Marine Biodiversity Records

RESEARCH Open Access

The status of *Clibanarius erythropus* after a recent range expansion to Great Britain, with the highest latitude recording of a gravid individual

Christophe Patterson[1*], Matt Slater[2], Regan Early[1] and Chris Laing[1]

Abstract

Background: In 2016, the range of the hermit crab *Clibanarius erythropus* expanded to South West Britain for the second time. *C. erythropus* primarily lives in the Mediterranean and the Atlantic coast of Europe from the Bay of Biscay to Morocco. The species has now been recorded on both the north and south coast of the South West peninsula of the UK from Newtrain Bay, on the north coast of Cornwall, to Wembury, on the south coast of Devon. It is unknown if the crab's reappearance in the UK has been caused by a one-off colonisation event or by a continued influx of larvae.

Results: The population in the UK is made up of individual within a narrow size bracket, indicating a single colonisation event took place, and that the population is an ageing one. However, we also report the highest latitude recording of a gravid individual for the species.

Conclusion: A lack of gravid individuals was suggested to be why the species was unable to sustain its presence in the UK following a previous colonisation in 1960. This discovery hints that rising water temperatures may allow *C. erythropus* and other warm-water species to expand and sustain themselves in the UK. We also found crossover in shell utilisation between *C. erythropus* and the native hermit crab *Pagurus bernhardus*, suggesting that competition might occur between the two species.

Keywords: Climate change, Range shift, Colonization, Expansion, Decapoda, Intertidal, Gravid, Hermit crab

Background

Clibanarius erythropus is a warm water hermit crab whose distribution extends from Morocco to the coast of France and includes the Mediterranean (Tricarico et al. 2009). In the 1950s, observations suggested that the range of *C. erythropus* was expanding northwards beyond the Bay of Biscay around Brittany with the highest latitude record being at Roscoff in 1955 (Southward and Southward 1977).

The species made even further progression northwards when it was discovered in the UK in the winter of 1959/60 (Carlisle and Tregenza 1961). However, at the majority of sites, the species' appearance was short-lived. In 1967, the 'Torrey Canyon' oil spill and subsequent toxic cleaning chemicals were observed to have directly killed most, if not all, the population (Southward and Southward 1977). After 1967 records of *C. erythropus* occurred at only two known sites, Wembury and Marazion (Southward and Southward 1977). These populations seemed unsustainable and disappeared sometime around the 1980s (Hawkins et al. 2017; Southward and Southward 1988).

It has been predicted that *C. erythropus* would return to the southwest of the UK as the water temperatures rose (Hawkins et al. 2008; Southward et al. 1995) and, in March 2016, *C. erythropus* was rediscovered in Cornwall at Castle beach (50°8′52″N, 5°3′19″W). This recording was followed by sightings at multiple locations along both the north and south coast.

* Correspondence: cwp206@exeter.ac.uk
[1]Centre for Ecology and Conservation, University of Exeter, Penryn Campus, Penryn, Cornwall TR10 9FE, UK
Full list of author information is available at the end of the article

The reappearance of *C. erythropus* is unlikely to have been caused by direct human translocation. When translocation occurs, sightings typically start at a single site and then spread outwards (Farnham and Morrell 1983). As recordings of *C. erythropus* appeared simultaneously across the coast, it is more likely that its planktonic larvae drifted to the UK from further south.

We describe the current known distribution of *C. erythropus* in the UK, as well as data on the abundance of *C. erythropus* at five locations in Cornwall. To explore the age structure of *C. erythropus* in the UK, we recorded the size range of the individuals. Hermit crabs cannot be aged directly and the shell species a hermit crab is occupying alters the growth rate (Bertness 1981); therefore, we use size as an approximation of age. If the UK population of *C. erythropus* is capable of reproducing or is the result of a continued influx of pelagic larvae, then the age structure of the UK population should resemble those at other sites in Europe. *C. erythropus*, in Europe, have cephalothorax shield lengths ranging from 1.3 mm to 7.4 mm, with a high ratio of individuals having shield lengths smaller than 3.0 mm (Cuesta et al. 2016). Gherardi and Benvenuto, (2001) found the mean *C. erythropus* cephalothorax shield length in Europe was 1.99–2.10 mm, although this does vary between sites (Benvenuto and Gherardi 2001). Conversely, if there has been a single incursion of pelagic larvae and no self-recruitment has occurred, individuals in the UK should be restricted to a narrow size range. Long term monitoring of the UK rocky shore has shown that the range of many intertidal species can alter in response to a changing climate (Hawkins et al. 2008; Mieszkowska et al. 2006). We suggest that the reappearance of *C. erythropus* on UK coasts could be an important indicator of how the ranges of other warm-water species could expand to the UK over time as climate changes.

We also explored the shell species that *C. erythropus* uses in the UK, in order to make predictions as to how the species could interact with the native UK fauna; mainly the UK's only abundant intertidal hermit crab *Pagurus bernhardus,* through shell competition. From the 1960s to the 1980s, *C. erythropus* predominantly utilised *Nucella lapillus* shells (Southward and Southward 1988) even though this is not the most abundant intertidal gastropod (Wilson-Brodie et al. 2017).

Methods

Following a series of sightings submitted to the Environmental Records Centre for Cornwall and Scilly (www.orks.org.uk), five different sites were surveyed along the south coast of Cornwall, between October and December 2017 (Fig. 1): Bream Cove (50°6′55″N, 5°5′27″ W), Gyllyngvase East (50°8′43″N, 5°3′48″W), Gyllyngvase West (50°8′ 32″N, 5°4′7″W), Porthleven (50°4′57' N, 5°19′20″W), and Prisk Cove (50°6′30″ N, 5°5′6″W). Sites were visited 2 h either side of low tide.

Rockpools were selected by moving parallel to the water along the mid tide mark, and all rockpools greater than two square metres were searched. Each rockpool was searched for 10 min per two square metres of the water's surface area. The species of shell occupied by any *C. erythropus* found was recorded according to Crothers (2001).

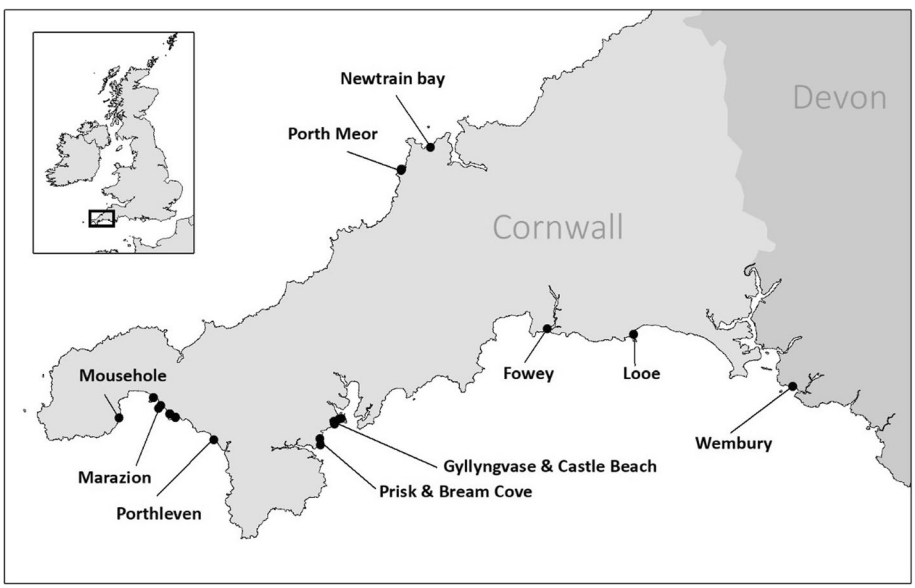

Fig. 1 The distribution of records for *Clibanaruis erythropus* in the South west of the UK since 2016. Notable locations are labelled. Data from *NBN Atlas* and *Environmental Records Centre for Cornwall and Scilly* (https://species.nbnatlas.org/species/NBNSYS0000188517#tab_recordsView)

In order to measure crab size, a camera (Olympus Tough TG-4) was placed 40 cm above the ground, pointing vertically downwards at a ruler, which had divisions of one millimetre, on a flat substrate. Each crab was placed adjacent to the ruler with the aperture of their shell facing vertically upwards. This induced the hermit crab to partly emerge from their shell and as this occurred, photographs were taken at 4x optical zoom. After each individual was measured, they were placed back into the rockpool. If an individual did not fully emerge within 10 min, they were placed back into the rockpool and another sought.

Photographs were analysed using Image J software (Schneider et al. 2012). The different anatomical structures were measured using the ruler in each photograph as a guide. The cephalothorax shield width (CSW), the cephalothorax shield length (CSL), and the total length of the cephalothorax (TCL) were recorded for each animal.

Follow up surveys monitoring the presence of *C. erythropus* at Gyllngvase beach (50°8′32″N, 5°4′7″W) were conducted at regular intervals from January 2018 to present.

Results

UK distribution

The first confirmed recording of *C. erythropus* in the UK since 1985 (Southward and Southward 1988) was at Castle beach in Falmouth (50°8′52″N, 5°3′19″W), on the 12th March 2016. Adrian Rowlands, who was taking part in a Shoresearch citizen science survey run by Cornwall Wildlife Trust, found a single individual that was identified as *C. erythropus* by Matt Slater.

Within a month, the species was also discovered at Mousehole (50°5′3″N, 5°32′7″W) and Porth Meor (50°30′14″N, 5°2′5″W). Sightings of the species now cover both the North and South coast with the highest latitude recording being at Newtrain bay, Cornwall (50°32′37″ N, 4°58′56″W) and the most eastward recording at Wembury, Devon (50°18′57.8″N, 4°5′3.8″W) (Fig. 1). In September 2016, *C. erythropus* was recorded at Marazion (50°7′23.0″N, 5°28′36.0″W) and Wembury, these sites have been repeatedly surveyed since 2010 and 1997, respectfully (Hawkins et al. 2017). Records of *C. erythropus* are downloadable from *NBN Atlas* and *Environmental Records Centre for Cornwall and Scilly* (https://species.nbnatlas.org/species/NBNSYS0000188517#tab_recordsView).

The survey in 2017 recorded a total of 29 *C. erythropus*, at Porthleven (16 individuals), Prisk Cove (12 individuals), and Bream Cove (one individual). Across all sites, we attained 13 measurements of CSW, 11 measurement of CSL, and seven measurements of TCL (Table 1). Sixteen individuals did not emerge far enough to take any of their measurements in the allocated time.

Size structure

Mean CSL was 2.47 mm (range 1.42–3.15 mm), mean CSW was 2.81 mm (range 1.73–3.63 mm), and mean TCL was 5.95 mm (range 5.16–7.65 mm). Both the largest and the smallest individuals were found at Porthleven where the majority of measurements were taken (Table 1). The mean CSL was significantly larger than the CSL of individuals from Gherardi and Benvenuto (2001) (one-sample t-test; $t_{10} = 2.85$, $p < 0.05$; $t_{10} = 3.70$, $p < 0.01$, Fig. 2).

Shell utilisation

C. erythropus was found utilising four different species of gastropod shell, across all study sites. *Nucella lapillus* was occupied by 83% of *C. erythropus* (24 individuals), *Littorina littorea* was occupied by 6.8% (two individuals), *Tritia reticulata* was occupied by 6.8% (two individuals), and *Buccinum undatum* was occupied by 3.4% (one individual). The number of *C. erythropus* occupying each species of gastropod shell differed significantly ($X_3 = 51.69$, $p < 0.001$). Elongated, opposed to globose, shells were utilised by 93% of individuals.

Individuals utilising *N. lapillus* shells had a mean CSL of 2.49 mm (range 2.18–2.86). The smallest individual

Table 1 The number of *Clibanarius erythropus* found and the number of measurements taken at each site

Location	Date Visited	Rockpools searched	Number of *C. erythropus*	CSW measured	CSL measured	TCL measured
Bream Cove (50° 6′ 55″N, 5° 5′ 27″ W)	23/11/17	4	1	0	0	0
Gyllyngvase East (50° 8′ 43″N, 5° 3′ 48″ W)	18/10/17	3	0	0	0	0
Gyllyngvase West (50° 8′ 32″N, 5° 4′ 7″ W)	12/10/17	5	0	0	0	0
	21/11/17	2	0	0	0	0
Porthleven (50° 4′ 57″ N, 5° 19′ 20″ W)	03/11/17	2	16	11	9	5
Prisk Cove (50° 6′ 30″ N, 5° 5′ 6″ W)	25/10/17	4	10	2	2	2
	06/11/17	4	2	0	0	0
		Total	29	13	11	7

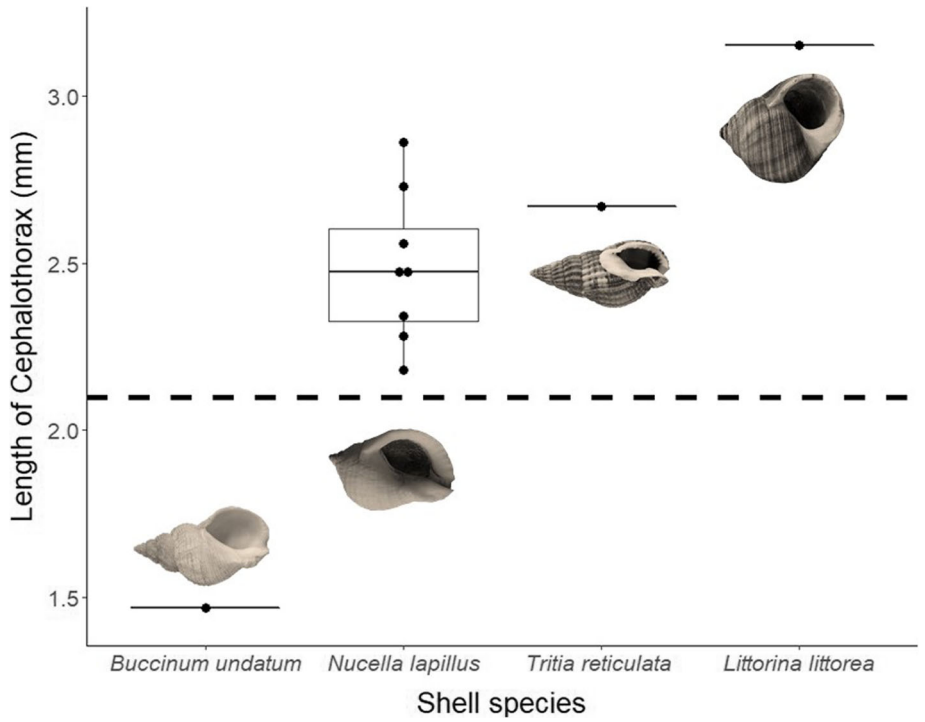

Fig. 2 The size structure (cephalothorax shield length) of *Clibanarius erythropus* across different species of Gastropod shell from all study sites. Dashed line marks the mean cephalothorax shield length of clustered individuals studied in Europe by Gherardi & Benvenuto (2001). Photographs adapted from those of H. Zell

(1.47 mm) was found utilising a *B. undatum* shell and the largest (3.15 mm) a *L. littorea* shell. One individual occupying a *T. reticulata* shell had a CSL of 2.76 mm (Fig. 2).

Gravid individual

On October 8th 2018, at Gyllyngvase West, a preliminary study that involved extracting three individuals from their shells was conducted. One individual was gravid with a mass of 300+ eggs gathered round its abdomen. Each egg had a visible eye pigment which was irregularly rounded, indicating they are at a late stage of development (Turra and Leite 2007). The gravid individual was found occupying a *N. lapillus* shell and had a CSL of 2.4 mm (Fig. 3). The other two individuals were a male with a CSL of 5.4 mm and a non-gravid female with a CSL of 3.3 mm both occupying a *L. littorea* shell.

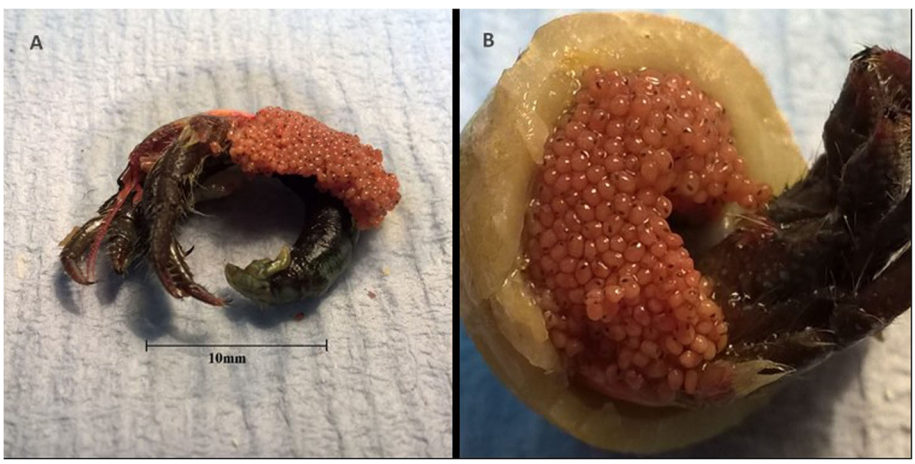

Fig. 3 Photographs of the gravid individual discovered at Gyllyngvase beach (50° 8′ 43″N, 5° 3′ 48″ W) on the 8th October 2018. **A** shows the individual fully extracted from its shell with the egg mass gathered around its abdomen using its pleopods. **B** shows the individual partly extracted with the egg mass held inside the cavity of the *N. lapillus* shell

Discussion

After a gap of 30 years, records of *C. erythropus* now frequently occur on both the north and south coast of Cornwall. Our measurements of CSL, the most commonly used measurement of size for *C. erythropus*, suggests that the range of sizes found in the UK population is reduced compared to those in the Mediterranean and Iberian Peninsula (Benvenuto and Gherardi 2001). No individual was larger than 3.5 mm (Fig. 2), indicating that individuals in Cornwall have not been able to reach the species' maximum size. This conforms with the theory that *C. erythropus* has only recently reappeared in the South West and was caused by a single incursion of the species pelagic larvae to the UK. The conclusion that *C. erythropus* arrived in a single incursion event and is an ageing population is based on the measurement of only 11 individuals and should be treated with caution. If this interpretation is correct, and no further colonisation events occur, we should see a gradual increase in the ratio of larger individuals as the population ages.

The growth rate of *C. erythropus* is unknown, meaning we cannot age the individuals in order to estimate when the larvae first settled in the UK. However, being part of the *Clibanarius* genus, *C. erythropus* is notably different from the other species of hermit crab found UK. This, combined with the active marine biological recording community in Cornwall, means the species is unlikely to have gone unnoticed for long. Thus the influx of larvae probably occurred in 2015 or early 2016.

The number of *C. erythropus* found, during this study, varied between survey sites (Table 1). This may have been because of an actual difference in abundance between sites or it could be because the species tends to congregate into small areas, possibly to increase shell exchange (Gherardi and Benvenuto 2001). As such, the stochasticity of finding clusters of individuals may have caused the high numbers of *C. erythropus* found at Prisk Cove compared to Gyllngvase beach and Bream Cove. At Porthleven, while only 16 individuals were measured and recorded due to constraints of the tide cycle, a high number of *C. erythropus* inhabited nearly all other rockpools at the site.

The majority of *C. erythropus* were found in *N. lapillus* (83%), with other shells being utilised at a much lower percentage, e.g. *L. littorea* (6.8%). This is similar to the percentages (72% *N. lapillus* and 11% *L. littorea*) used 2 years after the first colonisation, in 1961 (Southward and Southward 1977). In 1976 all individuals were found in *N. lapillus* (Southward and Southward 1988). This study further supports the notion that *N. lapillus* is the gastropod species most commonly occupied by *C. erythropus*, in the South West of the UK. However, in comparison to our results in 2017, research conducted in autumn 2016 showed a higher percentage use of *Littorea spp* (70%), while *N. lapillus* was occupied by only 22% (Antony 2017). This suggests that within the first year of colonising, *C. erythropus* occupied *Littorea spp* most frequently, but as individuals age, they began occupying *N. lapillus*.

It was suggested that the disappearance of *C. erythropus* in the 1980s was partly caused by the reduction in *N. lapillus* due to Tributyltin pollution (Southward and Southward 1988). The banning of Tributylin and the subsequent increase in *N. lapillus* (Birchenough et al. 2002) may have been a factor in allowing *C. erythropus* to return to the UK, but as *C. erythropus* did not reappear until 2016 and in an apparent single incursion this is unlikely to be the only factor involved.

The presence of *C. erythropus* in the UK may affect *P. bernhardus* the most common intertidal hermit crab in the UK. Records of *P. bernhardus* become rarer further south than Brittany (GBIF.org 2019); this means the expansion of *C. erythropus* from the Bay of Biscay to the UK has caused overlap in the ranges of the two species. While behavioural and dietary differences discussed in Southward & Southward (1977) may allow the species to coexist into the future, interspecific shell competition could occur. In the UK, *C. erythropus* is predominantly utilising *N. lapillus* shells, which are elongated and similar to those occupied in its traditional range (Tricarico et al. 2009). However, *C. erythropus* prefers globose shells (Gherardi and Benvenuto 2001), which allow them to reach larger sizes (Cuesta et al. 2016) and have increased locomotion (Benvenuto et al. 2003). It is possible that in the UK *P. bernhardus* is outcompeting *C. erythropus* for the preferred globose shells, such as *L. littorea*. However, *C. erythropus*, in the UK, have not reached the largest size class of the species and may currently be unable to utilise the larger globose *L. littorea* shells. As we predict the population of *C. erythropus* will grow into these large size classes in the future, competition between *C. erythropus* and *P. bernhardus,* for the larger and globose shell species, may become fiercer.

Gravid individuals of *C. erythropus* were not observed during the previous appearance in the UK and the sea surface temperature of the South West was thought to be too low for reproduction (Southward and Southward 1977). Within the Mediterranean and Atlantic range of *C. erythropus,* sea surface temperature extremes range from ~ 10 to 25 °C. Females are gravid during the warm summer months (Harms 1992), and on the Iberian coast, *C. erythropus* can reproduce where the average sea surface temperature in summer is 16.8 °C (Benvenuto & Gherardi, 2001). Harms (1992) concluded that larvae can develop successfully above temperatures somewhere between 15 and 18 °C. At 15 °C, the larvae developed through all 4 zoea stages but did not develop into the final megalopa stage, which can move into an empty

shell and moult into the adult form. At 18 °C complete larval development was accomplished.

The gravid individual found during this study was discovered on the 8th of October 2018 when the sea surface water temperature around the south coast of Cornwall was 13.3 °C (*Channel Coastal Observatory*, 2019). As water temperatures fall rapidly during this time of year, and given the results of Harms (1992), it is unlikely that these eggs would have produced larvae capable of surviving through to the adult stage. However, sea water temperatures around the southwest of the UK did exceed 15 °C, and briefly 18 °C, over the summer of 2018, and the maximum temperature of UK rockpools can reach 24 °C (Hopkin et al. 2006). As such, if *C. erythropus* were able to produce larvae earlier in the year a full reproductive cycle may be possible.

The return of *C. erythropus* to the UK may serve as in interesting proxy for other warm water species that have been expanding their range northwards in recent years (Keith et al. 2011; Mieszkowska et al. 2007; Mieszkowska et al. 2006), for example the Marble crab, *Pachygrapsus marmoratus* (Ingle and Clark 2008). The size structure of individuals suggests that the recent colonisation of *C. erythropus* to the UK was a single event and recruitment remains rare. Thus, ocean currents and temperatures may not be conducive to regular incursions by pelagic larvae from species native to European waters. Monitoring the distribution of *C. erythropus* across the UK, as well as observing the current populations for signs of reproduction or recruitment, could further our understanding of how quickly *C. erythropus* and other warm-water species can gain a larger foothold in the southwest of the UK as the climate changes.

Conclusion

The UK population of *C. erythropus* appears to be an ageing one, resulting from larvae founding populations in just 1 year. However, the discovery of a gravid individual suggests the potential reproduction of *C. erythropus* and that the species could extend its presence in the UK indefinitely. It took 25 years for *C. erythropus* to disappear from the UK after the previous colonisation event (Southward and Southward 1988). Therefore, even if no self-recruitment occurs *C. erythropus* will likely remain a noteworthy addition to the UK's intertidal fauna for another two decades.

Acknowledgements

The authors would like thank Adrian Rowlands for his original discovery of *C. erythropus* as well as Rachel Green and Victoria Hoare for invaluable help with transportation to and from study sites. CP was awarded the Sir Geoffrey Holland Prize, for excellent academic work within a field related to Cornwall and would like to thank everyone who was part of the selection process.

Authors' contributions

CP and MS both identified the topic could be of interest for research. The study was designed by CP and CL with guidance from MS and RE. Fieldwork was conducted by CP. CP complied the manuscript with guidance and editing throughout from MS, RE, and CL. All authors read and approved the final manuscript.

Funding

This work was part funded by the Genetics Society's Heredity Fieldwork Grant, as well as by the University of Exeter.

Availability of data and materials

Data are available upon request.

Ethics approval and consent to participate

Approval was obtained from the University of Exeter's Research Ethics Committee (2017/1970 (rev2)).

Consent for publication

All authors consent for publication.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Centre for Ecology and Conservation, University of Exeter, Penryn Campus, Penryn, Cornwall TR10 9FE, UK. [2]Cornwall Wildlife Trust, Five Acres, Allet, Truro, Cornwall TR4 9DJ, UK.

Received: 21 August 2019 Accepted: 6 February 2020
Published online: 19 February 2020

References

Antony S. The warm water hermit crab Clibanarius erythropus recently re-discovered in Cornwall. Cornwall collage group; 2017.
Benvenuto C, Gherardi F. Population structure and shell use in the hermit crab, Clibanarius erythropus: A comparison between Mediterranean and Atlantic shores. J Mar Biol Assoc UK Univ Exeter. 2001;81(1):77–84.
Benvenuto C, Sartoni G, Gherardi F. Foraging behaviour of the hermit crab Clibanarius erythropus in a Mediterranean shore. J Mar Biol Assoc UK. 2003; 83(3):457–61.
Bertness MD. The influence of shell-type on hermit crab growth rate and clutch size (Decapoda, anomura). Crustaceana. 1981;40(2):198–205.
Birchenough A, Evans S. Moss C, Welch R. re-colonisation and recovery of populations of dogwhelks Nucella lapillus (L.) on shores formerly subject to severe TBT contamination. Mar. Pollut. Bull. Pergamon. 2002;44(7):652–9.
Carlisle DB, Tregenza N. A hermit crab new to Britain. Nature Nature Publishing Group. 1961;190(4779):931.
Channel Coastal Observatory. http://www.channelcoast.org/. Accessed 19 Aug 2019.
Crothers JH. Common Topshells : an introduction to the biology of Osilinus Lineatus with notes on other species in the genus. F Stud. 2001;10:115–60.
Cuesta JA, Drake P, Pérez-Miguel M, Manzano R. Sex- and size-related differences in shell use by the intertidal hermit crab Clibanarius erythropus (Latreille, 1818) (Decapoda: Diogenidae) in the Gulf of Cádiz, southwestern Spain. J Crustac Biol Oxford University Press. 2016;36(1):23–32.
Farnham WF, Morrell SL. A chronology of new European sites of attachment for the invasive Brown alga, Sargassum Muticum, 1973–1981. J Mar Biol Assoc UK. 1983;63(4):799–811.
GBIF.org. (2019). GBIF Occurrence Download Accessed 19 Aug 2019.
Gherardi F, Benvenuto C. Clustering behaviour in a mediterranean population of the hermit crab. Clibanarius erythropus Ophelia. 2001;55(1):1–10.
Harms J. Larval development and delayed metamorphosis in the hermit crab Clibanarius erythropus (Latreille) (Crustacea, Diogenidae). J Exp Mar Bio Ecol Elsevier. 1992;156(2):151–60.
Hawkins SJ, Evans AJ, Mieszkowska N, Adams LC, Bray S, Burrows MT, et al. Distinguishing globally-driven changes from regional- and local-scale impacts: the case for long-term and broad-scale studies of recovery from pollution. Mar Pollut Bull. 2017;124(2):573–86.

Hawkins SJ, Moore PJ, Burrows MT, Poloczanska E, Mieszkowska N, Herbert RJH, et al. Complex interactions in a rapidly changing world: responses of rocky shore communities to recent climate change. Clim Res. 2008;37(2–3):123–33.
Hopkin RS, Qari S, Bowler K, Hyde D, Cuculescu M. Seasonal thermal tolerance in marine Crustacea. J Exp Mar Bio Ecol Elsevier. 2006;331(1):74–81.
Ingle RW, Clark PF. First reported occurrences of the marbled crab, Pachygrapsus marmoratus (Crustacea: Brachyura: Grapsoidea) in southern coastal waters of the British Isles. Mar Biodivers Rec Univ Exeter. 2008;1(1837):e26.
Keith SA, Herbert RJH, Norton PA, Hawkins SJ, Newton AC. Individualistic species limitations of climate-induced range expansions generated by meso-scale dispersal barriers. Divers Distrib Wiley/Blackwell (10.1111). 2011;17(2):275–86.
Mieszkowska N, Hawkins SJ, Burrows MT, Kendall MA. Long-term changes in the geographic distribution and population structures of Osilinus lineatus (Gastropoda: Trochidae) in Britain and Ireland. J Mar Biol Assoc UK. 2007; 87(2):537–45.
Mieszkowska N, Kendall MA, Hawkins SJ, Leaper R, Williamson P, Hardman-Mountford NJ, et al. Changes in the range of some common rocky shore species in Britain - A response to climate change? Hydrobiologia. 2006;555(1): 241–51.
Schneider CA, Rasband WS, Eliceiri KW, NIH Image to ImageJ: 25 years of image analysis. Nature Methods. 2012;9(7):671–75.
Southward AJ, Hawkins SJ, Burrows MT. Seventy years' observations of changes in distribution and abundance of zooplankton and intertidal organisms in the western English Channel in relation to rising sea temperature. J Therm Biol. 1995;20(1–2):127–55.
Southward AJ, Southward EC. Distribution and ecology of the hermit crab Clibanarius erythropus in the western channel. J Mar Biol Assoc UK. 1977; 57(2):441–52.
Southward AJ, Southward EC. Disappearance of the warm-water hermit crab Clibanarius erythropus from south-west Britain. J Mar Biol Assoc UK Univ Exeter. 1988;68(3):409–12.
Tricarico E, Bertocchi S, Brusconi S, Chessa LA, Gherardi F. Shell recruitment in the Mediterranean hermit crab Clibanarius erythropus. J Exp Mar Bio Ecol Elsevier BV. 2009;381(1):42–6.
Turra A, Leite FPP. Embryonic development and duration of incubation period of tropical intertidal hermit crabs (Decapoda, Anomura). Rev Bras Zool Sociedade Brasileira de Zoologia. 2007;24(3):677–86.
Wilson-Brodie RJ, MacLean MA, Fenberg PB. Historical shell size reduction of the dogwhelk (*Nucella lapillus*) across the southern UK. Mar Biol Springer Berlin Heidelberg. 2017;164(9):1–9.

Publisher's Note