Title

Designing Graduate Training Programs in Conservation Medicine—Producing the Right Professionals with the Right Tools

Journal

EcoHealth, 5(4)

ISSN

1612-9202

Authors

Kaufman, Gretchen E
Epstein, Jonathan H
Paul-Murphy, Joanne
et al.

Publication Date

2008-12-01

DOI

10.1007/s10393-008-0208-7

Peer reviewed

EcoHealth 5, 519–527, 2008
DOI: 10.1007/s10393-008-0208-7

ECOHEALTH

Forum

Designing Graduate Training Programs in Conservation Medicine—Producing the Right Professionals with the Right Tools

Gretchen E. Kaufman,[1] Jonathan H. Epstein,[2] Joanne Paul-Murphy,[3] and Jennifer D. Modrall[1]

[1]*Tufts Center for Conservation Medicine, Cummings School of Veterinary Medicine, Tufts University, 200 Westboro Road, North Grafton, MA 01536*
[2]*The Consortium for Conservation Medicine, 460 West 34th Street, 17th Floor, New York, NY 10001*
[3]*Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California at Davis, 2108 Tupper Hall, Davis, CA 95616*

Abstract: New challenges to human, animal, and ecosystem health demand novel solutions: New diseases are emerging from new configurations of humans, their domestic animals and wildlife; new pressures on once robust and resilient ecosystems are compromising their integrity; synthetic compounds and engineered organisms, new to the natural world, are spreading unpredictably around the globe. Globalization provides opportunities for infectious organisms to gain access to new hosts, changing in distribution and virulence. What type of training should be developed to provide professionals with the right tools to meet these challenges? In this article, we offer recommendations for developing academic programs in conservation medicine. We discuss the need for, and the advantages to, using a conservation medicine approach to address real world situations and present illustrations of how this is applied today. We suggest a core set of skills that are needed in a conservation medicine practitioner, and recommend key considerations for designing new conservation medicine training programs. We review existing programs that offer conservation medicine content, and provide examples of where opportunities exist for those interested in pursuing a conservation medicine career.

Keywords: conservation medicine, training, academic program, interdisciplinary

INTRODUCTION

Conservation medicine is the study of health relationships occurring at the interface of humans, animals, and ecosystems. It may be considered a meta-discipline: a field of study that incorporates the tools and perspectives of as many different scientific disciplines as necessary in order to address challenges or test hypotheses related to global health issues. Conservation medicine shares a similar philosophy with EcoHealth, One Health, and Global Health, all of which recognize the clear relationship between human and animal health; however, conservation medicine is also closely allied with the values of conservation biology, and recognizes that health and disease are fundamentally related to the integrity of ecosystems. Thus, understanding the importance of ecosystem functionality in the context of health is essential to conservation medicine, and it draws on the principles of both ecology and applied medicine as an approach to human and animal disease issues.

A conservation medicine professional is someone with expertise in one or more scientific disciplines, who uses their expertise to collaborate with other scientists (physicians,

Published online: February 11, 2009

Correspondence to: Gretchen E. Kaufman, e-mail: gretchen.kaufman@tufts.edu

biologists, virologists, geologists, anthropologists, veterinarians, etc.) to comprehensively address a health-related issue within an ecological context. The result is more than a collection of individual disciplinary perspectives; it aims to produce a fully integrated *interdisciplinary* analysis of a complex problem informing a practical applied conclusion (i.e., the whole is more than the sum of its parts). Many scientists have naturally cultivated a broad-based view of science throughout their careers, and some have worked as part of large-scale, multi-dimensional teams. Professionals from different fields that are practicing in a conservation medicine setting have generally developed their careers through perseverance, experience, and sometimes through the pursuit of multiple academic degrees. However, most will admit that experience and determination alone may not provide the necessary tools and skills that could be better developed through a focused academic training program.

Since the advent of conservation medicine (ca. 1997), few formalized graduate training programs have been specifically designed to train people in the field of conservation medicine. We contend that such a program could provide the scientific cross-training and interdisciplinary approaches that are missing from traditional academic programs. A training program that concentrates specifically on fundamental conservation medicine skills could accelerate achievement and more effectively provide the versatility that is needed to adequately address the challenges in conservation medicine. Just as conservation biology struggled to establish itself in the 1980s as a new interdisciplinary field, beginning with 16 programs in 1990 and growing to more than 108 programs in 99 colleges and universities (Meine et al. 2006), conservation medicine is now facing similar academic scrutiny and needs a place in the scholarly arena to support its legitimacy.

Conservation Medicine in Action

Here we present three examples of applied conservation medicine projects to illustrate the value of this approach and demonstrate some of the skills required in a conservation medicine practitioner: (1) uncovering the emergence of Nipah virus, (2) linking bushmeat hunting and zoonotic disease emergence, and (3) using seabirds as sentinels for ecological health.

Uncovering the Emergence of Nipah Virus

Nipah virus was first discovered during an outbreak of encephalitis among pig-farmers in Peninsular Malaysia (Chua et al. 2000). Following the initial outbreak investigation, a large-scale multi-year collaborative study was launched by the Henipavirus Ecology Research Group (HERG—http://www.henipavirus.net). This group used a conservation medicine approach to test two major hypotheses for Nipah virus' emergence. The first postulated that Nipah virus emerged due to climatic effects from El Niño-caused forest fires that created tremendous atmospheric haze, driving Nipah virus-infected bats from Sumatra to Malaysia (Chua et al. 2002). The second hypothesis was that the size, structure, and management of the pig farm where Nipah emerged had allowed the virus, once introduced to pigs by fruit bats, to persist and cause a wide-spread epidemic (Daszak et al. 2006). Epidemiology, veterinary medicine, and ecology were involved in examining the health data and management practices of the pigs on the index farm. These data were incorporated into a mathematical model which simulated the introduction and spread of the virus in pigs on the farm (Pulliam et al. 2007). Wildlife biology and ecology were used to study the population demographics and dynamics of the pteropid fruit bat and better understand the risk of future outbreaks (Epstein et al. 2007). Molecular biology, epidemiology, and classical virology were used to study Nipah virus in wild bat populations and peri-domestic animals using population-based studies and laboratory-based experimental infections. These studies gave the team a better understanding of the dynamics of the virus in wild populations, as well as the pathogenesis of Nipah virus in bats and its ability to survive in the environment under various experimental conditions (Epstein et al. 2007; Halpin and Mungall 2007; Fogarty et al. 2008). Ultimately, all aspects of the study were necessary to understand the factors that caused Nipah virus to emerge and also the risks associated with future outbreaks [Pulliam et al., submitted for publication].

Linking Bushmeat Hunting and Zoonotic Disease Emergence

Bushmeat hunting is widely considered a socially, economically, and nutritionally significant activity throughout much of the developing world (Asibey et al. 1974; Juste et al. 1995; Davies 2002). The practice of hunting and consuming wild animals potentially places hunters or market workers at particularly high risk of exposure to animal pathogens (Wolfe et al. 2005a), in addition to threatening the health of endangered animal populations (Milner-Gulland and Akcakaya, 2001; Brashares et al.

2004). Transmission of pathogens such as HIV-1 (Hahn et al. 2000), HTLV (Wolfe et al. 2005b), Simian Foamy virus (Wolfe et al. 2004), SARS coronavirus (Li et al. 2005), and Ebola (Leroy et al. 2004) have been linked to bushmeat hunting and the wild animal trade.

Investigation of zoonotic viral transmission from nonhuman primates to bushmeat hunters in Cameroon provides a second example of a trans-disciplinary study that combined epidemiology, molecular biology, and virology with medical anthropology. The research included sampling both hunters and nonhuman primates and testing them for novel pathogens, conducting extensive surveys of hunters designed to assess demographic and socioeconomic factors that contributed to bushmeat hunting practices, as well as determining the frequency and types of animals encountered in the bushmeat trade in rural Cameroon (Wolfe et al. 2005b; LeBreton et al. 2006). This study of bushmeat hunters and wildlife traders has been extended beyond Cameroon to several countries through a network of unified research sites as part of a multi-institutional research collaboration (http://www.gvfi.org).

Monitoring Seabirds As Sentinels for Human and Ecological Health

A final example of applied conservation medicine is the Seabird Ecological Assessment Network (SEANET) project. This project links marine ecological health and human health by monitoring seabird mortality in the coastal eastern U.S.A. and Atlantic Canada. The network includes more than 60 seabird and ecological health organizations from Canada to Florida, and over 300 ''Citizen-scientist'' volunteers that participate in regular beached bird surveys. Pathology is conducted on selected specimens and all data is entered online and housed at the United States Geological Survey (USGS). The information is used to establish morbidity and mortality, determine the causes of aberrant mass mortality events, and discover options for using seabirds as sentinels for larger environmental events. Data is also used to create a ''normal'' baseline against which impacts, such oil spills, disease outbreaks, contaminants, and algal blooms, can be assessed and to focus further investigations and inform new policy or conservation measures to counteract identified threats.

This collaborative effort has generated several research projects, including: (1) identification of a diversity of zoonotic agents including antibiotic resistant bacteria, *Brucella* spp, *Leptospira* spp, *Giardia* spp, and Cryptosporidium in marine mammals and birds (Bogomolni et al. 2008); (2) obstruction and starvation of seabirds associated with plastic ingestion (Pierce et al. 2004); (3) the first published report of a fungal aneurism in a wild bird (Courchesne and Garner, in press); (4) a microbial source tracking study that suggested that gulls obtain fecal bacteria from waste water (Nelson et al. 2008); and (5) potential discovery of new pathogens involved in Common Eider die-offs [Courchesne and Ellis, under investigation].

Conservation Medicine Training

As illustrated above, conservation medicine practitioners have to deal with policy and outreach as well as science (Deem et al. 2000). Consequently, a good start to a career in conservation medicine would be through a broad-based, liberal arts undergraduate education, because it exposes the student to a multitude of viewpoints and perspectives, opening their eyes to the wider societal concerns that intersect with conservation efforts. Efforts are needed to bring the concepts of conservation medicine and ecosystem health into the undergraduate curriculum. Using real-life examples of team-based conservation medicine problem solving in the undergraduate classroom will highlight the importance of communication and networking between community partners, organizations, agencies, and scientists. Early exposure to these concepts will provide students with a framework for problem solving that they can bring into their professional or graduate training, or pursue jobs that allow them to apply those values, and will introduce them to the options for incorporating conservation medicine into their future career goals.

Many institutions have begun to integrate conservation medicine material within their traditional curricula. For example, Tufts Cummings School of Veterinary Medicine has incorporated conservation medicine concepts into the core and elective veterinary curriculum (Kaufman et al. 2004). Other institutions are creating training opportunities by developing new elective courses and curriculum that supplement traditional offerings at both the undergraduate and graduate level. Another example is at the Nelson Institute of Environmental Studies at University of Wisconsin which encourages the cross-disciplinary approach in its undergraduate and graduate programs to foster translational skills in environmental sciences. Programs such as the Certificate on Humans and the Global Environment were created as supplements to any graduate major on campus

to prepare students to effectively devise solutions to interdisciplinary environmental problems. Other opportunities exist in targeted technical training programs (nurses, research technicians, lab technicians); certificates and diplomas; short courses and workshops; traditional degree programs from bachelors degrees to doctoral degrees; and combined degree programs such as MD or DVM/MPH, and MD or DVM/PhD.

However, there are significant limitations to adding material to a traditional academic or professional program. Programs are already saturated by content and operate within a rigid academic curriculum necessary to produce qualified graduates within an existing discipline. Time constraints make it difficult to justify adding new courses, or even new material within existing courses, at the expense of well established core topics. In addition, cross-fertilization between departments, schools, and programs remains a challenge for all of these programs. Creating opportunities for interdisciplinary interaction with other programs may be logistically impossible and require innovative solutions such as exploring the use of distance education or website-based courses to provide material to students. Administrative structures between disciplines within universities can also present significant barriers to program development for faculty interested in interdisciplinary collaborative research and teaching. This occurs despite major funding initiatives calling for institutions to develop collaborative multi-disciplinary programs, such as the Integrative Graduate Education and Research Traineeship (IGERT) grants program offered by National Science Foundation (NSF 2006) which funds students involved in interdisciplinary PhD programs.

Since the concept of conservation medicine was introduced and broadly promoted through publications such as *Conservation Medicine: Ecological Health in Practice* (Aguirre et al. 2002), several academic institutions have been developing focused conservation medicine and ecosystem health programs (Table 1). Currently, there are only a few programs worldwide that offer an advanced degree specifically in conservation medicine, and most of these have been created by veterinary schools. For example, Murdoch University in Australia offers a Master of Veterinary Studies in Conservation Medicine, as well as a pared down ''Postgraduate Certificate in Veterinary Conservation Medicine''; The University of Liverpool offers a ''Veterinary Conservation Medicine'' program as an intercalated honors course attached to a Bachelor of Veterinary Science degree (BVSc). Both programs incorporate the overarching philosophy and multi-disciplinary nature of conservation medicine and offer options of ''field placement or a research project,'' but are only open to veterinarians. Other graduate programs incorporate principles of conservation medicine, but are not exclusively devoted to this topic. Yet other programs facilitate an individual graduate student to customize their program to include conservation medicine, such as Michigan State University's (MSU) Graduate Specialization in Fish & Wildlife Disease Ecology & Conservation Medicine. Although conservation medicine implies a medical degree, the interdisciplinary nature of this field should not require it and, in fact, should encourage more cross-fertilization. Opportunities for non-veterinarians are more limited and need to be encouraged to effectively engage other critical disciplines.

Designing a Conservation Medicine Program

Graduate education is the best way to attain a high level of training in an area of expertise that includes conservation medicine, but currently, a single graduate degree may not be able to provide the necessary disciplinary focus plus the additional skills to work in the interdisciplinary context. This situation is similar in other bridge fields. For example, results of a survey on training recommendations for careers in wildlife medicine (Mazet et al. 2006) suggested that a second graduate degree is one of the most important types of additional training for success in this specialized field of veterinary medicine. What type of additional degree is most appropriate and most useful? For a large proportion of students completing a graduate or professional degree such as a PhD, MD, or DVM, a second round of four or more years in graduate school for another degree is often not practical. In some cases, institutional constraints in two separate degrees may still not easily enable the interdisciplinary perspective that is required by conservation medicine. Alternatively, 1–2 years of intensive scholastic training following a primary graduate or professional degree could be sufficient to obtain the skills required to successfully augment an individual's expertise with a conservation medicine approach.

Designing an effective conservation medicine training program requires identification of the core tools or skills that conservation medicine health professionals need, independent of their specific discipline or specialization. Some of these tools and skills are listed in Table 2.

Table 1. Current Educational Programs that Have a Conservation Medicine Focus[a]

Program	Institution	Duration	Resulting credential	URL
Master of Veterinary Studies in Conservation Medicine	Murdoch University (AUS)	1 year	MVSc	www.vetbiomed.murdoch.edu.au/vet/grad_courses/MVS_consmed.html
Postgraduate Certificate in Veterinary Conservation Medicine	Murdoch University (AUS)	6 months	Certificate	www.vetbiomed.murdoch.edu.au/vet/grad_courses/cert_cons.html
Veterinary Conservation Medicine	University of Liverpool (UK)	1-year course; BVSc, 5 years	Hons (BVSc)	www.liv.ac.uk/vets/study/vcm1.htm
MSc in Wild Animal Health	University of London (UK)	1 year	MSc	www.rvc.ac.uk/Education/Postgraduate/MScWildAnimalHealth/index.cfm
MSc in Wild Animal Biology	University of London (UK)	1 year	MSc	www.rvc.ac.uk/Education/Postgraduate/MScWildAnimalBiology/Index.cfm
Graduate Specialization in Fish & Wildlife Disease Ecology & Conservation Medicine	Michigan State University (USA)	Varies	MS or PhD	www.fw.msu.edu/graduates/conservationmedicine.htm
Ecology of Infectious Diseases Traineeship (IGERT)	University of Montana (USA)	~6 years	PhD	meid.dbs.umt.edu/graduateTraineeshipProgram.php
Masters of Veterinary Preventive Medicine (MPVM) with "emphasis" in Wildlife Disease & Ecology	University of California—Davis (USA)	1–2 years	MPVM	www.vetmed.ucdavis.edu/mpvm/options.html#wildlife
Conservation Biology Certificate with course in "Conservation Medicine: Disease Ecology"	Columbia University (CERC) (USA)	9 months–3 years	Certificate in Cons. Bio.	www.cerc.columbia.edu/education_certificate.html
Elective course in Conservation Medicine	Tufts Cummings School of Veterinary Medicine (USA)	40 hours	Elective course for DVM	tufts.edu/vet/ccm/ed_inclass_elective.html
Special Topics in Conservation Medicine	Virginia Commonwealth University (USA)	Semester	3-credit course (BS, MS, PhD)	www.pathology.vcu.edu/research/Conservation_Medicine www.has.vcu.edu/bio/bulletinboard/course.html
Conservation Biology & Conservation Medicine Summer Program	University of Georgia (Costa Rica)	Summer semester (6 weeks)	6–8 credits (BS, MS, PhD, DVM)	www.uga.edu/costarica/program_summer_vetmed.htm
Wildlife Ecology	University of Wisconsin—Madison/Nelson Institute (USA)	Varies	MS, PhD	forestandwildlifeecology.wisc.edu/ www.nelson.wisc.edu/grad/prospective
Envirovet Program in Wildlife and Ecosystem Health	University of Illinois Urbana–Champaign, CVM (USA)	7–8 weeks	None	vetmed.illinois.edu/envirovet/

[a]Program information obtained from school or program websites. This list is not meant to be comprehensive, thus may not include all schools and programs that incorporate conservation medicine material to some degree

Table 2. Core Tools for Conservation Medicine Professionals[a]

1. Expertise in a primary discipline (MS degree or higher)
2. Broad-based knowledge with big picture vision through liberal arts undergraduate education or cross-disciplinary exposure (e.g., science major with humanities minor)
3. Foreign language training and international experience
4. Scientific method/study design/research ethics
5. Biostatistics/epidemiology
6. Field experience and techniques
7. Laboratory and research techniques (incl. molecular genetics, PCR, GIS)
8. Public and international policy
9. Grant writing
10. Interdisciplinary teamwork, leadership and management skills
11. Communication/Outreach (incl. communication with the media, public)
12. Didactic training in the following core disciplines:
    - Environmental health
    - Conservation biology
    - Ecology (including modeling)
    - Comparative medicine (i.e., pathology, comparative physiology; immunology/endocrinology)
    - Population medicine and public health
    - Toxicology
    - Agricultural and trade systems
    - Global economics
    - Medical anthropology

[a]This set of core tools and skills came out of a workshop conducted by the authors and entitled ''Graduate training programs in conservation medicine—producing the right professionals with the right tools,'' EcoHealth One, Madison, Wisconsin, October 7th, 2006

In addition to core tools and skills, there is a fundamental need for developing a common language of conservation medicine, a necessary tool for successful communication in interdisciplinary work (Weiler 2007). The conservation medicine community needs to define the terminology and concepts that are directly applicable to the field. This will certainly be a composite of vocabulary and concepts from other areas of science, but it may also lead to new hybridized terminology and concepts that more easily bridge disciplinary gaps. Finally, to develop the communication skills essential to working in diverse groups, a training program should also create situations where students from different educational backgrounds are required to work together on common problems and apply their individual skills in the development of a team product.

Career Opportunities

Where are the opportunities to work or conduct research in conservation medicine? The first place to look is at the work of some of the organizations and institutions that are now practicing this approach (Table 3). Additional opportunities exist in settings where employers may be seeking conservation medicine skills, but may not use conservation terminology nor explicitly describe the skills in position descriptions. A recent review of U.S. Department of Labor (DOL) and the State of Minnesota statistics conducted by the authors in the spring of 2008 (DOL, 2008), found information on applicable environmental, conservation and wildlife occupations, including: ''Zoologists & Wildlife Biologists,'' ''Conservation Scientists,'' ''Environmental Engineers,'' ''Environmental Scientists and Specialists, including Health,'' ''Natural Science Managers,'' and ''Forestry and Conservation Science Post-Secondary Teachers.'' Natural Science Managers were included in this review since a substantial number of job postings were for managerial-type positions that often required higher education in the relevant science. No DOL statistics were available for ''Wildlife Veterinarians.'' Two of these DOL occupations, ''Environmental Engineers'' and ''Environmental Scientists and Specialists,'' were among the top 25 fastest growing occupations nationally, both had projected growth rates of 25% from 2006 to 2016. All other environmental or conservation occupations examined had positive projected national growth rates. These data suggest that environmental, wildlife, and conservation sciences will see overall growth and increased job opportunities.

Conservation medicine practitioners should take the lead in bringing their skills into traditional settings, building conservation medicine principles and approaches into preexisting positions, and promoting their strengths to employers that may not realize the value of this approach. For example, a veterinarian with conservation medicine interests might pursue a traditional state wildlife veterinarian position, or veterinary public health position, even though conservation is not mentioned in the job description. Once in the position, she or he may be able to incorporate conservation medicine principles as they conduct research, create policy, and implement decisions in their agency. It is expected that more agencies and employers will begin to seek out these skills in the future as the approach becomes wider known and proven effective.

Table 3. Examples of Organizations that Practice Applied Conservation Medicine[a]

Organization/institution	Program(s)	URL
Cary Institute of Ecosystem Studies	Multiple	www.ecostudies.org/index.html
Center for Large Landscape Conservation	Conservation Medicine and Wildlife Movement program and others	www.climateconservation.org/activities.php
Conservation Medicine Center of Chicago	Multiple	www.luhs.org/depts/cmcc/
The Consortium for Conservation Medicine	Multiple	www.conservationmedicine.org
International Rhino Foundation	Multiple	intlrhinofoundation.wordpress.com/category/conservation-medicine/
New England Aquarium	Conservation Medicine and Ocean Health	neaq.org/conservation_and_research/projects/conservation_medicine/index.php
North Carolina State University	Environmental Medicine Consortium	www.emc.ncsu.edu/programs/conservmed/index.html
Smithsonian National Zoological Park	Multiple: e.g., Conservation & Research Center Program	nationalzoo.si.edu/ConservationAndScience/CRC/disciplines.cfm
Tufts University	Tufts Center for Conservation Medicine	www.tufts.edu/vet/ccm/
United States Geological Survey	National Wildlife Health Center	www.nwhc.usgs.gov/
University of California—Davis, School of Veterinary Medicine	Wildlife Health Center	www.vetmed.ucdavis.edu/whc/default.htm
University of Georgia College of Veterinary Medicine and associated other agencies	Southeastern Cooperative Wildlife Disease Study	www.uga.edu/scwds/aboutus.htm
University of Wisconsin—Madison	Wisconsin Cooperative Wildlife Research Unit	forestandwildlifeecology.wisc.edu/coop/wcwru.htm
Virginia Commonwealth University Rice Center	Conservation Medicine Program	www.vcu.edu/rice/research/research-conservation.html
Wildlife Conservation Society	Field Veterinary Program	www.wcs.org
Wildlife Trust	Conservation Medicine Ecological Health in Practice	www.wildlifetrust.org/conservation_medicine/overview.shtml
The Wilds	Conservation Medicine program	www.thewilds.org/what/conservation.asp

[a]This list only represents a fraction of the organizations that work in this field and is not meant to be comprehensive

Federal health and research agencies (e.g., Centers for Disease Control and Prevention, National Research Council, Institute of Medicine), major scientific funding agencies (e.g., National Institutes of Health (NIH), National Science Foundation), and professional medical organizations (e.g., American Veterinary Medicine Association, American Medical Association) have also come to the realization that global health problems require multidisciplinary strategies. This has resulted in calls for new initiatives (AVMA 2008) and new funding opportunities that support academic programs and positions in conservation medicine. Some examples include the NSF's IGERT program mentioned above, the NSF/NIH Ecology of Infectious Diseases program, and NSF's Dynamics of Coupled Natural and Human Systems program. In addition, more professional societies and peer-reviewed publications are including conservation medicine topics in their focus, such as the Conservation Medicine section in *the Journal of Wildlife Diseases* (Wildlife Disease Association), and the *EcoHealth* journal (International Association of

Ecological Health) which is specifically devoted to the principles of conservation medicine. As the opportunities increase for peer-reviewed publication and unique interdisciplinary funding opportunities, universities will be encouraged to support research programs within their institutions.

Summary

Conservation medicine, as a discipline, is at the early stages of development. Academic programs are beginning to incorporate conservation medicine concepts into their curricula, funding agencies are beginning to encourage trans-disciplinary approaches to research, and journals are emerging that are devoted, wholly or in part, to conservation medicine. As seen in the early stages of the establishment of Conservation Biology, a more coordinated effort from academia is required to help this growing field become established.

Academic program development in conservation medicine is needed at several levels. It is imperative that scientists, practitioners, and educators work together to establish the common language of key concepts that should form the basis for this new field, and can be used as a framework for curricular efforts in both undergraduate and graduate education. A broad-based undergraduate education is desirable for future practitioners of conservation medicine because it strengthens the ability to communicate across diverse disciplines and leads to a greater appreciation of the value of multiple disciplines in problem solving. Undergraduate resources should be developed to introduce the basics of conservation medicine, appropriately orient students for employment in this area, and lay the foundation for graduate work.

Specialization in one of the key disciplines involved in conservation medicine should be a goal for graduate level study. To apply this expert knowledge using the conservation medicine approach, an additional skill set that incorporates the defined core tools is highly desirable. This skill set, if not acquired through a traditional graduate program, could be attained through an additional 1–2-year conservation medicine training program.

In addition, concerted efforts to educate potential employers, granting institutions and foundations, and professional associations is warranted. Directors of training programs need to promote conservation medicine as a valuable approach in order to build recognition for new certificates, diplomas, and degrees that provide this training. Presentations and workshops at professional meetings will help to build support for novel programming at the academic level and also foster appropriate career opportunities.

Acknowledgments

J.H. Epstein was funded by an award from the National Institute of Allergy and Infectious Diseases (grant K08AI067549).

References

Aguirre AA, Ostfeld RS, Tabor GM, House C, Pearl MC (2002) *Conservation Medicine: Ecological Health in Practice*, New York: Oxford University Press

American Veterinary Medical Association (AVMA) Task Force on One Health (2008) One Health: a new professional imperative. Available: http://www.avma.org/onehealth/default.asp [accessed October 22, 2008]

Asibey EOA (1974) Wildlife as a source of protein in Africa south of the Sahara. *Biological Conservation* 6:32–39

Bogomolni AL, Gast RJ, Ellis JC, Dennett M, Pugliares KR, Lentell BJ, et al. (2008) Victims or vectors: a survey of marine vertebrate zoonoses from coastal waters of the Northwest Atlantic. *Diseases of Aquatic Organisms* 81:13–38

Brashares JS, Arcese P, Sam MK, Coppolillo PB, Sinclair ARE, Balmford A (2004) Bushmeat hunting, wildlife declines, and fish supply in West Africa. *Science* 306:1180–1183

Chua K, Bellini W, Rota P, Harcourt B, Tamin A, Lam S, et al. (2000) Nipah virus: a recently emergent deadly paramyxovirus. *Science* 288:1432–1435

Chua KB, Chua BH, Wang CW (2002) Anthropogenic deforestation, El Niño and the emergence of Nipah virus in Malaysia. *Malaysian Journal of Pathology* 24:15–21

Courchesne S, Garner M (in press) What is your diagnosis? *Journal of Avian Medicine and Surgery*

Daszak P, Plowright R, Epstein JH, Pulliam J, Abdul Rahman S, Field HE (2006) The emergence of Nipah and Hendra virus: pathogen dynamics across a wildlife-livestock-human continuum. In: *Disease Ecology: Community Structure and Pathogen Dynamics*, Collinge SK, Ray C (editors), New York: Oxford University Press, pp 186–201

Davies G (2002) Bushmeat and international development. *Conservation Biology* 16:587–589

Deem SL, Kilbourn AM, Wolfe ND, Cook RA, Caresh WB (2000) Conservation Medicine. *Annals of the New York Academy of Sciences* 916:370–377

Epstein JH, Abdul Rahman S, Smith CS, Halpin K, Sharifah SH, Jamaluddin AA, et al. (2007) The emergence of Nipah virus in Malaysia: epidemiology and host ecology of Pteropus bats. *American Journal of Tropical Medicine and Hygiene* 77(5 Suppl):272

Fogarty R, Halpin K, Hyatt AD, Daszak P, Mungall BA (2008) Henipavirus susceptibility to environmental variables. *Virus Research* 132:140–144

Hahn BH, Shaw GM, De Cock KM, Sharp PM (2000) AIDS—AIDS as a zoonosis: scientific and public health implications. *Science* 287:607–614

Halpin K, Mungall BA (2007) Recent progress in henipavirus research. *Comparative Immunology Microbiology and Infectious Diseases* 30:287–307

Juste J, Fa JE, Delval JP, Castroviejo J (1995) Market dynamics of bushmeat species in equatorial-Guinea. *Journal of Applied Ecology* 32:454–467

Kaufman GE, Else JE, Bowen K, Anderson M, Epstein J (2004) Bringing conservation medicine into the veterinary curriculum—the Tufts example. *EcoHealth* 1(Suppl 1):43–49

Le Breton M, Prosser AT, Tamoufe U, Sateren W, Mpoudi-Ngole E, Diffo JLD, et al. (2006) Patterns of bushmeat hunting and perceptions of disease risk among central African communities. *Animal Conservation* 9:357–363

Leroy EM, Rouquet P, Formenty P, Souquiere S, Kilbourne A, Froment JM, et al. (2004) Multiple Ebola virus transmission events and rapid decline of central African wildlife. *Science* 303:387–390

Li WD, Shi ZL, Yu M, Ren WZ, Smith C, Epstein JH, et al. (2005) Bats are natural reservoirs of SARS-like coronaviruses. *Science* 310:676–679

Mazet JAK, Hamilton GE, Dierauf LA (2006) Educating veterinarians for careers in free-ranging wildlife and ecosystem health. *Journal of Veterinary Medical Education* 33:352–360

Meine K, Soule M, Noss RF (2006) "A mission-driven discipline": the growth of Conservation Biology. *Conservation Biology* 20:631–651

Milner-Gulland EJ, Akcakaya HR (2001) Sustainability indices for exploited populations. *Trends in Ecology and Evolution* 16:686–692

National Science Foundation (NSF) (2006) Integrative Graduate Education and Research Traineeship Program (IGERT). Available: http://www.nsf.gov/pubs/2007/nsf07540/nsf07540.htm [accessed October 22, 2008]

Nelson M, Jones SH, Edwards C, Ellis JC (2008) Characterization of Escherichia coli populations from gulls, landfill trash, and wastewater using ribotyping. *Diseases of Aquatic Organisms* 81:53–63

Pierce KE, Harris RJ, Larned L, Pokras MA (2004) Obstruction and starvation associated with plastic ingestion in a Northern Gannet *Morus bassanus* and a Greater Shearwater *Puffinus gravis*. *Marine Ornithology* 32:185–187

Pulliam JR, Dushoff J, Field HE, Epstein JH, Dobson AP, Daszak P (2007) Understanding Nipah virus emergence in peninsular Malaysia: the role of epidemic enhancement in domestic pig populations. *American Journal of Tropical Medicine and Hygiene* 77:273–273

U.S. Department of Labor (DOL) and the State of Minnesota (2008) CareerOneStop "Industry Information." Available: http://www.acinet.org/industry_intro.asp?id=8&nodeid=8 [accessed May 30, 2008]

Weiler CS (2007) Meeting Ph.D. graduates' needs in a changing global environment. *Eos* 88(13):149–151

Wolfe ND, Daszak P, Kilpatrick AM, Burke DS (2005) Bushmeat hunting deforestation, and prediction of zoonoses emergence. *Emerging Infectious Diseases* 11:1822–1827

Wolfe ND, Heneine W, Carr JK, Garcia AD, Shanmugam V, Tamoufe U, et al. (2005) Emergence of unique primate T-lymphotropic viruses among central African bushmeat hunters. *Proceedings of the National Academy of Sciences of the United States of America* 102:7994–7999

Wolfe ND, Switzer WM, Carr JK, Bhullar VB, Shanmugam V, Tamoufe U, et al. (2004) Naturally acquired simian retrovirus infections in central African hunters. *Lancet* 363:932–937