Limpets

2020 (+4)

Biology of Limpets: Evolution, Adaptation, Ecology and Environmental impacts

Flett Theatre

Natural History Museum, London

5th & 6th March, 2024

Hosted by:

The Malacological Society of London

Welcome to Limpets 2020 + 4

(Biology of Limpets: Evolution, Adaptation, Ecology and Environmental Impacts)

It is with great pleasure that the organising committee and The Malacological Society of London welcome you to this meeting that is focussed on all things limpet. Previous meetings have been a great success. Given the diversity of papers on offer, this meeting will undoubtedly be every bit as successful.

During this meeting, presenters will not only be able to showcase their research, but also have the opportunity to discuss current and future research with each other. It is also wonderful to see the large number of interesting presentations from postgraduate students. This meeting should be a casual, enjoyable experience for all.

We would like to take this opportunity to thank everyone who has helped us to make this meeting a reality.

We hope you enjoy the meeting.

STEPHEN HAWKINS, Organiser
Marine Biological Association of the U.K. & University of Southampton, U.K.

PHILLIP FENBERG, Organiser
University of Southampton, U.K.

LOUISE FIRTH, Organiser
University College Cork, Ireland

JONATHAN ABLETT, Organiser
President of the Malacological Society of London, Natural History Museum, London, U.K.

ALAN HODGSON, Organiser
Rhodes University, South Africa

Front page image *Scutellastra cochlear*, Cape Town. Photograph ©A.N.Hodgson

Arrival

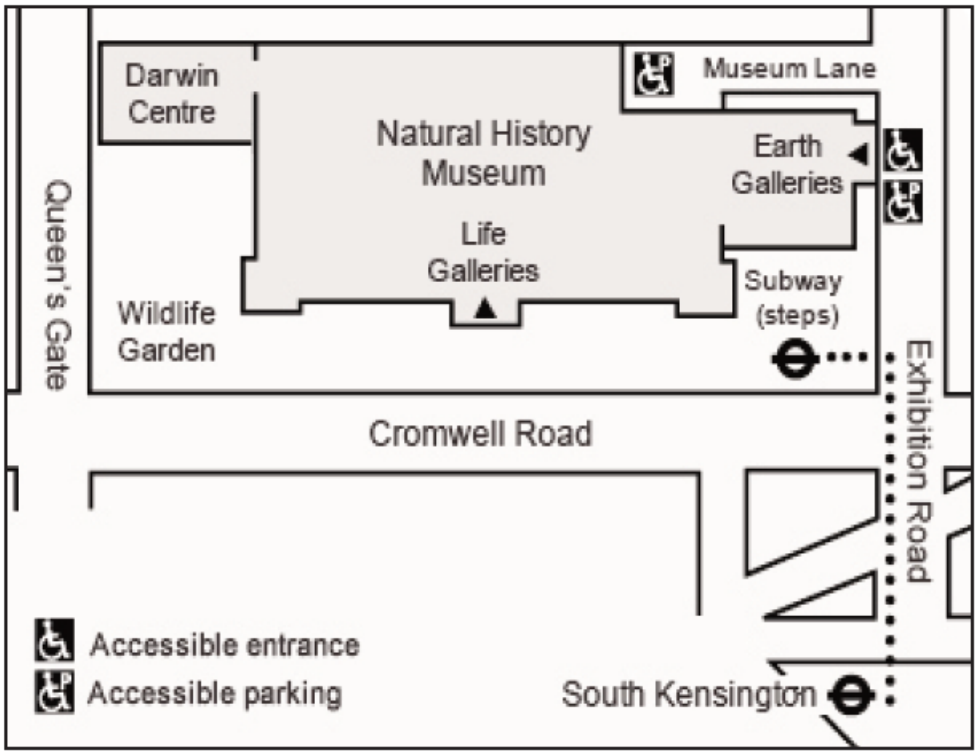
1. **Getting to the Natural History Museum**

The NATURAL HISTORY MUSEUM is located in South Kensington, London (SW7 5BD). It is easily accessible by bus, underground (to South Kensington served by the District, Circle and Piccadilly lines) or taxi. For detailed instructions, please see the museum website at www.nhm.ac.uk.

2. **Finding the Meeting Venue and Meeting Procedures**

The meeting will take place in the Flett Theatre, on the first floor of the Earth Galleries building. Non-NHM attendees should enter the museum through the staff entrance on Exhibition Road just before the public entrance to the Earth Galleries (see map below). All attendees must sign in at the staff entrance reception desk. Registration begins at 3.00 pm on the 5th of March and all speakers and those presenting talks or posters should arrive before this time to allow time to upload talks and prepare.

Once through the staff entrance, follow signs for the Limpet Meeting and the Flett Theatre. The door to the Flett Theatre reception room is not locked and so late comers will be able to enter the talks at any time. Out of consideration for the speakers, we kindly ask that late-arriving attendees only enter the Flett Theatre between talks.



Eating and drinking

Tuesday

Upon arrival at 3 pm refreshments will be available before the first talks.

After the talks everyone is invited meet in the Queens Arms for drinks and to socialise. https://www.thequeensarmskensington.co.uk/#/

From the Queens Arms delegates may then wish to proceed to a local restaurant for an evening meal.

Wednesday - Conference Lunch and Refreshments

Lunch will be provided for all attendees who have registered. Lunch will be served in the Flett Theatre reception area on Wednesday and will consist of sandwiches (meat, fish, vegetarian, and vegan options) and other snacks. Tea, coffee, and mineral water will be provided during refreshment breaks.

Wine Reception

On Wednesday afternoon there will be a final poster session and a chance to socialise over a glass of wine. Afterwards, the attendees may, once again, gather in a local pub to further discuss the day's events.

Poster session

Posters will be on display throughout the meeting in the Flett Theatre reception area with a dedicated poster session (with wine) in the late afternoon on Wednesday.

Conference Programme

Tuesday 5th March	**FLETT THEATRE, NATURAL HISTORY MUSEUM, LONDON**
15.00 – 15.20	Arrival at NHM, registration, refreshments, put up posters & load talks
15.20 – 15.30	Welcome – **Jon Ablett** (President MSL)
15.30 – 15.40	**Alan Hodgson -** Welcome and short introduction "Orton & His Legacy".
15.40 – 16.10	**Invited Talk** **Louise Firth**: What have limpets ever done for us? On the past and present provisioning and cultural services of limpets.
16.10 – 16.30	**Phil Fenberg**: Giving a Hoot: range shifts, phylogeography, and genetic vulnerability of the Owl Limpet, *Lottia gigantea*.
16.30 – 17.00	**Steve Hawkins**: Long-term changes in populations of *Patella depressa* towards its poleward range edge (44 years of chucking quadrats).
17.00 - 17.30	**Helen Garbett**: The Human Limpet Project: On being enchanted by limpets of all forms.
17.30 onwards	Social gathering at local ale house.

Wednesday 6th March	**FLETT THEATRE, NATURAL HISTORY MUSEUM, LONDON**
09.30 – 09.45	Registration, load talks
SESSION 1	Chair: Jessica Allen
09.45 - 10.15	**Invited Talk** **Fernando Lima**: Robolimpets: origin, evolution, and applications.
10.15 - 10.30	**Ignacio A. Cienfuegos**: Growth in the margins: field measured protein metabolism rates in the keystone, intertidal limpet, *Patella vulgata*.
10.30 - 10.45	**Andre Ampuero**: Limpet stories through shells and anatomy.
10.45 - 11.00	**Mar Humet Caballero**: Assessing basal thermal stress in a natural population in a non-invasive way.
11.00-11.30	**Refreshment Break**
SESSION 2	Chair: Ignacio Cienfuegos
11.30 – 11.45	**Javier Guallart**: Why so many efforts to justify unsuccessful translocations of the endangered limpet *Patella ferruginea*?
11.45 - 12.00	**Camilla Della Torre**: Investigating the adaptive mechanisms to ocean acidification in the limpet *Patella caerulea* from the CO_2 vent systems of Ischia (Italy).
12.00 – 12.15	**Alvaro Sabino-Lorenzo**: When the population of an endangered marine mollusc (*Patella ferruginea*) increases almost three-fold in ten years. Reality or fiction?
12.15 – 12.25	**Conference photograph**
12.25 - 13.00	**Informal Discussions and LUNCH**
13.00 – 14.00	**Malacological Society AGM, Non-members free to continue discussions or explore Natural History Museum**

SESSION 3	Chair: Franz Bauer
14.00-14.30	**Invited Talk** **Juan Sempere-Valverde**: Surviving the urbanised world: ecological implications of shoreline artificialisation on limpet population conservation.
14.30-14.45	**Karolina Zarzyczny**: The ecological and evolutionary consequences of tropicalisation: a case study from limpets.
14.45-15.00	**Maria Inês Seabra:** Limpet dynamics within and beyond eco-engineered rockpools: a ten-year study on rock-armour structures in the Port of Sines (SW Portugal).
15.00-15.15	**Bhavik Vakani**: Diversity of true gastropod limpets of mainland coastal India.
15.15 – 15.45	**Refreshment Break**
SESSION 4	Chair: Javier Guallart
15.45-15.50	**Debora Borges**: Insights for addressing climate change effects on *Patella* spp. early life stages.
15.50-15.55	**Sarah Hinckley**: The role of mucus in patellid limpet distribution.
15.55-16.00	**Rocío Nieto-Vilela**: Unveiling climate-driven shifts: exploring range expansion and thermal limits of *Siphonaria pectinata* in NW Iberia rocky shores.
16.00-16.15	**Julia Sigwart**: Observations on the enigmatic mangrove limpet.
SESSION 5	
16.15-17.30	**Poster session, discussions with refreshments**, closing remarks
17.30	Conference closure, Depart Conference Venue, Evening Free

Poster Papers

Franz Bauer, Antony M. Knights, John N. Griffin, Mick E. Hanley, Andy Foggo, Austin Brown, Emma Jones, Louise B. Firth. Superficial, but sophisticated - How does surface topography determine abundance and spatial distribution of key benthic species?

Charlotte Clubley, Jessica Allen. An investigation into the influence of eco-engineered tiles on the biota and biodiversity of artificial shores.

Aeden Cooper, Sandalia Walker, Juan Sempere-Valverde, Chris Moocarme, Antony M. Knights, Louise B. Firth. How limpets affect succession in an artificial environment.

J. Guallart, M.P. Ferranti, M. Chiantore. Larval development of *Patella rustica* in the laboratory: how it can help us to understand clues about the threatened *P. ferruginea*.

Sally Henderson, John Griffin, Matthew Perkins, Louise Firth. Self-cleaning slipways: harnessing species interactions for sustainable management of coastal infrastructure.

Jack Hollister, Phil Fenberg. Computer vision-based morphological assessment of limpet species along the Baja California coast.

A.Martín-Zorrilla, E. Ostalé-Valriberas, A. Sabino-Lorenzo, A. A. Pavón-Paneque, J. Sempere-Valverde, G. A. Rivera-Ingraham, J. C. García-Gómez, F. Espinosa. Predicting the fate of the most endangered marine invertebrate of the Mediterranean: The power of long-term monitoring in conservation biology.

E. Ostalé-Valriberas, J. Sempere-Valverde, A. Pavón-Paneque, S. Coppa, F. Espinosa, J. C. García-Gómez. Artificial marine micro-reserves as a new ecosystem-based management tool for marine conservation: The case of *Patella ferruginea* (Gastropoda, Patellidae), one of the most endangered marine invertebrates of the Mediterranean.

E. Ostalé-Valriberas, A. Martín-Zorrilla, A. Pavón-Paneque, A. Sabino-Lorenzo, J. C. García-Gómez. Advances in the management and translocation methodology of the endangered mollusc *Patella ferruginea* in artificial habitats of port infrastructures: implications for its conservation.

Sandalia Walker. Understanding the effects of man-made artificial structures on the population-size structures of a keystone species *Patella vulgata*.

ABSTRACTS

Alphabetical by type of presentation (Presenting author is underlined)

INVITED 30 MINUTE TALKS

What have limpets ever done for us? On the past and present provisioning and cultural services of limpets

Louise B. Firth

School of Biological, Earth and Environmental Sciences, University College Cork, Ireland.

Limpets are one of the most abundant and familiar rocky shore organisms globally. They are perhaps most famous for their ability to cling onto rocks, but they are also well known for their grazing activity, which has an important structuring function. In contrast to other molluscs, such as oysters and mussels, which are celebrated for their gastronomic and cultural importance, little is known about the provisioning and cultural services of the humble limpet, and they are often referred to as 'famine food'. In this talk, I will provide an overview of the importance of limpets in the diets and cultures of humans globally. Not only were limpets often the dominant shellfish eaten by early modern humans, but also they sustained the poor during times of famine and destitution. Today, they are considered a delicacy in many cultures. They were popular as bait and their shells have been used for a wide variety of uses, including tools, currency, offerings, traditional medicine, jewellery and artworks. They have important spiritual and religious relevance, featuring in myriad traditions, superstitions and folklore. Whilst limpets are not exploited on a global scale, there are many regions where populations are vulnerable to over-exploitation and possible extinction. Appropriate management is required if we are to protect these underappreciated animals.

For more information the full paper can be accessed at https://press-files.anu.edu.au/downloads/press/n9154/pdf/01_firth.pdf:

Firth LB. (2021). What have limpets ever done for us? On the provisioning and cultural services of limpets. International Review of Environmental History, 7: 5-46.

Robolimpets: origin, evolution, and applications

Fernando P. Lima

CIBIO/BIOPOLIS, Porto, Portugal

Despite steady advancements in remote temperature sensing, it is now clear that natural and human-altered thermal environments often exhibit intricate small-scale complexities in both spatial and temporal dimensions, which can only be adequately resolved through *in situ* monitoring. This is most apparent in coastal areas, which are among the most thermally dynamic environments on Earth but also notoriously difficult to monitor. Consequently, many studies rely on broad-scale spatial and temporal averages, overlooking the fact that organisms respond to changing local conditions rather than to overall global temperature patterns, reducing the impact of most analyses and forecasts. In this talk, I will discuss our progress in creating reliable and miniaturized autonomous data loggers. These devices were designed to effortlessly gather fine-scale data in extreme conditions, such as being submerged in saltwater, battered by waves, and subjected to temperature extremes, UV radiation, and ice scouring. Originally inspired by limpets (hence the name "robolimpets"), these loggers have since evolved and diversified. Today, we have access to a wide range of temperature loggers, each tailored for specific functions. I will use various field examples to highlight the advantages, opportunities, and limitations of this innovative family of instruments.

Surviving the urbanised world: ecological implications of shoreline artificialisation on limpet populations conservation

Juan Sempere-Valverde[1,2]; Enrique Ostalé-Valriberas[1]; Free Espinosa[1]

[1]*Laboratorio de Biología Marina, Departamento de Zoología, Universidad de Sevilla,Avda, Spain*
[2]*Biological and Environmental Sciences and Engineering (BESE), Red Sea Research Center (RSRC), King Abdullah University of Science and Technology (KAUST), Saudi Arabia*

Limpets are important habitat engineer species present in marine zones that are subject to extensive anthropogenic impacts such as pollution, coastal sprawl, and human collection. The increasing presence of artificial structures in coastal ecosystems can cause population fragmentation, limiting the genetic flow and dispersion capacity of limpets. Moreover, limpets colonising artificial structures can differ in population demography from natural reefs, which affects their reproductive potential. However, these structures also present a managerial opportunity for mitigation of impacts and, in particular cases, to conserve the limpet species that naturally settle on them. This includes the restoration of our degraded, artificialized shorelines, to better approximate those on natural shores, although there is still much to learn to effectively minimize and mitigate the impacts on limpet populations and other marine life. In the face of rapid urbanisation and anthropogenic global change, the study of limpets' adaptation to shoreline features offers valuable insights into the ecological implications of coastal artificialisation. It underscores the importance of

balancing ecological, social, and governmental principles for achieving sustainable development.

CONTIRBUTED 30 MINUTE TALK

Long-term changes in populations of Patella depressa towards its poleward range edge – 44 years of chucking quadrats

S.J. Hawkins[1,2,3,4,5,6], M. Orostica, N. Mieszkowska[1,3], S.R. Jenkins[1,5], P.M. Moore[1,8], M.T. Burrows[3,7], L.B. Firth [4,5,6,9]

[1]Marine Biological Association of the UK, [2]University of Manchester, [3]University of Liverpool, [4]University of Southampton, [5]University of Bangor, [6]University of Plymouth, [7]Scottish Association for Marine Science, [8]University of Newcastle. [9]University College Cork

Long-term changes in the relative proportions of warmer water *Patella depressa* and colder water *Patella vulgata* in limpet populations on the mid shore have been charted on the rocky shores of the British Isles since the 1950s (Crisp and Southward), and from December 1979 by SJH. In the early 1980s following the cold spell from 1962-1963, the proportion of *Patella depressa* was lower on many shores. From around 1988 onwards warming conditions led to an increase in *Patella depressa* in south-west England.

Re-surveys at range edges from the 2000s-2020s onwards found modest range expansion *Patella depressa* in the English Channel with breeding populations in the eastern Isle of Wight and established on an artificial shore at Southsea in Portsmouth, with scattered individuals along the south coast. In N. Wales in contrast, the range edge populations extending as far north as Anglesey in the 1950s, with scattered individuals still present in the 1980s, has retracted mostly to south of the Llyn.

Whilst the ultimate factor of climate change is driving relative abundance of the two species, proximate factors such as hydrographic barriers and habitat suitability are setting range limits. The Llyn seems to be a hard barrier in contrast to those present in Southern England where proliferation of artificial habitat may be aiding spread (also in *P. ulyssiponensis*). In parallel observations on growth and mortality show strong performance by *P. depressa* at its range edges. Experiments show that intraspecific competition is stronger than interspecific except under simulated canopies where P. depressa is negatively impacted by *P. vulgata*.

CONTRIBUTED 15 MINUTE TALKS

Limpet stories through shells and anatomy

Andre Ampuero, Julia Sigwart

Department of Marine Zoology, Senckenberg Research Institute, Frankfurt am Main, Germany

Limpet shape is broadly extended not only in Gastropoda, but other groups within and outside Mollusca. Animals that fall into this condition possess a flattened armour protecting its soft parts, which attaches firmly to the substratum. Its prevalence suggests advantages like shielding against predators and wave forces; this partly explains why it has evolved multiple times. This study looks into the limits and potential of limpet evolution in Gastropoda by studying a diverse set of information, including µCT scans of shells and soft body parts, to understand how limpets have changed over different clades including extinct forms. We are especially interested in how the degree of shell coiling affects the soft body inside, for example, how much the shell has changed across different taxa. We have examined specimens from scientific collections to review not only limpet taxa, but also coiled shell species where this limpet shape appears. We are obtaining shells µCT scans of most genera of limpet. For anatomical comparison, we are using literature review and studying anatomy of limpets with poor or no information available using µCT scan and histology. By exploring these facets, we aim to disentangle the evolutionary narrative of limpets and their anatomical adaptations.

Growth in the margins: field measured protein metabolism rates in the keystone, intertidal limpet, *Patella vulgata*

Ignacio A. Cienfuegos[1], Benjamin J. Ciotti[1], Richard A. Billington[1], Paul A. Sutton[2], Keiron P.P. Fraser[1]

[1]*School of Biological and Marine Sciences, University of Plymouth, U.K.*
[2]*School of Geography, Earth and Environmental Sciences, University of Plymouth, U.K.*

Seasonality in both shell and soft tissue growth has been reported in intertidal molluscs since early rocky shore studies. Reproductive cycle, shore height and annual changes in food availability and temperature, among other factors, have an effect on growth in these species. Protein metabolism, a key biological process responsible for tissue growth, has also proven to be aligned with seasonal changes in temperature and food availability in other species. However, to date no studies have measured protein metabolism in the field in any organism. The common limpet *Patella vulgata* is ubiquitous to North-Eastern Atlantic intertidal rocky shores. Their growth is reduced in summer, during gametogenesis, and in winter compared to autumn and spring. Low shore populations, formed by younger individuals, show faster growth compared to their higher shore conspecifics. No studies had previously examined protein metabolism in *P. vulgata*, and it was unclear whether growth patterns would extrapolate to protein synthesis (k_s), degradation (k_d) and growth (k_g) rates. Here, we measured growth, protein metabolism and oxidative stress in *P. vulgata* in the field over a year, at three different shore heights. Shore height had a significant effect on k_s and mass growth and there were significant

seasonal variations in protein metabolism, mass growth and oxidative stress. k_s was highest in spring, whereas k_g peaked in summer and decreased in spring due to increased k_d. Total mass growth rates were higher in winter, especially in low shore animals. Tissue mass growth rates were higher in spring/summer compared to winter/autumn. This study demonstrates that the reproductive cycle appears to drive seasonal variations in protein metabolism and tissue growth in *P. vulgata*.

Investigating the adaptive mechanisms to ocean acidification in the limpet *Patella caerulea* from the CO_2 vent systems of Ischia (Italy)

Camilla Della Torre[1,2*], Silvia Giorgia Signorini[1,2], Fabio Crocetta[2], Lara Nigro[1], Ilaria D'Aniello[4], Marco Munari[2,4]

[1]*Department of Biosciences, University of Milan, Milan, Italy*
[2]*Department of Integrative Marine Ecology, Stazione Zoologica Anton Dohrn, Naples, Italy*
[3]*Department of Earth and Environmental Sciences, University of Milano-Bicocca, Milan, Italy*
[4]*Department of Biology, Stazione Idrobiologica Umberto d'Ancona, University of Padova, Chioggia (Venice), Italy*

The continuous increase in CO_2 emissions in the atmosphere generates the ocean acidification phenomenon (OA). Based on laboratory studies, OA has several detrimental effects across many taxa. However, different investigations performed in CO_2 vent systems demonstrated the ability of some species, including calcifying organisms, to survive even in the most acidified areas. In particular, the gastropod limpets of the genus *Patella* occur also under naturally acidified conditions at the CO_2 vents of the Castello Aragonese (Ischia Island, Italy). Nonetheless, the complex mechanisms that allow survival and adaptation to natural OA conditions still need to be understood.

In this study, specimens of *Patella caerulea* were collected along the pH gradient of the Castello Aragonese vent (N1 pH 8.1 – N2 pH 7.7 – N3 pH 7.4) and from a nearby control site to investigate the mechanisms that allow survival and may be involved in acclimation/adaptation. Biomarkers related to oxidative stress and physiological traits were assessed, together with an untargeted metabolomics analysis.

Limpets sampled in the acidified sites N2 and N3 displayed higher shell length and soft-body weight with respect to organisms collected in the ambient pH sites. Moreover, a significant increase in carnitine and in 11 of its metabolites was assessed in specimens collected under acidified conditions. Finally, limpets in N3 significantly boosted their respiration rate in comparison with all other sites, and a slight induction of oxidative stress was detected along the pH gradient.

Giving a Hoot: range shifts, phylogeography, and genetic vulnerability of the Owl Limpet, *Lottia gigantea*

Phillip B Fenberg

School of Ocean and Earth Science, National Oceanography Centre, University of Southampton, U.K.

The Giant Owl Limpet, *Lottia gigantea*, is perhaps the most well-studied limpet of the west coast of North America. Not only is it the largest limpet in the genus, it is also an important space occupier because of its territoriality, a sequential hermaphrodite, and has been size-selectively harvested by coastal human communities for millennia. In this talk, I review the latest research on *L. gigantea*, including recent observations of range changes at both its poleward and equatorward range limits, and present new research on its population genetics and phylogeography. I conclude by discussing the conservation implications of these results, including the possibility of the loss of genetically unique equatorward populations with ongoing climate warming.

The Human Limpet Project: On being enchanted by limpets of all forms

Helen Garbett

University of the Highlands and Islands, Centre for Island Creativity, Shetland Institute of Archaeology, Orkney

The story of limpets, when told through socially engaged, art-based research reveals an accessible, captivating, richly entangled human-nonhuman tale which unfolds over thousands of years. If given careful, prolonged attention, room to express themselves and an open-minded, receptive audience, limpets can engender a sense of curiosity and wonder, enchanting people with potentially life affirming consequences (Bennett, 2001). A methodology comprised of *Limpeteering*, *Corresponding* and *Wunderkammering*, underpinned by new materialist thinking enrols limpets in a process of questioning the habitual ways by which we know and conduct ourselves towards the natural world. Stimulating an original form of public dialogue and creating *The Limpetarium*, a contemporary, limpet-focused wunderkammer or wonder-room, this long-term undertaking is creating new connections between art, archaeology and marine ecology, contributing to interdisciplinary research and knowledge-making both now and in the future.

Reference:
Bennett, Jane. The Enchantment of Modern Life: Attachments, Crossings, and Ethics. 1st paperback edition., Princeton University Press, 2001.

Why so many efforts to justify unsuccessful translocations of the endangered limpet *Patella ferruginea*?

Javier Guallart

Independent researcher, Valencia, Spain

The ferruginous limpet *Patella ferruginea* is one of the most endangered Mediterranean marine invertebrates, threatened mainly by over-harvesting and habitat destruction and fragmentation. Its recovery has been considered hampered by its supposed low capacity for natural dispersal, and reinforcement with specimens in areas where it was previously present has been considered the best strategy for recovery of this species. Translocation of individuals between natural populations has been repeatedly attempted over the last 20 years but has generally resulted in low survival. Consequently, the Strategy for the conservation of this species in Spain (updated in 2023) discouraged such translocations among natural populations as a conservation or compensatory measure. Instead, it recommends the development of aquaculture techniques for the production of recruits (juveniles) by controlled reproduction to be used for eventual reintroduction or restocking projects. However, several recent papers attempt to demonstrate that translocations from natural populations are feasible with a "reasonable" mortality rate. A critical review of all translocation attempts made so far in this species is presented, discussing the different methodologies used and analysing their results. The reasons for trying to justify the interest of translocations as a conservation measure are also discussed, distinguishing between those attempting to translocate juveniles obtained from aquaculture and those transferring specimens from natural populations.

Assessing basal thermal stress in a natural population in a non-invasive way

Mar Humet[1,2], Rocío Nieto-Vilela[1,2], Fernando P. Lima[1,2], Rui Seabra[1,2]

[1] *CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado*
[2] *BIOPOLIS Program in Genomics, Biodiversity and Land Planning*

The intertidal zone is among the most physically demanding environments on the planet and has long served as a model for examining the role of environmental stressors. Temperature is one of the most determinantal modulators of animal physiological performance and survival. Therefore, accurate assessments of thermal stress in rocky intertidal natural populations are critical for forecasting the likely impacts of extreme events driven by climate change. Here, we explore the usability and applicability of a non-invasive method to assess thermal stress in *Patella depressa*, a key species on the ecology of the rocky intertidal coast of the NE Atlantic. We measured heartbeat frequency using a portable system equipped with an infrared sensor connected to a smartphone running a dedicated mobile app. We show how heartbeat measurements of *Patella depressa* made *in situ* reveal patterns of thermal stress, presenting a strong correlation between heart rate and temperature. We also documented a deviation of the heartbeat baseline simultaneous with a marine heat wave. Additionally, we found implications in

the thermal stress response related to solar exposure (i.e., animals exposed to the sun/animals in shaded locations) and to the animal size. This simple and user-friendly technique creates new possibilities for monitoring physiological responses to sub-lethal stress levels in a changing environment.

When the population of an endangered marine mollusc (*Patella ferruginea*) increases almost three-fold in ten years. Reality or fiction?

A. Sabino-Lorenzo[1], A. Ali-Ahmed[1], A. Pavón-Paneque[1], J. Sempere-Valverde[1], F. Espinosa[1], J. C. García-Gómez[1], E. Ostalé-Valriberas[1]

[1] *Laboratorio de Biología Marina de la Universidad de Sevilla (LBMUS)/Área de Investigación I+D+i del Acuario de Sevilla/Estación de Biología Marina del Estrecho (Ceuta), Universidad de Sevilla, Seville, Spain.*

Over the past decade, the temporal change of the critically endangered species *Patella ferruginea* (Gastropoda, Patellidae), endemic to the western Mediterranean, has been monitored (structure and density) using exhaustive censuses along Ceuta's coast (Strait of Gibraltar). This study focuses on the population dynamics of *P. ferruginea* in Ceuta and the environmental factors that affect the structure of this population, such as wave exposure, coastline heterogeneity, substratum roughness, substratum lithology, and chlorophyll-a concentration, as the statistical modelling has shown in the study. Different potential negative interactions were also considered: angling, shell fishing, and recreational activities. The results have shown in a ten-year period, 2011-2021, the estimated size of *P. ferruginea* population has increased by 300 %, from 55,902 to 168,463 individuals (of which 131,776 are adults). The subpopulation with the greatest increase in these years was the one settled inside Ceuta's harbour. The results of the study indicate that Ceuta hosts the main population of this endangered species through its natural distributional range, being a source population on the Southern Iberian Peninsula that its preservation must be prioritized. These results also support "Artificial Marine Micro-Reserves" as a new area-based conservation measure that could promote genetic flow among populations, with eventual recolonization.

Limpet dynamics within and beyond eco-engineered rockpools: a ten-year study on rock-armour structures in the Port of Sines (SW Portugal)

Maria Inês Seabra[a], Stephen J. Hawkins[bcd], Cristina Espírito-Santo [a], Susana Celestino [a], Alina Sousa[a], Marta Mamede[a], André Costa[a], Nuno Mamede[a], Teresa Silva[a], João J. Castro[ae], Teresa Cruz [ae]

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[d] *School of Biological and Marine Sciences, University of Plymouth, Plymouth, United Kingdom*
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Rockpools are nurseries for intertidal limpets. Limpet abundance is low on mid-tidal levels of rock-armour structures in the Port of Sines (Portugal), where rockpools are scarce. Eco-engineered rockpools were created on two locations inside this port (General Cargo and Petrochemical Terminals), by drill-coring mid-tidal boulders of rock-armour structures. Within Cored (with pools) boulders, we monitored the cover of sessile organisms in pool-bottom surfaces, the recruitment of limpets onto the pools, and the density and size-structure of limpets on open-rock surrounding pools (Around) and away from pools (Away). Limpets were also censused on Control (without pools, unmanipulated) boulders. We tested whether there was a proximity effect (Away vs. Around) and a landscape-unit effect (Cored vs. Control boulders) of eco-engineered rockpools on the abundance of *P. depressa* and *S. pectinata* on mid-tidal open-rock over ten-years (2010-2020). Both the abundance of crustose corallines and the recruitment of patellids were low at Petrochemical. For *P. depressa*, a significant landscape-unit effect was found at General Cargo whereas no proximity effect was detected. Proximity and landscape-unit effects were significant on both locations for *S. pectinata*. Eco-engineered rockpools can provide nursery-grounds and source-areas of emigration to adjacent open-rock, enhancing limpet populations over long-time and across distinct microhabitats.

Observations on the enigmatic mangrove limpet

Julia Sigwart[1], Leena Wong[2]

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Enigmonia aenigmatica represents the farthest reaches of the limpet form: a motile anomiid and often referred to as a bivalve limpet. The species is widespread in the Indo-West Pacific, occurring in coastal mangrove. Thus, they are also the only known arboreal limpet, or arboreal bivalve. New observations from two populations in peninsular Malaysia confirm this species is moderately mobile, the juveniles actively crawl in

laboratory conditions and in the field are mainly found attached onto larger adults. Adults can reattach and reorient but would not readily move. The movement is unlike gastropods, not a smooth gliding but rather inching forward pulled by the long foot. Adults occur above the mean high-water mark but depend on periodic immersion for filter feeding and grow well in captivity when fully submerged. We present here the first video of this limpet like behaviour in *Enigmonia.*

Diversity of true gastropod limpets of mainland coastal India

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The ecological importance and worldwide diversity of patellogastropods have attracted researchers from numerous biological disciplines. For a review of the current status of the diversity of true limpets of the Indian coastline, 77 coastal areas in the Gujarat, Western and Eastern Ghats having a rocky shoreline or rocky outcrops were surveyed during December 2014 to December 2016. From the study, seven species of true limpets were recorded from the entire mainland Indian coastline. The initial study and analysis of the observed limpets revealed that all of them have many morphs (variants) and creates taxonomic confusion within their species complex. Our study provides annotated taxonomical and ecological characters for identification to resolve species complexes. Results of the study also found the need for better tools for identification of species complexes by the combination of molecular phylogenetic with traditional taxonomy.

The ecological and evolutionary consequences of tropicalisation: a case study from limpets

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Tropicalisation is a marine phenomenon arising from contemporary climate change. It is characterised by the range expansion of tropical species and the retraction of temperate

species, and has a multitude of ecological consequences for species and communities. However, to date, tropicalisation has been predominantly studied in charismatic subtidal species, with minimal focus on intertidal gastropods, particularly limpets. Moreover, our understanding of its evolutionary consequences remains largely limited.

We used distributional data obtained from field surveys spanning over 3,000km along the eastern Pacific rocky coastline, museum collections, and genetic data from partial COI gene to document tropicalisation and assess its implications on phylogeographic patterns of multiple limpet species.

We detected tropicalisation along the rocky shore coastline and provided baseline distributions for previously understudied limpet species to allow for future tropicalisation monitoring. We showed that tropicalisation may lead to genetic erosion of evolutionarily distinct lineages through range contraction in some limpets. Whilst some range extending gastropods can maintain high levels of genetic diversity, this was not the case for some limpets. We highlight that more investigation into species-specific larval development is necessary as species-specific barriers to dispersal are likely to influence patterns of tropicalisation and its consequences in the future.

CONTRIBUTED 5 MINUTE SPEED PRESENTATIONS

Insights for addressing climate change effects on *Patella* spp. early life stages

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Larval and juvenile stages of invertebrates are more sensitive to environmental stress than adults. Therefore, climate change will very likely have a negative impact on the early stages of limpets by reducing juvenile survival and growth, that might extend into adulthood and reduce limpet population fitness. Previous *Patella* spp. studies have investigated the effects of climate change on the biology and distribution of adults. However, studying the effects of climate change on different life stages is fundamental to fully comprehend its impact on marine assemblages. To investigate these possible effects, a set of specific objectives were defined: comparison of current limpet abundance and reproductive cycles with historical data; optimization of methodologies to induce spawning, development of larvae and settlement of spat; and assessment of climate change stressors effects on larvae and spat survival. The methods to be implemented to achieve these objectives will be presented to promote exchange of knowledge and practices. This research constitutes the first approach to understanding how climate change affects survival and settlement of early life stages of the most common limpet species from the northwest Portuguese coast.

The role of mucus in patellid limpet distribution

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Patellid limpets are influential gastropod grazers that provide top-down control and contribute to the structure of intertidal communities. In Britain, three species (*Patella vulgata*, *P. ulyssiponensis* and *P. depressa*) co-exist in the same environmental conditions but show species specific distributions across spatial and temporal scales. Within this, each species also displays further segregation according to life stage, as well as differing group behaviours such as random aggregations like *P. vulgata*, or uniform distributions as seen in *P. ulyssiponensis* populations.

The observed differences in patellid limpet distribution can be partially attributed to physical interspecific interactions. However, another important driver of behaviour, chemical mediation, is less understood in this group. The use of mucus trails in communication and navigation has been documented in many intertidal gastropod species, such as littorinid, neretid and haliotid species, but remains poorly understood in patellids. Preliminary results on behavioural experiments investigating the attractant or deterrent role of UK patellid mucus trails in conspecifics and heterospecific interactions will be presented.

Unveiling climate-driven shifts: exploring range expansion and thermal limits of *Siphonaria pectinata* in NW Iberia rocky shores

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Changes in the physiology, ecology, and, ultimately, biogeography of several native and non-native species have been related to climate change. One notable trend among non-native species is their expanding distributional range, most commonly poleward, concurrent with increasing temperatures. As winter warming is projected to increase in the mid and high latitudes of the northern hemisphere, an increased likelihood and dominance of warm-adapted species is expected, and these regions are emerging as 'hotspots' for non-native species. Notably, on the rocky shores of NW Iberia, warm-adapted sub-tropical and Mediterranean species, like the gastropod *Siphonaria pectinata*, are proliferating. Compared to its historical distribution, this species has significantly extended its range northwards along the Iberian Peninsula. Our research is focused on understanding the potential distribution potential of *S. pectinata* by exploring the thermal tolerance of its larvae. We experimentally subjected eggs to low temperatures and monitored larval development, revealing a critical tolerance threshold at 10 ± 2°C and suggesting this

temperature as a pivot limiting factor determining the species distribution and change. This study contributes to our comprehension of climate-induced species shifts and highlights the importance of considering cold thermal tolerance when predicting the expansion potential of warm-adapted species.

CONTRIBUTED POSTER PAPERS

Superficial, but sophisticated - How does surface topography determine abundance and spatial distribution of key benthic species?

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In response to ongoing coastal urbanization, it is critical to develop effective methods to optimise the biodiversity and ecological sustainability of artificial shorelines. Enhancing the topographic complexity of coastal infrastructure through the mimicry of natural substrata may facilitate the establishment of ecosystem engineering species and associated biogenic habitat formation. However, interactions between ecosystem engineers and their substratum are likely determined by organismal size and resource needs, thus making responses to topography highly scale-dependent. Here, we assessed the topographic properties (rugosity, surface area, micro-surface orientations) that underpin the abundance and distribution of three ecosystem engineers (fucoids, limpets, barnacles) across six spatial scales (1-500 mm). Field surveys and 3D scanning, conducted across natural and artificial structures, showed major effects of rugosity and associated structural variables on assemblage composition and spatial occupancy, while abiotic and biotic covariates only had weak influences. Natural substrata exhibited ≤67% higher rugosity than artificial ones. Fucoids were predominantly associated with high-rugosity substrata and horizontal micro-surfaces, while limpets predominated on smoother substrata. Barnacle-driven rugosity homogenized substrata at scales ≤10 mm. Our findings suggest that scale-dependent rugosity is a key driver of fucoid establishment and limpet habitat use, with wider eco-engineering applications for mimicking ecologically impactful topography on coastal infrastructure.

An investigation into the influence of eco-engineered tiles on the biota and biodiversity of artificial shores

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Hard infrastructure is becoming increasingly prolific along global coastlines in to meet growing demand of coastal resources; however artificial shores support lower biodiversity than their natural counterparts. Ecological engineering initiatives are altering coastal infrastructure to make artificial structures better suited to the survivorship of taxa. The aim of this study was to identify whether differing complexity of four eco-engineered tiles, and the presence or absence of limpets, would impact biotic communities on eco-engineered tiles after a seven-month deployment in Torquay Marina. Flat, rippled and two complex tiles, with either 2.5 cm crevices or 5 cm crevices, were photographed alongside concrete controls. Half of the tiles were protected from limpet grazing, while the remaining tiles had limpets transplanted onto them to investigate potential grazing impact. Percent cover of biota was broken down by taxa, with calculations of species richness and Shannon Diversity index used to quantify biodiversity. There was a positive relationship between tile complexity and both live coverage and biodiversity. Low survivorship of transplanted limpets was attributed to mud accumulation, and thus insights into limpet grazing impacts were limited. It was concluded that in a different location the impact of limpet grazing on biodiversity may have greater influence.

How limpets affect succession in an artificial environment

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Limpets are key structuring agents on rocky shores globally. Their grazing exerts strong control over the cover of algae with cascading ecosystem effects. Topographically smooth coastal infrastructure such as breakwaters favour limpets, which may explain why such artificial habitats support lower biodiversity than their natural counterparts. Since 1954 large concrete blocks have been added annually on Plymouth Breakwater for erosion protection. Over time, the blocks deteriorate and become more topographically complex. Through surveying blocks of different ages (1-30 years old) we examined successional patterns and tested the hypothesis that limpet and algal abundances would change over time and would be inversely related. Specifically, we expected older, more complex blocks to support fewer limpets and greater algal cover. Analyses revealed that ephemeral green, then fucoid algae dominated early successional stages. After 2 years, limpets arrive and graze down the algae and prevent other taxa from establishing, creating long-term

limpet barrens. Pitted, older blocks supported fewer limpets and greater cover of non-ephemeral algae. The role of complexity in moderating limpet grazing is discussed. The unique long-term nature of this study sheds light on successional changes over time on concrete infrastructure. These results are informative for planning biodiversity management on marine artificial structures.

Larval development of *Patella rustica* in the laboratory: how it can help us to understand clues about the threatened *P. ferruginea*

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The larval development of *Patella rustica* is described, from fertilization to the post-larval phase, achieved in the laboratory from specimens from the Ligurian Sea within the framework of the ReLife project, aimed at the controlled reproduction of *P. ferruginea*. The results obtained generally show a great similarity to the larval development of *P. ferruginea* achieved within the project: (1) the timing of larval development is similar, reaching at about 20°C the crawling-pediveliger phase approximately 72 h.p.f.; (2) the morphology of the larvae is macroscopically very similar in both species and does not allow the identification between them. However, we did not achieve spawning stimulation using the techniques successfully developed for *P. ferruginea*, and the gametes were obtained by dissecting mature specimens. This difference with respect to *P. ferruginea* may be due to the habitat it occupies, at a higher tidal level, so that, although the reproductive cycle is seasonally almost identical, the spawning stimuli may be slightly different. Apart from describing for the first time the larval development of *P. rustica*, the results show that the cause of the regression of *P. ferruginea* cannot be attributed to some specific biological constraints as has been suggested. The similarity of the biological parameters with the coexisting, abundant and widely distributed *P. rustica*, seems to confirm that human collection is the main cause of the current state of *P. ferruginea*.

Self-cleaning slipways: harnessing species interactions for sustainable management of coastal infrastructure

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Combining intertidal molluscan grazers with ecological engineering could provide a nature-based solution to socio-environmental challenges of slipway maintenance. Slipways must be periodically cleaned to prevent algal growth and meet health and safety regulations. Current maintenance is expensive and environmentally damaging, utilising

short-term solutions such as chemicals and scrapers. The foraging activity of molluscan grazers, such as the common limpet (*Patella vulgata*) plays an important role in structuring the ecological state of rocky shores around the UK. *Patella vulgata* graze efficiently on smooth, flat surfaces often maintaining algae-free states. However, smooth surfaces enhance slip hazards and do not protect grazers from physical harm or biological stressors such as desiccation. Providing refuge on slipways as surface features can reduce these issues but may also collect sediment and water, reducing grazing efficiency and encouraging algal growth. This project investigates whether *P. vulgata* can be used as a longer-term, ecological solution to manage algal growth and create 'self-cleaning' slipways. In this study, topographic influences on grazing and algal growth are being tested in Pembrokeshire, Wales. Data will be presented from this experiment alongside an overview of the experimental design.

Computer vision-based morphological assessment of limpet species along the Baja California coast

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The Baja California peninsula harbours a variety of limpet species. Along this coastline, several geographical barriers have led to the isolation of some of these species' populations, resulting in phylogeographic breaks. Deciphering if there are morphological variations between these populations are challenging to discern through visual methods, and it remains unclear whether significant morphological differences exist between populations separated by a phylogeographic break. In this study, we utilise computer vision techniques to demonstrate if a specially crafted image classification model can learn to identify morphological features between populations. Additionally, we investigate which pixels and corresponding morphological features the model used to make their decisions. Limpet specimens (from the genera *Lottia* and *Fissurella*) were collected from various sites across the peninsula and southern California from populations north and south of phylogeographic breaks. Additional specimens were sourced from the Natural History Museum of Los Angeles, supplementing our study with their in-house collection of limpets from the same regions.

Predicting the fate of the most endangered marine invertebrate of the Mediterranean: The power of long-term monitoring in conservation biology

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Patella ferruginea is the most endangered endemic marine invertebrate of the western Mediterranean coasts according to the European Union Directive 92/43. The present temporary monitoring program commenced in 2007 aims to know the dynamics and ecology of this species. The methodology used consists of establishing 11 monitoring stations in the city of Ceuta (Strait of Gibraltar), each of which consists of three ten- meter transects. To understand variations in mean size, age structure, and sex of the population, the longitudinal axis of the shell was measured with calipers for all individuals within each transect. The proportion of females in the population remained below 10% (ranging from 4.35% to 8.82%) until 2017, but in subsequent years exceeded this proportion, reaching 12% in 2019. The station with the highest number of individuals was found inside the port of Ceuta, reaching 130.57 ind/m in 2022. In general, the population numbers of *P. ferruginea* have shown a highly positive trend due to high recruitment rates in 2009, 2011 and 2013, the latter years being those with the highest density of adults and overall number of individuals, reaching a density of 33.36 ind/m in 2021 and a density of adults of 18.65 ind/m in 2022.

Artificial marine micro-reserves as a new ecosystem-based management tool for marine conservation: The case of *Patella ferruginea* (Gastropoda, Patellidae), one of the most endangered marine invertebrates of the Mediterranean

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Among the different factors that affect the natural environment, fragmentation of ecosystems by urbanization processes can cause a reduction in species population sizes, thus enhancing their risk of extinction. Nevertheless, some species can maintain stable populations in these urbanized ecosystems. This is the case of the intertidal mollusc *Patella ferruginea* (Gmelin, 1791), a broadcast spawner, and a sequential protandrous

hermaphrodite limpet, whose populations have been historically decimated due to human harvesting. In this study, we analyse the benefits of a new marine conservation tool called

¨Artificial Marine Micro-Reserves¨ (AMMR) in *P. ferruginea*, one of the most endangered marine invertebrates of the Mediterranean Sea. The present study was conducted in Ceuta (North Africa, Gibraltar Area), and among its varying results, it shows that in the same body of water inside the port, the proportion of females of *P. ferruginea* in the area without accessibility (high protection) was 4.68 and 43.54 times higher than in the medium and low accessibility (non-protected areas), respectively. Therefore, the effective protection of these artificial areas has a positive effect on population size structures, as the female's percentage in the population is crucial for fostering the creation of genetic bridges for the recolonization of natural habitats.

Advances in the management and translocation methodology of the endangered mollusc *Patella ferruginea* in artificial habitats of port infrastructures: implications for its conservation

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The limpet (*Patella ferruginea*), endemic to the western Mediterranean, is the most endangered intertidal mollusc listed in the Habitats Directive (EU). The translocation methodology of this species is a scientific challenge faced by those port infrastructures – where there are established breeding subpopulations - that may be subject to emergency works, restoration, or extension of breakwaters. The present study was conducted in Ceuta (North Africa, Gibraltar Area), and show the results of an innovative methodology used to relocate individuals of this species from artificial coastal defense structures to natural protected areas. The translocation program for these specimens was implemented due to emergency works to repair the damage inflicted by the seasonal storms of March and April 2022 on certain artificial structures along the coast of Ceuta. In the course of the current project involving the extraction, transfer, and relocation of ferruginous limpet individuals, a total of 76 specimens of different sizes were selected for transfer. Unfortunately, two specimens died prior to their transfer, five perished during the extraction process (usually small individuals) and five during the resettlement process in the receiving area. As of 14 months post-transfer and settlement of the 64 remaining individuals, 13 have died and there are now 51 surviving specimens in the receiving area, reflecting a survival rate of 79.69%. Survival of the control individuals in the receiving area was 92.93%. If we apply this natural mortality (correction factor) to the transferred individuals, survival during this first 14 months of monitoring has been 86.77%.

Understanding the effects of man-made artificial structures on the population-size structures of a keystone species *Patella vulgata*

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Coastal environments are important as they provide a wide range of ecological services and benefits both socially and economically. Humans populating these areas have resulted in the addition of coastal urbanisation and sea defences. These artificial structures, including sea walls, sea armour and sea groynes, have a variety of impacts on the organisms and ecosystems originally there. This study uses the relationship between the body mass/size and abundance at sites across the south coast of England to better understand the relationship between body mass/size and abundance of *Patella vulgata* and how this varies across natural and artificial rocky shores. A non-destructive sampling method was used to avoid removing a key species from the shoreline. A selection of samples was weighed on-site to create a mass vs volume conversion curve. The study found that there were significant differences in abundance, length and mass across the two site types, with more limpets located at the artificial sites than at the natural sites. Moreover, those found at the artificial site were, on average, smaller than those found at the natural sites in both mass and length. The results showed no correlation between the abundance and mass/length.

Patella vulgata (Guernsey) – Photograph ©A.N. Hodgson

Lottia gigantea with *Lottia conus* on its shell – Photograph ©P.B.Fenberg