

BRIEF COMMUNICATIONS

Avoidance of disease by social lobsters

These gregarious animals shun lobsters that carry a lethal virus, even when they still seem to be healthy.

Transmissible pathogens are the bane of social animals¹, so they have evolved behaviours to decrease the probability of infection^{2,3}. There is no record, however, of social animals avoiding diseased individuals of their own species in the wild. Here we show how healthy, normally gregarious Caribbean spiny lobsters (*Panulirus argus*) avoid conspecifics that are infected with a lethal virus. Early detection and avoidance of infected, though not yet infectious, individuals by healthy lobsters confers a selective advantage and highlights the importance of host behaviour in disease transmission among natural populations.

Panulirus argus virus 1 (PaV1) is a lethal pathogenic virus that infects juvenile spiny lobsters⁴. It is transmitted by physical contact and, among the smallest juveniles, through sea water. Spiny lobsters are social and share communal dens, so these modes of viral transmission could have devastating consequences in the absence of a mechanism to check its spread.

During underwater surveys of juvenile lobsters, we observed that infected lobsters rarely shared shelters with conspecifics (less than 7% shared dens and more than 93% were solitary), even though healthy lobsters generally preferred to live together (more than 56% shared dens and less than 44% were solitary).

To test whether this could be explained by healthy lobsters avoiding diseased individuals, we set up a laboratory experiment (for methods, see supplementary information) in which healthy and diseased lobsters were given a choice between an empty den and one containing either a healthy or a diseased individual. We found that the healthy lobsters avoided dens containing diseased conspecifics and preferred to share dens with other healthy lobsters. But diseased lobsters did not discriminate between dens, irrespective of whether the animal inside was sick or well (Fig. 1a). These results confirm our observations in the wild.

For an avoidance strategy to reduce the transmission of infection effectively, healthy lobsters must also start to avoid infected individuals before they actually become infectious. We therefore investigated whether there was any link between the timing of infectivity and the avoidance of diseased individuals by healthy lobsters; we found that these were remarkably coincident (Fig. 1b). Lobsters inoculated with PaV1 developed symptoms of disease after six weeks and became infectious after eight weeks (Fig. 1b). Most of the healthy

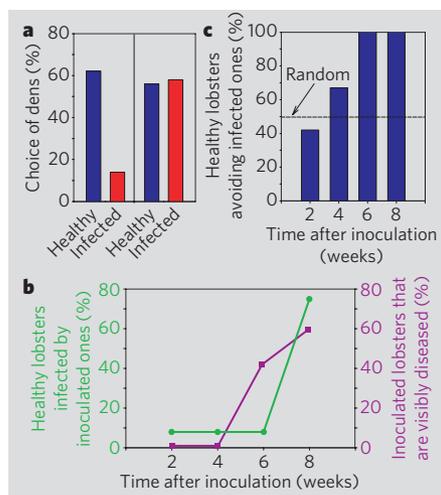


Figure 1 | Laboratory results showing avoidance by lobsters of diseased individuals and its relation to infectivity. **a**, Den selection by healthy (left panel) and infected (right panel) lobsters, showing the aversion of healthy lobsters for diseased lobsters. All lobsters were either given a choice of sheltering alone or with a healthy conspecific (blue bars), or given a choice of sheltering alone or with an infected (red bars) conspecific that was tethered in the den. **b**, Increase of infectivity over time for lobsters inoculated with PaV1 virus: green line shows the increasing percentage of healthy lobsters infected by inoculated lobsters, and purple line indicates the increasing percentage of inoculated lobsters that became visibly diseased. **c**, Cohabitation time series indicating that healthy lobsters started to avoid inoculated (but non-infectious) lobsters four weeks after inoculation and completely avoided them after six weeks, which is before they became infectious.

lobsters avoided these inoculated lobsters from four weeks after their inoculation and all of them avoided inoculated individuals at six to eight weeks after inoculation (Fig. 1c).

Other evidence (our unpublished results) indicates that avoidance of diseased conspecifics may act powerfully against the spread of disease in the wild. Laboratory confinement of healthy juvenile lobsters with lobsters infected with PaV1 results in more than 60% of them succumbing within 80 days. However, field surveys conducted since 1999 indicate that the prevalence of PaV1 in Florida's juvenile lobster population remains at less than 7% and does not correlate with lobster density (our unpublished results). The high transmissibility under laboratory conditions and the much lower prevalence in the wild, even at high density, can be reconciled if healthy, normally social lobsters thwart transmission of PaV1 by avoiding diseased lobsters.

Although infection may alter the subtle visual displays used by lobsters to establish aggregations, avoidance of diseased lobsters is likely to be chemically mediated, given that olfaction mediates dominance hierarchies, mate choice, foraging and aggregation^{5,6}. Lobsters do not have an adaptive immune system, so disease may be signified by broad-spectrum defensin compounds or by degradatory products that are associated with poor health.

Pathogens can alter host dynamics and modify communities by disrupting species interactions⁷⁻⁹, but their effect on the behaviour of uninfected hosts and on disease dynamics has been largely unexplored. Epidemiological

models have not generally included avoidance strategies^{10,11}, despite the possible fitness advantages conferred by such behaviour^{12,13}. Our findings indicate that lobsters can identify infected individuals before they become infectious and that by avoiding them they may limit disease transmission in the wild.

Donald C. Behringer*, Mark J. Butler*, Jeffrey D. Shields†

*Department of Biological Sciences, Old Dominion University, Norfolk, Virginia 23529, USA
e-mail: mbutler@odu.edu

†Virginia Institute of Marine Science, Gloucester Point, Virginia 23062, USA

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