3), though the areas of search from 1999/2000 and 2007 are not identical. Plate 3 shows several small individuals amongst larger ones in an image taken just to the west of the Knoll Pins Cave site in July 2008. However, within the cave itself (which lies between these two areas), the number of *Leptopsammia pruvoti* corals has declined dramatically (78%, 1984 to 2009).
- A large number (22.5% of the total number counted) of 'juvenile' *Leptopsammia pruvoti* are present at the Knoll Pins East site. This compares with 5.8% from the Knoll Pins Cave area, and 2.3% from the north side of the Knoll Pins canyon. It is not clear why the number of juveniles is so different at different locations. One possible influence may be the lushness of the bryozoan turf growing within the cave area and on the north side of the canyon, which appeared to be 'smothering' some corals (see also Plate 3). This same turf may also hinder the settlement of larvae. There was much less bryozoan turf apparent at the Knoll Pins East site.

Possible causes of variation in numbers

Factors affecting recruitment

Goffredo *et al.* (2006) found that, working in the Mediterranean, *Leptopsammia pruvoti* had separate sexes and that fertilized larvae were brooded before release as planulae. Polyps were sexually mature when the maximum diameter of the coral disc was as little

as 3 mm across. However, their study was of preserved individuals and did not address settlement mechanisms or larval duration before settlement. Viable larvae have been produced from individuals collected from Lundy and successfully placed in aquarium tanks on three occasions (Keith Hiscock, own observations). The larval settling time is generally short, but may be as much as a day from the time of expulsion, although eggs may exist for up to six weeks. The chances for viable larvae to survive, though, are still slight: they may be swept away from suitable habitat by water currents; or be consumed by attached carnivorous animals before settling and metamorphosing.

The level of new recruitment to the population at Lundy since the early 1980s appears to be very low indeed (Irving, 2004). Hiscock (2003) believed the level of recruitment over a 13-year period during the 1980s and early 1990s to be less than 1%. Apparently, recruitment in the Mediterranean is also sporadic (Jackson, 2007). According to Jackson (2007), recruitment may fail for several reasons including that environmental conditions (primarily temperature) may be unsuitable for gamete production to occur or to occur synchronously.

Production of larvae in anthozoans (such as *Leptopsammia*) may depend upon them being well fed. Observations of aquarium maintained sea anemones and corals revealed that well-fed individuals reproduced more readily (Paul Tranter, pers. comm.).

Recruitment events may not just be confined to the local population. Recruitment may also occur from distant sources such as populations to the south in continental Europe, but this is only likely to happen sporadically when appropriate water bodies move into south-west England (UK Biodiversity Action Group, 1999). There is evidence that this sort of movement of water bodies might occur every 25-30 years (Hiscock, 2003).

Contaminants may affect reproductive ability and, although the authors feel that it is unlikely Lundy is affected by sufficiently high levels of pollutants to have an adverse affect on the several species of anthozoans that have shown decline at Lundy since the 1980s, relevant studies to assess levels of contaminants in organisms and sediments at Lundy would be welcome.

Currently, studies are being undertaken of the genetic structure of *Leptopsammia* populations at Lundy and elsewhere that should help to clarify whether localized populations are self-recruiting and isolated from other populations (the work is being undertaken by Dr Phil Watts at the University of Liverpool, assisted by Keith Hiscock).

Recent indications of new recruitment

Evidence of some recruitment to *Leptopsammia pruvoti* populations in the south-west in recent years was first noted in the Isles of Scilly. Here Fowler & Laffoley (1992) reported a single new recruit to the population at Gap Point (on the east side of St Mary's) in 1991. This was the first new recruit detected during the period of photographic monitoring and was presumed to have occurred sometime between 1988 and 1991. New recruits within the Lundy populations were not documented for a further 7 years: at the Knoll Pins, several very small individuals of between 3-5 mm in diameter were reported in 1998 (Irving & Northen, 2004).

Weakening of the attachment of corals to the substratum

A small number of organisms, mostly worms, are known to bore into the base of the calcium carbonate skeletons of cup corals. Hiscock & Howlett (1976) recorded 30% of Devonshire cup corals *Caryophyllia smithii* collected at Gannets' Rock to have contained boring organisms. One of these organisms is the horseshoe worm *Phoronis hippocrepia*, which is very easily identified and, when expanded, is conspicuous to divers (Plate 5).

In 1997, *Phoronis* was noted for the first time emerging from the base of several cup corals at the Knoll Pins and in 1998, a diver survey found *Phoronis* to be present around the base of 9% of the *Leptopsammia pruvoti* cup corals inspected at the Knoll Pins, and 7% of those inspected at Gannets' Rock Pinnacle (Irving & Northen, 2004). At the same time, a number of dead skeletons of both *Leptopsammia pruvoti* and *Caryophyllia smithii* were located within the silt at the foot of walls where these corals were growing. The skeletons of both species had evidence of small tunnels bored into their bases by worms. It is believed that the boring action is likely to weaken the attachment of individual cup corals to the rock face and render them prone to be knocked off by foraging animals, anchors, shot lines, fishermen's pots or divers.

With the continuation of the volunteer diving conservation projects on an annual basis until 2001, checks were made each year for the presence of *Phoronis hippocrepia* at the base of each *Leptopsammia pruvoti* individual encountered. Horseshoe worms were again found in 1998 but no sign of the worms could be found in 1999, 2000 or in 2001 and no *Phoronis* were recorded during the 2007 study described here. Its apparent disappearance remains a mystery.

Colonisation by the barnacle *Megatrema anglicum*

The barnacle *Megatrema anglicum* (formally *Boscia anglica* and prior to that *Pyrgoma anglicum*) is another animal with an 'apparent commensal' relationship with cup corals. This small barnacle (no more than 6 mm basal plate diameter) attaches to the outer rim of the calyx of *Caryophyllia* cup corals, though in *Leptopsammia*, which grows taller, it may also attach to the corallum (see Plate 5). Manuel (1988) points out that the exact nature of the relationship between the barnacle and its host species is unknown - the barnacle may cause irregular septal growth of the coral, but otherwise the coral appears to suffer little inconvenience. The barnacle appears to be using the coral as a platform for its normal feeding activities and the relationship should therefore be described as inquilinistic, literally meaning 'settling on someone else's home'. It seems quite plausible though, that the presence of several barnacles around the rim of a coral's calyx would lead to competition for food and be likely to affect the efficiency of feeding by the coral. Both of these actions could well affect the overall health of the coral and may lead to it succumbing to other factors, ultimately culminating in the coral's death.

Table 4 sets out the mean level of colonisation of *Leptopsammia pruvoti* corals by *Megatrema* barnacles in 1998, 1999 and 2007.

Table 4: Mean levels of colonisation of *Leptopsammia pruvoti* by *Megatrema anglicum* in 1998, 1999 (from Irving & Northen, 2004) and 2007

% *Leptopsammia* individuals with *Megatrema* at the Knoll Pins		
1998	**1999**	**2007**
16%	44%	16.5%

Overgrowth by bryozoan turf

Evidence from the photographs taken at the Knoll Pins Cave site and the Knoll Pins East site shows there was noticeably more growth of bushy bryozoan 'turf' on the vertical and near-vertical bedrock at the cave site (Plates 1 and 3). The turf, mostly comprised of *Crisia* spp., *Scrupocellaria* spp. and some *Cellaria* sp., is fast-growing and could be having a number of possible effects. It could be hindering or preventing the settlement of *Leptopsammia pruvoti* larvae; it could be reducing access of smaller *Leptopsammia pruvoti* individuals to food particles suspended in the water column; it could be out-competing the *Leptopsammia pruvoti* for the same planktonic food items; and it could be smothering smaller individuals including 'juveniles'. In 2007, there were certainly many more 'juveniles' present at the Knoll Pins East site (50 out of a total of 272 or 18%) than at the Knoll Pins Cave site (7 out of a total of 128 or 5%).

CONCLUSIONS

A total of **954** *Leptopsammia pruvoti* individuals (± approximately 1-2%) were recorded during the 2007 study from three sites at Lundy: the Knoll Pins (703), Gannets' Rock Pinnacle (189) and Anchor Pinnacle (62). It is estimated that this accounts for approximately two thirds of the total *Leptopsammia pruvoti* population at Lundy, based on an estimate given by Irving & Northen (2004) that the total population size at Lundy in 2000 was in the region of 1,400-1,500 individuals.

Comparisons have been made of *Leptopsammia pruvoti* numbers at the Knoll Pins Cave site from various photographs taken between 1981 and 2009. These have shown a **maximum decline of 78%** in *Leptopsammia pruvoti* numbers over 25 years between 1984 and 2009. Counts of *Leptopsammia pruvoti* individuals by divers have been compared with similar counts undertaken in 1999 & 2000. These have also shown a decline in numbers in certain areas (such as **a loss of 65%** on the north side of the Knoll Pins canyon), but an increase in numbers in others (such as **a gain of 44%** between the Knoll Pins Cave site and the Knoll Pins South site). It is thought the gain of 44% is largely due to recent recruitment at the Knoll Pins East site.

Whilst there has been little evidence of new recruitment to the Lundy *Leptopsammia pruvoti* populations during the 1980s and 1990s, this situation appears to have changed in recent years. The present study found the proportion of 'juveniles' to 'adults' varied considerably from site to site. The highest proportion of 'juveniles' was found at the Knoll Pins East site, with 50 'juveniles' out of a total of 272 individuals (or 22%). With gaps in the temporal coverage of the photographic monitoring over the years, it is not possible to say whether these new recruits are all from the same year class or not.

The presence of species that burrow into the base of the skeleton (including the horseshoe worm *Phoronis hippocrepia*, various polychaete worms and the bivalve *Hiatella arctica*), is considered to be particularly significant. Their tunnelling action into the bases of *Leptopsammia pruvoti* individuals is likely to weaken attachment to the rock face and render the corals prone to being knocked off by foraging animals, anchors, shot lines, fishermen's pots or divers. It is unclear what effect, if any, the presence of *Megatrema anglicum* barnacles may have on the corals.

The growth of bryozoan species which form a lush faunal 'turf' over near-vertical rock faces is also thought to be significant. The height and density of the turf may prevent or hinder larval settlement of the corals or may well out-compete recently settled *Leptopsammia pruvoti* individuals for food. The bryozoan turf at the Knoll Pins Cave site, growing on a steeply sloping bedrock surface, is noticeably more prolific than at the Knoll Pins East site, where the rock face is vertical. A much higher proportion of 'juveniles' were present at the Knoll Pins East site (22%) than at the Knoll Pins Cave site (6%).

A sufficient food supply is important for successful reproduction in anthozoans but whether or not the *Leptopsammia pruvoti* population at Lundy is well fed is unknown.

Leptopsammia pruvoti is a warm-temperate species at the northern limits of its range at Lundy. In the years ahead, the gradual warming of the UK's coastal waters as a result of climate change may be good for these corals. If the number of larvae being produced increases as a result of seawater warming, there will be higher local recruitment and an increased possibility that some larvae will be swept by currents to new locations.

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