EVALUATING SCIENTIFIC INSTITUTIONAL CAPACITY FOR BIOLOGICAL CONTROL: A CALIFORNIA STUDY AS A MODEL REGIONAL NETWORK ASSESSMENT

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ABSTRACT.

Assessing scientific institutional capacity investigates the ability of scientists and their organizations to achieve their goals. This can be measured using social science metrics, including publications, funding, scientist-years (SYs), and research projects. We report a 3-year long capacity assessment of the 8 regional institutions engaged in arthropod biological control in California 1962-2006. Biological control in California has a strong reputation, but this reputation was established by researchers at the University of California, which does not currently provide support at historical levels. The most significant consequence of this has been a marked decline in the number of dedicated biological control scientists: entomologists dedicated to applied research without responsibilities for administration or undergraduate teaching. Other factors affecting this decline are: changes in organization of entomology departments; new configurations of entomology faculty positions; and the broader forces restructuring the practice of biological control science itself. The California Department of Food and Agriculture's Biological Control Program has assumed a somewhat greater role, but it cannot compensate for the losses at UC, and it has suffered serious budget cuts as well. The state biological control program hosts scientists dedicated to biological control research and practice. We recommend methods for conducting institutional capacity analysis in other regions.

INTRODUCTION.

Scientometrics is the measurement and analysis of scientific activity. Its methods can be used to assess the capacity of scientific institutions to achieve their goals (Leydesdorff 2001), including agricultural science institutions (Warner 2007). This can be measured using social science metrics, including publications, funding, scientist-years (SYs), and institutional connectivity through networks. Perkins & Garcia (1999) were the first to deploy scientometrics to evaluate biological control institutions. Here we report select findings from a 3-year long study of California's institutions that host scientists conducting biological control of arthropods (Warner *et al.* 2008). Biological control in California has a strong reputation, largely established by researchers at the University of California (UC). Critics such as Jennings (1997) have charged that the UC administration abolished the UC Division of Biological Control under political pressure, but the evidence for this is ambiguous. To date, only anecdote has been used to argue that UC has lost capacity for conducting biological

Procceedings of the Third International Symposium on Biological Control of Arthropods, Christchurch, New Zealand.
Peter G. Mason, David R. Gillespie & Charles Vincent (2008)

control research. Our study sought to evaluate trends in research capacity among leading regional institutions by using scientometric data.

MATERIALS AND METHODS.

We adapted the methods of Perkins & Garcia (1999) to focus on one region, California. We gathered 7 types of original data on 8 different institutions, but due to space limitations, we only report 4 types of data on 3 institutions (see Table 1).

Table 1. Data collected on key California biological control institutions

	Scientist positions	Quantitative survey	Qualitative interviews	Targeted pests
University of California entomology faculty	SY	X	X	#
California Department of Food & Agriculture Biological Control Program	SY	X	X	#
Other California universities	SY	X	X	

#=number of targeted pests; SY=scientist year; X=data gathered

We identified all UC entomology faculty members at all 3 campuses for the period 1962 to 2006 and gathered data about their scientific activities to assess their research in biological control relative to other interests (for this paper, nematologists are included in the general category of entomology). We included all full-time faculty and extension specialists assigned to these departments. We excluded emeritus and adjunct (part-time) faculty, and staff research assistants. We excluded faculty for whom dates of employment were missing or ambiguous. This resulted in a population of 246 scientists. We relied on different kinds of data to determine their scientific activities. We devised the following hierarchy of data sources, from most preferable (A) to least preferable (E). If data from source A was unavailable, then we would turn to B, then C, then D. In several cases we examined multiple types of data.

A. Survey questionnaire querying about the types and numbers of biological control projects and publications. This was possible only for scientists currently on faculty at the 3 departments. The survey of contemporary UC entomology faculty was conducted by email and webpage in May 2007. Of the current 83 faculty, 32 responded, for a response rate of 38.5%.
B. Curriculum Vitae (CV).
C. Obituaries. These scientific obituaries, prepared by colleagues or fellow members of a department, provide a summary narrative of the research agenda of the scientist.
D. Abbreviated CVs, campus catalogues or departmental files.

Of the 246 scientists identified, we gathered sufficient data on 199. Interviews with 8 UC scientists provided historical perspective and interpretation of these records. We evaluated SYs at the California Department of Food & Agriculture (CDFA) Biological Control Program, drawing from annual program reports from 1993 to 2004. We surveyed and interviewed 2 scientists at other universities involved in this field. We analyzed records of university scientists to determine their degree of

involvement in biological control, using the coding system of Table 2. We also coded this biological control work according to taxa targeted (chiefly arthropod; chiefly weed; or, mixed).

Table 2. Coding system for scientific activities

Code	Description
1. Dedicated biological control scientist	These have met one of the following criteria: publishing 2 or more major books on biological control; having >30 publications on this topic; or >30% of > 50 publications.
2. Biological control scientist	This category designates scientists who have devoted a considerable portion of their research to biological control, such as foreign exploration. They have published 4 or more papers with the term "biological control" in their title.
3. Scientist supportive of biological control	This category designated scientists who have done some biological control research, but it has not been the major thrust of their work. Survey entry reports research in biological control, they have but 1-3 publications within the field of biological control. Many scientists working on IPM fall into this category.
4. Scientist not involved in biological control	These have not conducted any measurable biological control research.

We evaluated the number of targeted pests by these institutions. For baseline data we used a list of arthropod pests actively targeted by biological control projects and a list of arthropods proposed as targets in 1992 (Division of Agriculture and Natural Resources, 1992, pages 10-11). These are titled "some insect and mite pests currently targeted by biological control projects using predators and parasitoids in California" (Table 2 on page 10-11), and "a partial list of California insect and mite pests thought to be good candidates for control by importation of natural enemies" (Table 3 on page 11). UC researchers identified the current status of these projects, using the coding system of DeBach (1964) of complete, substantial or partial. With the help of CDFA Biological Control Program scientists, we likewise assessed the arthropods it targeted 1993-2004 as identified in the program's annual reports.

RESULTS.

Of the 199 scientists we were able to code, 72 participated in biological control research (Fig. 1). Entomologists in the UC system peaked slightly above 110 in the mid-1980s, and dropped dramatically during the early 1990s owing to university restructuring. At UC Berkeley, the number of entomology positions dropped from 52 in 1984 to 21 in 1996. Of particular interest are the most active researchers (code 1 and 2). During this study period, UC had 19 dedicated biological control scientists (code 1), and 25 biological control research scientists (code 2), chiefly at the Berkeley and Riverside campuses. The number of UC entomologists coded 1 and 2 rose from the mid-teens in the 1960s to the high teens in the 1970s to the high twenties in the 1980s, but then declined to 17 in 2006. Between 1965 and 1984, the number of entomologists coded 1 fluctuated between 12 and 15; this declined down to 6 in 2006. Of the 19 code 1 scientists, 17 chiefly targeted arthropods, 1 weeds,

and 1 mixed. Of the two other entomologists conducting arthropod biological control research, one is code 2 and one is code 3. Of the 2 biological control scientists working at other universities, 1 is a code 2 and 1 code 3.

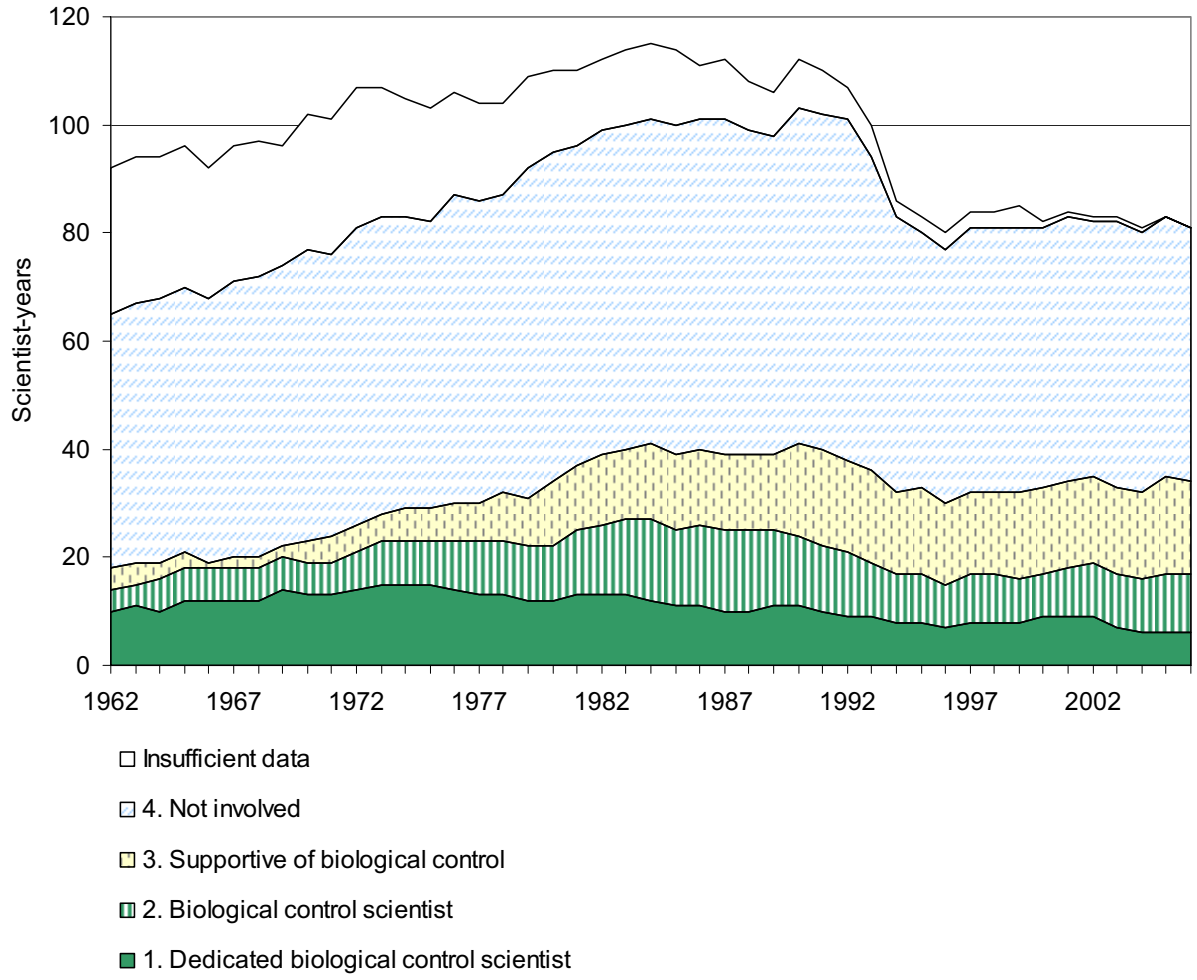

Fig. 1. Scientist-years and their relative investment in biological control at the University of California, 1962-2006.

The CDFA Biological Control Program began in 1974 with 4 SYs and rose as high as 14 in 2001, but has suffered major budget cuts due to state funding since then (Fig. 2). The program is dedicated exclusively to biological control. CDFA scientists have been assigned in equal numbers to arthropod and weed pests.

Of the 43 arthropod pests targeted in 1992, 19 were under some degree of biological control in 2007 (Table 3). For projects with unknown status, we assume no control. Some control was provided in 44% of those arthropods targeted in 1992, although only 9% were complete or substantial. Less than 6% of those “thought to be good candidates” were under any reported biological control in 2007. Even though a list of proposed targets is qualitatively different than pests actively targeted, the difference between 44% of those targeted under some control versus only 6% under any control for those proposed for a target is striking.

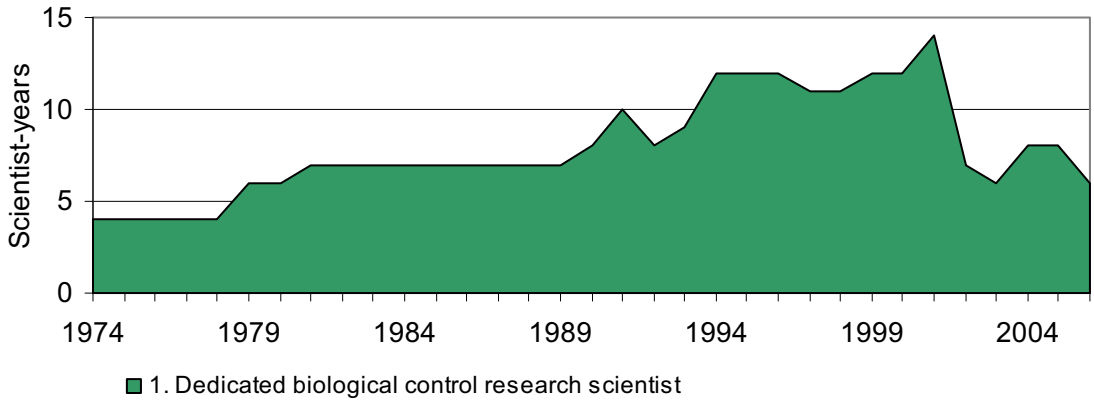

Fig. 2. Scientist-years and relative investment in biological control at the California Department of Food & Agriculture Biological Control Program, 1974-2005.

Table 3. Status as of 2007 of arthropod pests targeted by or proposed for UC biological control efforts in 1992

	Pests targeted by researchers in 1992	Pests "thought to be good candidates" in 1992
Complete control	1	2
Substantial control	3	--
Partial control	15	--
Unsuccessful	18	--
Deemed inappropriate target	--	6
No data	6	26
TOTAL	43	34

Between 1993 and 2004, the CDFA Biological Control program evaluated 24 arthropod pests, achieving some form of biological control with 10 (Table 4). The category "no data" may indicate that the pest project is in the early stages of development, or that the project has been suspended for lack of results or to prioritize other projects. Weed projects are not reported here, even though they constitute half the program's effort.

Table 4. Status as of arthropod pests considered by CDFA Biological Control Program between 1993 and 2004

	Arthropod species evaluated as targets
Complete control	3
Substantial control	3
Partial control	4
Unsuccessful	-
Deemed inappropriate target	4
No data	10
TOTAL	24

DISCUSSION.

Arthropod biological control in California has a global reputation, but it was not as vigorous in 2007 as it was historically. UC and CDFA are the only institutions of significance hosting biological control research activities targeting arthropods in California. All the data presented indicate a declining institutional capacity to conduct biological control research. The most important declines have been in the number of overall SYs, the proportion of the most active (code 1 and 2) researchers, and the elimination of UC departments dedicated to biological control. The SYs working in this field in UC and CDFA have substantially declined, starting in 1985 and 2001 respectively. The decline of capacity at UC is notable owing to losses of dedicated biological control scientists. In the case of arthropod pests targeted by UC scientists, data also suggest a decline. It is not possible to determine a trend in pests targeted by the CDFA program with this data.

Several caveats are in order. First, these metrics illustrate within-institution trends. Direct comparison of UC and CDFA SYs and targets is not appropriate, however. Entomologists with academic appointments in research universities have different responsibilities and professional incentives than do those working for a dedicated state program. The decline in UC SYs dedicated to biological control is indicative of changes in entomology positions during the study period. Many biological control scientists in the 1960s and 1970s conducted their own foreign exploration and did their own systematics work. With increasing specialization of entomology (as in other biological sciences), few entomologists today are trained in all subfields of the discipline necessary to implement a biological control project. The loss of SYs conducting biological control research at UC are not the result of one single factor. Key influences are: changes in organization of UC entomology departments; new configurations of life science faculty positions; and the broader forces restructuring the practice of biological control science itself. Few new entomology positions are constituted as dedicated to biological control research. The public university-based knowledge system which has served as the anchor for biological control research is not being supported financially as it once was. UC administrators have directed funding and other resources to other academic pursuits over the past 20 years. Few incentives exist for researchers to pursue applied questions, and this poses a much broader set of challenges for California agriculture than merely crop biological control. The elimination of the two UC departments dedicated to biological control marked the loss of more than diminished resources for individual researchers. These departments also provided coordination between different types of researchers, and focus for overall network efforts.

CDFA's program consists exclusively of dedicated biological control scientists, but only half of them work in arthropod control. It began with technicians and only started hiring research scientists in 1991. Its scientists are free from faculty responsibilities, but it has lost more than 50% of its SYs since 2001. It has tried to compensate for the diminished capacity for institutional coordination with the loss of the UC departments, but it still depends upon UC for quarantine space and specialized research. Even though CDFA's program has had many successful projects with a small number of SYs, it draws heavily on UC specialized researchers, and the decline in UC SYs may constrain this program in the near future.

The successful projects in Tables 3 and 4 do not represent all the biological control of arthropod work in California between 1992 and 2006. Many new and serious arthropod pests have invaded California since 1992, and some of these have been targeted by biological control scientists and are under some control. Nonetheless, the number of targeted arthropods and successful projects appears to have declined during this study period. This downward trend is unlikely to be reversed unless additional efforts are made to relate the value of this work to the public (Warner *et al. in press*).

This article demonstrates that assessing institutional capacity for biological control research is possible using scientometric methods. It indicates the importance of investigating the dynamics of change not only in SYs but also in the orientation and activities within SYs. It also points to the importance of studying networks for assessing capacity (Warner, 2007), because as the science of biological control becomes more complex, it requires sharing of specialized knowledge and resources.

ACKNOWLEDGEMENTS.

This research was supported by the California Department of Food & Agriculture, and National Science Foundation award 0646658. This report would not have been possible without the active interest of many members of these institutions helping us to understand the history and constitution of biological control in California. John Steggall, Michael Pitcairn, Charles Pickett, Mark Hoddle, Daniel Sullivan, and David Headrick provided important insights on this data. Laurie Allen at UC Riverside, Louise Meyer Ozawa at UC Berkeley and Brenda Wing at UC Davis were particularly helpful in tracking down CVs and other information about UC SYs.

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