

and reproduced many qualitative experimental features.

REFERENCES AND NOTES

1. T. E. Creighton, *J. Phys. Chem.* **89**, 2452 (1985).
2. ———, *Proc. Natl. Acad. Sci. U.S.A.* **85**, 5082 (1988).
3. C. Levinthal, *J. Chim. Phys.* **65**, 44 (1968).
4. R. L. Baldwin, *Annu. Rev. Biochem.* **44**, 453 (1975).
5. N. Gö, H. Abe, H. Mizuno, H. Taketomi, *Protein Folding*, N. Jaenicke, Ed. (Elsevier/North-Holland, Amsterdam, 1980), pp. 167–181.
6. J. Richardson, *Adv. Protein Chem.* **34**, 167 (1981).
7. W. J. Chazin and P. E. Wright, *J. Mol. Biol.* **202**, 623 (1988); J. M. Moore, G. P. Gippert, D. A. Case, P. E. Wright, unpublished results.
8. J. M. Guss and H. C. Freeman, *J. Mol. Biol.* **169**, 521 (1983); J. M. Guss, P. R. Harrowell, M. Murata, V. A. Norris, H. C. Freeman, *ibid.* **192**, 361 (1986).
9. H. Taketomi, F. Kano, N. Gö, *Biopolymers* **27**, 527 (1988).
10. H. C. Chan and K. A. Dill, *Macromolecules* **22**, 4559 (1989).
11. K. F. Lau and K. A. Dill, *Proc. Natl. Acad. Sci. U.S.A.* **87**, 638 (1990).
12. A. Sikorski and J. Skolnick, *ibid.* **86**, 2668 (1989).
13. J. Skolnick, A. Kolinski, R. Yaris, *Biopolymers* **28**, 1059 (1989).
14. ———, *Proc. Natl. Acad. Sci. U.S.A.* **86**, 1229 (1989).
15. J. Skolnick and A. Kolinski, *J. Mol. Biol.* **212**, 787 (1990).
16. A. Sikorski and J. Skolnick, *ibid.*, p. 819.
17. P. Flory, *Statistical Mechanics of Chain Molecules* (Interscience, New York, 1969), chap. 7.
18. J. Skolnick and A. Kolinski, unpublished results.
19. N. A. Metropolis, A. W. Rosenbluth, M. N. Rosenbluth, A. H. Teller, E. Teller, *J. Chem. Phys.* **21**, 1087 (1953).
20. K. Binder, *Monte Carlo Methods in Statistical Physics*, K. Binder, Ed. (Springer-Verlag, Berlin, 1987), pp. 1–45.
21. A. Baumgartner, *Annu. Rev. Phys. Chem.* **35**, 419 (1984).
22. G. Nielsen, A. Sikorski, A. Kolinski, J. Skolnick, unpublished results.
23. S. Miyazawa and R. L. Jernigan, *Macromolecules* **18**, 534 (1985).
24. D. G. Covell and R. L. Jernigan, *Biochemistry* **29**, 3287 (1990).
25. Y. Nozaki and C. Tanford, *J. Biol. Chem.* **246**, 2211 (1971).
26. A. Holtzer and J. Skolnick, *Biopolymers* **27**, 87 (1988).
27. S. Y. M. Lau, A. K. Taneja, R. S. Hodges, *J. Biol. Chem.* **259**, 13253 (1986).
28. H. J. Dyson, J. R. Sayre, R. A. Lerner, P. E. Wright, unpublished results.
29. P. Privalov, *Adv. Protein Chem.* **33**, 167 (1979).
30. D. A. Dolgikh *et al.*, *FEBS Lett.* **136**, 311 (1981).
31. Stimulating discussions with J. Dyson, L. Walters, R. A. Lerner, and P. E. Wright are gratefully acknowledged. We thank M. Pique for assistance with computer graphics, and V. Taurasi for preparation of the manuscript.

17 May 1990; accepted 24 August 1990

Scaling Population Density to Body Size in Rocky Intertidal Communities

PABLO A. MARQUET,* SERGIO A. NAVARRETE,† JUAN C. CASTILLA

Interspecific comparisons of animal population density to body size has been the subject of active research in the last decade, especially for terrestrial animals when considering particular taxa or taxonomic assemblages. Studies of rocky intertidal communities showed that animal population density scales with body size to the -0.77 power. This relation held within local communities representing a broad array of animal taxa and was not affected by a dramatic alteration in the network of between-species interactions, as revealed by two long-term human exclusion experiments.

THE RELATION BETWEEN POPULATION density and body size (scaling) has been investigated primarily in terrestrial habitats, with a strong taxonomic bias toward related species (1–3). Natural communities, that is assemblages of species populations that co-occur in space and time (4), have not been well studied. Reconstructed taxonomic assemblages (5) formed by the compilation of published data on particular groups of related species have frequently been used. Because the species

come from communities in which the degrees of biotic and abiotic influences are not known, it is not possible to assess the effect of present-day ecological processes on the statistical pattern shown between body size and population density. However, despite these constraints, explanations of the population scaling, based on the action of competition and predation, have been advanced (1, 6, 7).

We focused on natural communities that include species in distantly related taxa. In this way, we can set aside evolutionary constraints imposed by phylogenetic similarity and examine constraints imposed by ecological interactions on a local scale. This makes it possible to assess the effect of ecological processes on the interspecific relation between population density and body size. We used data from natural rocky intertidal com-

munities in central Chile to obtain the general relation between population density and body size for invertebrates, and then we tested the effects that markedly different community structures exert on such a relation.

The study sites were located at two marine preserves, Las Cruces and Montemar, from which man has been excluded for an extended time (8). These two large-scale long-term experiments of human exclusion produced alterations in the species interaction network, which in turn resulted in dramatic and persistent changes in the intertidal landscape (9). Inside the marine preserves the substratum is dominated by chthamaloid barnacles and outside by mussel beds. Moreover, as a result of human exclusion, sizes and densities of algae, herbivores, and predators also differ from inside and outside the preserves (9–10). By comparing the scaling of population density with body size between the communities inside and outside each marine preserve, the effects of present-day ecological differences (10) could be assessed.

At Las Cruces and Montemar, we selected by chance ten transects inside the marine preserves and ten outside. Ecological population density (11) and mean body length of the species included in the analysis (12) were evaluated along each transect. Body weights were obtained from regression analysis with weight and length data (13).

The relation of population density and body size for data pooled from outside and inside the two marine preserves is shown in Fig. 1. Body size explains a significant amount of the variation observed in population density [$F(1,46) = 50.8$; $P = 0.0001$]. The relation is characterized by a slope of -0.77 ($SE = 0.11$), which is not significantly different from the slope of -0.75 reported for terrestrial animals (1, 14). This similarity expands the generality of this relation, despite known ecological differences between these two systems (15). The observation of this relation in intertidal systems, where usually space is a limiting resource for sessile species, suggests that explanations based on energetic constraints acting through differences in the per capita use of a limited resource, such as food (6), are not completely satisfactory. A similar point has been raised by Gaston and Lawton (7) for bracken herbivores.

In Fig. 2, the relation with the same species inside and outside of each marine preserve is shown. Although the community structures differ inside and outside the preserves (9), their characteristic scalings of population density with body size were not significantly different (16). This result gives a strong basis to suggest that the population

Departamento de Ecología, Facultad de Ciencias Biológicas, Universidad Católica de Chile, Casilla 114-D, Santiago, Chile.

*Present address: Department of Biology, University of New Mexico, Albuquerque, NM 87131.

†Present address: Department of Zoology, Oregon State University, Corvallis, OR 97331–2914.

density scaling is not affected by changes in the ecological processes that take place within natural communities.

Explanations proposed for the scaling power of animal population density with body size have considered the action of ecological and evolutionary processes (1, 6). Damuth (1, 17) proposed that population density scale to body size with a slope of -0.75 , which would be the result of inter-specific competition acting to keep energy use of all species within similar bounds (that is, energy use independent of body size) (18). On the other hand, Peters (6) suggested that, as a rule, population density scales to body size with a slope of -1.0 , implying that the total biomass per unit area is independent of body size (that is, all species attain the same biomass) (19) and that this pattern would be the result of numerical and facultative responses of predators (7). These explanations, however, have two major flaws. The first, competition as well as predation are characteristic of natural communities. Thus it is misleading to infer their actions from patterns derived from the compilation of data on organisms that belong to different communities around the world. Second, the slope of the relation is highly susceptible to sampling bias (3, 20) which hinders generalizations about how energy is allocated or how biomass is distributed among populations. This is particularly apparent if we compare the slope of our general relation (Fig. 1) with those reported in Fig. 2. These slopes ranging from -0.77 to -0.96 are not statistically different (21). Further, here we have shown that the slope of the relation of density to body size is not affected by drastic changes in the direction

Fig. 1. Linear regression of population density (D) on body size (W), both expressed as logarithms, for intertidal animals. Points represent average density and body size for particular species, pooling data from inside and outside both marine preserves. The regression equation is, $\log D = 1.57 + (-0.77) \log W$. Each numbered point represents one species: 1, *Concholepas concholepas*; 2, *Fissurella limbata*; 3, *Chiton granosus*; 4, *Acanthopleura echinata*; 5, *Haliaster helianthus*; 6, *Balanus flosculus*; 7, *Phymactis clematis*; 8, *Balanus laevis vis*; 9, *Fissurella crassa*; 10, *Chthamalus scabrosus*; 11, *Jehlius cirratus*; 12, *Perumytilus purpuratus*; 13, *Stichaster striatus*; 14, *Tonicia sp.*; 15, *Fissurella maxima*; 16, *Chiton cumingsi*; 17, *Littorina peruviana*; 18, *Littorina araucana*; 19, *Siphonaria lessoni*; 20, *Acari no ident.*; 21, *Collisella sp.1*; 22, *Fissurella costata*; 23, *Chiton chilensis*; 24, *Chiton latus*; 25, *Austromegabalanus psittacus*; 26, *Collisella araucana*; 27, *Collisella ceciliania*; 28, *Collisella sp.2*; 29, *Collisella bohemia*; 30, *Collisella parasitica*; 31, *Scurria parasitica*; 32, *Scurria scurra*; 33, *Pachycheles grossimanus*; 34, *Alpheus chilensis*; 35, *Allopetrolisthes spinifrons*; 36, *Pilumnoides perlatus*; 37, *Petrolisthes tuberculatus*; 38, *Petrolisthes tuberculatus*; 39, *Allopetrolisthes angulosus*; 40, *Allopetrolisthes punctatus*; 41, *Semimytilus algosus*; 42, *Brachidontes granulata*; 43, *Tegula atra*; 44, *Acanthocyclus gayi*; 45, *Acanthocyclus hassleri*; 46, *Loxechinus albus*; and 47, *Tetrapygyus niger*.

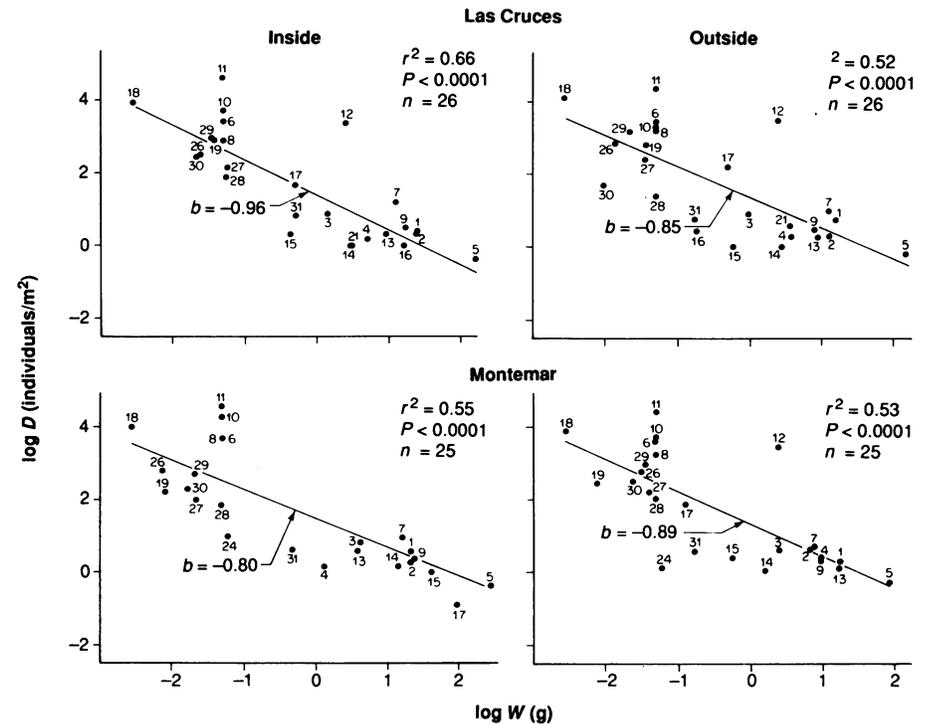
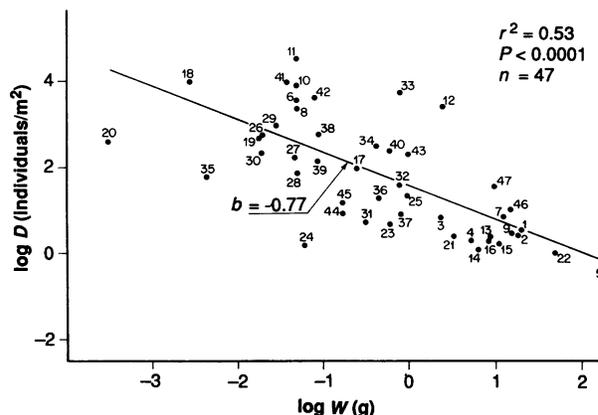


Fig. 2. Population density scaling, inside and outside two marine preserves (Las Cruces and Montemar). The regression equations were: Las Cruces inside, $\log D = 1.44 + (-0.96) \log W$; Las Cruces outside, $\log D = 1.38 + (-0.85) \log W$; Montemar inside, $\log D = 1.49 + (-0.80) \log W$; Montemar outside, $\log D = 1.35 + (-0.89) \log W$. Species identity and symbols as in Fig. 1.

and intensity of community-level biological interactions. In light of this evidence and the inconsistencies noted above, it is clear that explanations for the density scaling pattern, based on the action of biotic interactions, are rather premature.

The shape of the relation between population density and body size is also at issue. Some investigators point out that the best

descriptor of this relation is a line, whereas others advocate a surface of points (22). Lawton (20) suggested three possible reasons that may account for the observed discrepancies: the range of body sizes used in the study, the way data are compiled from the literature, and the difficulties in comparing different estimates of population density. Our analysis controls for the biases that Lawton mentioned. We used only one data set (11), and all data were taken in the same manner, with special care to include small and rare species, and with a range of seven orders of magnitude of body size. We are confident that for this system a regression line is a good descriptor of the relation between population density and body size.

A general explanation for the population density scaling is difficult to attain. We observed that in intertidal natural communities the scaling of population density with body size is not influenced by changes in the network of species' interactions that take place within ecological time frames (23). This means that after a perturbation, species within each community (inside and outside either marine preserve) reassemble in a way the net result of which is the same population density scaling. This points to the operation of density compensation phenomena in which some species decrease in density while others increase, coupled with body size shifts. Both phenomena interact to pro-

duce the same population density scaling inside and outside both marine preserves. To explore scaling patterns in other intertidal communities with a different species composition might prove the generality of this relation and help explain the underlying mechanisms.

REFERENCES AND NOTES

- J. Damuth, *Nature* **290**, 699 (1981); R. H. Peters and K. Wassenberg, *Oecologia (Berlin)*, **60**, 84 (1983).
- R. H. Peters and J. V. Raelson, *Am. Nat.* **124**, 498 (1984); J. G. Robinson and K. H. Redford, *ibid.* **128**, 665 (1986); F. Juanes, *ibid.* p. 921; J. H. Brown and B. Maurer, *Science* **243**, 1145 (1989).
- J. H. Brown and B. Maurer, *Nature* **324**, 248 (1986).
- M. Begon, J. L. Harper, C. R. Townsend, *Ecology: Individuals, Populations, and Communities* (Sinauer, Sunderland, MA, 1986).
- J. Damuth (1) used the term "constructed communities" to refer to taxonomic assemblages.
- R. H. Peters, *The Ecological Implications of Body Size* (Cambridge Univ. Press, Cambridge, 1983).
- K. J. Gaston and J. H. Lawton, *Am. Nat.* **132**, 662 (1988).
- The marine preserve at Las Cruces (33°30'S, 71°38'W) encloses a 500-m stretch of exposed rocky shore, from which man has been excluded for more than 6 years. The marine preserve at Montemar (32°57'S, 71°33'W), presents similar characteristics, but man has been excluded for more than 11 years [J. C. Castilla, *Ambiente Desarrollo (Chile)* **2**, 53 (1986)].
- After human exclusion at Las Cruces (8), increased densities of the predatory gastropod *Concholepas concholepas* produced drastic changes in local species diversity. Density and size of several invertebrate and algae species also changed, and man-induced cascade effects and indirect interactions have been apparent when comparing inside and outside communities in both marine preserves. The main changes at Las Cruces are discussed by J. C. Castilla and L. R. Durán [*Oikos* **45**, 391 (1985)]; D. Oliva and J. C. Castilla [*Publ. Stazione Zool. Napoli Mar. Ecol.* **7**, 201 (1986)]; J. C. Castilla (8); L. R. Durán, J. C. Castilla, and D. Oliva [*Environ. Conserv.* **14**, 143 (1987)]; J. C. Castilla [*Arch. Biol. Med. Exp.* **20**, 146 (1987)]; and L. R. Durán and J. C. Castilla (10). Similar changes occurred after exclusion of humans from the marine preserve of Montemar [J. C. Castilla (8); *Informe Unesco Cienc. Mar.* **47**, 115 (1988)].
- L. R. Durán and J. C. Castilla, *Mar. Biol.* **103**, 555 (1989).
- Transects were placed haphazardly on rocky platforms with 20° to 45° of slope. Along them, cover of sessile animals was measured with a 1-m² quadrat (196 regular intersection points), placed continuously from the lowest to the highest tidal levels. Density of sessile species was obtained by counting individuals in 100-cm² quadrats and multiplying by the corresponding cover. Densities of periwinkles and limpets were evaluated with 0.10-m² quadrat; all other organisms were evaluated with 1-m² quadrat. Data entered in the analysis are averages of samples conducted in March and April of 1986 for both preserves, December 1988 and October 1989 for Las Cruces, and February and September 1989 for Montemar. Additional data for species inside holdfasts of macroalgae and mussel beds were obtained from other sources [J. Cancino and B. Santelices, *Rev. Chil. Hist. Nat. (Chile)* **57**, 23 (1984); M. Muñoz and B. Santelices, *Mar. Ecol. Prog. Ser.* **54**, 277 (1989)]. Density ranged from 0.52 to 30,071 (individuals m⁻²) and body size from 0.0003 to 173.46 g.
- Representative measures of length (millimeters) of at least 150 individuals of each species were taken in randomly selected quadrats along the transects.
- Body size (weight) of species was obtained from logarithmic regressions of modal length (measured in millimeters) versus weight (grams) of individuals (including shells). Regressions were based on 30 to 120 individuals collected in November 1988 and March 1989.
- Comparison of slopes by *t* tests (d.f. = 46): *P* > 0.05.
- T. W. Schoener, *Ecology* **70**, 1559 (1989); M. W. Denny, *Am. Zool.* **30**, 111 (1990); R. R. Strathmann, *ibid.* **30**, 197 (1990).
- Analysis of covariance comparing regression lines inside and outside marine preserves. Las Cruces: intercepts *P* = 0.72 (d.f. = 1,51); slope *P* = 0.61 (d.f. = 1,51); Montemar: intercepts *P* = 0.73 (d.f. = 1,49); slopes *P* = 0.70 (d.f. = 1,49).
- J. Damuth, *Biol. J. Linn. Soc.* **37**, 193 (1987).
- Because individual basal metabolic requirements (*R*) scale with size (*M*) by the 0.75 power [M. Kleiber, *The Fire of Life* (Krieger, New York, 1975)] and population density (*D*) scales with body size by the -0.75 power, the energy used by a local population of a species (*D* × *R*) scales with body size as *M*⁰.
- The biomass of populations equals the product of individual body size and its population density. If population density scales body size with a slope of -1.0, then biomass is independent of body size.
- J. H. Lawton, *Oikos* **55**, 429 (1989).
- Analysis of covariance comparing regression lines renders statistically insignificant (*P* > 0.30) differences for both intercepts and slopes in the eight contrasts performed.
- T. M. Blackburn, P. H. Harvey, M. D. Pagel, *J. Anim. Ecol.* **59**, 335 (1990).
- L. B. Slobodkin, *Growth and Regulation of Animal Populations* (Holt, Rinehart & Winston, New York, 1961).
- Research funded by FONDECYT Projects F-1100 and 0432/88 and Fundación Andes special grant to J.C.C. P.A.M. acknowledges support of project FONDECYT 0589/89. S.A.N. and P.A.M. also acknowledge support of Fellowship of the Departamento de Ecología (Universidad Católica). J. H. Brown, F. M. Jaksic, M. A. R. Koehl, G. Medel, B. A. Menge, and three anonymous referees provided helpful criticism and suggestions to improve the manuscript. Our special thanks to C. Espoz, J. Alvarado, and D. Oliva for field assistance.

12 June 1990; accepted 3 October 1990

Detection of a Human Intracisternal A-Type Retroviral Particle Antigenically Related to HIV

ROBERT F. GARRY,* CESAR D. FERMIN, DARRENN J. HART
STEVEN S. ALEXANDER, LAWRENCE A. DONEHOWER,
HONG LUO-ZHANG

Sjögren's syndrome is an autoimmune disease that is characterized by dryness of the mouth and eyes. The loss of salivary and lacrimal gland function is accompanied by lymphocytic infiltration. Because similar symptoms and glandular pathology are observed in certain persons infected with human immunodeficiency virus (HIV), a search was initiated for a possible retroviral etiology in this syndrome. A human intracisternal A-type retroviral particle that is antigenically related to HIV was detected in lymphoblastoid cells exposed to homogenates of salivary tissue from patients with Sjögren's syndrome. Comparison of this retroviral particle to HIV indicates that they are distinguishable by several ultrastructural, physical, and enzymatic criteria.

SJÖGREN'S SYNDROME (SS) IS AMONG several autoimmune diseases that overlap clinically with diseases induced by HIV (1, 2). The characteristic symptom of SS is dryness of the mouth and eyes, which is also sometimes observed as a manifestation of HIV infection (2). The dryness in both SS and HIV disease is due to loss of salivary and lacrimal gland function and is accompanied by lymphocytic infiltration of these glands. An additional link between SS and HIV disease is our observation that approximately 30% of primary SS patients produce serum antibodies that react with the

major capsid protein of HIV (CA, p24/25) (3). In some SS patients, reactivity to another Gag protein, p17 (MA), was also observed. Similar percentages of patients with systemic lupus erythematosus (SLE), scleroderma, and juvenile rheumatoid arthritis (JRA) also produce HIV Gag-reactive serum antibodies (3, 4). Lower percentages (1 to 4%) of healthy individuals or individuals with other chronic diseases produce antibodies cross-reactive to HIV proteins. These observations suggest the possibility of a retroviral etiology in SS and perhaps in other autoimmune diseases.

The pathology of SS is more localized than other autoimmune diseases. Therefore, we attempted to culture an infectious agent from SS patients. Salivary gland tissue was collected by lip biopsies of six persons with SS, homogenized in a tissue grinder, and the crude tissue homogenates were added to cultures of the RH9 subclone of HUT 78, a T-lymphoblastoid cell line (5). After 6

R. F. Garry, D. J. Hart, H. Luo-Zhang, Department of Microbiology and Immunology, Tulane University School of Medicine, New Orleans, LA 70112.

C. D. Fermin, Department of Pathology, Tulane University School of Medicine, New Orleans, LA 70112. S. S. Alexander, Cambridge Biotech Corporation, Rockville, MD 20850.

L. A. Donehower, Division of Molecular Virology, Baylor College of Medicine, Houston, TX 77030.

*To whom correspondence should be addressed.