Chapter 17
Insect Conservation Biology: What Can We Learn from Ornithology and Birding?

David L. Pearson and Fabio Cassola

17.1 Introduction

In a search for patterns within the history of scientific studies, historians have analysed several fields from physics (Nye 1996), astronomy, and computer software (Leadbeater and Miller 2004) to biology (Killingsworth and Palmer 1992; Pearson and Cassola 2007). Are there steps common to all scientific endeavour? What recognisable patterns of change take place and what are the significant factors causing the changes? How can they best be compared?

Apart from satisfying intellectual curiosity, a solid understanding of factors in the development of science could prove useful for conservation biology in many ways. It could: (1) help determine priorities for funding agencies, (2) enable biologists to better communicate with and inform non-scientific decision makers, (3) focus individual researcher goals, (4) prepare cooperative research agendas, and (5) formulate more reliable and efficient models for management and conservation goals.

The goal of this chapter is to test if the experiences from one field of interest with a long history of advances and mistakes, such as ornithology, can be used to help guide the goals and emphases of a less developed field, such as the study of tiger beetles (Fig. 17.1).

17.2 Materials and Methods

History does not lend itself to experimental repeatability (Gould 1989), and thus tests of patterns in history rely on alternative methods. One of the most reliable techniques for answering pertinent historical questions and testing for patterns is

D.L. Pearson (✉)
School of Life Sciences, Arizona State University, Tempe, AZ 85287-4501, USA
e-mail: dpearson@asu.edu

F. Cassola
Via F. Tomassucci 12, 00144 Rome, Italy (Studies of tiger beetles. CXCII)

T.R. New (ed.), *Insect Conservation: Past, Present and Prospects*,
DOI 10.1007/978-94-007-2963-6_17,

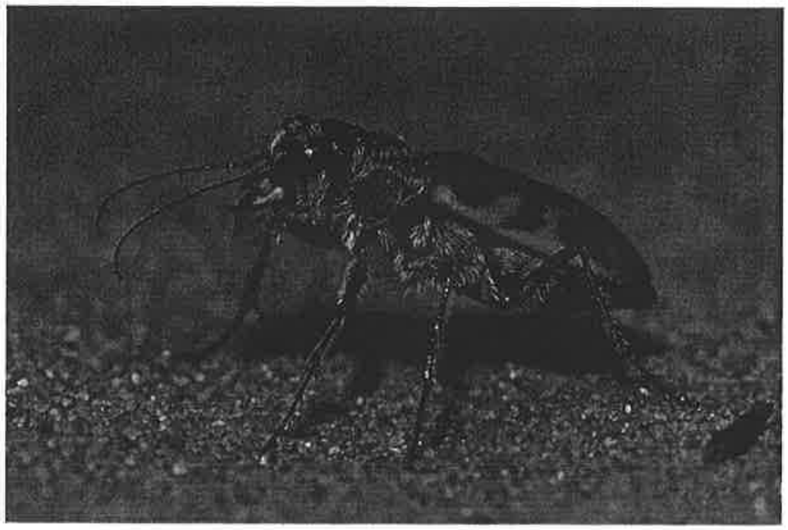

Fig. 17.1 Adult Big Sand Tiger Beetle (*Cicindela formosa*) from Michigan, USA (Photograph by Rod Planck)

by using insights from one field to tell us something about another – a process called consilience by historians (Wilson 1998). In so doing, we can make sense of the past and perhaps anticipate the future (Gaddis 2004). One general model of the history of science proposed to predict historical patterns in biology is the General Continuum of Scientific Perspectives on Nature (GCSPN) (Killingsworth and Palmer 1992). According to the GCSPN, earliest biological studies begin with natural history and concentrate on observations in the field and specimen collecting, followed by observing and measuring in the field, manipulations in the field, observations and manipulations in the laboratory, and finally enter theoretical science, including systems analysis and mathematical models. Battalio (1998) refined this model and listed some specific characters that would demonstrate historical changes within the GCSPN model for scientific phases of biology:

- **(STEP 1)** Natural history and search for new species predominate
- **(STEP 2)** Now an experimental science rather than a natural history model
- **(STEP 3)** Power is transferred from expert amateurs to trained professional scientists, and graduate training for employment in the field has become available
- **(STEP 4)** Systematics and natural history no longer dominant, and research focused more on theoretically complex issues with extensive use of graphs and statistical inference in publications
- **(STEP 5)** Formation of research teams and increasing evidence of socialization, such as use of acknowledgments sections, associations of peers, and co-authored publications
- **(STEP 6)** Technical terminology and methodology so refined they now limit the audience that can fully comprehend it

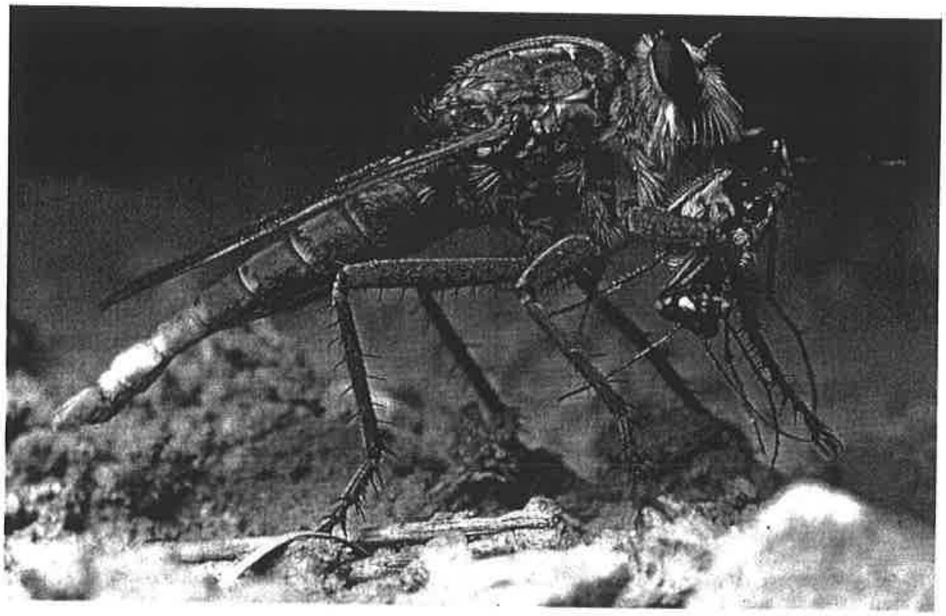

Fig. 17.2 A tiger beetle captured by a Robber-fly (Asilidae) (Photograph by ES Ross)

We applied these steps and an additional one to two relatively discrete taxonomic fields whose history is well documented but whose biology and taxonomic levels are sufficiently different that the latitude of the model can be better assessed – birds and tiger beetles (Coleoptera: Carabidae: Cicindelitae). Birds are among the most thoroughly documented of all animal taxa, and about 10,000 species are presently recognized. Historical accounts of their study are numerous (Walters 2003). Tiger beetles are a small but distinct group of nearly 2,800 species whose historical background of studies is relatively well known (Pearson and Vogler 2001; Pearson 2006). These beetles are attractive, fast-flying and fast-running insect predators that occur in many diverse habitats around the world. Many of their adaptations, such as for thermoregulation, competition and avoiding their own enemies (Fig. 17.2) are well studied (Pearson and Vogler 2001).

Using a combination of narrative and comparative analysis, we contrast the history of tiger beetle (Pearson and Cassola 1992, 2005) and bird studies (Walters 2003) around the world and the growth of research on these groups from earlier centuries to today. We examine if the predicted pattern of steps applies and compares these scientific phases within a historical framework. Even though conservation problems and specific solutions are often different for these two taxa (Thomas 1995), do studies of both conform to the GCSPN model? If there are divergent patterns, to what can they be attributed? How can the model and its assumptions be improved so that we can better understand broad patterns in scientific development and use this understanding to meet the goals of insect conservation biology?

17.3 Results

17.3.1 (STEP 1) Natural History and Search for New Species Predominate

The earliest studies of birds in the fourth century BC were descriptive, anecdotal, and often associated with economic use, such as falconry and hunting or with art and religion. By the twelfth century AD, bird studies were more organised but remained descriptive. A desire for wealth and power encouraged geographical exploration and colonisation around the world. Exotic birds were among the treasures with which explorers returned. For instance, the North American turkey, at first imported as a novelty, became domesticated as a food source in Europe in 1530. Parrots and other brightly coloured birds aroused heightening interest as pets for Europeans, especially as status symbols among the upper classes. By 1756, specimen collections had become extensive, and positions such as professional curators began to appear.

In the tenth edition of his Systema Naturae, Carl von Linné (1758), one of the founders of modern binomial taxonomy, described 8 tiger beetle species and 564 bird species. By the end of the eighteenth century, an ever growing group of collectors and museum curators had described 50 tiger beetle species and more than 800 bird species (Table 17.1). During the first half of the nineteenth century, studies of birds and tiger beetles continued as almost completely a search for new species and under the nearly exclusive control of Europeans.

The number of new bird species described each year peaked in 1837 and decreased thereafter, so that by the 1950s only 2–5 new species were described each year. In marked contrast, throughout the rest of the nineteenth century and well into the latter part of the twentieth century, the number of new species of tiger beetles rose rapidly (Wiesner 1992). Nearly one third of the world's 2,791 tiger beetle species were described in the last half of the twentieth century and in the early twenty-first century (Table 17.1). Along with species description, some tiger beetle systematists also described significant natural history observations (Wallace 1869; Bates 1869; Hamilton 1925), a combination of effort that continues into the present (Erwin 1983; Desender et al. 1992; Cassola and Pearson 1999; Cassola et al. 2000; Zerm and Adis 2000, 2001).

This descriptive step was also critical for the establishment of interest in conservation biology. Much of the earliest history of conservation biology revolved around documentation of species, in this case their extinctions. In the midst of manifest destiny and impressions of inexhaustible resources, the unexpected disappearance of once abundant species of birds, such as the Passenger Pigeon, first made extinction seem a real possibility, and the causes of extinction of individual species became an important area of study for the nascent field of conservation biology. To a much lesser extent tiger beetles lent themselves to early studies of declining populations and extinctions. As such, several species and populations of tiger beetles became some of the first insects declared legally endangered or threatened with extinction.

Table 17.1 Numbers of species of birds and tiger beetles described in periods between 1758 and 2000 and 10 years from 2001 to 2011, and the percent of total known at present

Periods (years)	No. species of birds (% of total)	No. species of tiger beetles (% of total)
1758–1800	1,714 (17)	51 (2)
1801–1850	3,888 (29)	418 (15)
1851–1900	3,233 (32)	787 (28)
1901–1950	874 (9)	493 (18)
1951–2000	232 (2)	699 (25)
2001–2011 (estimated)	23 (0.2)	253 (9)
Total	9,964	2,791

Fig. 17.3 Controlled area in Santa Cruz Co., California, to protect the officially endangered Ohlone Tiger Beetle *(Cicindela ohlone)* (Photograph courtesy University of California Santa Cruz Grounds Dept)

Two North American subspecies of tiger beetles are now considered extinct (Knisley and Fenster 2005). Pearson et al. (2006) estimate that at least 33 (15%) of the 223 named species and subspecies of tiger beetles in Canada and the United States may be declining at a rate that justifies their consideration for inclusion on the US Fish and Wildlife Service's List of Endangered and Threatened species (Fig. 17.3). However, at present, only four of these are officially listed by the federal government, and several others are under consideration for listing. In addition, several other countries (Belgium, Canada, Germany, Great Britain, Lithuania, Netherlands, South Africa and Sweden), at least 24 individual states and provinces within the United States and Canada, and international NGOs (World Conservation

Monitoring Centre and IUCN) have developed lists of endangered and threatened species that include tiger beetles.

Few other insects are well-enough known globally to document these types of population decline. Because of the rich collections of tiger beetle specimens available for study, however, the disappearance of species from former parts of the range can be authenticated. From these historical records, some long-term changes in the environment can also be deduced (Nagano 1980; Desender and Turin 1989; Desender et al. 1994; Yarbrough and Knisley 1994; Kamoun 1996; Trautner 1996; Berglind et al. 1997; Diogo et al. 1999; Knisley and Hill 2001; Richoux 2001; Sikes 2002; Goldstein and Desalle 2003; Horgan and Chávez 2004; Mawdsley 2005). Thus, tiger beetles help offer a window into our past and can provide insight as to where protective measures are needed (Babione 2003).

17.3.2 (STEP 2) Now an Experimental Science Rather than a Natural History Model

The major intellectual advance during the last half of the eighteenth century for birds and tiger beetles was an often-conflicting attempt to place the growing number of species into a natural array of groupings. By moving to cause-and-effect questions, these attempts at phylogenetics were also some of the first signs of a change into an experimental paradigm (Erwin 1985; Barrow 1998; Arndt and Putchkov 1997; Barraclough et al. 1998; Barraclough and Vogler 2000), an area that has also become important for use in conservation (Pearson 1994; Cassola and Pearson 2000; Pearson and Carroll 2001).

By the end of the nineteenth century, the number of known tiger beetle species had risen to 1,256 and the number of bird species to more than 8,800. With a greater array of species known, better chances for comparisons, and greater competition for research subjects among the increasing number of experts, bird and tiger beetle systematists ventured into more sophisticated areas of research. Field naturalists such as A.R. Wallace (1869) and H. W. Bates (1869) often collected birds and tiger beetles wherever they traveled. Nascent but significant ideas about behaviour, ecology and evolution also grew from their experiences of collecting and observing.

In the centenary issue of the British Ornithologist Union journal, The Ibis, Moreau (1959) indicated that by then more than 75% of all publications in The Ibis were "scientific" ornithology that emphasised explanation. By the XXI International Ornithological Congress in 1994, major portions of presentations were on molecular genetics, physiology, neurology, endocrinology, immunology, evolutionary ecology and social behaviour, all fields of research that involved experimentation and none of which existed at the beginning of the century (Walters 2003).

In contrast to the burgeoning number of ornithologists and the breadth of their experimental fields throughout the first half of the twentieth century, tiger beetles continued as the interest of only a few taxonomists, including the German medical doctor, Walther Horn. He was to become the greatest authority and acknowledged specialist of the tiger beetle family, working almost solitarily for more than 50 years. Although predominantly taxonomic in nature, his articles began, later in the century, to incorporate ideas of habitat, biogeography and intraspecific variation (subspecies), a concept Spencer Baird and Joel Allen established in ornithology 75 years earlier.

Besides reconstructing the past, tiger beetles are useful for conservation in other ways. Because of political, sociological and economic pressures, conservation policy and research are under pressure to produce quick results. This pressure is so pervasive, and the time, money and personnel to do the work are so limited that conservation biology is called a 'crisis discipline', in which risk analysis has become a major element (Maguire 1991). A common approach to resolving these problems has been to use indicator taxa as test organisms that purportedly represent other taxa in a complex environment. By focusing studies on a small but representative subset of the habitat or ecosystem, patterns of habitat degradation and population losses can be more quickly and clearly distinguished (Noss 1990). Tiger beetles have been used throughout the world to test and develop better guidelines for choosing bioindicators (Holeski and Graves 1978; Schultz 1988; Bauer 1991; Pearson and Cassola 1992; Rivers-Moore and Samways 1996; Kitching 1996; Rodríguez et al. 1998; Cassola and Pearson 2000; Cassola 2002; Arndt et al. 2005).

17.3.3 (STEP 3) Power is Transferred from Expert Amateurs to Trained Professional Scientists, and Graduate Training for Employment in the Field has Become Available

In the 1860s, bird conservation organisations, such as the Audubon Society, were formed with both professional and amateur participants. In the next few decades, the work of these professionals and amateurs created many conflicts, such as the benefits of specimen collecting and use of common names. Gradually professional academicians and government employees with advanced degrees, such as Aldo Leopold and Rachael Carson, took over the study and communication of conservation problems.

For tiger beetles, the near monopoly of a single expert, Walther Horn, had great influence on the direction of studies (Horn 1926). Beyond his tight control of tiger beetle taxonomy, however, a few other professional biologists began to publish scientific articles using tiger beetles as test organisms for geological history (Wickham 1904), behaviour (Shelford 1902), physiology (Shelford 1913), and ecology (Shelford 1907).

Growing numbers of bird researchers quickly diversified their research questions, many of which required sophisticated field and laboratory skills that amateurs could not easily acquire. By the mid 1980s, the separation of professional ornithologists and amateur birders was made even more profound with the introduction of technical analyses, such as gel electrophoresis, radar for bird migration, sound spectrography, and statistical software packages. Not only had the preponderance of ornithological research shifted, both in systematics and other fields, from private hands to university professionals, but by 1999 there were 100 professional ornithologists in the world for every one there had been in 1960 (Walters 2003).

Over the same period, the advent of prismatic binoculars, cameras, field guides, popular birding magazines, conservation groups emphasising birds, and electronic web sites all helped advance the interest of amateurs in ornithology, but they became largely excluded from all but the most basic descriptions of identification, range extensions and environmental protection.

Even more subtly, professionalisation of ornithology was reflected in its scientific language, writing styles, and grammar. Linguistic analysis shows an evolving use of words and phrases that indicate levels of expertise and establish levels of authority that further separated professionals from amateurs. These words include adverbs that show degrees of reliability, such as 'undoubtedly' and 'possibly'; induction, such as 'must' and 'evidently'; identification of hearsay evidence, such as 'it seems' and 'apparently'; reservations of deduction, such as 'presumably and could'; and hedges, such as 'approximately' (Chafe 1986). In addition, professional science writers use distinctive writing devices that include reduced use of personal pronouns, reliance on passive voice, a decrease in the number of simple sentences, the presence of technical terminology, an emphasis on reliability of evidence, and the use of citations (Lakoff and Johnson 1980). Carter (1990) also showed that although professionals rewriting scientific articles for semi-popular or popular consumption tend to write in broader generalities and use methods more similar to amateurs, they retain a concept of domain-specific knowledge that distinguishes them from the style of amateurs. The preliminary signs of this transformation also are becoming evident among tiger beetle researchers (Desender and Turin 1989).

In studies of birds, a trend developed to separate professional ornithologists and amateur birders into different organisations, each with their own meetings and publications. Amateurs joined organisations such as the American Birding Association, and conservation organisations, such as the Audubon Society and The Nature Conservancy. Professionals were regularly invited to contribute articles and serve on boards of directors of these associations, but rarely were amateurs invited to return the favor in professional meetings or publications. Professionals congregated in their own societies, such as the American Ornithologists' Union, British Ornithologists' Union, and Deutsche Ornithologen-Gesellschaft.

At the same time, the few graduate studies on tiger beetles focused on their coloration (Schultz and Rankin 1983a, b), ecology (Hori 1982; Mury-Meyer 1987; Fahr 1998), physiology (Zerm et al. 2004a, b), neural anatomy (Strausfeld et al. 2009), and use in conservation efforts, such as a search for bioindicators (Knisley and Hill 1992; Mittermeier and Mittermeier 1997; Mittermeier et al. 2004; Rodríguez et al. 1998; Kremen et al. 1993; Andriamampianina et al. 2000; Torres and Ruberson 2005; Arndt et al. 2005; Bhargav et al. 2009; Michels et al. 2010; Topp et al. 2010), local extinction (Knisley et al. 1987; Spomer and Higley 1993; Knisley and Fenster 2005; Mawdsley 2005; Knisley and Haines 2007; Satoh 2008; Karube 2010), and reintroduction (Omland 2002; Fenster et al. 2006).

17.3.4 (STEP 4) Systematics and Natural History no Longer Dominant and Research Focused on Other Theoretically Complex Issues with a Growing Use of Graphs and Statistical Inference in Publications

The Zoological Record, published by the Zoological Society of London, shows that of 500 scientific articles on birds in 1900 nearly 85% dealt with systematics and natural history. By 1990, the total reached more than 14,000 articles, but only 5% of them focused on taxonomy or natural history (Walters 2003). In addition, ornithological journals included a significant percent of articles using birds as test organisms in fields other than systematics and taxonomy. New specialised journals emphasised such specialties in ornithology as bird protection, avian pathology, and avian ecology (Pearson et al. 2011).

Other evidence for this change to more complex problems was found in the frequency of illustrations and statistics included in articles. By the 1970s, photographs and lists of bird species had declined or disappeared from articles in The Auk. They were replaced by increasing use of complex graphs, cladograms, scatter plots, regression lines, and DNA fingerprints. By 1990, 77% of articles published in The Auk were based on statistical inference (Battalio 1998).

Among tiger beetles, in areas other than taxonomy and natural history, the latter part of the twentieth century saw a relatively small increase in articles published on behaviour, ecology, morphology (Cassola and Miskell 1990; Freitag 1992) and ecology (Palmer 1978; Pearson 1980, 1988). Starting in the 1980s, physiological studies of tiger beetles emerged (Dreisig 1980; Hadley et al. 1988; Gilbert 1997). In the 1980s genetics studies began to appear (Serrano and Yadav 1984; Galián et al. 1990; Proença et al. 1999a). These non-taxonomic publications contained 85% of the articles on tiger beetles with statistical procedures and graphs.

One area in which tiger beetles were at the forefront of more complex conservation biology studies was in the statistical application of assumptions of dependence among data points. In initial comparisons of species patterns across regions and countries, Pearson and Cassola (1992) claimed that among the tested attributes of tiger beetles was a high correlation between their species numbers and those of other groups. If one goal is to establish conservation areas with the highest species diversity, tiger beetles were very useful because where you found more of them you also found more species of other groups, such as birds and butterflies. But tiger beetles, at the right season, could often be surveyed in a few weeks whereas birds took years to survey adequately in the same area. In addition, it was easy to train students and local workers to observe and sample tiger beetles, but training these same people to observe other taxa, such as birds and butterflies, was an enormous undertaking. Thus, one could argue that tiger beetles are logistically useful and biologically appropriate candidates to help represent entire habitats or ecosystems for species inventories. Tiger beetles were among the first taxa for which use of modern analytical techniques showed a correlation between their diversity and that of other taxa (Carroll and Pearson 1998a, b; Carroll 1998; Pearson and Carroll 1998, 1999, 2001).

In addition to pioneering statistical analyses, tiger beetles also were used in early applications of molecular analysis for geographical implications of conservation. For instance, the subdivision of lineages of the tiger beetle species, *Cicindela dorsalis*, in Florida between the Gulf of Mexico and the Atlantic Ocean, can be detected only with molecular markers. However, the fact that species of several taxa on one side of a barrier are consistently different from those on another is highly significant for conservation (Pearson and Vogler 2001). These regions of distinctive genetic overlap can reflect historical events in evolutionary time (Crandall et al. 2000; Goldstein et al. 2000; Satoh et al. 2004). By incorporating an evolutionary time scale, we not only gain another valuable factor to include in our conservation planning, but it also makes us aware that areas chosen for protection require management goals focused not just on 10, 20 or even 100 years, but for much longer into the past as well as the future (Schwartz 1999; Barraclough and Vogler 2002).

17.3.5 (STEP 5) Socialisation Such as Use of Acknowledgments Sections, Associations of Peers, and Co-authored Publications

Unlike ornithologists, tiger beetle researchers showed little socialisation well into the twentieth century. There were no organised peer groups, meetings, or associations of those interested in tiger beetles, and only in the 1990s did field guides or general books on the biology of tiger beetles appear (Knisley and Schultz 1997; Leonard and Bell 1999; Acorn 2001; Choate 2003; Pearson et al. 2006). Before this time, only those with time and interest to search through often obscure journals and arcane terms could acquire the basic knowledge to do research using tiger beetles.

Another test of socialisation is in co-authored publications. Among ornithological publications, the proportion of those co-authored in The Auk in the 1890s was less than 15%. By the 1990s it reached 60% of articles, and almost 25% of all articles had more than three authors (Battalio 1998). For tiger beetles, a similar increase in co-authored articles has been significant with a recent book on general tiger beetle biology having 40% of its citations co-authored (Pearson and Vogler 2001).

In 1969, an informal correspondence among tiger beetle enthusiasts developed into a journal called 'Cicindela'. Its publication goals were to provide a forum to share observations, collecting sites, natural history, distributional data, identification help, and taxonomic insight of tiger beetles. The subscriber list to this journal quickly rose to about 200 but stayed at that level for the next 40 years, and they included primarily enthusiastic amateurs from North America and Europe. Small groups of subscribers would go on collecting trips together, but there were few attempts to organise meetings or symposia where these people could interact face to face. Nevertheless, another indicator of socialisation showed advances within this highly specialised journal.

In the 1970s only 2% of its articles had acknowledgments sections; in the 1980s 26% had these sections; and in the 1990s, 83% of them did. Despite these signs of socialisation, a continued aura of exclusivity among tiger beetle workers was apparent in the paucity of support programs for active recruitment of new and especially young enthusiasts. There are fewer than 1,000 tiger beetle professional and amateur enthusiasts in the world. In contrast, today the American Ornithologists' Union alone has more than 4,000 members, most of whom are professionals. Similar organizations in England, Latin America and many other parts of the world also have additional thousands of members. Among amateur bird watchers, the latest estimates by the US government in its 'National Survey on Recreation and the Environment – 2000' calculated that 69 million Americans had formally observed or photographed birds.

The complex nature of modern conservation biology research necessitates more and more research teams involving both professionals and expert amateurs (Pearson et al. 2011). For instance, many modern conservation biologists working on rare and endangered species now rely heavily on molecular markers (Avise 1994; Galián and Vogler 2003) to distinguish species and populations within species. The importance of conserving intra-specific variation is reflected in the U.S. Endangered Species Act, which calls for the conservation of 'independent population segments'. This makes conservation of distinct populations within a species a legal requirement, and involves coordination of field biologists, laboratory technicians, lawyers, and politicians. This coordination of effort is obvious in many areas of conservation biology, and recently has also become a dominant theme in tiger beetle studies (Knisley and Hill 1992; Vogler et al. 1993; Moritz 1994; Vogler and Desalle 1994; Vogler 1998).

These and other such sophisticated uses of tiger beetles have direct ramifications for conservation biology, and most of them will involve teams that are interdisciplinary. This team effort is in areas such as climate change (Ashworth 2001), reintroductions (Omland 2002; Brust 2002; Knisley et al. 2005), habitat reclamation (Hussein 2002), habitat management (Omland 2004; Cornelisse and Hafernik 2009) and location of conservation reserves and parks (Mittermeier and Mittermeier 1997; Desender and Bosmans 1998; Andriamampianina et al. 2000; Pearson and Carroll 2001; Mittermeier et al. 2004; Knisley et al. 2008).

17.3.6 (STEP 6) Technical Terminology and Methodology so Refined they Now Limit the Audience that Can Fully Comprehend it; Development of Mathematical and Statistical Models

For both birds and tiger beetles, the rapidly growing use of highly sophisticated fields, such as molecular biology, statistical modeling, and satellite imagery has introduced many technical words and concepts that can quickly limit comprehension to a narrow array of associated professionals. This trend, as measured in terms of scientific discourse, includes increasing length and number of published articles, increasing sentence complexity, use of multi-word noun phrases, as well as narrowly defined technical terms, is well advanced among ornithologists (Battalio 1998). Among tiger beetle workers, until recently this tendency has been less obvious than in ornithology, but many signals indicate that a growing separation is underway for them as well, especially in complex fields, such as molecular studies (Vogler et al. 1993; Vogler and Desalle 1994; Vogler and Pearson 1996; Vogler et al. 1997; Vogler and Barraclough 1998; Diogo et al. 1999; Proença et al. 1999b, 2004; Morgan et al. 2000; Goldstein and DeSalle 2003; Pons and Vogler 2006; Vogler et al. 2008), physiology (Irmler 1973, 1981, 1985; Hudson et al. 1988; Guido and Fowler 1988; Yager et al. 2000; Zerm et al. 2004a, b; Toh and Mizutani 1994; Mizutani and Toh 1995; Gilbert 1997) and mathematical modeling (Pearson and Juliano 1993; Pearson and Carroll 2001; Carroll and Pearson 1998a, b, 2000).

17.3.7 (STEP 7) Resurgence of Expert Amateurs

Paradoxically the growing sophistication of professional ornithologists, and to some degree among tiger beetle professionals, has manifested itself as a previously unrecorded Step 7 in the historical march of science. A rejection of taxonomy and natural history as valid pursuits for many professionals (Acorn 2009) and a general decline in funding for these areas of research has created a paucity of these critical data (Bossart and Carlton 2002; Pearson et al. 2011). In addition, beginning in the last third of the twentieth century, governments in many countries listed several tiger beetle and bird species as endangered or threatened. Legislators, economists, sociologists, foresters, politicians, land owners and many members of the public, who had little or no previous interest in these taxa, suddenly needed to know about them. Often by default, the pursuit of these basic taxonomic, distributional and natural history data has fallen to individuals searching for an avocation. Their interest levels range from an occasional observer to serious and committed citizen scientists who function at the level of some professionals (Pro-Ams) but are not paid for their work (Leadbeater and Miller 2004).

The sources of these amateurs lie in an understanding of economics. As the economy of a country or region rises, its middle class grows. Families will have fewer children and invest more time and money into each child including increased support of higher education (Barro 2001), donations to private organizations (NGOs), time and money for avocations (Leadbeater and Miller 2004), and concern for the environment (Bhattarai and Hammig 2004). Increased access to the internet (Godfray 2007) and published field guides (Pearson and Shetterly 2006) are especially significant factors in attracting and training Pro-Ams into biology and conservation.

Although there appears to be a general decline in the numbers of professional taxonomists (Hopkins and Freckleton 2002), Pro-Ams or citizen scientists are notably active and numerous among those studying birds, especially in relation to their conservation and protection. Professionals direct the energies and abilities of amateurs through data gathering web sites such as Ebird (Cornell Lab of Ornithology), Christmas bird counts (National Audubon Society), Etudes des Populations d'Oiseaux de Quebec (Droege et al. 1998), Hawk Migration Association of North America, and many other programs (Evans et al. 2005; Greenwood 2007). These informal data bases then become available for sophisticated modeling and statistical analysis (Pearson and Carroll 1998; Cohn 2008; Pearson et al. 2009).

The influence of these active bird amateurs appears to be spilling over into other taxa. Based on notices of regional/national meetings and ecotourist tours published on line, amateurs studying such insect groups as dragonflies, butterflies, and tiger beetles, are populated by a large proportion of birding enthusiasts. Some local Audubon Society-sponsored field trips in Virginia, Florida and Arizona focused specifically on tiger beetles. The appearance of published field guides for tiger beetles in North America (Pearson et al. 2006), Thailand (Naviaux and Pinratana 2004), Colombia (Vítolo 2004) and other parts of the world was quickly followed by a notable increase in the number of amateurs and professionals interested in tiger beetles as a hobby or research organism. A large proportion of these initiates had begun their observations of Nature with birds (Pearson and Shetterly 2006).

17.4 Discussion

Does the history of bird and tiger beetle studies follow a common pattern?

Despite substantial differences in their biology and taxonomic level, both bird and tiger beetle studies show similar patterns of change over their histories. However, for both taxa, overlap between adjacent steps makes analysis at a small temporal scale difficult, and at least 50-year intervals are necessary to distinguish the patterns. The most obvious divergence between them is the speed with which some steps were completed and the comparable maturity of research at any given time, differences similar to those suggested by theories of paradigm shifts (Kuhn 1996).

Amateurs have had powerful influences on both fields. They initiated natural history and taxonomic studies of birds and tiger beetles at the same time in the eighteenth century. In the nineteenth century amateurs, especially bird enthusiasts, were instrumental in initiating conservation societies and influencing legislation for protection of the environment. However, professionalisation of the field became apparent much earlier in ornithology as tiger beetle studies lagged in these changes by at least 75 years. Collectors and authors working alone have been very important over the entire history of tiger beetles. This pattern was also apparent in ornithology, but only through the middle of the nineteenth century.

The rise of such issues as trinomial use, biological studies, and graduate education are a few additional examples of differential rates of change by bird and tiger beetle researchers. The use of common English names versus scientific names was debated among ornithologists in the nineteenth century, probably because birds had attracted so much attention from the public early on. Amateurs complained of too much dependence on scientific names in ornithology (Barrow 1998). For tiger beetles, in contrast, scientific names were retained as virtually the only nomenclature until the twenty-first century (Pearson 2004; Wu and Shook 2010). More recently, the publication of tiger beetle field guides with English names helped recruit a huge increase in amateur involvement, most of whom eschewed scientific names of tiger beetles.

The minimisation by professionals of basic but critical studies of natural history and range distributions, and in many cases descriptions of new species (Acorn 2009) impacted ornithology earlier than tiger beetle studies. Today, largely because few undescribed species remain in the world, descriptions of new bird species are so few that bird taxonomists spend little time in this effort. Instead they concentrate on refining studies such as phylogenetic and evolutionary relationships, areas that are also more likely to be funded and recognised as intellectually appropriate. Also, most professional ornithologists no longer pursue studies of long term presence-absence data, range expansions and descriptions of natural history, even though these types of data are often critical for sophisticated modeling and hypothesis testing. Instead professional ornithologists are helping empower citizen scientists to gather long term data and basic descriptive natural history observations (Droege et al. 1998; Pearson et al. 2009). This trend is also apparent among tiger beetle professionals (Pearson et al. 1988), but less formally than the programs organised by ornithologists. If tiger beetles and other insect groups are to be widely incorporated into studies and management plans for conservation biology, the history of bird studies shows that facilitating the interaction of amateurs and professionals should be a high priority.

17.5 Causes of Differential Rates of Change

In contrast to ornithology, relatively few professional scientists have used tiger beetles as test organisms for biological hypotheses. Graduate studies and paid positions for tiger beetle workers have remained scarce. Based on our comparisons of the historical development of bird and tiger beetle studies, we propose that at least four causes can explain much of the difference in their speeds of change through the development of these fields of science:

1. Number of species – Both taxa have sufficiently small species numbers so that researchers can expect to understand general patterns of species relationships as well as details of biology and distribution, but with three times the species numbers, bird research has a wider range of examples and potential concepts to test.
2. Range of habitats – Although both tiger beetles and birds occur over a wide range of latitudinal and altitudinal habitats, some bird species extend into higher latitudes, altitudes and extreme habitat types not occupied by tiger beetles. Bird studies thus provide a wider range of questions and potential biological problems to solve.
3. Obviousness and economic importance – Although many birds and tiger beetles are colourful and attractive, tiger beetles are generally less conspicuous. In addition,

the early economic significance of birds in hunting and domestication is in stark contrast to the insignificant economic importance of tiger beetles. Thus birds may be more inherently attractive as a subject of interest.

4. The number of researchers – A combination of the previous three factors likely contributed to the number of researchers using each taxon. In early steps, they influenced how many taxonomists could compete for descriptions. For tiger beetles, fewer taxonomists led to slower rates of socialisation, less formation of peer groups, few specialised journals, little recruitment of additional enthusiasts, and slower and narrower development into more experimental studies.

What uses does the comparison of birds and tiger beetles in the GCSPN have for identifying and attaining conservation biology goals?

These results can help us answer questions, such as: At what points should funding agencies support specific efforts? Are there better periods than others in which to attract young recruits to maintain or increase interest in specific taxa or fields such as conservation biology? Can or should dominance by a single individual or small clique be avoided? Will professional biologists exclude the expert amateurs, or how can they be encouraged to cooperate? Can professional publications and communications be written so as not to exclude non-experts?

We now have a better idea of priorities for selecting which taxa or fields will yield the most useful and broadest results. With limited funds, time and personnel, how do we balance the costs and benefits of speciose habitats and taxa, economic importance, detectability, and human or natural threats (Sorensen 1995). How do we redefine the training and support of professional conservation biologists so that they are rewarded for developing and applying communication skills among scientists, Pro-Ams, legislators, decision makers and the public? How can we most effectively educate, recruit and mentor Pro-Ams who will probably provide the bulk of future taxonomic and natural history data for most taxa in the future?

With some immediate solutions and the promise of even more important long range solutions made possible by examinations of historical models, such as the GCSPN, we can be encouraged that conservation biology can make use of its history. With improvements in the model and future tests of the process of science itself, we may have the best chance to develop foresight, learn from history, and better know if and what changes can be made to better reach our goals. 'We know the future only by the past we project into it' (Gaddis 2004).

Acknowledgments We are indebted to J. Alcock, K. R. Johnson, B. A. Minteer, N. B. Pearson, S. J. Pyne, and J. V. Remsen for reading early drafts of this manuscript and providing helpful criticism to improve it. A. Peterson provided data on bird species descriptions.

References

Acorn JH (2001) Tiger beetles of Alberta: killers on the clay, stalkers on the sand. University of Alberta Press, Edmonton

Acorn JH (2009) Amateurs and abandoned science. Am Entomol 55:127–128

Andriamampianina L, Kremen C, Vane-Wright D, Lees D, Razafimahatratra V (2000) Taxic richness patterns and conservation evaluation of Madagascan tiger beetles (Coleoptera: Cicindelidae). J Insect Conserv 4:109–128

Arndt E, Putchkov AV (1997) Phylogenetic investigation of Cicindelidae (Insecta: Coleoptera) using larval morphological characters. Zool Anz 235:231–241

Arndt E, Aydin N, Aydin G (2005) Tourism impairs tiger beetle (Cicindelidae) populations – a case study in a Mediterranean beach habitat. J Insect Conserv 9:201–206

Ashworth AC (2001) Chap. 8: Perspectives on Quaternary beetles and climate change. In: Gerhard LC, Harrison BM (eds) Geological perspectives of global climate change, vol 47, American Association of Petroleum Geologists Studies in Geology. American Association of Petroleum Geologists in collaboration with the Kansas Geological Survey and the AAPG Division of Environmental Geosciences, Tulsa, pp 153–168

Avise JC (1994) Molecular markers, natural history and evolution. Chapman and Hall, New York

Babione M (2003) Bringing tiger beetles together. Endangered Species Bull 28:28–29

Barraclough TG, Vogler AP (2000) Detecting the geographical pattern of speciation from species-level phylogenies. Am Nat 155:419–434

Barraclough TG, Vogler AP (2002) Recent diversification rates in North American tiger beetles estimated from a dated mtDNA phylogenetic tree. Mol Biol Evol 19:1706–1716

Barraclough TG, Vogler AP, Harvey PH (1998) Revealing the factors that promote speciation. Philos Trans R Soc Lond B 353:241–249

Barro RJ (2001) Human capital: growth, history, and policy – a session to honor Stanley Engerman. Am Econ Rev 91:12–17

Barrow MV Jr (1998) A passion for birds: American ornithology after Audubon. Princeton University Press, Princeton

Bates HW (1869) Notes on Cicindelidae from tropical America, with descriptions of four new species (gen. *Odontocheila* and *Pseudoxycheila*). Entomol Mon Mag 5:287–291

Battalio JT (1998) The rhetoric of science in the evolution of American ornithological phases, vol 8, ATTW contemporary studies in technical communication. Ablex Publishing Corporation, Stamford

Bauer KL (1991) Observations on the developmental biology of *Cicindela arenicola* Rumpp (Coleoptera, Cicindelidae). Great Basin Nat 51:226–235

Berglind S-A, Ehnström B, Ljungberg H (1997) Strandskalbaggar, biologisk mångfald och reglering av små vattendrag – exemplen Svartån och Mjällån. Entomologisu Tidskrift 118:137–154

Bhargav V, Uniyal VP, Sivakumar K (2009) Distinctive patterns in habitat association and distribution of tiger beetles in the Shivalik landscape of North Western India. J Insect Conserv 13:459–473

Bhattarai M, Hammig M (2004) Governance, economic policy, and the environmental Kuznet's curve for natural tropical forests. Environ Dev Econ 9:367–382

Bossart JL, Carlton CE (2002) Insect conservation in America: status and perspectives. Am Entomol 48:82–92

Brust ML (2002) Reintroduction study on *Cicindela formosa generosa* in Marinette County, Wisconsin. Cicindela 34:5–7

Carroll SS (1998) Modelling abiotic indicators when obtaining spatial predictions of species richness. Environ Ecol Stat 5:257–276

Carroll SS, Pearson DL (1998a) Spatial modeling of butterfly species richness using tiger beetles (Cicindelidae) as a bioindicator taxon. Ecol Appl 8:531–543

Carroll SS, Pearson DL (1998b) The effects of scale and sample size on the accuracy of spatial predictions of tiger beetle (Cicindelidae) species richness. Ecography 21:401–414

Carroll SS, Pearson DL (2000) Detecting and modeling spatial and temporal dependence in conservation biology. Conserv Biol 14:1893–1897

Carter M (1990) The idea of expertise: an exploration of cognitive and social dimensions of writing. Coll Compos Commun 41:265–286

Cassola F (2002) Le cicindele e le coste: biogeografia e conservazione (Studi sui Cicindelidi. CXIX). Biogeographia 23:55–69

Cassola F, Miskell JE (1990) Somalian tiger beetles: faunistics and biogeography (Coleoptera: Cicindelidae). Biogeographia 14:175–227

Cassola F, Pearson DL (1999) Revision of the South American tiger beetle complex of *Brasiella balzani* (W. Horn) (Coleoptera: Cicindelidae). Ann Mus Civ Stor Nat 'Giacomo Doria" 7:1–12

Cassola F, Pearson DL (2000) Global patterns of tiger beetle species richness (Coleoptera: Cicindelidae): their use in conservation planning. Biol Conserv 95:197–208

Cassola F, Roque-Albelo FL, Desender K (2000) Is the endemic Galápagos tiger beetle threatened with extinction? Notas Galápagos 61:23–25

Chafe W (1986) Evidentiality in English conversation and academic writing. In: Chafe W, Nichols J (eds) Evidentiality: the linguistic coding of epistemology. Albex Press, Norwood, pp 261–272

Choate PM (2003) A field guide and identification manual for Florida and eastern U.S. University Press Florida, Gainesville

Cohn JP (2008) Citizen science: can volunteers do real research? Bioscience 58:192–197

Cornelisse TM, Hafernik JE (2009) Effects of soil characteristics and human disturbance on tiger beetle oviposition. Ecol Entomol 34:495–503

Crandall KA, Bininda-Emonds ORP, Mace GM, Wayne RK (2000) Considering evolutionary processes in conservation biology. Trends Ecol Evol 15:290–295

Desender K, Bosmans R (1998) Ground beetles (Coleoptera, Carabidae) on set-aside fields in the Campine region and their importance for nature conservation in Flanders (Belgium). Biodivers Conserv 7:1485–1493

Desender K, Turin H (1989) Loss of habitats and changes in the composition of the ground and tiger beetle fauna in four west European countries since 1950 (Coleoptera: Carabidae, Cicindelidae). Biol Conserv 48:277–294

Desender K, Baert KL, Maelfait JP (1992) El Niño-events and the establishment of ground beetles in the Galápagos Archipelago. Bull Inst R Sci Nat Belg Entomol 62:67–74

Desender K, Dufrêne M, Maelfait J-P (1994) Long term dynamics of carabid beetles in Belgium: a preliminary analysis on the influence of changing climate and land use by means of a data base covering more than a century. In: Desender K, Dufrene M, Loreau M, Luff ML, Maelfait JP (eds) Carabid beetles: ecology and evolution. Kluwer Academic Publishers, Dordrecht, pp 247–252

Diogo AC, Vogler AP, Gimenez A, Gallego D, Galian J (1999) Conservation genetics of *Cicindela deserticoloides*, an endangered tiger beetle endemic to southeastern Spain. J Insect Conserv 3:117–123

Dreisig H (1980) Daily activity, thermoregulation and water loss in the tiger beetle *Cicindela hybrida*. Oecologia 44:376–389

Droege S, Cyr A, Larivée J (1998) Checklists: an under-used tool for the inventory and monitoring of plants and animals. Conserv Biol 12:1134–1138

Erwin TL (1983) Beetles and other insects of tropical forest canopies at Manaus, Brazil, sampled by insecticidal fogging. In: Sutton SL, Whitmore TC, Chadwick AC (eds) Tropical rain forest: ecology and management. Proceedings of the tropical rainforest symposium; 1982; Blackwell, Leeds, Oxford, pp 59–75

Erwin TL (1985) The taxon pulse: a general pattern of lineage radiation and extinction among carabid beetles. In: Ball GE (ed) Taxonomy, phylogeny and zoogeography of beetles and ants. W. Junk, Dordrecht, pp 437–472

Evans C, Abrams E, Reitsma R, Roux K, Salmonsen L, Marra PR (2005) The neighborhood nest-watch program: participant outcomes of a citizen-science ecological research project. Conserv Biol 19:589–594

Fahr J (1998) Die Sandlaufkäfer (Coleoptera: Cicindelidae) des Comoé-Nationalparks, Elfenbeinküste: Faunistik, Zoogeographie und Ökologie. Bonn zool Beitr 47:321–343

Fenster MS, Knisley CB, Reed CT (2006) Habitat preference and the effects of beach nourishment on the federally threatened northeastern beach tiger beetle, *Cicindela dorsalis dorsalis*: Western Shore, Chesapeake Bay, Virginia. J Coastal Res 22:1133–1144

Freitag R (1992) Biogeography of West Indian tiger beetles (Coleoptera: Cicindelidae). In: Noonan GR, Ball GE, Stork NE (eds) The biogeography of ground beetles of mountains and islands. Intercept, Andover, pp 123–158

Gaddis JL (2004) The landscape of history: how historians map the past. Oxford University Press, New York

Galián J, Vogler AP (2003) Evolutionary dynamics of a satellite DNA in the tiger beetle species pair *Cicindela campestris* and *C. maroccana*. Genome 46:213–223

Galián J, Serrano J, Ortiz AS (1990) Karyotypes of nine species of Cicindelini and cytotaxonomic notes on Cicindelinae (Coleoptera, Carabidae). Genetica 82:17–24

Gilbert C (1997) Visual control of cursorial prey pursuit by tiger beetles (Cicindelidae). J Comp Physiol A 181:217–230

Godfray HCJ (2007) Linnaeus in the information age. Nature 446:259–260

Goldstein PZ, DeSalle R (2003) Calibrating phylogenetic species formation in a threatened insect using DNA from historical specimens. Mol Ecol 12:1993–1998

Goldstein PZ, Desalle R, Amato G, Vogler AP (2000) Conservation genetics at the species boundary. Conserv Biol 14:120–131

Gould SJ (1989) Wonderful life: the Burgess Shale and the nature of history. Norton Publications, New York

Greenwood JJD (2007) Citizens, science and bird conservation. J Ornithology 148(Supplement 1): S77–S124

Guido AS, Fowler HG (1988) *Megacephala fulgida* (Coleoptera: Cicindelidae): a phonotactically orienting predator of *Scapteriscus* mole crickets (Orthoptera: Gryllotalpidae). Cicindela 20:51–52

Hadley NF, Schultz TD, Savill A (1988) Spectral reflectances of three tiger beetle subspecies (*Neocicindela perhispida*): Correlation with their habitat substrate. N Z J Zool 15:343–346

Hamilton CC (1925) Studies on the morphology, taxonomy, and ecology of the larvae of Holarctic tiger beetles (Family Cicindelidae). Proc US Natl Mus 65:1–87

Holeski PM, Graves RC (1978) An analysis of the shore beetle communities of some channelized streams in northwest Ohio (Coleoptera). Great Lakes Entomol 11:23–36

Hopkins GW, Freckleton RP (2002) Declines in the numbers of amateur and professional taxonomists: implications for conservation. Anim Conserv 5:245–249

Horgan FG, Chávez JC (2004) Field boundaries restrict dispersal of a tropical tiger beetle, *Megacephala angustata* Chevrolet 1841 (Coleoptera: Cicindelidae). Entomotropica 19:147–152

Hori M (1982) The biology and population dynamics of the tiger beetle, *Cicindela japonica* (Thunberg). Physiol Ecol Jpn 19:77–212

Horn W (1926) Carabidae: Cicindelinae. In: Junk W (ed) Coleopterorum Catalogus, Pars 86. W. Junk, Berlin, pp 1–345

Hudson WG, Frank JH, Castner JL (1988) Biological control of *Scapteriscus* spp. mole crickets (Orthoptera: Gryllotalpidae) in Florida. Bull Entomol Soc Am 34:192–198

Hussein ML-a (2002) Ground beetle (Coleoptera, Carabidae) communities of the exhausted opencast mining area K™nigsaue and of agricultural areas in the District Aschersleben-staßfurt (Saxony-Anhalt). Arch Phytopathol Plant Prot 35:125–155

Irmler U (1973) Population-dynamic and physiological adaptation of *Pentacomia egregia* Chaud (Col. Cicindelidae) to Amazonian inundation forest. Amazoniana 3:219–227

Irmler U (1981) Survival strategies of animals in the seasonally flooded Amazonian inundation forest. Zool Anz 206:26–38

Irmler U (1985) Temperature dependent generation cycle for the cicindelid beetle *Pentacomia egregia* Chaud. (Coleoptera, Carabidae, Cicindelinae) of the Amazon valley. Amazoniana 9:431–439

Kamoun S (1996) Occurrence of the threatened *Cicindela senilis frosti* Varas Arangua in an inland salt marsh in Riverside County, California (Coleoptera: Cicindelidae). Coleopt Bull 50:369–371

Karube H (2010) Endemic insects in the Ogasawara islands: negative impacts of alien species and a potential mitigation strategy. In: Kawakami K, Okochi I (eds) Restoring the oceanic island ecosystem impact and management of invasive alien species in the Bonin Islands. Springer, Tokyo, pp 133–137

Killingsworth MJ, Palmer JS (1992) Ecospeak: rhetoric and environmental politics in America. Southern Illinois University Press, Carbondale

Kitching IJ (1996) Identifying complementary areas for conservation in Thailand: an example using owls, hawkmoths and tiger beetles. Biodivers Conserv 5:841–858

Knisley CB, Fenster MS (2005) Apparent extinction of the tiger beetle, *Cicindela hirticollis abrupta* (Coleoptera: Carabidae: Cicindelinae). Coleopt Bull 59:451–458

Knisley CB, Haines RD (2007) Description and conservation status of a new subspecies of *Cicindela tranquebarica* (Coleoptera: Cicindelidae), from the San Joaquin Valley of California, U.S.A. Entomol News 118:109–126

Knisley CB, Hill JM (1992) Effects of habitat change from ecological succession and human impact on tiger beetles. Virginia J Sci 43:134–142

Knisley CB, Hill JM (2001) Biology and conservation of the Coral Pink Sand Dunes tiger beetle, *Cicindela limbata albissima* Rumpp. West N Am Nat 61:381–394

Knisley CB, Schultz TD (1997) The biology of tiger beetles and a guide to the species of the South Atlantic states. Virginia Museum Natural History, Special Publ No 5, Martinsville

Knisley CB, Luebke JL, Beatty DR (1987) Natural history and population decline of the coastal tiger beetle, *Cicindela dorsalis dorsalis* Say (Coleoptera: Cicindelidae). Virginia J Sci 38:293–303

Knisley CB, Hill JM, Scherer AM (2005) Translocation of threatened tiger beetle *Cicindela dorsalis dorsalis* (Coleoptera: Cicindelidae) to Sandy Hook, New Jersey. Ann Entomol Soc Am 98:552–557

Knisley CB, Woodcock MR, Vogler AP (2008) A new subspecies of *Cicindela limbata* (Coleoptera: Cicindelidae) from Alaska, and further review of the *maritima* group by using mitochondrial DNA analysis. Ann Entomol Soc Am 101:277–288

Kremen C, Colwell RK, Erwin TL, Murphy DD, Noss RF, Sanjayan MA (1993) Terrestrial arthropod assemblages: their use as indicators in conservation planning. Conserv Biol 7:796–808

Kuhn TS (1996) The structure of scientific revolutions, 3rd edn. University of Chicago Press, Chicago

Lakoff G, Johnson M (1980) Metaphors we live by. University of Chicago Press, Chicago

Leadbeater C, Miller P (2004) The Pro-Am revolution: how enthusiasts are changing our economy and society. Demos Publishers, London

Leonard JG, Bell RT (1999) Northeastern tiger beetles: a field guide to tiger beetles of New England and eastern Canada. CRC Press, Boca Raton

Maguire LA (1991) Risk analysis for conservation biologists. Conserv Biol 5:123–125

Mawdsley JR (2005) Extirpation of a population of *Cicindela patruela* Dejean (Coleoptera: Carabidae: Cicindelini) in suburban Washington, DC, USA. Proc Entomol Soc Wash 107:64–70

Michels GJ Jr, Carney VA, Jones EN, Pollock DA (2010) Species diversity and qualitative assessment of ground beetles (Coleoptera: Carabidae) in three riparian habitats. Environ Entomol 39:738–752

Mittermeier RA, Mittermeier CG (1997) Megadiversity: Earth's biologically wealthiest nations. CEMEX, Mexico City

Mittermeier RA, Gil PR, Hoffmann M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, Da Fonseca G (2004) Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecosystems. CEMEX, Mexico City

Mizutani A, Toh Y (1995) Optical and physiological properties of the larval visual system of the tiger beetle, *Cicindela chinensis*. J Comp Physiol A 177:591–599

Moreau RE (1959) The Centenarian "Ibis". Ibis 101:19–38

Morgan M, Knisley CB, Vogler AP (2000) New taxonomic status of the endangered tiger beetle *Cicindela limbata albissima* (Coleoptera: Cicindelidae): evidence from mtDNA. Ann Entomol Soc Am 93:1108–1115

Moritz C (1994) Defining "evolutionary significant units" for conservation. Trends Ecol Evol 9:373–375

Mury Meyer EJ (1987) Asymmetric resource use in two syntopic species of larval tiger beetles (Cicindelidae). Oikos 50:167–175

Nagano CD (1980) Population status of the tiger beetles of the genus *Cicindela* (Coleoptera: Cicindelidae) inhabiting the marine shoreline of Southern California. Atala 8:33–42

Naviaux R, Pinratana A (2004) The tiger beetles of Thailand (Coleoptera, Cicindelidae). Brothers of San Gabriel, Bangkok

Noss RF (1990) Indicators for monitoring biodiversity: a hierarchical approach. Conserv Biol 4:355–364

Nye MJ (1996) Before big science: the pursuit of modern chemistry and physics, 1800–1940. Twayne Publishers, New York

Omland KS (2002) Larval habitat and reintroduction site selection for *Cicindela puritana* in Connecticut. Northeast Nat 9:433–450

Omland KS (2004) Puritan tiger beetle (*Cicindela puritana*) on the Connecticut River: habitat management and translocation alternatives. In: Akçakaya HR, Burgman MA, Kindvall O, Wood CC, Sjögren-Gulve P, Hatfield JS, McCarthy MA (eds) Species conservation and management: case studies. Oxford University Press, Oxford, pp 137–148

Palmer MK (1978) Growth rates and survivorship of tiger beetle larvae. Cicindela 10:49–66

Pearson DL (1980) Patterns of limiting similarity in tropical forest tiger beetles (Coleoptera: Cicindelidae). Biotropica 12:195–204

Pearson DL (1988) Biology of tiger beetles. Annu Rev Entomol 33:123–147

Pearson DL (1994) Selecting indicator taxa for the quantitative assessment of biodiversity. Philos Trans R Soc Lond B 345:75–79

Pearson DL (2004) List of suggested common English names for species of tiger beetles (Coleoptera: Cicindelidae) occurring in Canada and the US. Cicindela 36:31–39

Pearson DL (2006) A historical review of the studies of Neotropical tiger beetles (Coleoptera: Cicindelidae) with special reference to their use in biodiversity and conservation. Stud Neotrop Fauna Environ 41:217–226

Pearson DL, Carroll SS (1998) Global patterns of species richness: spatial models for conservation planning using bioindicators and precipitation. Conserv Biol 12:809–821

Pearson DL, Carroll SS (1999) The influence of spatial scale on cross-taxon congruence patterns and prediction accuracy of species richness. J Biogeogr 26:1079–1090

Pearson DL, Carroll SS (2001) Predicting patterns of tiger beetle (Coleoptera: Cicindelidae) species richness in northwestern South America. Stud Neotrop Fauna Environ 36:123–134

Pearson DL, Cassola F (1992) World-wide species richness patterns of tiger beetles (Coleoptera: Cicindelidae): indicator taxon for biodiversity and conservation studies. Conserv Biol 6:376–391

Pearson DL, Cassola F (2005) A quantitative analysis of species descriptions of tiger beetles (Coleoptera: Cicindelidae), from 1758 to 2004, and notes about related developments in biodiversity studies. Coleopt Bull 59:184–193

Pearson DL, Cassola F (2007) Are we doomed to repeat history?: a model of the past using tiger beetles (Coleoptera: Cicindelidae) and conservation biology to anticipate the future. J Insect Conserv 11:47–59

Pearson DL, Juliano SA (1993) Evidence for the influence of historical processes in co-occurrence and diversity of tiger beetle species. In: Ricklefs R, Schluter D (eds) Species diversity in ecological communities: historical and geographical perspectives. University of Chicago Press, Chicago, pp 194–202

Pearson DL, Shetterly JA (2006) How do published field guides influence interactions between amateurs and professionals in entomology? Am Entomol 52:246–252

Pearson DL, Vogler AP (2001) Tiger beetles: the evolution, ecology and diversity of the cicindelids. Cornell University Press, Ithaca

Pearson DL, Blum MS, Jones TH, Fales HN, Gonda E, White BR (1988) Historical perspective and the interpretation of ecological patterns: defensive compounds of tiger beetles (Coleoptera: Cicindelidae). Am Nat 132:404–416

Pearson DL, Knisley CB, Kazilek CJ (2006) A field guide to the tiger beetles of the United States and Canada: identification, natural history and distribution of the cicindelids. Oxford University Press, New York

Pearson DL, Anderson CD, Mitchell BR, Rosenberg MS, Navarrete R, Coopmans P (2009) Testing hypotheses of bird extinctions at Rio Palenque, Ecuador, with informal species lists. Conserv Biol 24:500–510

Pearson DL, Hamilton AL, Erwin TL (2011) Recovery plan for the endangered taxonomy profession. Bioscience 61:58–63

Pons J, Vogler AP (2006) Size, frequency, and phylogenetic signal of multiple-residue indels in sequence alignment on introns. Cladistics 22:144–156

Proença SJR, Collares-Pereira MJ, Serrano ARM (1999a) Karyological study of *Cicindela trifasciata* (Coleoptera, Cicindelidae) from Cuba: evidence of B chromosomes. Genet Mol Biol 22:45–48

Proença SJR, Serrano ARM, Collares-Pereira J (1999b) First record on the cytotaxonomy of cicindelids (Insecta, Coleoptera) from an Afrotropical region. Caryologia 52:37–47

Proença SJR, Collares-Pereira MJ, Serrano ARM (2004) Cytogenetic variability in three species of the genus Cicindela (s. l.) (Coleoptera, Cicindelidae): karyotypes and localization of 18S rDNA genes. Genet Mol Biol 27:555–560

Richoux P (2001) Sensibilité de *Cylindera arenaria* aux aménagements fluviaux: l'example de la région lyonnaise (Coléoptères Cicindelidae). Cahiers scientifique Mus d'Histoire nat Lyon 2:63–74

Rivers-Moore NA, Samways MJ (1996) Game and cattle tramping, and impacts of human dwellings on arthropods at a game park boundary. Biodivers Conserv 5:1545–1556

Rodríguez JP, Pearson DL, Barrera R (1998) A test for the adequacy of bioindicator taxa: are tiger beetles (Coleoptera: Cicindelidae) appropriate indicators for monitoring the degradation of tropical forests in Venezuela? Biol Conserv 83:69–76

Satoh A (2008) The current status and conservation of coastal tiger beetles (Coleoptera: Cicindelidae). Jpn J Conserv Biol 13:103–110

Satoh A, Sota T, Uéda T, Enokido Y, Paik C, Hori M (2004) Evolutionary history of coastal tiger beetles in Japan based on a comparative phylogeography of four species. Mol Ecol 13:3057–3069

Schultz TD (1988) Destructive effects of off-road vehicles on tiger beetle habitat in central Arizona. Cicindela 20:25–29

Schultz TD, Rankin MA (1983a) The ultrastructure of the epicuticular interference reflectors of tiger beetles (*Cicindela*). J Exp Biol 117:87–110

Schultz TD, Rankin MA (1983b) Development changes in the interference reflectors and colorations of tiger beetles (*Cicindela*). J Exp Biol 117:111–117

Schwartz MW (1999) Choosing the appropriate scale of reserves for conservation. Annu Rev Ecol Syst 30:83–108

Serrano J, Yadav JS (1984) Chromosome numbers and sex determining mechanisms in adephagan Coleoptera. Coleopt Bull 38:335–357

Shelford R (1902) Observations on some mimetic insects and spiders from Borneo and Singapore. Proc Zool Soc London 1902:230–284

Shelford VE (1907) Preliminary note on the distribution of the tiger beetles (*Cicindela*) and its relation to plant succession. Biol Bull Marine Biol Lab, Woods Hole 14:9–14

Shelford VE (1913) The reactions of certain animals to gradients of evaporating power of air. A study in experimental biology. Biol Bull 25:79–120

Sikes DS (2002) Beetles of Block Island: rare species that once occurred on the mainland, Chapter 11. In: Paton PW, Gould LL, August PV, Frost AO (eds) The ecology of Block Island: proceedings of the Rhode Island Natural History Survey Conference, October 28, 2000. Rhode Island Natural History Survey, Kingston, pp 183–191

Sorensen WC (1995) Brethren of the net: American entomology 1840–1880. University of Alabama Press, Tuscaloosa

Spomer SM, Higley LG (1993) Population status and distribution of the Salt Creek Tiger Beetle, *Cicindela nevadica lincolniana* Casey (Coleoptera: Cicindelidae). J Kans Entomol Soc 66:392–398

Strausfeld NJ, Sinakevitch I, Brown SM, Farris SM (2009) Ground plan of the insect mushroom body: functional and evolutionary implications. J Comp Neurol 513:265–291

Thomas JA (1995) Why small cold-blooded insects pose different conservation problems to birds in modern landscapes. Ibis 137(supplement):S112–S119

Toh Y, Mizutani A (1994) Neural organization of the lamina neuropil of the larva of the tiger beetle, *Cicindela chinensis*. Cell Tissue Res 278:135–144

Topp W, Katrin T, Kappes H (2010) Soil dumping techniques and afforestation drive ground-dwelling beetle assemblages in a 25-year-old open-cast mining reclamation area. Ecol Eng 36:751–756

Torres JB, Ruberson JR (2005) Canopy- and ground-dwelling predatory arthropods in commercial *Bt* and non-*Bt* cotton fields: patterns and mechanisms. Environ Entomol 34:1242–1256

Trautner J (1996) Historische und aktuelle Bestandssituation des Sandlaufkäfers *Cicindela arenaria* Fuesslin, 1775 in Deutschland (Col., Cicindelidae). Entomol Nacht Berichte 40:83–88

Vítolo A (2004) Guía para la identificación de los escarabajos tigre (Coleoptera: Cicindelidae) de Colombia. Instituto de Investigación de Recursos Biológicas Alexander von Humboldt, Bogotá

Vogler AP (1998) Extinction and the evolutionary process in endangered species: what to conserve? In: DeSalle R, Schierwater B (eds) Molecular approaches to ecology and evolution. Birkhäuser Verlag, Basel, pp 191–210

Vogler AP, Barraclough TG (1998) Reconstructing shifts in diversification rate during the radiation of Cicindelidae (Coleoptera). Mus Reg Sci Nat Torino 1998:251–260

Vogler AP, DeSalle R (1994) Diagnosing units of conservation management. Conserv Biol 8:354–363

Vogler AP, Pearson DL (1996) A molecular phylogeny of the tiger beetles (Cicindelidae): congruence of mitochondrial and nuclear rDNA data sets. Mol Phylogenet Evol 6:321–338

Vogler AP, Desalle R, Assmann T, Knisley CB, Schultz TD (1993) Molecular population genetics of the endangered tiger beetle *Cicindela dorsalis* (Coleoptera: Cicindelidae). Ann Entomol Soc Am 86:142–152

Vogler AP, Welsh A, Hancock KM (1997) Phylogenetic analysis of slippage-like sequence variation in the V4 rRNA expansion segment in tiger beetles (Cicindelidae). Mol Biol Evol 14:6–19

Vogler AP, Knisley CB, Glueck SB, Hill JM, Desalle R (2008) Using molecular and ecological data to diagnose endangered populations of the puritan tiger beetle *Cicindela puritana*. Mol Ecol 2:375–383

von Linné K (1758) Systema Naturae, (Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis). Vol. I Editio decima, reformata. Laurentii Salvii, Holmiae

Wallace AR (1869) The Malay Archipelago. The land of the Orang-Utan and the Bird of Paradise. A narrative of travel, with studies of man and nature. Macmillan & Co, London, pp XVIII–515 [Unabridged reprint of the 1922 edition: Dover Publications Inc., New York]

Walters M (2003) A concise history of ornithology: the lives and works of its founding figures. Christopher Helm, London

Wickham HF (1904) The influence of the mutations of the Pleistocene lakes upon the present distribution of *Cicindela*. Am Nat 38:643–654

Wiesner J (1992) Verzeichnis der Sandlaufkäfer der Welt. Checklist of the tiger beetles of the world. Verlag Erna Bauer, Keltern

Wilson EO (1998) Consilience: the unity of knowledge. Random House, New York

Wu X-Q, Shook G (2010) Common English names and Chinese names for tiger beetles of China. J Entomol Res Soc 12:71–92

Yager DD, Cook AP, Pearson DL, Spangler HG (2000) A comparative study of ultrasound-triggered behaviour in tiger beetles (Cicindelidae). J Zool 251:355–368

Yarbrough WW, Knisley CB (1994) Distribution and abundance of the coastal tiger beetle, *Cicindela dorsalis media* (Coleoptera: Cicindelidae), in South Carolina. Entomol News 105:189–194

Zerm M, Adis J (2000) On the life cycles of *Phäeoxantha* species (Coleoptera: Cicindelidae) from central Amazonian floodplains (Brazil). Ecotropica 6:141–155

Zerm M, Adis J (2001) Further observations on the natural history and survival strategies of riverine tiger beetles (Coleoptera, Cicindelidae) from open habitats in central Amazonian floodplains (Brazil). Ecotropica 7:115–137

Zerm M, Walenciak O, Val AL, Adis J (2004a) Evidence for anaerobic metabolism in the larval tiger beetle, *Phaeoxantha klugii* (Col. Cicindelidae) from a central Amazonian floodplain. Physiol Entomol 29:483–488

Zerm M, Zinkler D, Adis J (2004b) Oxygen uptake and local PO_2 profiles in submerged larvae of *Phaeoxantha klugii* (Coleoptera: Cicindelidae), as well as their metabolic rate in air. Physiol Biochem Zool 77:378–389