מחקר והוראת המגוון הביולוגי באוניברסיטאות המחקר של ישראל

דוח שאושר במועצת האקדמיה כמסמך יהלו"ם,
ביום כ"ט בניסן תשע"א, 3 במאי 2011

ירושלים תשע"ב / 2012

דוח על מחקר והוראת המגוון הביולוגי באוניברסיטאות המחקר של ישראל

יהלו"ם – יחידת האקדמיה לייעוץ והערכה מדעיים

האקדמיה הלאומית הישראלית למדעים

מדיניות מדע בישראל

Issues in Science Policy

דוח מחקר והוראת **המגוון הביולוגי** בישראל

Report on **Biodiversity** Research and Higher Education in Israel

Biodiversity Research and Higher Education at the Research Universities of Israel

The Academy Council approved the report as a YAHALOM document, on May 3, 2011

Jerusalem 2012

Biodiversity Research and Higher Education at the Research Universities of Israel

YAHALOM – Academy Unit for Scientific Counsel and Evaluation

The Israel Academy of Sciences and Humanities

Biodiversity Research and Higher Education in Israel

Submitted by:
Tamar Dayan, Zvi Ben-Avraham, Ran Nathan, Dan Yakir, Arnon Lotem, David Saltz, Amatzia Genin
Forum on Biodiversity and the Environment
Israel Academy of Sciences and Humanities

Yehudith Birk, Rafael Mechoulam, Yossi Loya, Oded Navon, Yael Lubin, Ehud Spanier, Tamar Dayan
The Steering Committee for the National Collections of Natural History
Israel Academy of Sciences and Humanities

Also participated in preparing the report:
Shimshon Belkin, Menachem Goren, Abraham Hefetz, Micha Ilan, Jaime Kigel, Noga Kronfeld-Schor, Shai Meiri, Uriel Safriel, Sharon Shafir, Uri Shanas

Data collection and management:
Emmanuelle Cohen-Shacham

"Biodiversity, which plays a critical role in overall sustainable development and poverty eradication, is essential to our planet, human well-being and to the livelihood and cultural integrity of people" (Section 42 of the World Summit on Sustainable Development Action Plan, Johannesburg 2002)

Content

Preamble

The powerful scientific method of searching the simplest explanations for natural phenomena does not imply that nature is simple. With a complex web of ~10-30 million species forming our ecosystem, and with an increasing recognition that crops, health, and economic prosperity are not independent of this complex network, the study of Biodiversity is no longer considered a luxury. On both global and national scales, scientists are called to provide answers to questions that cannot be studied indoors with a few species of laboratory animals. The list of questions outlined on the right side of this page (see Box 1) illustrates how important many of these questions can be.

In the past two decades scientists and decision-makers have realized that the natural ecosystems upon whose services our economy, agriculture, health, and well-being are dependent are endangered. Biodiversity research and scientific expertise are now key to maintaining functioning ecosystems and for rational and educated decision-making in many aspects of economy and development.

Israel with a population of seven million is one of the most densely populated western world countries; it has a western world economy and resource exploitation, yet a population growth rate of a third world country. Thus Israel faces enormous challenges in protecting, managing, and exploiting its natural environments for the benefit of society. We asked whether the university system is ready to meet the needs of the State of Israel in biodiversity research and higher education.

Box 1 – some representative questions for biodiversity research

- What biologically active substances within living organisms can be used for the pharmaceutical industry?
- How can wetlands be used for bioremediation of human waste?
- Did levels of mercury contamination in marine and aquatic environments change over the past half century?
- How can models and experiments of population biology be used to eradicate invasive crop pests?
- How are plant communities expected to respond to climate change?
- Which bee species can be used as alternative pollinators for agricultural crops?
- What is the effect of Red Sea species that are transported through the Suez Canal into the Mediterranean?
- Which species can be used for biological control and how?
- How do we set priorities for development while maintaining functioning ecosystems?
- How do natural woodlands, shrublands, and pine plantations contribute to carbon sequestration and to local and regional water availability?
- How do we manage agricultural landscapes to be environmental friendly?
- How do we restore Israel's rivers and wetlands?
- How can we use behavioral ecology to manage invasive species?
- How can we model the role of movement between populations to make predictions regarding future trajectories in view of climate change and current connectivity in fragmented landscapes?
- What is the physiological adaptive potential of animal species to climate change?
- How does the behavior of individuals scale up to population dynamics, and community resilience?

Executive summary

Biodiversity research receives global priority both scientifically and socially, but is stagnating in Israel. If no changes are made within few years this field in Israel will fall well below a critical level, impacting science-based agriculture, conservation of natural resources, health, planning, and national adaptation to global change. Action must be taken at the science policy realm and at the universities, to elevate biodiversity research in Israel to cutting edge western standards.

We recommend:

1. Significant increase in the number of academic positions in biodiversity, in particular within specific highly vulnerable sub-fields (see below).
2. New fellowships and study programs in the field of Biodiversity.
3. Participation of biodiversity scientists in all relevant decision-making forums and committees.

* * *

Biodiversity research has developed dramatically around the world over the past two decades. We surveyed the status of biodiversity research in Israel's seven research universities in order to assess whether this field of research can answer the country's needs in terms of research and higher education, and whether the trajectories in the past two decades reflect the growth of this field globally. We categorized as biodiversity researchers scientists who study living non-model animals and plants from an ecological and/or evolutionary approach. At the time of this report there are 87 biodiversity researchers with tenured or tenure track positions in all of Israel's research universities (fewer than 9% of the total of biomedical researchers), compared to 91 in 1990. This is in contrast to a 15% increase (from 89/90) or 9% increase (from 91/92) in the total number of faculty members over this period. We

conclude that the global trend of growth in biodiversity research is not reflected in Israeli research universities.

The overriding majority of biodiversity researchers are found in four universities: Tel Aviv University (TAU), the Hebrew University (HUJ), the University of Haifa (UH), and Ben-Gurion University of the Negev (BGU). Only at TAU is there a fair sized cohesive program, while in each of the three other universities scientists are divided into two campuses and to varying degrees also into separate teaching programs.

The programs at HUJ and TAU, the larger and more prominent universities, have suffered major cutbacks during the past 20 years: in HUJ primarily during the '90s (continuing a trend established in the '80s) and in TAU in the past decade. An increase occurred in the smaller and geographically peripheral universities (BGU [including the Blaustein Institutes for Desert Research] and the University of Haifa [including Oranim]). Moreover, 22 of the 87 researchers (>25%) are expected to retire within the next five years, a decline which is unlikely to be compensated by current recruitment rates of new faculty members (so far the maximum recruitment rate stands at 18 within five years). Because of the severe cuts at TAU and HUJ, the two universities in which over 75% of Israel's faculty members recruited in the past two decades were trained, hiring the next generation of biodiversity researchers may be particularly challenging for want of a sufficient number of strong candidates.

Taxonomy and systematics, the basic study of living organisms and their evolutionary relationships, has dwindled dramatically, and the discipline's last faculty member retires in six years time; wetlands ecology is now studied by a single scientist who retires in two years; scientists who are the sole experts on various taxa are expected to retire shortly. For example, Israel's only two fish biodiversity scientists retire within the next five years, as does the only expert on spiders; parasitoid ecology, key to science-based

biological control of crop pests, is lost from Israeli universities, a loss that is bound to have serious economic and environmental repercussions. Within a few years physiological ecology will have dwindled much below a critical mass for research and teaching; aspects of plant ecology (e.g., study of lower, marine, and aquatic plants, systematics) are practically lost and other sub-fields are seriously under-represented; conservation biology as well as global change ecology seem to have hardly developed yet in Israel; the ability of the university system to research and to provide courses on specific groups of fauna and flora has decreased significantly. Generally, we see a loss of zoological and botanical expertise, which provides crucial building blocks for ecological, behavioral, and evolutionary research. **These losses are expected to seriously limit the ability of scientists to provide expertise needed to advise and act on such issues as adaptation to global change, development, land-management, environmental conservation, public health, and agriculture.**

Various topics and taxa in Israel are studied by a single or very few scientists, implying lack of critical mass required for excellence and risk of loss to science in Israel. **Because of the small numbers of scientists in many fields of biodiversity research, entire fields are prone to extinction and require special attention, in particular those that have direct economic or societal benefits.** Special care at the national and university levels must be taken to promote biodiversity research in Israel.

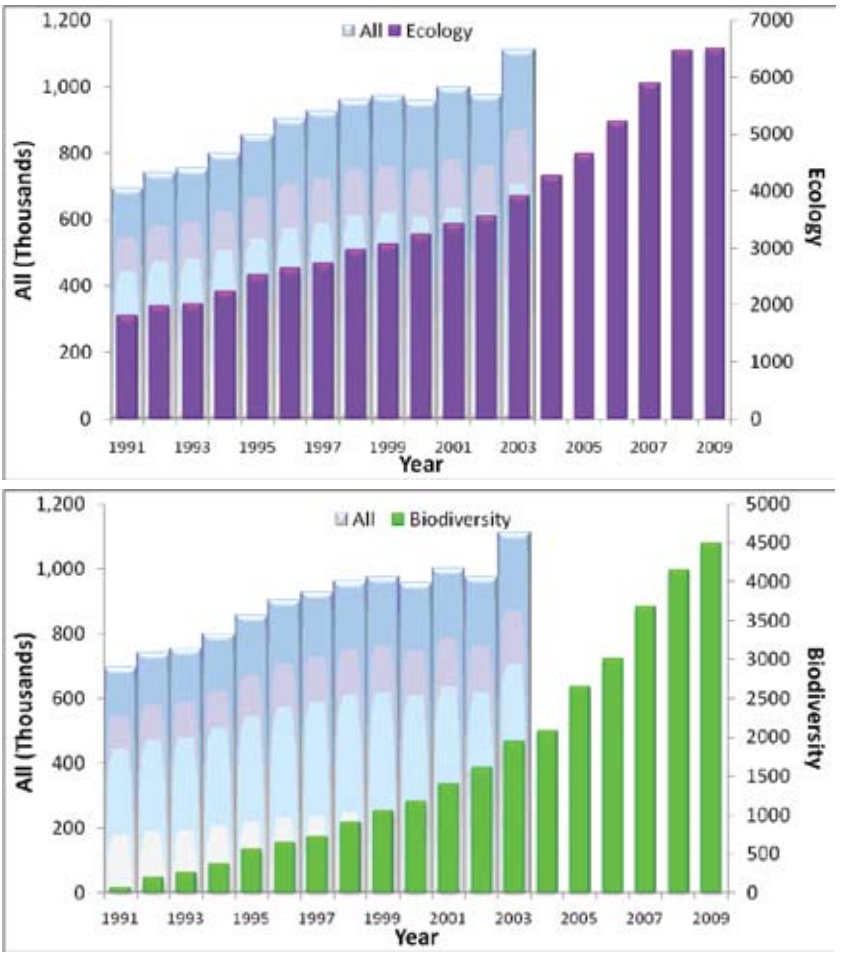
Recommendations

Israel's research universities have an obligation to meet societal needs in science, training, and higher education. Our survey findings are that biodiversity research, now a global priority for both scientific and direct societal reasons, is stagnating in Israel, and the coming few years are critical in terms of training and hiring as some crucial sub-fields are actually on the brink of extinction or declining below a reasonable critical mass. Thus, the situation of biodiversity research in Israel requires special attention at the national and the university scales. We recommend:

- Re-balance the field of biology by increasing significantly the number of positions for biodiversity research over the next decade. Fields in need of special care are listed below.
- In the meantime – ascertain that no further positions are lost as of today in all Israeli universities. This is crucial in light of the huge wave of retirements in the coming five years.
- Ascertain that within the vast field of biodiversity research, a balance is maintained between disciplines, taxa, and environments. Encourage diversity; it is crucial for a healthy and balanced science that can meet the country's needs.
- Because basic zoological and botanical courses on different biological taxa can now be taught by so few scientists, pool resources and develop a joint inter-university program for faunistic and floristic studies; this knowledge is a crucial building block for biodiversity research.
- Provide specific PhD fellowships to promote this field; it is crucial to ensure that a next generation of young scientists can be trained at the required rate.
- Provide specific post-doctoral fellowships to train abroad; this is a crucial stage in developing the next generation of biodiversity researchers.
- Earmark specific positions for taxonomy and systematics; the state of this field compels aggressive intervention.
- Ascertain that wherever and whenever biology is to be represented in committees or otherwise – a biodiversity scientist is there to represent this research perspective.

Background

In the past two decades biodiversity research has become a global priority. This was in contrast to the preceding three decades, when following the discovery of the double-helix of DNA, amazing breakthroughs in understanding biological mechanisms at the sub-cellular level, and great progress in biomedical research became the focus of most funding and job opportunities in biological science.



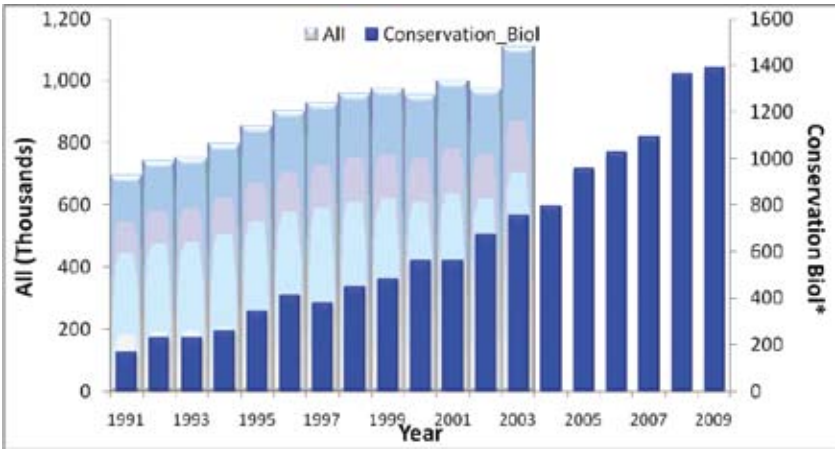


Figure 1 - # of publications of global studies searched by either 'biodiversity' or 'conservation and biolog*' or 'ecology'; the background depicts the total number of publications in the ISI database (available only for 1991-2003). While increase in the total # of publications slows, perhaps even asymptotes, around 1997, the reviewed fields continue to increase greatly.

In the mid- to late '80s, scientists and science decision-makers realized that many phenomena in biology at higher organizational levels cannot be understood and studied solely or at all from underlying molecular mechanisms. It was also realized that with a rapidly growing world population, overexploitation of natural resources, and already detectable adverse impacts on ecosystem services – **the scientific study of Earth's most complex biological systems is a crucial basis for protecting, managing, and sustainably exploiting natural resources for the benefit of society.** Therefore biodiversity research has regained a central place in science (Figure 1). Between 1991 and 2003 the general volume of scientific publications increased at most by a factor of ca. 1.6 while the field of Ecology increased by a factor of 2.2, Conservation Biology increased by a factor of 5.2, and Biodiversity publications by a factor of over 30 (see Figure 1), reflecting the highly significant growth of these fields of research globally.

The past decade has seen a tremendous surge in biodiversity research at the global scale. The number of scientific journals in ecology has increased and an even more dramatic increase can be noted in the field of Conservation Biology (Figure 1), established only in 1986 and already featuring 28 scientific journals. Impact factors of the leading journals in these fields, primarily driven by number of scientists in the field, have also increased, sometimes quite dramatically. 'Biodiversity Conservation' first appears as a field by the ISI (JCR) in 2000, with 16 journals reviewed. In the 2008 JCR edition the number of journals went up to 28 (a 75% increase) and **mean impact factors of the five strongest journals increased by 40%**. During the same period 'Ecology' as a field increased in journal numbers from 100 to 124 (a 24% increase) and the **mean impact factor of the top five non-review journals increased by 47%**.

Some of the progress in biodiversity research resulted from natural changes in scientific perceptions. Other aspects required special support, opening new positions, and creating earmarked funding opportunities. Specifically taxonomy as a scientific discipline is still a cause for worry at the global scale and measures are taken to save the field as part of the convention on biological diversity http://www.cbd.int/gti/ . All progress has required a significant measure of understanding from science decision-makers.

Biodiversity research ranges from very basic science to the very applied. It encompasses very diverse taxonomic groups; it involves understanding the basic evolutionary framework, the biology and physiology of individuals and species, the genetics of populations, interspecific interactions and their bearing upon the structure and composition of ecological communities; it seeks to understand the processes at the ecosystem level that include nutrient cycling; research is conducted in the terrestrial, marine, and aquatic realms, and involves a wide and extremely diverse array of organisms whose numbers can only be guessed at this

point. Correspondingly, biodiversity research encompasses an extremely wide range of organisms, environments, mediums, scientific questions, and research techniques. There are no shortcuts: basic zoological and botanical research remains crucial in providing the building blocks for understanding and modeling processes at the population, community, ecosystem, and landscape levels. **Therefore a healthy program at the national level must include a blend of taxa, environments, research levels and techniques, and scientific queries.**

Our goal was to assess the status of biodiversity research in Israel in its widest sense, including systematics, evolution, ecology, physiological ecology, evolutionary development, behavior, behavioral ecology, and conservation. Several years ago a report submitted to the Israel Academy of Sciences and Humanities found that systematics was a dying field of research in Israel; consequently the Israel Taxonomy Initiative was established to save this crucial scientific expertise. We now wish to see how other fields of biodiversity research are faring, and how the university system of Israel is expected to meet the scientific, training, and conservation challenges of the first half of the 21st century.

The survey

Our survey spanned Israel's seven research universities (Appendix 1); we estimate that we have full data for faculty members currently active and almost all data for those retired in the past two decades. While we focus on the present, we do analyze patterns in the past 20 years as a benchmark, as well as expected trajectories.

We omitted microbial ecology from our assessment at this first stage. The next stage of the analysis will include this field. We also omitted two Israeli research institutes whose focus is agricultural and maricultural (ARO and IOLR), but do have several scientists each who study issues in biodiversity. This does not imply that there is no importance in strengthening biodiversity research in these institutes.

Our survey included Israeli scientists who study animals and plants at the genetic, developmental, physiological, individual, population, community, and ecosystem levels. We did not survey scientists whose focus is livestock or other agricultural production, neurobiologists and developmental biologists whose research is not primarily driven by ecological and evolutionarily scientific questions, and scientists who study various molecular mechanisms of laboratory model species (*Arabidopsis*, zebra fish, *Drosophila*, chickens) and those whose focus is biomedical or agronomical; we also omitted zooarcheologists, archeobotanists, palynologists, and paleoanthropologists. These cutoff lines as a general rule and per individual were placed in consultation with colleagues and judged by publication records. In the very few cases where the lines were fuzzy, we may have erred by being inclusive rather than exclusive.

We omitted Kamea and Giladi funded new immigrant scientists from our survey. These are nationally funded absorption schemes for scientists. There are a number of Kamea and Giladi fellows who do biodiversity research (ca. 10) and some contribute quite significantly to science in Israel. However, they are nationally funded positions that come with the individual rather than the

institution, and are not part of the development trajectory of the higher education system of Israel.

We obtained several key data fields for each individual (see Appendix 2). Most of the data were provided by the scientists. The general field of research was determined by us, by analyzing the data provided by the scientists. We categorized the scientists as studying one of the following main disciplinary categories: evolution, ecology, ecology and evolution, ecology and conservation, behavior, behavioral ecology, physiological ecology, biogeography and systematics. Because some scientists publish in several of these fields, we determined by the chief focus as reflected by publications and by personal recognition. Additionally we noted whether the scientist was involved in conservation practice, although not necessarily in conservation research. A notable example is Prof. Amotz Zahavi who publishes in behavioral ecology and evolution but is one of the most influential figures in conservation in Israel.

We used the entire biomedical community statistics for Israel's seven research universities for general comparison (Appendix 1). Biodiversity research is a biological field of study, so we compared it with the Faculties of Biology, Medicine, the biologists within Faculties of Science, and the Faculty of Agriculture, Food and Environment. There is currently a significant overlap between Faculties of Biology and Medicine in biomedically driven science. In Faculties of Medicine we used only data for PhDs in active and basic research and occupying regular tenure track academic positions, not MDs doing clinical research, valuable as it may be. There are some 1000 active scientists in biomedical-related fields (Appendix 1), and a new Faculty of Medicine is planned at Bar Ilan University, which will increase this number. Additionally there are numerous MDs with affiliation to universities who do scientific research. In the period we surveyed there was an overall increase in the number of senior faculty positions in the seven research universities, from 4337 positions in 89/90 or 4590 positions in 91/92 to 4985 positions in 2008/2009, an increase of 9-15% in the system.

Results

Distribution among Israeli universities

In all we surveyed 87 active individual scientists and 62 scientists who retired within the past 20 years. The active scientists researching biodiversity are thus fewer than 9% of the Israel biomedical community. They are distributed very unevenly within Israeli universities (Figure 2): a single scientist in the Weizmann Institute (Department of Environmental Sciences and Energy Research) studying carbon fluxes; two in the Technion (one in Biology and the other in Civil and Environmental Engineering); three in Bar Ilan University (one member is located at the Inter-University Institute at Eilat [IUI]), and the remainder in the other four Israeli universities: two older, larger, and more prominent universities (HUJ and TAU; see Appendix 1) and two smaller, younger, and geographically peripheral universities (UH and BGU).

In three of those four universities, faculty members are divided between two campuses: the main University of Haifa campus (one of whose members is located at the IUI) and the Oranim Campus (ratio of 12:8); the Beer Sheva Campus of Ben-Gurion University (with two members located at the IUI) and the Blaustein Institutes for Desert Research at Sede Boqer (8:9); the Hebrew University main Campus in Jerusalem (one member is located at the IUI) and the Faculty of Agriculture at Rehovot (10:7).

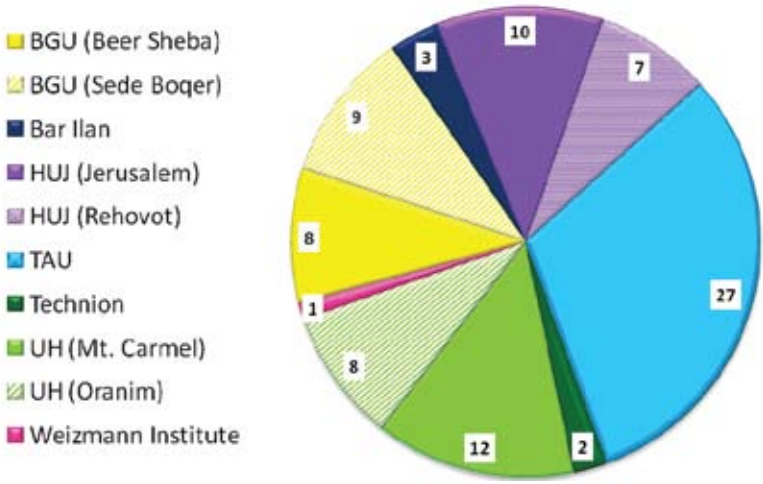


Figure 2 – pie chart of number of biodiversity researchers by university. Patterns for HUJ, BGU and UH denote scientists in campuses other than the main campus.

These divisions are sometimes more than geographical: in HUJ they translate into separate research and teaching programs at both the undergraduate and the graduate levels. The faculty members at the Oranim Campus of UH share an undergraduate and graduate program with their colleagues at the Haifa Campus, in the newly established (2000) Faculty of Science & Science Education. However, their teaching load is extremely high compared with that of scientists in other Israeli universities, reflecting the fact that Oranim is a teaching seminar, and they do not enjoy the same level of university support that do scientists in other institutions (see Appendix 3).

Only at TAU is there a critical mass of scientists (27; 30% of Israeli biodiversity researchers) who are located on the same campus and who take part in the same research and teaching programs. TAU has also special research and teaching infrastructures – botanical gardens and natural history collections (as does the Hebrew University at the main campus in Jerusalem), as well as unique zoological research garden. This infrastructure is used by scientists from most other universities for teaching and research.

Five (~6%) of the surveyed scientists have been hired by departments other than biology and agriculture: one by a Department of Environmental Sciences and Energy Research (Weizmann

Institute); one by a Faculty of Civil and Environmental Engineering (Technion); two by departments of geography (UH and BGU), and one by an Institute of Maritime Civilizations (UH). We include them in the survey; however, they do not represent trajectories in biological research in their institutions but rather the recognition by other departmental heads of the significance of ecology to geography, biogeochemistry, and civil engineering. It should be noted that in the past, the Faculty of Medicine at HUJ also employed several faculty members who studied aspects of biodiversity (taxonomy, physiological ecology) but this is no longer the case.

Demographic trends

There are currently 87 active biodiversity researchers in Israel's seven research universities (see above and Figure 2). This number is lower than 20 years ago; it contrasts with the overall growth in the Israeli university system as well as the growth of the field in the rest of the western world. Figure 3 shows that some increase did occur during the '90s, peaking at 99 biodiversity researchers throughout the system, but that during the past decade, this field underwent a 12% reduction.

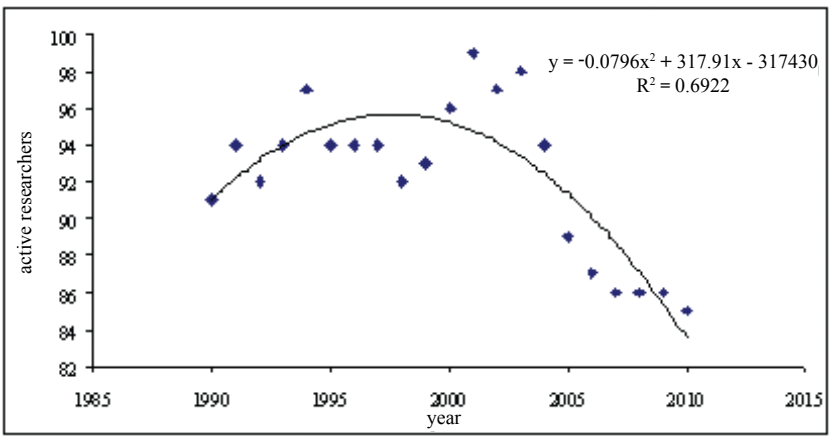


Figure 3 – numbers of biodiversity researchers in the research universities in the past two decades. Two biodiversity researchers are scheduled to retire at the end of the current academic year, hence Figure 3 shows only 85 biodiversity researchers for the current year, although in fact in the next few months the number is still 87. The same is true for Figure 5.

We wanted to gain insight into the demographics and hence the trajectory of the field. We divided the database into expected retirements (in Israeli universities normally at the age of 68) at five year bins, and also included in our analysis our colleagues who have already retired or passed away prior to retirement in the past 20 years (Figure 4). Some 31% of the scientists in this field are expected to retire by the end of 2015. If a trajectory of growth in the field had occurred over the past two decades, as is the case at the global scale, one might expect the next six years' retirements to be lower than 18%. This, sadly, is not the case.

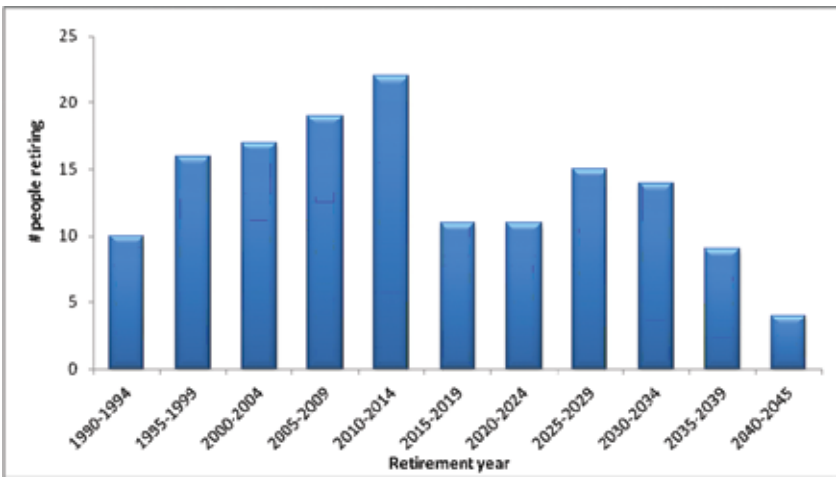


Figure 4 – retirements and expected retirements at the entire university system in five year bins.

If we add to Figure 3 data on the expected trajectory of retirements over the next few decades we see that the number of active researchers will decrease to about 60% of current level within the coming decade if no new faculty are hired (Figure 5).

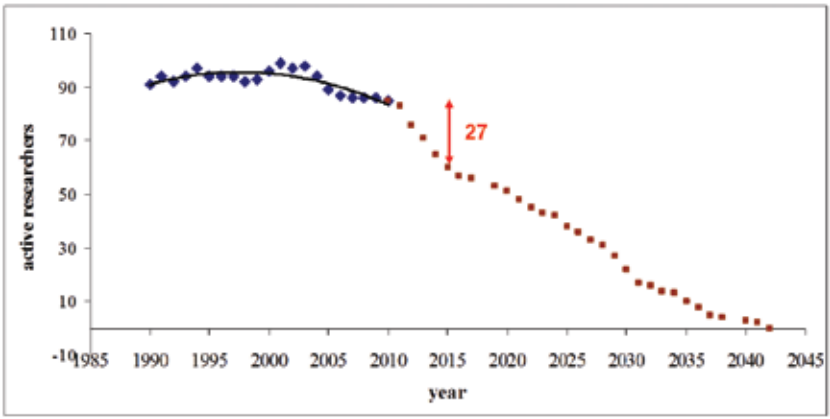


Figure 5 – numbers of biodiversity researchers in Israeli universities in the past two decades (in blue) and expected numbers based upon the expected trajectory of retirements. 27 is the number of retirements expected until the end of 2015.

We explored the retirements curve for the four universities with biodiversity programs (Figure 6). The past 20 years' retirements are dominated by HUJ and TAU faculty. This is to be expected given the older age of these universities (and to some extent also their larger size).

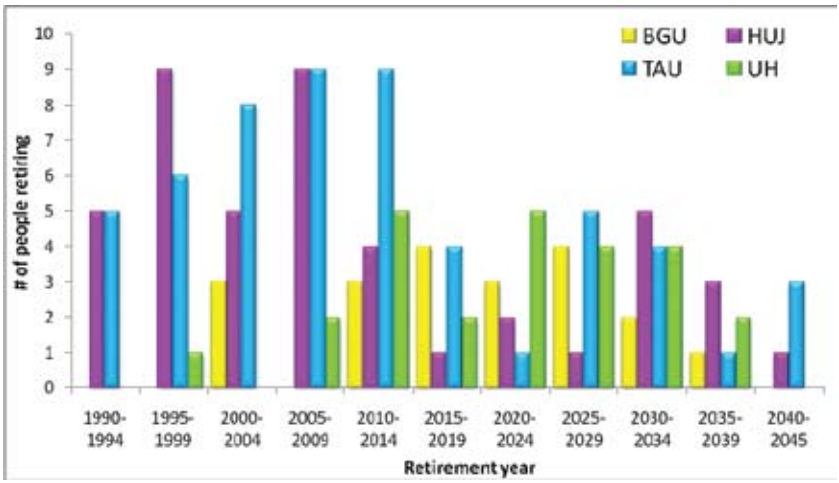


Figure 6 – numbers of retirements in the past 20 years and scheduled retirements by university, in five year bins.

In the coming five years 22 of 87 (25%) of scientists studying various aspects of biodiversity are scheduled to retire: 9 (of 27; 33.33%) at TAU; 6 (of 20: 30%) at UH; 4 (of 17; 23.5%) at HUJ; 3 (of 17; 18%) at BGU, making it the only university with a retirement rate close to conforming to the expected if retirements were stable over the years (ca. 3% annually).

We explored the number of recruitments per university in the past two decades. Figure 7 displays two trends: while at HUJ there is an overall tendency of increase in number of recruits per each five year bin (although the past half decade shows some decrease), at TAU the opposite trend occurs, with number of recruits decreasing throughout the past two decades. The greatest number of recruitments so far was 16 statewide within a five year bin.

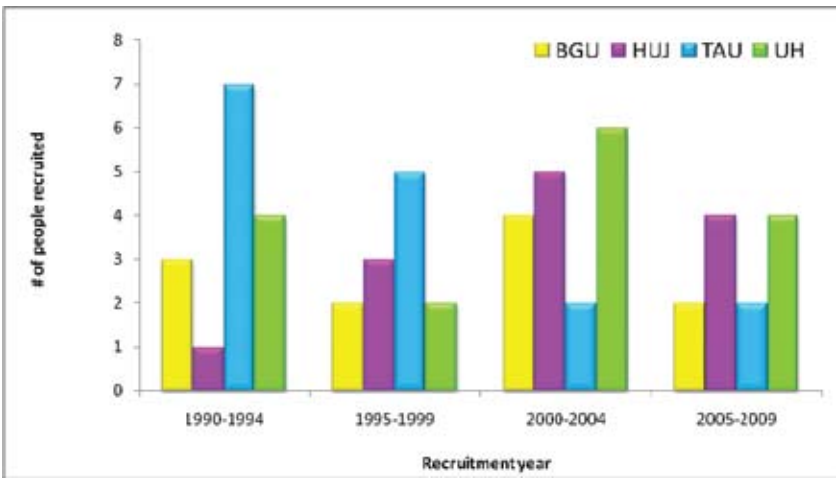


Figure 7 – numbers of recruits per university in five year bins over the past two decades.

We calculated the number of new recruits *vs.* that of retirements in the four major universities, asking whether academic positions were lost upon retirement or whether new faculty members in this field took the place of the retirees (Figure 8). This analysis was carried out only for the past 20 years, since we have no predictions for future recruits. It encompasses only four data points so we did not attempt statistical analysis, but general trends are quite clear.

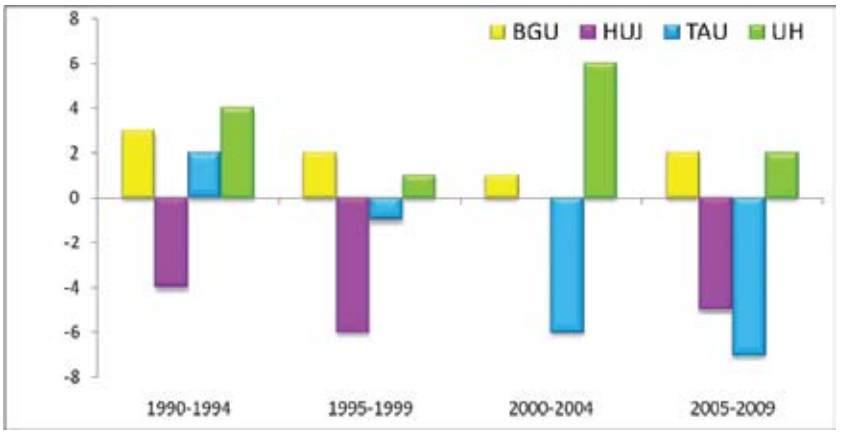


Figure 8 – number of recruits minus number of retirees by university, in five year bins. If number of new recruits equals that of retirees – we expect zero, in which case the data match the x axis.

In the past 20 years, as biodiversity research grew rapidly in the western world, the total number of Israeli scientists in this field decreased by four, i.e. 5% (to the sum total in Figure 8 we add four newly hired faculty members at the three other universities and three retirements at BIU; see Figure 3). The pattern at UH and BGU is that of growth. In HUJ there appears to be a significant decline during the 1990s, which continues a trend established already in the '80s. This trend is experienced also during the past five years.

An even more jarring pattern appears at TAU; in contrast to the global trend we see a very major decrease in the past decade. The field lost 13 positions at TAU during the past decade – a reduction of more than a third of the discipline. Because TAU has Israel's largest biodiversity program, this sharp reduction accounts for a significant part of the system-wide pattern of decrease.

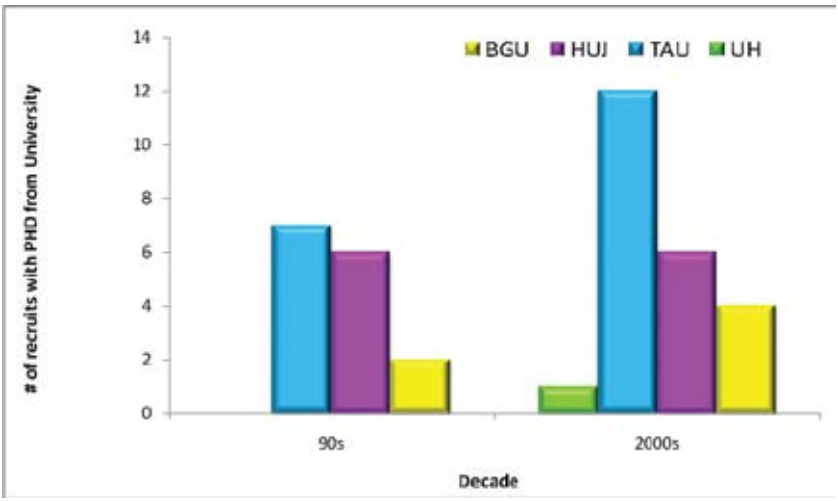


Figure 9 – numbers of PhD graduates who were subsequently hired as faculty members in an Israeli research university

In the past 20 years 59 new biodiversity scientists were recruited in Israel, 29 during the '90s and 30 from the beginning of 2000 (three of them have already retired). Some did their PhDs abroad: ten went abroad for their studies and another six are new immigrants with regular academic positions (most were recruited during the '90s; a few have already retired). However, the majority did their PhD work in Israel: BIU, WI, and UH contributed very little (1 each); the only UH graduate was hired by UH and the only BIU graduate was hired by BIU. BGU graduates hired, while showing a trend of increase (Figure 6), were hired as faculty members either by BGU or UH (3 each), the younger, geographically peripheral universities. TAU and HUJ contributed most; the growing difference between TAU and HUJ graduates in the past decade (Figure 9) may reflect the highly significant cuts in HUJ biodiversity researchers in the '80s and '90s, which opened a big gap in faculty between these two programs. This gap is now narrower due to the serious cuts in this field at TAU in the past decade.

In the past two decades in Israel more than 75% of PhDs who were subsequently hired were trained either at TAU or at HUJ, and they were hired by all Israeli universities. Based upon these data and in view of the major cuts at HUJ during the '80s and '90s and in particular those at TAU in the past decade, there is serious cause for concern regarding the pool of future scientifically competitive recruits in biodiversity research in Israel's seven research universities. This is particularly disturbing in view of the major retirement wave in the coming five years. So far the highest number of new recruits in biodiversity research within a five year period was 16, but now 22 will be required if we are to maintain the current situation which is already reduced.

In sum, biodiversity research, growing in focus and breadth globally, deteriorated in Israel over the past two decades. The number of scientists has not changed in spite of a growth of 24% in the number of faculty positions in Israeli research universities. The number of positions in Israel's more prominent universities has decreased dramatically and is balanced by an increase in the smaller and peripheral universities, some of whose members work under conditions that are less favorable than in other Israeli universities, and whose overall rating is much lower. In particular in the past decade six faculty members were hired by Oranim while only three were hired for the Department of Evolutionary and Environmental Biology at the Mt. Carmel Campus of UH. However, in the coming five years five faculty members of the Department of Evolutionary and Environmental Biology retire, and only one at Oranim. This implies that UH, which has undergone significant growth in the past two decades, may be shifting to relatively more positions at Oranim seminar, where the scientists do not enjoy the working conditions of the other universities (see Appendix 3).

Because most of the new recruits in the past two decades did their dissertation work at TAU or HUJ, the severe cuts in these programs bode ill for future recruitments in this field.

Research environments

We divided the biodiversity researchers by their research environment (Figure 10). The majority of scientists study terrestrial systems. **Only two scientists focus on aquatic systems and both are scheduled to retire in the coming five years**. **One of them is Israel's sole wetland ecologist.** Wetlands are a focus of much attention globally both because they are often threatened habitats and because they provide crucial ecosystem services including water filtering and bioremediation. Professionals working for the Ministry of Environmental Protection require university level training, and many open research questions remain for the management of natural and other wetlands in Israel. However, within two years there will be no scientist in an Israeli university able to carry out research or train graduate students, and nobody for practitioners to rely upon.

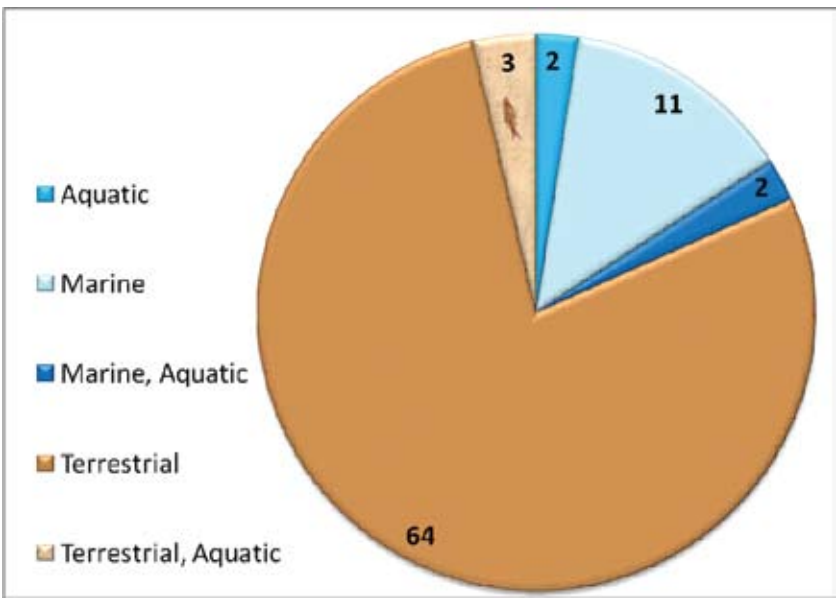


Figure 10 – biodiversity researchers divided by study environment. Modelers which study various systems were excluded from the analysis.

Another five scientists study aquatic systems but also terrestrial or marine systems. The aquatic and marine group comprises a

fish expert, scheduled to retire within three years, and an expert on marine and aquatic sponges. The terrestrial and aquatic group comprises two researchers who study also amphibians and a newly hired malacologist whose precise research program is yet to be defined.
It should be noted that in the IOLR and its Kinneret and Eilat laboratories there are some active scientists in marine and limnological fields, who cooperate in research and training with university scientists. However, they can only complement, not substitute, research, teaching, and training at a university.

A focus on the marine realm – Micha Ilan

Israel lies between two distinct marine environments: the Eastern Mediterranean and the Red Sea. The two environments are different and until recently were totally separated. The Mediterranean fauna is heavily influenced by Atlantic elements and the Red Sea is an extension of the Indian Ocean with Indo-Pacific fauna and flora. During the last century a major faunal migration of Indo-Pacific species occurred via the Suez Canal to the Eastern Mediterranean. Thus, it presents a unique opportunity to study a variety of topics and also conduct a comparative study within a very close geographical distance that in other places on the globe are separated by thousands of KM. Moreover, beyond their basic scientific value, studies of both seas have high environmental and economic significance: the Mediterranean as an environment suffers various sources of pollution (chemical, organic, brine from desalination plants) and there is a regional effort to halt and manage it. These efforts in themselves have economic significance and should enlighten decision-making. The Mediterranean is also used for fishing, an economic activity whose management requires profound understanding of marine environments and biota. The spectacular coral reef on the Gulf of Aqaba has economic value

for tourism. In addition, the biodiversity of marine environments harbors large biotechnological and pharmaceutical potential.
These environments have traditionally been studied mostly by researchers from the largest universities HUJ and TAU; recently BIU replaced HUJ with more researchers in this field. Currently there are 19 researchers of whom 6 have already retired (2 much earlier than the expected date). Of the 13 left 4 (3 of them from TAU) will retire within 3 years (by 2013). One more will retire within 6 years another within 9 years; then for 6 years no retirement is anticipated. The researchers study several groups of invertebrates mostly in the Red Sea. The only person who studies marine plants is expected to retire within 2 years. The trajectory thus is that without new recruitments within 6 years a severe decrease in number of researchers will occur – especially in TAU (2 will be left from 9), BGU and BIU (already 2 each), UH (1) and HUJ (none) leaving 7 researchers studying various aspects of marine biology.

Taxa studied
Overall we identified 59 scientists who study primarily animals, 19 who study primarily plants (including fungi), and 9 who study both. Ecologists in general tend to study a combination of animal and plant populations, so generally they publish studies of a variety of organisms, although they may actually have primary expertise only in a single taxon. It should be noted that these taxon based groupings are extremely wide; for example plant scientists are a disparate group that ranges from fungal systematics to carbon sequestration.
We divided the scientists by the taxa upon which their studies focus (Figure 11). Almost 30% of all researchers and almost 40% of those that focus on animals study vertebrate species; some additional 15% of the latter group study also invertebrates. While vertebrates constitute only a very small part of the local biota, this bias is not uncommon worldwide.

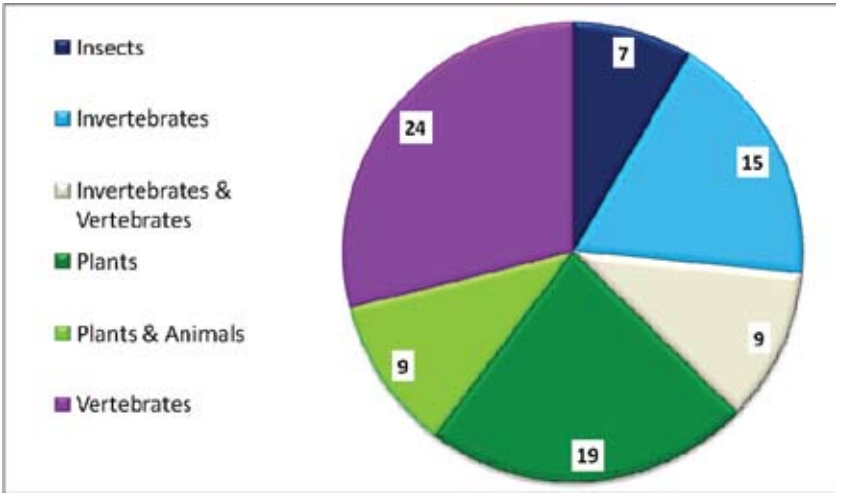


Figure 11 – scientists divided by taxa studied. Invertebrates category includes non-insects only. Modelers which study various systems were excluded from the analysis.

A closer look at the lists of taxon specialization reveals that **Israel's two fish experts retire in the coming five years, as does Israel's only expert on spider biology, Israel's only expert on fungi, etc**. Too many taxa, some of them quite large, are dependent upon a single scientist, and statistically that scientist is quite likely to retire shortly. Moreover, once the expertise in a local taxonomic group is lost, it may be difficult or even impossible to reestablish it.

Basic zoological and botanical research is a particular challenge. Because of trends in science, funding opportunities, and impact factors, biological expertise in a taxon is not highly rated and is not sought particularly in Israeli universities, although without doubt it is a crucial tier in producing ecological and evolutionary understanding. An inherent bias in a small country surrounded by a region with little science is that producing quality scientific data on species that are not studied by the rest of the world's scientific community deflates the potential for citations, and by modern academic standards artificially 'reduces' the value of the research.

The only universities with a vested interest in research in systematics and taxonomy, and with responsibility towards producing this scientific knowledge, are HUJ and TAU. These two universities are responsible for the national collections of natural history. In the '80s and several times since, the Israel Academy of Sciences and Humanities in dialogue with the universities has recommended that the HUJ and TAU collections be considered national collections and fulfill the missions of a national museum (as is the case in Norway, Denmark, and some other countries). However, HUJ has retired most of its zoologists and botanists already in the '80s and '90s, and the severe cuts at TAU in the past decade renders such hiring extremely difficult. Special care is required at the national and university levels to ensure that this basic biological knowledge and these skills are maintained for the benefit of science and society.

Specific fields

Biodiversity research as we defined it comprises a wide array of scientific fields. We therefore took a closer look at the status and trajectory of specific fields within it (Figure 12). These field designations were determined by us and are inherently overlapping. Many members of the Israeli scientific community are somewhat generalist by necessity and would fit into several of our designated categories. On the other hand, fields such as evolution in our survey comprise many disciplines such as evolutionary development, phylogenetic analyses, ecomorphology, population genetics, etc. Ecology, in particular, includes everything from bird migration to carbon cycles and ecotoxicology.

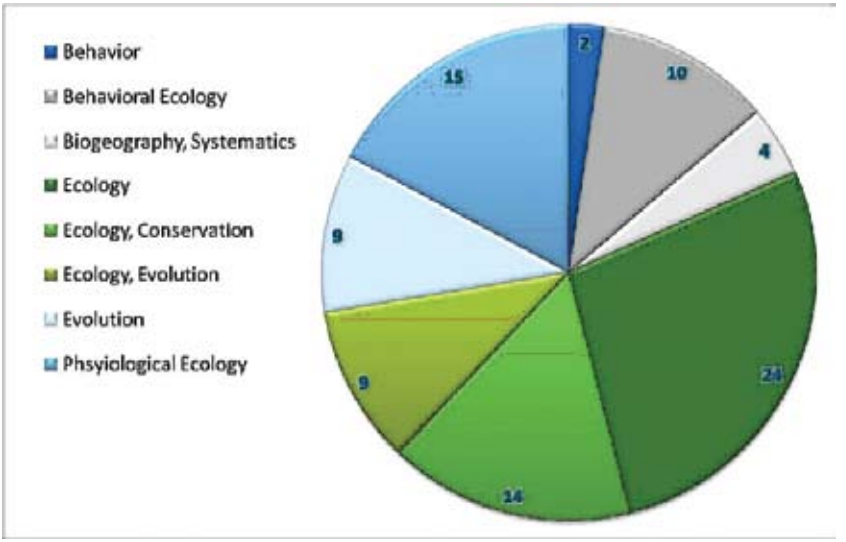


Figure 12 – biodiversity researchers divided by gross scientific disciplines

A crucial point to note is that many of the fields are studied by a single or very few individuals in the entire country. The implication is that these fields are susceptible to extinction because of stochastic events, or may simply dwindle into extinction if care is not taken. Some of these fields have direct applications; some are basic to such applications; some have direct or indirect economic benefits. Maintaining them requires a measure of responsibility at the university and national scales. Taxonomy and systematics are an excellent case in point, but there are also others, such as ecotoxicology or wetland ecology. These fields usually appear in Figure 9 within a wider category; therefore we took a closer look into the research coverage and trajectories within each category. The brief status of the fields of research follows. Note that because of the difficulty to categorize research fields, the numbers below may differ somewhat from those above and they do not sum up to 87.

Behavior and behavioral ecology – Abraham Hefetz

The discipline of behavioral ecology has emerged in the past three decades when an increasing number of studies have shown that animal behavior is not detached from its ecology and evolutionary history. It has immense importance for our understanding of biodiversity because it provides a tool for understanding animal-animal and animal-plant interactions, an important component in population demography, thence biodiversity. The study of behavior *per se* has shifted more and more towards animal psychology and evolutionary psychology on the one hand, and as a sub-discipline of neurosciences on the other hand.

There are currently only two scientists whose research focus is behavior *per se*. The majority of scientists are either behavioral ecologists or evolutionary ecologists. Since the number of scientists in both disciplines is rather small, it is best to clump them together in order to get a better overview of the field. Today there are about 20 active scientists (non-retired) whose research encompasses a variety of animal groups, invertebrates and vertebrates. Age distribution of the active scientists is somewhat bimodal, with **close to half retiring within the next 6 years**. There is a marked gap of 6 years before the next wave of retirement starts. This may prove problematic unless there is specific recruitment. The high diversity of animal groups and the themes studied have both advantages and disadvantages. It allows the coverage of many subjects in behavioral ecology but the groups working in specific aspects are too small to create a cooperative and productive critical mass.

Evolution – Arnon Lotem

In recent decades, evolutionary theory has penetrated almost all fields of biodiversity research, and its critical role for biological thinking is increasingly recognized also among people from

the bio-med community (as well as among non-biologists). However, not many researchers in Israel can currently be classified as evolutionary biologists, or can be viewed as experts in evolutionary theory. About half of the researchers classified as ecologists, evolutionary ecologists, or behavioral ecologists (in Figure 9) integrate the study of evolution in their research. Under the more restricted field of Evolution (see Figure 9) we classified 9 people. Two of them work on the interface between evolution and development (i.e. Evo-Devo); two others are theoretical biologists dealing with evolutionary and population genetic theory; and only one specializes in the reconstruction of phylogenic trees based on molecular data (an essential field for modern taxonomy). The other four researchers combine different aspects of population genetics with biogeography, conservation, and speciation. No active researcher in Israel is currently working on natural selection or speciation in the wild, implying that this central aspect of evolutionary biology research is missing in Israel. While some of the reasons for the decentralization of the field of Evolution in Israel are related to its successful spread into other fields, it is still important to maintain a community of hard-core evolutionary biologists of the highest academic standards.

Ecology – Uriel Safriel and Tamar Dayan

Ecology has indisputably become a leading biological discipline, and owing to the global environmental crises, a household term. At the global scale ecology as a research field is enjoying a major renaissance (Figure 1). In addition to their basic scientific work, ecologists provide the theoretical basis for much of conservation biology and are increasingly called upon to make science-based recommendations to decision-makers.

While we categorized 19 scientists as exclusively ecologists, a further six are behavioral ecologists with an ecological approach, another seven are physiological ecologists with an ecological angle

to their research, nine are ecologists who are also conservation biologists, a further three are also biogeographers, and several are evolutionary ecologists, bringing the sum total to 59 scientists. A much smaller number would qualify (< 50%) if our measure was publishing primarily in ecological journals.

Of the currently active ecologists (full 59 scientists list) 10 are marine ecologists, two are aquatic ecologists, and two are both marine and aquatic ecologists. Two are theoretical ecologists. By the end of 2014, 24% (14) of the people with some ecological angle to their work will have retired, and by the end of 2015, 30% (18), including the only two fish ecologists, the only ant specialist, the only spider ecologist, etc. Because of the significance of some of these taxa to natural and agricultural ecosystems, this loss is worrisome. Moreover, the only wetlands ecologist and the only ecotoxicologist are about to retire in the next two or three years. **These losses are bound to have serious environmental and conservation repercussions.**

While four ecologists deal with aspects of pollination, only four biodiversity researchers are primarily insect ecologists, a very small number, and one is expected to retire within the coming five years. This implies a major lacuna in the most species-rich taxon whose biology has a strong negative and positive impact on human economy. For example, parasitoid biology, an important ecological research focus worldwide and key to science-based biological control of crop pests, is lost from Israeli universities. A TAU retiree in his mid-70s still provides support to Israeli agriculture, but no new generation is in sight. **This loss is bound to have serious economic and environmental repercussions and to limit informed decision-making in these fields.**

It is instructive to point at the areas that are currently at the cutting edge of global ecology, yet hardly addressed by Israeli ecologists, or not at all. Mentioning just a few, these would include the role of biodiversity components in the provision of specific ecosystem services, the detection of thresholds in biodiversity

losses that move ecosystems between different stable states, the nature of the bidirectional flow of services between agricultural and natural ecosystems, the role of soil biodiversity components in carbon sequestration under each of the different climate change scenarios, the expected change in ecosystem service provision under different climate change scenarios coupled with the effect of human responses to climate change on ecosystem functions, the effects of the carbon market evolution on the management of ecosystems and its indirect effects on their services, the economic implications of service tradeoffs resulting from human impact on biodiversity, the significance of plant architectural diversity on soil conservation, runoff regulation and freshwater provision, and the response of coastal ecosystems to the joint effect of rise in sea level and in sea surface temperatures. Also still very limited in Israel are the apparently indispensable tight interactions of ecology, and especially of ecosystem ecology, with non-biological disciplines, such as economics and social, policy and education sciences. Furthermore, old disciplines like social ecology, and younger ones like ecological economics need to have their own specific practitioners, rather than the current situation in Israel in which an ecological issue of economic implication is tackled by a team made of an ecologist and an economist that still do not share a common language. **These fields of research are important for adaptation to global change and ecosystems management for the provision of their services. Their weakness or absence limits informed decision-making at the national scale.**

Plant ecology and Plant systematics (including Fungi) – Jaime Kigel

There are currently 23 active, non-retired, scientists in the research universities of Israel whose main research activities are related to different fields of Plant Ecology and Plant Systematics, compared to 29 scientists five years ago. Only 2 additional plant ecologists were

recruited during this period. Seven scientists will retire in the next 5 years. If the current balance between retirement and recruitment will be maintained, a bleak future is expected for Plant Ecology and Plant Systematics in Israel. Representation of plant ecologists in the academic staff of the research universities is quite low: 2 at TAU (one retiring soon), 6 at HUJ (2 retiring), 4 at BGU, 1 in the Technion, 1 at the Weizmann Institute, and 9 (2 retiring) at UH. Most current research is centered on terrestrial plant ecology, with little or no efforts in aquatic and marine plant ecology. Distribution of presently active plant ecologists among research fields is quite biased: spatial and temporal processes at the plant community and landscape level (9), population genetics of wild plant species (4), plant ecophysiology (2), modeling (3), pollination ecology (3), dispersal (2). Of the non-retired scientists, only 2-3 have a good background in floristics and systematics of seed plants, but lately they are less active in these subjects. There are practically no active experts in lower plants (ferns, mosses) and algae. Fungal taxonomy is practically an "extinct species" in our universities. Furthermore, there are no academic curators in the National Herbarium and the Ecological Botanical Garden at the HUJ. Finally, very few scientists in Israel are involved in plant systematics and evolution of higher taxa based on molecular biology approaches, in contrast to current patterns in developed countries.

Physiological ecology – Noga Kronfeld-Schor

Physiological ecology takes a multidisciplinary and integrative approach that encompasses both field and laboratory based research, from the molecular to the community level, with an evolutionary overview. It is extremely important for the understanding of ecological processes, and hence for conservation practices.

Physiological ecologists are uniquely trained to investigate the mechanisms and capacities of organisms to adapt to changing

environments and climates, and therefore to assist in predicting the degree of threat to organisms which is essential for setting priority areas for conservation action.
As in other fields, physiological ecology includes scientists working on diverse fields only remotely related, including plant physiology, vertebrate and invertebrate physiology, aquatic, marine and terrestrial organismal physiology. Israel used to have a world leading, productive team of physiological ecologists. The future of this research field is disturbing. Out of 26 physiological ecologists in our data set, 11 have already retired. Of the rest, another 12 are scheduled to retire by 2017, which, without recruitments, will leave Israel with **only 3 physiological ecologists**: one plant physiologist at HUJ, one vertebrate physiologist at TAU, and one invertebrate physiologist at UH -Oranim. Such a small community of physiological ecologists is far below the critical mass for productive science in the field, and will have a devastating influence on research, teaching, and graduate training.

Conservation biology – David Saltz

Conservation biology is a crisis discipline aimed at identifying threats to biodiversity, and developing and providing tools to combat these threats. As such, it requires a multidisciplinary approach and most fields of biodiversity research mentioned herein have conservation connotations. The field is probably the fastest growing field in biology in the past 30 years resulting from the recognition of the extent of the threats to biodiversity. Departments of Conservation in academic institutions in the US were unheard of before 1980 as were faculty members defining themselves as conservation biologists. Currently departments including the term conservation in their name exist in all states. The leading journal in this field ('Conservation Biology') was established only in 1986 and

is considered today one of the ten most influential journals amongst biodiversity related journals in the past century. It is listed as one of the 10 most influential scientific journals of the past century.
We identified 39 active (non-retired) scientists from the list described herein as involved in some capacity in conservation issues. However, for only 14 Israeli scientists is conservation part of their research program. If one considers the proportion of publications in applied ecology and conservation oriented journals as an index of conservation-related scientific activity, most of the 38 scientists (25) make little to no contribution to this field (Figure 13; for two scientists data were not available). Only three scientists in the entire community publish over 30% of their work in conservation-oriented journals.

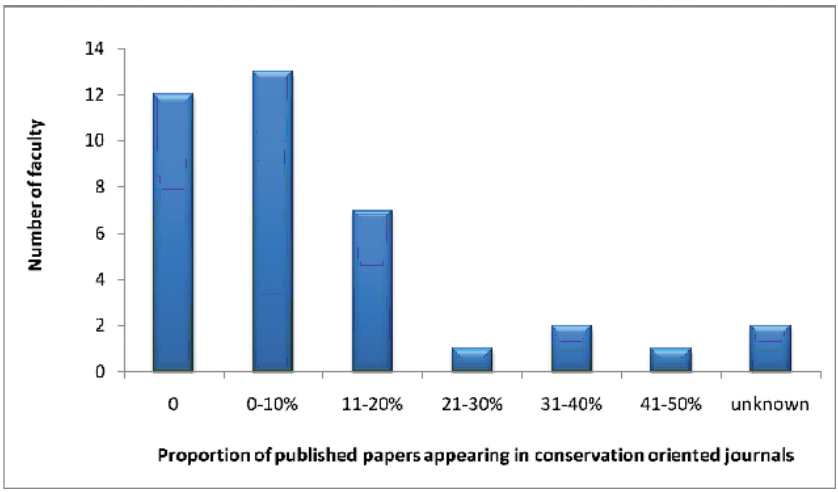


Figure 13 – Proportion of publications in conservation oriented journals per active scientist for scientists that we considered as involved in conservation.

Systematics and taxonomy – Menachem Goren

Identifying and classifying living organisms and elucidating their evolutionary relationships are basic to all biodiversity research as well as a wide array of biotechnological uses. It is also crucial for

a modern agriculture, for nature and environmental conservation, and to human health. While not all of Israel's taxonomists should be university faculty members, a hard core should remain in the higher education system to carry out university level research and teaching, to train graduate students, and to give scientific support to practitioners in conservation and agriculture.

Only four systematists conduct research in Israeli universities: three of them are faculty members at TAU (fishes, flies, soft corals), and one at UH (fungi). Three are scheduled to retire within the coming five years and the last one will retire in six. **Thus, university level teaching and research in taxonomy and systematics as well as graduate student training are nearing an abrupt end**. Taxonomy and systematics are a crucial basis for most of biological research as well as for conservation, agriculture, health, and biotechnology.

The Israel Taxonomy Initiative was established to help save this field of basic research in Israel, but without concerted efforts by the higher education system and at university levels – Israeli taxonomy and systematics will disappear. This situation stands in stark contrast to the global effort to promote this crucial field of research (see the Global Taxonomy Initiative as part of the Convention on Biological Diversity, http://www.cbd.int/gti/).

In sum, because so few scientists study such a diverse field, some disciplines have lost or stand to lose shortly the critical mass required for a strong and viable field of research. Of course, a small country may not be a world leader in all fields of research, but most of those listed are quite basic and most form the scientific basis for for management, conservation, agriculture, and sustainable exploitation of biodiversity.

Some fields of biodiversity research have already declined or are expected to decline in the coming few years to the point of disappearing entirely. Systematists have declined and will become extinct in few years. This field is crucial and its loss will have serious economic and environmental ramifications. In

coming years it is crucial that new systematists are trained and hired in Israel's research universities. Wetland ecology, crucial for studying and managing Israel's wetlands and their services, is about to become extinct, as is ecotoxicology, both fields of major environmental significance. Many elements of plant biology and ecology are dwindling to the point of loss, and require special care. The same is true in general for expertise in various taxonomic groups, some of them quite significant economically: spiders, fishes, marine mollusks stand out, but there are others. A balanced hiring policy should consider these needs. Particularly surprising is the expected dramatic dwindling in the field of physiological ecology. This field is vital to understanding the underlying mechanisms affecting the behavior, distribution, and evolution of animals, and is particularly important in times of global change as part of the effort to model the expected trajectories of species and communities. It is also key to understanding large-scale patterns of energy flow within the ecosystem, and its dwindling to the point of loss is worrisome. Conservation biology as a field of research appears not to have developed yet in Israel. A new field, formally established in the mid '80s, it is developing very rapidly in the world. While a number of Israeli ecologists and behavioral ecologists do study aspects of conservation, it appears not to be the focus of research for the overriding majority.

Organizational barriers to the development of the field

In the past half century two scientific cultures have developed in the life sciences: on the one hand – study of sub-cellular mechanisms ('molecular biology'), with a very strong focus on biomedical research; on the other – biodiversity research at all organizational levels, aimed at understanding ecological and evolutionary patterns and processes. Starting in the '60s and until the later '80s', biomedically oriented research developed dramatically, often at the expense of biodiversity research.

A conflict developed between these scientific cultures, with 'molecular biology' usually having the uncontested upper hand. Starting in the later '80s and often with specific support and encouragement, biodiversity research has begun to gain strength again and is a major focus of research worldwide. This scientific revival is not yet evident in Israeli universities, where scientists conducting biodiversity research remain a very small fraction in the biomedical community, hence under-represented in science decision-making.

A technical obstacle is the level of research funding, which is potentially higher in medically oriented research, and where many more funding opportunities exist. A higher level of funding translates also into university level national support, as well as numbers of graduate students, again a measure of national support, and in a time of budget cuts, this is increasingly a problem

Moreover, all too often biodiversity research is represented in various committees (Alon Fellowships Committee, Planning and Budgeting Committee of the Higher Education of Israel, various fellowships, funding, and appointments committees) by 'molecular biologists' with at best little understanding of the field, and at worst, with little appreciation of it.

A telling situation occurred in the past year, when the Council of Higher Education of Israel established a committee to review the research universities' biology faculties. The committee comprised five 'molecular biologists', all but one from faculties or institutes that have no biodiversity research whatsoever; all the relevant deans in Israel's research universities accepted the committee membership as appropriate. Only at our request was an ecologist added to the committee. Our American colleagues assured us that similar situations occurred in the US 20 years ago. Israel is somewhat provincial but a time lag of 20 years is extreme.

Appendix 1

University list, abbreviations, ratings among world universities for Israel's research universities, and number of scientists in the biology (all fields), medicine, and agriculture.

University	Abbreviations	Times rating	ARWU* rating	# Biomed
Bar Ilan University	BIU	Below 500	303-401	43
Ben Gurion University	BGU	323	303-401	202
Hebrew University	HUJ	102	64	270
Technion	TI	132	101-151	114
Tel Aviv University	TAU	114	101-151	200
University of Haifa	UH	Below 500	402-501	40
Weizmann Institute	WI	---	151-200	120

* Academic Ranking of World Universities

Appendix 2

Data fields used for survey purposes

Name
Gender
Year of birth
Specific research fields (as outlined by the researchers)
General field of research
Conservation activity
Taxonomic groups studied
Environment studied

Appendix 3

Four Israeli universities account for almost all of biodiversity research in Israel. The different programs differ in their organizational structure and in their strengths; each focuses on a somewhat different blend of fields. Moreover, they are of different breadths, they are embedded in different academic environments, and they have different academic histories.
We took a closer look at these institutions:

Hebrew University of Jerusalem – Ran Nathan and Sharon Shafir
Biodiversity research suffered dramatic cuts during the '80s and '90s at HUJ, with botanists, zoologists, and parasitologists retiring and hiring directed elsewhere. Biodiversity research at HUJ is currently conducted in two main groups, one at the Alexander Silberman Institute of Life Sciences (AS-ILS) in Givat Ram, Jerusalem (10 faculty members) and the other in the Faculty of Agriculture, Food and Environment in Rehovot (7 faculty members). Nine HUJ faculty members belong to the AS-ILS Department of Ecology, Systematics and Evolution (ESE) and one faculty member to the AS-ILS Department of Plant and Environmental Sciences. In an entirely separate teaching program at the Faculty of Agriculture, the scientists are divided between a Department of Entomology with four insect behavioral ecologists and ecologists and two plant ecologists in the Institute of Plant Sciences and Genetics. HUJ researchers have been the core of the IUI in Eilat, but currently only one member works on biodiversity-related research.
Two faculty members at Givat Ram and one in Rehovot will retire within the next five years. The AS-ILS has experienced a severe decline (31%) over the last two decades, and the number of researchers in biodiversity-related fields has declined even more drastically (45%). In the 1990s only two faculty members have been recruited to ESE, but 6 in the 2000s, comprising 20% of AS-ILS recruits in this period. Yet, no new faculty member has been

recruited to ESE over the last 3 years, reflecting overall lower recruitment at AS-ILS during this period. ESE is currently pursuing new faculty members in ecology, animal behavior, and evolution, as well as researchers with expertise in specific taxonomic groups to head the relevant scientific collections. A key obstacle in recruiting young faculty members to available biodiversity-related positions is the lack of suitable candidates, especially in systematics.

In Rehovot, a Center for Environmental Sciences and Natural Resources in Agriculture was established in 2009, mainly to promote interdisciplinary research between members of four departments: Entomology, Plant Pathology and Microbiology, Soil and Water Sciences, and Agricultural Economics and Management. This is part of a program to build a new institute with a similar mission, which will jointly house these departments. Building of the new institute is arrested by lack of funds. The entomology department currently has an open position for an entomologist studying insect-plant interactions, with relevance to the mission of the new institute.

Biodiversity research at HUJ combines diverse areas including molecular evolution, evolution and development, animal behavior and ecology at various levels of organization, using modeling, fieldwork, advanced technology, and molecular techniques as research tools. HUJ keeps its strength in ecology and evolution, and has recently augmented research in animal behavior, but the field of systematics has experienced drastic decline. There is currently only a single non-retired genuine systematist at HUJ, a member of the department of plant and environmental sciences who specializes in prokaryotes, a topic not yet covered in the present report. HUJ holds about half of the national collections of natural history, established by world-renown zoologists and botanists that founded biological research in Israel. Yet, only two faculty members, an evolutionary developmental scientist and an archaeozoologist, currently act as academic curators in the collections. The National Herbarium, the largest of its kind in Israel and the Middle East, no longer has a curator. Considerable efforts are being made to recruit a suitable candidate.

HUJ has the largest Botanical Garden in Israel at Givat Ram with 10,000 species, as well as the largest living collection of the wild flora of Israel in the Ecological Botanical Garden at Har Hatzofim. The Botanical Garden at Givat Ram has a full time chief scientist (a field botanist with PhD from ESE), a retired PhD botanist works in this Garden on a daily basis, a scientific committee has recently re-established, and an ecologist serves a member of the board of directors in the last 5 years. The Givat Ram Botanical Garden went through a remarkable recovery program over the last 5 years, and is currently actively promoting research and conservation of the Israeli flora and exploring new grounds for scientific development. A new initiative to establish a long-term scientific program is currently under consideration, potentially incorporating a national center for plant biodiversity. The Har Hatzofim Garden currently has no chief scientist - this function is temporarily being served by the scientific committee of this Garden.

Tel Aviv University – Micha Ilan

Biodiversity researchers at TAU are members of the Department of Zoology (22 biodiversity researchers, six of whom are scheduled to retire within the coming five years) and Department of Plant Sciences (five biodiversity researchers, three of whom are scheduled to retire within the coming five years). The two departments share an undergraduate and a graduate program, and the focus is integrative biology – with physiological ecology, systematics, behavior, behavioral ecology, ecology, and evolution. TAU has held the leaderships in some fields in the past two decades, such as systematics, wetland ecology, and ecotoxicology, and has the country's last department that identifies itself as 'zoology', reflecting a commitment to basic biodiversity research. So the serious cuts in this program (see below) impact the entire field in Israel. TAU also has a very strong tradition in contributing to conservation and to public education. With 70% of the *Nature* publications and 40% of the *Science* publications in the Faculty of Life Sciences in the past dozen years, the Department of Zoology

had a particularly strong research program, reflected also by a high percentage of Alon Fellows, honorary degrees, and prizes.
However, the TAU program suffered severe losses in the past decade, when the university also closed down its Institute of Nature Conservation Research, the only one of its kind in Israel. This institute, established during the mid '60s, aimed to provide scientific support to the Israel Nature and Parks Authority and the Ministry of Environmental Protection. The trajectory of retirements in the coming five years (a full one third of biodiversity researchers in the Faculty) puts the TAU program at serious risk. Although TAU has downsized in the past decade, the downsizing in number of biodiversity researchers (35%) far exceeds that of the Faculty of Life Sciences (22% currently and planned to stabilize at 18%).
TAU holds half of the national collections of natural history which are considered a national research infrastructure and enjoy government funding as such. The collections, a dynamic archive of biodiversity, are used annually by over 200 scientists, are used for teaching ca. 20 university level courses (of various institutions), and provide scientific support to agriculture and conservation. The collections still enjoy six curators and five associate curators, all faculty members of TAU. However, two of the three systematists are scheduled to retire within the coming five years and the third retires in six. TAU has also two additional research and teaching facilities for biodiversity research – botanical gardens and a zoological garden, comprising together the best record of terrestrial fauna and flora in Israel. The gardens are used for research, teaching, training, nature conservation, and public education. Both suffered from severe budgetary cuts, and from lack of institutional support and long-term planning. The botanical gardens now enjoy government support hence a more stable and successful existence. The proposed new natural history museum building for the collections together with the botanical and zoological gardens may provide a unique opportunity to establish a center for biodiversity research and education at Tel-Aviv University based on existing infrastructure.

University of Haifa – Uri Shanas

Biodiversity research at Haifa is conducted in two campuses – the main Mt. Carmel campus and the Oranim Campus. At Haifa the traditional strength has been research within the Institute of Evolution. A decade ago a Faculty of Sciences & Science Education was established on its basis and on the basis of the Biology Department in Oranim campus, and it now comprises also ecologists, physiological and behavioral ecologists. The biodiversity researchers are distributed today among several departments, the two major ones are the Biology Department in Oranim and the Department of Evolutionary and Environmental Biology. The other researchers are part of the School of Marine Sciences, and the Department of Geography. The undergraduate training in this field is conducted solely in Oranim campus by the department of Biology, and the graduate training is based in the Haifa campus, conducted by researchers from both the Biology Department in Oranim and the Department of Evolutionary and Environmental Biology. The department in Oranim is heavily oriented into biodiversity research, as more than half of the biology faculty members are biodiversity researchers. The commitment of the department is manifested in a newly established a mandatory Conservation Biology course for all biology undergraduates, and numerous field trip courses dedicated to biodiversity. The researchers of this department are backed with infrastructure that Oranim provides such as a small Zoological garden, a large botanical garden and various collections, including two national ones. Nevertheless, the department in Oranim suffers from major drawbacks as it is not supported by the Council for Higher Education, but by the Ministry of Education. The faculty members of this department do not receive much of the standard benefits of other similar departments in Israel in general, and in Haifa in particular. This includes a heavy teaching load, a lack of startup money for new faculty members, lack of assistantship, and inferior salary conditions. Therefore, even though the department is biodiversity oriented, its recruiting competence is relatively low. It is expected in the following 5 years

to replace one of its 8 biodiversity researchers who is about to retire. The Department of Evolutionary and Environmental Biology was established to promote the training of master and PhD students in these fields. There are 9 biodiversity researchers, 4 of whom will retire in the next 5 years. Much of the department facilities depend on Oranim and on the Institute of Evolution. However, recently the Carmel Center was established and is expected to utilize the nearby Hai Bar facility and the nearby Biosphere reserves into new studies and collaborations with the Israel Nature and Park Authority.

Ben Gurion Univesity of the Negev – David Saltz

Biodiversity researchers are divided between the main campus at Beer Sheva - mostly at the Department of Life Science (6) and one at the Department of Geography, and the Jacob Blaustein Institutes for Desert Research at Sede Boqer – mostly at the Institute for Dryland Environmental Research (7) and two at the French Associates Institute for Agriculture and Biotechnology of Drylands. In addition there is one researcher at the IUI in Elat. The focus of research at Beer Sheva is ecology, while the focus at the Institutes for Desert Research is, as expected, the study of desert biodiversity. The teaching program is a joint program between the Department of Life-Sciences and the Blaustein Institutes for Desert Research via its graduate teaching program, The Albert Katz School for Desert Studies. All researchers in ecology *sensu lato* participate (except for the member of the Department of Geography). The program includes an undergraduate degree offered by the Department of Life Sciences with an emphasis in Ecology, and a graduate degree (M.Sc. and Ph.D.) offered either by the Department of Life Sciences or the Albert Katz International School for Desert Studies at Sde Boqer. There is a joint teaching committee and course requirements are the same at both. Graduate Student Seminars are given in Beer Sheva and weekly ecology seminars (which the students have to attend) are in Sede Boqer. The program focuses mostly on organism ecology (mostly behavioral) and has a strong conservation orientation (five courses).

Appendix 4

The following individuals took part in the team that produced this report:

- Shimshon Belkin is a professor at the Institute of Life Science at HUJ, past director of the university's Environmental Studies Program and current director of its inter-faculty Biotechnology Program.
- Zvi Ben-Avraham is a Professor of Geophysics and Head, Minerva Dead Sea Research Center, TAU, and member of the Israel Academy of Sciences and Humanities.
- Yehudith Birk is a Professor at the Institute of Biochemistry, Food Science and Nutrition, Robert H. Smith Faculty of Agriculture, Food and Environment, HUJ, and member of the Israel Academy of Sciences and Humanities.
- Tamar Dayan is a Professor of Zoology and the director of the national collections of natural history, TAU.
- Menachem Goren is a Principal Research Associate, TAU; Curator of fish collection at TAU; Chairman of the Committee for Fauna and Flora of Israel - The Israel Academy of Sciences and Humanities.
- Abraham Hefetz is a Professor of Zoology, TAU.
- Micha Ilan is a Professor of Zoology and Chair of the Department of Zoology, TAU.
- Jaime Kigel is a Professor in Plant Sciences, Head Botanical Garden at Har Hatzofim, HUJ
- Noga Kronfeld-Schor is a Senior Lecturer in Zoology and the Academic Director of the I. Meier Segals Garden for Zoological Research, TAU.
- Arnon Lotem is an Associate Professor of Zoology, TAU.
- Yossi Loya is a Professor of Marine Ecology, TAU, and member of the Israel Academy of Sciences and Humanities.
- Yael Lubin is a Professor of Ecology in the Mitrani Department of Desert Ecology at BGU.

- Raphael Mechoulam is a Professor of Pharmacology at the Faculty of Medicine, HUJ, and Head of the Natural Sciences Section, the Israel Academy of Sciences and Humanities.
- Shai Meiri is a Senior Lecturer in Zoology and Curator of Tetrapods, Tel Aviv University Zoological Museum.
- Ran Nathan is a Professor of Ecology and Head of the Alexander Silberman Institute of Life Sciences, HUJ.
- Oded Navon is a Professor and the incumbent of the Gerald M. Friedman Chair in Geology, Institute of Earth Sciences, HUJ.
- Uriel Safriel is a Professor Emeritus of Ecology, the Hebrew University of Jerusalem.
- David Saltz is a Professor of Conservation Biology and is director of the Blaustein Center for Scientific Cooperation.
- Sharon Shafir is an Associate Professor of Entomology and Head of the Department of Entomology, Faculty of Agriculture, HUJ.
- Ehud Spanier is a Professor at the Department of Maritime Civilizations, the University of Haifa.
- Uri Shanas is a Senior Lecturer and Head of the Department of Biology, University of Haifa-Oranim.
- Dan Yakir is a Professor and Head of the Department of Environmental Sciences and Energy Research, the Weizmann Institute of Science.
- Amatzia Genin, Professor of M arine Ecology and Head of the Ecology, Evolution & Behavior Curricular Group at the Hebrew University of Jerusalem and Scientific Director of the National Monitoring Program of the Gulf of Eilat (Aqaba) at the Interuniversity Institute of Marine Sciences of Eilat.

Yossi Steinberger (BIU), Aaron Kaplan (HUJ), Zvika Abramsky (BGU), Abraham Haim (UH), Marcelo Sternberg (TAU), Bella Galil (IOLR), Ilan Chet and Yossi Segal (Israel Academy of Sciences and Humanities), Marc Feldman (Stanford University) and two senior administrators in Israel's higher education system provided data and valuable criticisms and insights to this report.