Journal of Scientometric Res. 2018; 7(3):189-193
http://www.jscires.org

Research Article

The Paradox of Enrichment in Chile's Ecological Science Funding

Jaime R. Rau[1], Fabián M. Jaksic[2]

[1]Laboratorio de Ecología (LABECOL), Departamento de Ciencias Biológicas y Biodiversidad, Universidad de Los Lagos, P.O.B. 933, Osorno, CHILE.
[2]Center of Applied Ecology and Sustainability (CAPES), Pontificia Universidad Católica de Chile, P.O.B. 114-D, Santiago, CHILE.

ABSTRACT

Aim/Background: Considering its population, Chile is one of the leading countries in scientific research in Latin America. Historically, ecology and environmental sciences have shown productivity and scientific excellence. Proof of this is the award of public funding to the Center for Advanced Studies in Ecology and Biodiversity (CASEB), operational since 2002. Criteria for the allocation of public funds to this Center gave preference to the most productive environmental research group in the country. Thus, scientometric productivity of CASEB researchers may be analyzed critically, before 2002, during its initial (2002-2006) and its final (2007-2011) phases of operation. **Results and Conclusion:** Before researchers joined CASEB (the 5-year window 1996-2000), their collective median h-index (M) was 6. During the first five years (2002-2006) it dropped to M = 5, while in its final phase (2007-2011) it jumped to M = 12. Published articles increased at an annual percentage growth of 5.7% during its 10 yr operation, while citations did at 6.8%. The direct public investment in CASEB resulted in an increase in the productivity and academic excellence indicators of its 27 researchers. However, significant scientometric changes could only be verified at the end of the decadal funding period. We call this phenomenon "the paradox of enrichment."

Keywords: CASEB, Chile, Scientometrics, Ecology and Environmental Sciences, Science Policy.

Correspondence
Jaime R. Rau
Laboratorio de Ecología (LABECOL), Departamento de Ciencias Biológicas y Biodiversidad, Universidad de Los Lagos, P.O.B. 933, Osorno, CHILE.
Email: jrau@ulagos.cl

Received: 10-03-2018
Revised: 22-06-2018
Accepted: 07-12-2018
DOI: 10.5530/jscires.7.3.30

INTRODUCTION

Chile is one of the most scientifically productive countries in Latin America (including Ecology and Environmental Sciences), especially by per capita standards.[1,2,3] The Chilean government´s FONDAP program (National Fund for Priority Areas) of CONICYT (National Committee for Scientific and Technological Research) finances the establishment of thematic centers based on excellence and a multi-disciplinary approach (when applicable); and offers a long-term (ten-yr) funding (http://www.conicyt.cl/fondap/centros/fondap). Centers of excellence financed by FONDAP were expected to improve their publications' productivity and impact, but there was no expectation as to when that would happen, short, medium or long term. Indeed, the expected result of improved publications productivity may well be delayed, due to a variety of factors including: the involved researchers' new commitments in establishing a convergence or synergy between lines of research, the onset of training of post-graduate human resources (i.e., doctorates and post-doctorates) and the initiation of social outreach of that research work; all these factors may theoretically lead to a temporary weakening of any given center's scientific productivity. Here, we show that in the first 5-yr phase of operations, there was a decrease in per capita publications output of the center of excellence surveyed, followed by a recovery that exceeded the stated 10-yr prospects.

CASEB (Center for Advanced Studies in Ecology and Biodiversity) was one of those centers financed. CASEB's objective was to analyze Chilean biodiversity, not only in terms of species distribution patterns, but also the underlying processes that determine the long-term sustainability of certain habitats, biomes or ecosystems facing anthropogenic impacts (pollution, resource exploitation, species invasions) or natural impacts (climatic forcing, volcanic or seismic activities). Furthermore, CASEB targeted resolving issues such as: (a) Biodiversity functioning: from genetic adaptations manifest in individual physiology and behavior, to population outbreaks, community changes and eco-systemic regulation, both terrestrial and marine; (b) biodiversity conservation: from the identification of biodiversity hot-spots, to the analysis of the consequences of habitat fragmentation on biodiversity functioning at different space-time scales in terrestrial and marine environments; (c) biodiversity management: from defining how biodiversity resources are being exploited by humans, to exploring how

physical and biotic factors influence the sustainability of such exploitations, e.g., in forestry and coastal fisheries; (d) biodiversity disruption: from climatic forcing (such as the climatic oscillation El Niño/La Niña, in both terrestrial and marine environments), to human disruptions caused by pollution and resource over-exploitation.

The present scientometric research conducted a critical analysis of CASEB's scientific productivity, before, at earlier and at later phases of funding. Our hypothesis was that the creation of such a scientific center of excellence should result in a significant increase of its researchers' *h*-index[4,5] in the long run, but that this result could be reversed or at least delayed in time due to other activities expected of such a center (e.g., the training of human capital on a quaternary level, outreach and contact with civil society, including governmental agencies, private companies and NGOs). No authority had foreseen this seemingly paradoxical result.

METHODS

Taking into account CASEB's founding year (2002), we compared the *h*-index of its *n* = 27 (the total number of researchers in CASEB) over three five-year periods: 1996-2000 (before), 2002-2006 (initial phase) and 2007-2011 (final phase). The *h*-index[4,5] is considered a powerful estimator of scientific productivity, because it combines in a single value, researchers who publish a lot but are rarely cited and vice versa.[3,6,7] We did not distinguish between autocitation or allocitation [see 8, 9, for this rationale]. With respect to Chilean ecologists, it has been suggested that researchers with a lower *h*-index tend to autocite themselves more.[10] *h*-index values were obtained directly from the WoS by a single person (see acknowledgments), filtering the search, when necessary, by institutional address and country. Only the database "Core Collection" (which includes what is traditionally known as the ISI database, which does not consider books or chapters of books) was consulted. The obtained medians for this index were statistically compared with the Kruskal-Wallis H test, using the online computational package http://www.vassarstats.net. For the *a posteriori* statistical analysis the ranked multiple contrasts test was applied.[12]

In order to compare the initial and final five-yr periods of operation, annual increase (%) in articles and citations over five-yr windows were calculated using the Rau 2[11] formula. A simple linear regression analysis was performed (on the last five years only) with the same computational program, between the *h*-index (independent variable) and the number of articles (dependent variable) and between the *h*-index (independent variable) and the number of citations (dependent variable). Based on these results, the number of articles and citations equivalent to a particular *h*-index were obtained. For a sample of 119 Chilean ecologists and environmental scientists (*sensu lato*), the mean and standard error were 9.2 +/- 0.5; therefore, *h*-index > 9 can be considered a high score for Chilean ecologists.[11] To determine if data followed Lotka's inverse quadratic law,[12] which states that the number of authors publishing *n* articles is inversely proportional to its square, the homonymous computational program was used.[13] In the case of a good fit, the *beta* parameter should vary between 1.27 y 3.29 and additionally D_{max} (of the Kolmogorov-Smirnov test) should be higher than the critical tabled value for P = 0.05 [see 16]. The relevance of this test is that rejection of the null hypothesis indicates that Chilean ecologists and environmental scientists do not follow Lotka's law.

RESULTS

As can be seen in Table 1, the median (M) of the 27 scientists' *h*-index before their incorporation to CASEB was 6, with ranges (R) varying between 0 and 17. During the first phase of the Center's operation (2002-2006) this value dropped to M = 5 and R = 1 – 12. In the final phase of the Center's operation (2007-2011) M reached 12, with R values of 3 – 18. These differences were statistically significant (H = 20.85, P = 0.0001). The ranked multiple contrast test presented statistically significant differences (P = 0.05) between the final 5-yr period (2007-2011) and the two previous ones (1996-2000 and 2002-2006).

Table 1 also shows an increase in the number of published articles from 322 in the first five years (before CASEB) to 757 in the last (final phase of CASEB), which represents an annual exponential growth (%) of 5.7. The number of citations rose from 4,626 to 12,876 (dropping to 2,489 during the intermediate five years), which corresponds to an annual exponential growth (%) of 6.8. As expected, the *h*-index explained 64.8% of the variance in the simple linear regression model and 68.3% in the case of the citations. The regression equations were: N° of articles = -7.1 + 3.2*h* and N° of citations = -396.3 + 79.9*h*. If we substitute in both equations the average value of *h* = 9 the results indicate that a graduate or postdoctoral student should publish *ca.* 22 articles and accumulate *ca.* 323 citations in ten years to reach an *h*-index = 9. Furthermore, the LOTKA program[13] yielded the *beta* parameter = 1.27 and D_{max} = 0.6911, as expected,[7] which leads to the conclusion that the observed results did not obey Lotka's law.[13] This indicates that Chilean ecologists and environmental scientists are more equitable than expected in their respective contribution to the total publications output of the country. Similar results were obtained by analyzing the observed distribution of *h*-index values of the most cited ecologists and environmental scientists (*sensu lato*) in Chile.[7]

Table 1: Scientometric Parameters of CASEB's Productivity.

Shown are the h-index and median values of n = 27 CASEB principal and associate researchers and their total number of published articles and citations accumulated during the three five-yr periods analyzed: 1996-2000, 2002-2006 and 2007-2011. CASEB's principal researchers during the first five years were: JA, FB, JCC, JC, FJ, PM and PO (n = 7); and during the second five years: JA, FB, SN, JC, ML and PM (n = 6). Full names not disclosed for reasons of privacy.

	Before CASEB 1996-2000			*Initial Phase 2002-2006*			*Final Phase 2007-2011*		
Researchers	*Nº articles*	*Nº citations*	*h-index*	*Nº articles*	*Nº citations*	*h-index*	*Nº articles*	*Nº citations*	*h-index*
MA	0	0	0	7	71	4	17	559	12
JA	15	177	8	28	151	8	47	588	14
FB	49	441	14	86	432	12	76	938	16
BB	0	0	0	6	58	4	23	570	13
JCC	35	809	14	38	356	12	45	882	18
SC	2	13	2	5	19	3	12	96	6
JC	24	209	9	29	111	7	30	524	15
FD	0	0	0	1	1	1	3	36	3
LE	5	71	4	16	76	5	30	355	12
JMF	6	25	2	6	27	3	15	102	6
MF	11	126	7	23	114	6	10	156	8
SF	2	16	2	12	36	3	19	268	11
SG	0	0	0	2	3	1	20	682	13
EG	19	193	10	30	100	7	53	672	14
BG	11	136	6	23	130	6	18	284	8
FJ	40	727	17	23	104	6	25	383	10
CL	1	1	1	3	41	3	42	775	15
RL	4	223	4	8	42	4	33	764	14
ML	16	258	9	19	254	8	29	563	14
PM	26	438	13	30	192	8	47	2082	18
SN	7	152	6	23	232	8	50	622	14
PO	15	229	9	13	30	3	14	92	7
AP	1	26	1	7	57	4	11	48	4
EP	2	37	2	12	29	3	24	243	10
PS	9	93	6	28	88	5	45	434	11
BS	19	186	9	18	64	5	6	42	3
CS	3	40	3	7	31	4	13	116	6
Totals and medians	322	4626	6	503	2849	5	757	12876	12

DISCUSSION

In the Latin American context and in relative terms, Chile is one of the most productive countries in the Biological Sciences, including Ecology and Environmental Sciences. According to Macilwain[1] "Chile produces more international papers *per capita* of population than Argentina and three times as many as Brazil or Mexico." More recently, Astudillo[2] pointed out that "we are a highly productive player in Latin American science, ranking above Brazil, Mexico and Argentina in terms of the number of articles per capita." In addition, Chile currently ranks first in Latin America in patent registration. [3] As far as Chilean Ecology is concerned, early scientometric analyses[8] show that Chilean ecologists publish in mainstream journals and are well cited by their colleagues worldwide. Our results show the same trend, even though more recent Latin American articles in prestigious international journals are reported to be less cited than expected.[14]

Another problem concerning the productivity and visibility of Chilean environmental and ecological sciences is the lack of funds for their sustained long-term development. As far as biological sciences are concerned, it has been shown[15] that resources allocated for the main competitive funds on the national level (FONDECYT, FONDAP, ICM, FB) keep diminishing. In fact, the scientific community's protestations

have reached the streets, denouncing the scarcity of funds for scientific research in the country.[16,17]

Long-term ecological studies in Chile have been outstanding in productivity.[18-21] However, the fact that scientific policies on the national level are designed solely on a short-term basis, from 3 to 10 years,[18] has been continuously criticized. Our data demonstrate that productivity metrics of ecologists ascribed to centers of excellence increased significantly, but with a time delay: the increase appeared only at the end of the public decadal-funding period; this fact presents another paradoxical result, namely, that an obvious success story stops being financed.

It is worth mentioning that the theoretical number of articles and citations expected in order to reach a high *h*-index does not agree with the empirical data, given that the CASEB graduate and postdoctoral students took 6 and 3 years, respectively, to reach an average of 3 WoS articles (FM Jaksic, pers. obs.). However, the scientific production of CASEB's assigned researchers has been quite even, which indicates that Lotka's law (stating that half of the article production in a given area of knowledge is generated by only 5% of the authors) was not followed.[14] It may be inferred from this pattern that the center's critical mass (n = 27), although productive and probably well selected, was small in terms of the number of researchers. Assuming an equivalent rate of articles per researcher, an increase in the number of researchers would concomitantly increase the center's total scientific production, although probably delayed in time.

Paraphrasing the threshold hypothesis,[22] in which the quality of life decreases when the nation's GDP increases, this study reveals another "paradox of enrichment:" The more funding, the less individual productivity of the researchers in the initial phase of a center of excellence in Ecology and Environmental Sciences. We believe the solution to this problem is the planning of long-term ecological science policies (longer than a decade), sustainable over time and that would ideally reconcile scientific quality with the social impact of science, especially in countries like Chile.[16]

CONCLUSION

The direct economic public investment in CASEB (10 million US Dollars over the decade 2002-2011) resulted in an increase in the productivity and academic excellence indicators of its 27 researchers. However, significant metric changes could only be verified at the end of the funding period (2011) and not during its full decade of existence. This fact demonstrates the difficulties faced by scientific policies in long-term planning. The expected productivity increase was not observed during the first five years of funding (2002-2006) but only during the last five years (2007-2011). We call this phenomenon "the paradox of enrichment." A complete paradox would have been if more funding had resulted in decreased productivity over the decade; this case presents a partial paradox: poor results obtained in the beginning and outstanding ones at the end.

ACKNOWLEDGEMENT

To Soraya Sade, for extracting the *h*-index of CASEB's ex-members and to Patricio Camus and Pablo Marquet for their reading and critical comments on a preliminary version of the manuscript. Also, to Matthew R. Lee for their edits to the ms. Funding was provided by FB 0002-2014 to CAPES.

CONFLICT OF INTEREST

The authors declare no conflict of interests.

ABBREVIATIONS

CASEB: Center for Advanced Studies in Ecology and Biodiversity; **CONICYT:** National Committee for Scientific and Technological Research (freely translated); **FB:** Basal Funding (freely translated); **FONDAP:** National Fund for Priority Areas (freely translated); **GDP:** Gross Domestic Product; **ICM:** Millennium Scientific Initiative (freely translated); **NGO:** Non-Governmental Organization; **WoS:** Web of Science.

REFERENCES

1. Macilwain C. Stability offers unique opportunity for research. Nature. 2002;398:A11-2.
2. Astudillo P. Chile needs better science governance and support. Nature. 2014;511(7510):385.
3. Noorden RV. South America by the numbers. Nature. 2014;510(7504):202-3.
4. Hirsch JE. An index to quantify an individual´s scientific research output. PNAS. 2005;102(46):16569-72.
5. Hirsch JE. Does the h-index have predictive power?. PNAS. 2007;104(46):19193-8.
6. Bornmann L, Hans-Dieter D. Selecting scientific excellence through committee peer review-A citation analysis of publications previously published to approval or rejection of post-doctoral research fellowship applicants. Scientometrics. 2006;68(3):427-40.
7. Rau JR. Índice-*h* (2000-2004) de los científicos ambientales más citados que residen en Chile. Rev Chile Hist Nat. 2007;80(3):381-3.
8. Jaksic F, Santelices B. Alguien lee a los ecólogos chilenos?. Rev Chile Hist Nat. 1991;64:13-8.
9. Gianoli E, Molina-Montenegro M. Insights into the relationship between the *h*-index and self-citations. JASIT. 2009;60(6):1283-5.
10. Zar JH. Biostatistical Analysis. 5th Ed. Pearson New International Edition. Essex, U.K. 2015.
11. George-Nascimento M. Una evaluación de los índices bibliométricos I e Is de Molina-Montenegro & Gianoli aplicada a investigadores en ciencias ecológicas en Chile. Rev. Chile. Hist. nat. 2010;83:229-35.
12. Lotka AJ. The frequency distribution of scientific productivity. J Wash Acad Sci. 1926;16(12):317-23.
13. Rousseau B, Rousseau R. LOTKA: A program to fit a power law distribution to observed frequency data. Cybermetrics. 2000;4. http://www.cindoc.csic.es/cybermetrics/articles/v4ip4.html
14. Rau JR. Sigue la producción de artículos ISI de los ecólogos chilenos (sensu lato) la ley de Lotka (1926)?. Rev Chile Hist Nat. 2011;84(2):213-6.
15. Jaksic F. Artículos clásicos, modas e impactos en Ecología: los ecólogos chilenos en el contexto internacional, regional y local. Rev Chile Hist Nat. 1994;67:245-51.
16. Meneghini R, Packer AL, Nassi-Calo L. Articles by Latin American authors in prestigious journals have fewer citations. PLoS One. 2008;3(11):e3804. doi: 10.1371/journal.pone.003804.

17. Anderson CB, Monjeau A, Rau JR. Knowledge dialogue to attain global scientific excellence and broader social relevance. Bio Science. 2015;65(7):709-17.
18. Jaksic FM, Silva SI, Meserve PL, Gutierrez JR. A long term study of the vertebrate predator responses to an El Nino (ENSO) disturbance in western South America. Oikos. 1977;78:341-54.
19. Meserve PL, Kelt DA, Milstead B, Gutierrez JR. Thirteen years of shifting top-down and bottom up control. Bio Science. 2003;53(7):633-46.
20. Gutierrez JR, Meserve PL, Kelt DA, Engilis JR, Previtali MA, Milstead WB, *et al.* Long term research in Bosque Fray Jorge National Park: Twenty years studying the role of biotic and abiotic patterns in a Chilean semiarid scrubland. Rev Chile Hist Nat. 2010;83(1):69-98.
21. Astudillo P, Blondel CJ, Norambuena T, Soto K. Chile´s research planning falls short. Science. 2012;336(6080):412.
22. Max-Neef M. Economic growth and quality of life: a threshold hypothesis. Ecological Economics. 1995;15(2):115-8.