

Are pygmy hogs resilient enough to survive long-term? As pygmy hogs show low levels of genetic variation, they may not have the evolutionary potential required to adapt to sudden changes. Because populations have shrunk so drastically, inbreeding has started to pose a real threat next to habitat loss. Interestingly, however, evolutionary studies have shown that pygmy hogs have historically thrived despite experiencing small population sizes. It appears that the pygmy hog even survived a severe bottleneck in the ancient past, from which the species was recovering. This shows that the pygmy hog may be a resilient survivor, but at the same time the consequent low levels of genetic variation left the species extra vulnerable. Whether long-term recovery of the pygmy hog is possible now that it is in the midst of yet another bottleneck is hard to predict. More reintroductions, more research, ongoing monitoring, and safeguarded grasslands are all needed. This requires interdisciplinary collaborations, of which many are, luckily, already in place. But there is still a long way to go in order to save the pygmy hog from extinction.

Where can I find out more?

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In situ observation of sponge trails suggests common sponge locomotion in the deep central Arctic

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In 2016, the research ice-breaker Polarstern surveyed the submerged peaks of the permanently ice-covered Langseth Ridge, a tectonic feature comprising the Karasik seamount and two deeper seamount peaks, abutting the Gakkel ultra-slow spreading ridge (87°N 62°E to 85.5°N 57.4°E)¹. A towed marine camera sled and a hybrid remotely operated vehicle revealed these peaks to be covered by a dense demosponge community, at first glance reminiscent of North Atlantic *Geodia* grounds (*sensu*²). Sponges were observed on top of a thick layer of spicule mat (Figure 1 and Video S1), intermixed with underlying layers of empty siboglinid tubes and bivalve shells, a substrate covering almost the entire seafloor. We observed trails of densely interwoven spicules connected directly to the underside or lower flanks of sponge individuals (Figure 1), suggesting these trails are traces of motile sponges. This is the first time abundant sponge trails have been observed *in situ* and attributed to sponge mobility. Given the low primary production in this permanently ice-covered region, these trails may relate to feeding behavior and/or a strategy for dispersal of juveniles. Such trails may remain visible for long periods given the regionally low sedimentation rates.

Located 10° further north than any sponge ground yet reported, the population, primarily comprising *Geodia parva*, *G. hentscheli* and *Stelletta raphidiophora* individuals, covers the great majority of the Langseth Ridge from ~1,000 m upward, to a shallowest peak of 580 m depth, at very high

abundance¹. Sizes of individual sponges varied, with a median diameter of 17 cm (±0.10 cm SE, n=10,839, and IQR 11–25 cm); the maximum diameter observed was 110 cm and the smallest were just over 1 cm. This size range equates to a median wet weight of 1.4 kg (±0.12 kg SE, n=10,839; IQR 0.4–5 kg; Figure S1). Sponges are opportunistic feeders; although they efficiently retain particulates by filter feeding, dissolved organic matter in seawater often represents the main food source². The low productivity and nutrient fluxes that characterize this region — due to high latitude, permanent sea ice cover, and distance from land — raise the question of how this abundant biomass is maintained.

We analyzed the many trails of interwoven spicules across the seamount peaks. Trails were observed to be several centimeters in height and up to meters in length, often connected directly to living sponges. These trails were particularly visible in areas of low sponge density, that is, where trails crossed bedrock in areas sparsely covered by sediments or organic debris (Figure 1A–E and Video S1). Spicule trails in areas of denser sponge aggregation exhibited a higher vertical thickness than observed elsewhere (Figures 1F and S1A, and Video S1). Our observations also suggest that the spicule trails correlated with the distribution of smaller juvenile sponges (Figure S1A).

Sponges have no muscles or specialized organs for locomotion, but their entire body or parts thereof can contract or expand independently when subjected to external stimuli³. Mobility linked to spatial movement has been observed in the laboratory and field for some primarily encrusting species, which utilize various strategies for locomotion^{3,4}. Mobility allows sponges to re-position for improved food acquisition^{4,5}, to avoid unfavorable environmental conditions^{5,6} or to improve dispersal following sexual or asexual reproduction⁴.

Bond and Harris⁴ conducted laboratory studies investigating sponge locomotion across a range of predominantly encrusting freshwater and marine species. They observed that sponges could move across smooth surfaces by the sequential remodeling of their whole body.



Tethya actinia, they report, moved by extensional processes: extended spicules were attached to the substrate, then retracted back into the sponge body in such a way that the sponge was hauled forward, toward and across the anchored spicules. During this locomotion Bond and Harris⁴ reported loss via breakage of spicules, discarded as a trail of debris by the sponges. The predominantly massive *Geodia* spp. and *S. raphidiophora* individuals observed at the Langseth Ridge are far larger than the small, previously described individuals⁴, and other unknown mechanisms may be involved in their locomotion. Fleshy process extensions found exclusively on the underside of the sponges following spicule extrusion (Figure S1B) may play a role, suggesting that mobility may be facilitated primarily by macroscopic spicule rearrangements⁷. Furthermore, such tissue projections may be the sources of asexual buds spotted attached to laboratory samples and in the OFOBS images (Figure S1), with spicule trails providing an appropriate substrate for the settlement of sponge larvae. The large protruding spicules, often with hooks, that stud the sponge cortex of *Geodia* spp.⁸ may be involved in generation of traction during locomotion. Circular, wider spots observed on the tracks may reflect expansion or growth of individual sponges (Figure 1C,E) as observed for other species⁵.

Spicule trails were observed in 69% of images containing living sponges. 3D models generated from the image and video data show the interweaving and overpassing of these sponge trails (3D models and video available at <https://doi.org/10.17605/OSF.IO/GDFSP>). These data suggest changes of direction during movement. These features are all indicative of feeding and population-density behavioral trends previously observed in encrusting sponges⁵. The extremely low primary productivity, sedimentation, and particle advection rates of the Langseth Ridge region result in some of the lowest standing stocks of benthic life⁹, so potentially this Arctic *Geodia* community relies on particulate and dissolved fractions from the degradation of old organic debris trapped within the spicule mat (organic matter content 8%) as an additional food source. The

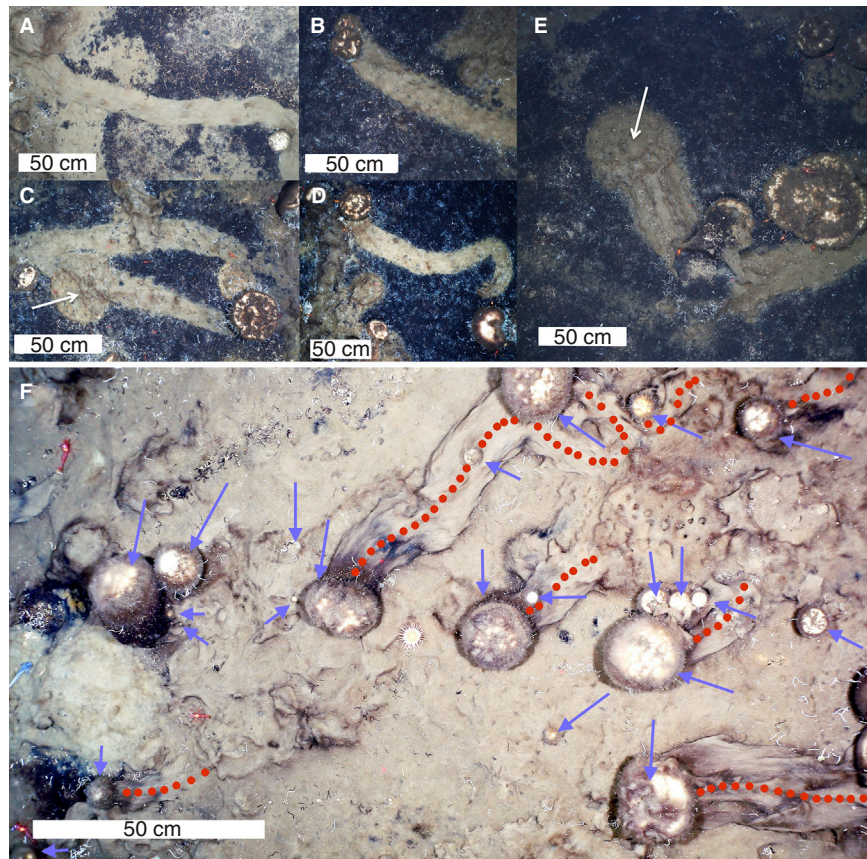


Figure 1. View of the typical sponge spicule trails.

The light brown spicule trails are clearly visible, connected directly to the underside or lower flanks of sponge individuals. (A–E) Sponges are set on top of dark substrate composed of organic debris (empty tubes of siboglinids and shells). (C,E) Particularly common are circular wider spots observed along the tracks as indicated by the white arrows. (E) Note that the central sponge specimen has two protrusions, which suggest intrinsic remodeling during locomotion. In (F) sponge trails can be seen on an area of seafloor wholly covered by spicule mat. Purple arrows indicate individual sponges, with red dotted lines indicating the midpoints of sponge trails. All images collected by the OFOBS still camera (see Supplemental Information).

mobility indicated here may further play a role in reproduction, supporting the dispersal and settlement of juvenile sponges, via either asexual budding or by providing a suitable substrate for larval settlement onto the trails (Figure S1A). Movement in *G. cydonium* has been reported in a Mediterranean setting⁶, but without the spicule trails, and was hypothesized to result from transport by high-velocity currents, of which there is no evidence across the Langseth Ridge summits¹. We considered the hypothesis that gravity could be the key cause of downhill sponge movement. Given the low relief topography of the Langseth Ridge summits, where seafloor slope in images containing sponges

has a mean angle of 8.5° (standard deviation 6.2°), gravity assist seems highly doubtful. Further, inspection of the collected videos and 3D seafloor models indicates sponges are primarily on the ‘uphill’ end of trails, suggesting movement against the slope direction. Tantalizingly, a similar trail structure was pictured in a previous study from a *Geodia* spp. ground on the Arctic Canadian shelf, but with no description or discussion of what the structure may represent¹⁰. To better determine the rates and drivers of sponge mobility in this most northerly sponge ground, time-lapse imagery and histological studies are required to validate and better understand this unexpected phenomenon, and place the significance

of this mobility within the functioning of this unusual ecosystem.

SUPPLEMENTAL INFORMATION

Supplemental information includes one figure, one video, experimental procedures, author contributions, acknowledgements, and supplemental references and can be found with this article online at <https://doi.org/10.1016/j.cub.2021.03.014>.

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Independent origins of powered flight in paravian dinosaurs?

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Feathered dinosaurs discovered during the last decades have illuminated the transition from land to air in these animals, underscoring a significant degree of experimentation in wing-assisted locomotion around the origin of birds. Such evolutionary experimentation led to lineages achieving either wing-assisted running, four-winged gliding, or membrane-winged gliding. Birds are widely accepted as the only dinosaur lineage that achieved powered flight, a key innovation for their evolutionary success. However, in a recent paper in *Current Biology*, Pei and colleagues¹ disputed this view. They concluded that three other lineages of paravian dinosaurs (those more closely related to birds than to oviraptorosaurs) — Unenlagiinae, Microraptorinae and Anchiornithinae — could have evolved powered flight independently. While we praise the detailed phylogenetic framework of Pei and colleagues¹ and welcome a new attempt to understand the onset of flight in dinosaurs, we here expose a set of arguments that significantly weaken their evidence supporting a multiple origin of powered flight. Specifically, we maintain that the two proxies used by Pei and colleagues¹ to assess powered flight potential in non-avian paravians — wing loading and specific lift — fail to discriminate between powered flight (thrust generated by flapping) and passive flight (gliding).

In their study, Pei and colleagues¹ inferred powered flight potential for 11 non-avian paravians on the basis of their wing loading estimates falling at or below 2.5 gcm⁻² — a threshold established from empirical observations indicating that living birds surpassing this value are unable to fly (references 44, 71, 123–126 in Pei et al.¹). While this

threshold discriminates well between flighted and flightless birds, it cannot discriminate between powered flight and gliding among aerial vertebrates (Figure 1). Gliding vertebrates without powered flight capacity, such as flying fishes, reptiles and gliding mammals, have significantly lower wing loading values (<1.5 gcm⁻²) than the above-mentioned threshold^{2,3} (Figure 1). Furthermore, among birds and bats — the only extant vertebrates capable of powered flight — the wing loading values of species that glide over very long distances, such as frigate birds, raptors, albatrosses and some flying foxes, are indistinguishable from the values of species that exclusively use flapping flight (Figure 1). While wing loading provides information about vertical lift, it applies only to fixed-wing models (i.e., gliding and parachuting), lacking a direct relationship to powered flight⁴.

When the net value of upward force to body mass overcomes gravity (>9.8 NKg⁻¹), the body of a flier is lifted. Based on estimates of specific lift greater than 9.8 NKg⁻¹, Pei and colleagues¹ proposed five non-avian paravians as candidates for powered flight (*Rahonavis*, *Microraptor*, *Eosinopteryx*, *Aurornis*, and *Anchiornis*). Pei and colleagues¹ calculated these values using Marden's approach⁵, a model derived from modern birds that requires knowledge of the flight muscle ratio (FMR), the maximum muscle mass-specific power output (Po,m), and the lift-to-power ratio (L/P), as shown in the following equations:

$$\text{Specific lift} = \text{FMR} \times \text{Po,m} \times \text{L/P} \\ \log_{10} \text{L/P} = -0.440 \log_{10} \text{muscle mass} \\ + 0.845 \log_{10} (\text{wingspan}/2) - 2.239$$

Pei and colleagues¹ assigned a FMR of 10% and a Po,m of 225–287 WKg⁻¹ to all paravians, a range of Po,m that corresponds to the maximum power from anaerobic muscles in burst flight⁵; Po,m for sustainable aerobic flight is significantly lower. Given that the forward speed is not accounted for, this approach evaluates specifically the capacity for standstill takeoff⁶. Marden's model allows a fair discrimination between modern birds capable of standstill takeoff (specific lift >9.8 NKg⁻¹) and those ones that cannot (<9.8 NKg⁻¹)^{5,6}. However, calculations of specific lift for non-avian paravians

