CONTRIBUTIONS

Commentary

A History of the Ecological Sciences, Part 8.

Frederick II of Hohenstaufen: Amateur Avian Ecologist and Behaviorist

It is possible to survey ecological aspects of natural history in the Latin West from late Antiquity to the early Middle Ages in a way similar to my surveys on Byzantine and Arabic natural history (Egerton 2002*a*, *b*, *c*). Glacken (1967, Part II) provides a guide for an ecological survey of Latin natural history. It was generally less sophisticated than contemporary Byzantine and Arabic writings, and only became more sophisticated after those foreign writings were being translated into Latin (Haskins 1927, Lindberg 1978). Rather than survey here the relevant Latin writings from late Antiquity and the early Middle Ages, it seems more interesting to consider a West European example of what was built upon Byzantine and Arabic legacies.

A remarkable example is the *De Arte Venandi cum Avibus* (*The Art of Hunting with Birds*), written in the 1240s by the King of Sicily and southern Italy and the Emperor of the Holy Roman Empire. In English, he is called Frederick II, although he never answered to that name (unless that form was used by his third queen, who came from England). He was raised in Sicily, where he was called Federico; during his 8-year stay in Germany, he was called Friedrich; and in government documents, his name appeared in Latin as Fredericus or Federicus. He was born in 1194, and his father, Emperor Heinrich VI, died in 1197, and his mother, Queen Constance of Sicily, died in 1198 after appointing Pope Innocent III as his guardian. Constance's father was Roger II, who had a strong interest in geography and gathered scholars from diverse places at his court. That intellectually stimulating court had not been maintained after Roger's death in 1154, but the memory lingered, and Frederick recreated it on a grander scale (Haskins 1927:242–271, Van Cleve 1972: 299–346, Tronzo 1994, Mariani and Cassano 1995).

In Palermo, Frederick had tutors but no playmates beyond what he found for himself. He wandered about and developed a strong permanent interest in animals, both domestic and wild (Abulafia 1988:107). Sicily was one of the most cosmopolitan places on earth, and Frederick enjoyed associating with Italians, Greeks, Jews, Moslems, Germans, and anyone else who could satiate his curiosity. He discovered that Christians had no monopoly on wisdom, and throughout his life his interest in religion was political rather than spiritual. The disapproving monk, Salimbene (c.1221–1289), who could never resist a good story, characterized Frederick as follows (Salimbene 1907:241–242):

Of faith in God he had none; he was crafty, wily, avaricious, lustful, malicious, wrathful; and yet a gallant man at times, when he would show his kindness or courtesy; full of solace, jocund, delightful, fertile in devices. He knew to read, write, and sing, and to make songs and music. He was a comely man, and well-formed, but of middle stature. I have seen him, and once I loved him . . . . He knew to speak with many and varied tongues, and, to be brief, if he had been rightly Catholic, and had loved God and His Church, he would have had few emperors his equal in the world.

Salimbene's lament seems rather restrained, considering that Frederick spent much of his career struggling against the Papacy—which feared he might try to unite his German empire with his south Italian kingdom—and that Frederick was excommunicated twice.

Frederick's favorite relaxation from affairs of state was to retreat to one of his hunting-lodge palaces (three of which survive, as does his castle at Lucera [Frederick II of Hohenstaufen 1943:xliv, xcii–cx, Van Cleve 1972:Plates 12–13, Tronzo 1994, Mariani and Cassano 1995]) where he hunted with trained falcons. In the "General Prologue" to *De Arte Venandi cum Avibus*, he tells us (Frederick II of Hohenstaufen 1943:3) that he only began writing his treatise after contemplating doing so for 30 years. Haskins thinks he began writing it about 1244, which means that he was already a somewhat experienced falconer at age 20 (Haskins 1927:310–311).

Falconry arose in Mesopotamia (Reiter 1988–1989); our earliest evidence comes from the reign of Sargon II (reigned 722–705 BC). There is little indication of its practice in Europe, however, until the AD 400s, when the Huns and Alans invaded from the east and perhaps introduced the sport (Epstein 1943:505–509). Manuals on falconry also came first from the East, and Frederick's location in Sicily gave him an awareness of them (Zahlten 1970:52–54). He also gained firsthand knowledge of Arabic falconry during his crusade to the Holy Land, June 1228–June 1229 (not counted by historians as an official crusade because he negotiated his objectives instead of fighting for them). He obtained, then or later, a copy of Moamin's manual on falconry and had Theodore of Antioch translate it from Arabic into Latin; Frederick made corrections to the translation in 1241. Moamin's manual survives in French translation from the Latin, made for Frederick's son, Enzio (Tjerneld 1945).

Knowledge of falconry consists of hunting technology and applied avian biology. Aside from naming and describing hawks used in falconry, all of the manuals before Frederick's were limited to hunting technology—how to train and manage falcons (Van den Abeele 1994:45–91). This subject occupies most of Frederick's manual as well, but he was well equipped by education and intellect to go further and investigate the biology of both predators and prey. The result has been called "one of the most remarkable productions of the Middle Ages" (Singer 1982:262). How did he do it?

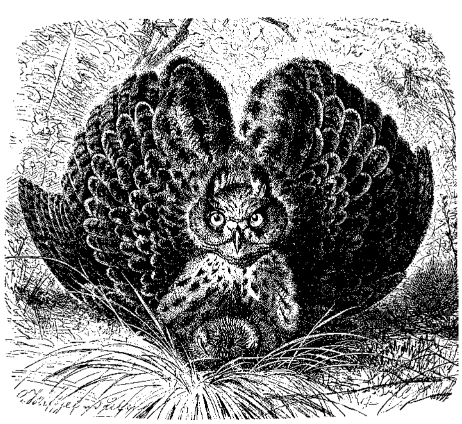
The intellectuals whom Frederick gathered at Palermo included Michael Scot (pre-1200–c.1236; Minio-Paluello 1974), who was an influential author and translator. He traveled from his native Scotland to Toledo by 1217, where by 1220 he had translated from Arabic Aristotle's *Historia Animalium*, *De Partibus Animalium*, and *De generatione Animalium* (Thorndike 1965:24, van Oppenraay 1999). He then traveled to Bologna and later attracted the interest of two popes. He was at Frederick's court by 1227, if not before, and remained there until his death. Michael Scot had a strong interest in astrology, wrote on it, and interested Frederick in it. At Frederick's request, he translated from Arabic Ibn Sina's *Abbreviatio de Animalibus*, an abridgement of Aristotelian zoology with Ibn Sina's commentary, which he finished by 1232. Most likely this was part of Frederick's preparation for writing his own book. However, Frederick cited few authorities besides Aristotle, with whom he frequently disagreed, because Aristotle did not know falconry and he relied on the reports of others (Frederick II of Hohenstaufen 1943:xxxix, xlviii–xlix).

In the six-book version of *De Arte Venandi cum Avibus* (there is also a two-book version), Book I is on "The Structure and Habits of Birds," and the other five are on aspects of falconry. Histories of science focus on Book I (Haskins 1927:320–326; Stresemann 1975:9–12), but there are many ecological and behavioral observations throughout. The English translators, Wood and Fyfe, provide a helpful "Annotated roster of birds that are mentioned, depicted by, and were probably familiar to the Emperor Frederick II" (Frederick II of Hohenstaufen 1943:531–556), yet Yapp (1983:598) complains that they sometimes leave a word in Latin when they do not know an English equivalent, and they do not always use the same English name for a given Latin word. Kraak (1955–1956) drew upon Wood and Fyfe's work, but provides his own list of identifications. I myself find that Wood and Fyfe's translations of terms are sometimes anachronistic—most obviously in translating "sperma" as "spermatazoa" (p. 53); the existence of "animacules" in semen was discovered in 1677 (Leeuwenhoek 1679). Studies beyond a casual reading should be made with the Latin text and the authoritative French translation (Frederick II of Hohenstaufen 1942: 2000), as well as the English translation.

The 12 manuscript copies of Frederick's book have illustrations, although not the same number and not identical (Frederick II of Hohenstaufen 1943: liii–lxxxvii). Yapp (1983) studied the colored marginal drawings in the facsimile publication of the Vatican manuscript of *De Arte Venandi cum Avibus* (Frederick II of Hohenstaufen [1969]; Henss [1970:465] counted 915 drawings of birds and 48 drawings of other animals in this edition). Yapp found that although the drawings do illustrate points made in the text, the birds depicted are not of definite species; they are generic ducks, geese, and so on. Yapp doubts that they were drawn during Frederick's lifetime, but perhaps shortly thereafter.

Frederick's Book I on the natural history of birds is similar in organization to the *Historia Animalium* of Aristotle, except for its more limited scope. In Aristotelian zoology, facts were collected and organized to serve as the basis for generalizations, and generalizations were organized to explain how nature works. At times the results were impressive (Bodson 1996), but there was no way to know whether one had enough facts to support a given generalization. In practice, whatever facts were available seemed sufficient. Frederick had two advantages in playing this game: first, by limiting his study to birds, he could better master his subject, and second, he actively collected facts while hunting and engaging in other activities and was seldom dependent upon others for information. He developed a general interest in avian biology, but also had a specific interest in birds as either trained hunters or as prey for his falcons. His general and specific interests reinforced each other. He began with a discussion of two ways to classify birds: (1) aquatic, land, and neutral, the latter meaning birds that are on both land and water; and (2) raptorial and nonraptorial (I, 2–3). He discussed the daily habits of different kinds of birds under these categories. The anatomy and physiology of a species were its adaptations for its environment and did not seem to require explanations. However, it was useful to make generalizations about particular groups in order to be able to anticipate their behavior.

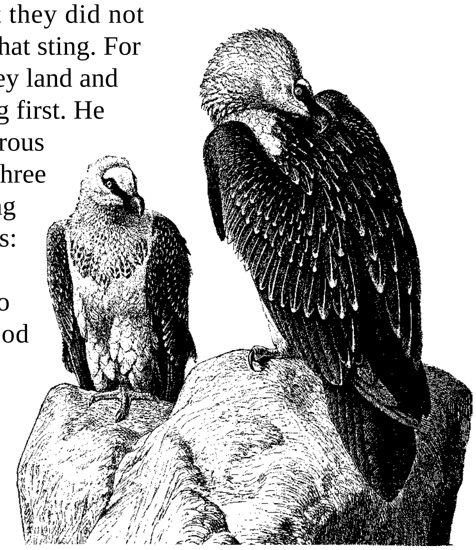
Aristotle had claimed that birds that are limited in flight are to an equal extent good pedestrians, but Frederick observed that cormorants do not fly with ease and are even worse at walking. Frederick's son, Manfred, annotated his father's manuscript, and in this case added that their adaptation for swimming makes cormorants awkward on land and in the air (I, 4). Frederick's own generalizations included the facts that: (1) certain birds, such as swans and pelicans, swim and fly well, yet rarely leave the water; and (2) rails and their kin neither swim nor fly well, yet are true water birds. Some bird habits seemed inherent, but nevertheless were susceptible to environmental influences. For example, many aquatic birds depart at dawn for their feeding places and return at the third hour [9 am], but may return earlier on a hot day and remain feeding longer if it is cool or cloudy. Yet ducks, teal, and similar birds do not feed at particular times but at all hours (I, 5). Waterfowl return home during the day while they can see otters, foxes, and raptors. They stay in water at night to avoid otters, foxes, and wolves (I, 7). Waterfowl vary their feeding grounds according to season and the ease or difficulty of avoiding birds of prey. They prefer pasturage during the rainy days of September–November when rain dislodges seeds and when worms come to the surface of the ground to escape saturated soil (I, 6). Frederick explained why owls hunt at night (I, 15-A):



> *not so much because they can see at night and not in the daytime (as Aristotle asserts* ["owl does not see sharply by day" 609a9])*—for they have good vision both by day and by night—but because they feed on the young of other birds. They are hateful to such birds and, therefore, do not dare to hunt during the day. Like certain quadrupeds that possess poor physical armament, they hide by day and seek their food by night and in this way avoid the harm that might befall them if plainly seen.*

Other species go out at night to avoid diurnal rapacious birds and other animals that would harm them.

"Certain land birds take their food on the wing," such as swallows and siskins (I, 9). He observed them eating flies, beetles, bees, wasps, and other insects, but he thought that while aloft they did not swallow those that sting. For such insects, they land and remove the sting first. He divided carnivorous land birds into three groups according to feeding habits: (1) vultures and lammergeiers do not kill their food but eat carrion; (2) kites and common eagles prefer to eat dead animals but sometimes do kill for food; and (3) true falcons and hawks devour only what they kill and never eat carrion. He determined that vultures can only find food by sight and not by smell by sealing their eyes (undoubtedly by suturing) and placing food nearby which they did not find (I, 10). Experimentation was very rare in natural history during antiquity and the Middle Ages, and Frederick probably experimented in this case because he was used to manipulating hawks during training and hunting.



Because we know that Frederick experimented on vultures, Salimbene's stories of his experiments on humans may also be true, although no one can vouch for Salimbene's sources. If, indeed, Frederick had infants raised in silence to discover what language they would speak, he was repeating an inconclusive experiment conducted by an Egyptian pharaoh as reported by Herodotos (II, 2). The other experiments certainly reflect Frederick's known interest in physiology and medicine: he had a man shut up in a cask to see whether his soul could be detected when he died; to discover how deep a man can dive, he had a diver retrieve objects at progressively greater depths until he drowned; to learn whether one should relax or exercise after eating (Salimbene 1907:242–243):

> *he fed two men most excellently at dinner, one of whom he sent forthwith to sleep, and the other to hunt; and that*

same evening he caused them to be disembowelled in his presence, wishing to know which had digested the better: and it was judged by the physicians in favour of him who had slept.

Frederick did execute the alleged enemies of church and state; perhaps a few humans sacrificed for science did not seem very different, especially if men condemned to execution were the subjects.

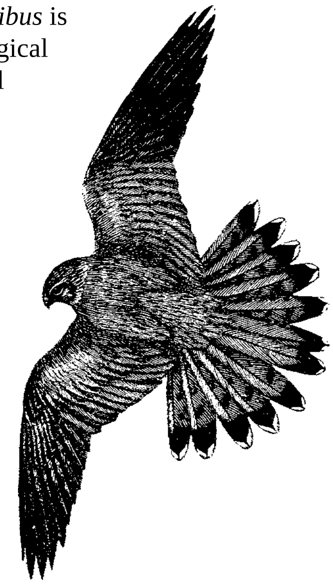
There is much more of what we could call avian ecology in Book I of *De Arte Venandi cum Avibus* than can be discussed here. Equally remarkable, however, is Frederick's account of training falcons to hunt with humans and dogs. In this discussion, he was indebted to earlier manuals, such as the one by Moamin (Tjerneld 1945), to his extensive discussions with other falconers (he had about 50 on his staff), and to his own experience. Although this lore came much more from trial and error than from planned experiments, it is nevertheless remarkably sophisticated. Tame falcons used for hunting were not raised in captivity but were captured wild. An impatient or careless handler could render a captive hawk untrainable with improper treatment (II, 47). Training was done using positive reinforcement (food and stroking) and deprivation (lack of food and sight), but without punishment. Mountjoy (1976:110–111) has rephrased Frederick's instructions for training falcons in behaviorist terminology:

The process of manning the newly captured wild falcon (that is, taming it so that it sat quietly upon the fist of the falconer and ate) was carried out in the mews while the falcon's [eyes] remained sealed. This process of manning combined not only Pavlovian pairing of stimuli but also operant shaping and the principle of stimulus fading as well.

* * *

At the beginning of the process of manning, meat was rubbed on the bird's beak to elicit the response of eating. The falconer continued to apply the principles of Pavlovian conditioning by softly producing the sound which would later be used to recall the falcon to the falconer. In time this vocalization of the falconer became a discriminative stimulus, . . . a signal to eat. The discriminative stimulus was gradually conditioned to a functional state by presenting the call and requiring that the falcon attend to the meat within a brief time or meat was withheld. The latency requirement, or contingency, was gradually tightened until a discriminated operant was performed . . . . first meat would be available for perhaps 10 or 15 seconds after presentation of the vocalization, and then withdrawn if the desired response was not forthcoming. When the bird reliably responded within the time interval, the interval was gradually shortened.

Frederick even trained falcons to hunt cranes and herons, which they do not normally attack in the wild because they are large enough to be dangerous to falcons. He and his trainers achieved this by training a pair of falcons to hunt together, along with their trainers (Books III–V).



De Arte Venandi cum Avibus is judged to be "the first zoological treatise written in the critical spirit of modern science" (Mountjoy et al. 1969:61). Unfortunately, its influence was quite limited for centuries. Frederick died in 1250 and both his sons and grandsons continued with falconry, but then his royal line died and so did its influence. Although there were 12 manuscript copies of his work, apparently none circulated among naturalists. It was not published until 1596, and did not attract the attention of ornithologists until 1788 (Stresemann 1975:10).

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Pseudoreplication in Russian Ecological Publications

Introduction

The use of inferential statistics to test for treatment effect with data from experiments where either the treatments were not replicated (although samples may be) or the replicates are not statistically independent leads to a serious methodological problem. This problem, discovered by Hurlbert (1984), is called pseudoreplication, a word that is now in the lexicon of biologists and statisticians (Heffner et al. 1996). During 1987–2001, the paper by Hurlbert (1984) was cited in 2105 articles covered by the Science Citation Index (compiled by the Institute for Scientific Information), and several recent publications discuss the pseudoreplication issue in detail (Riley and Edwards 1998, Morrison and Morris 2000, Ramirez et al. 2000, Kroodsma 2001, Mantgeim et al. 2001, Oksanen 2001). The percentage of pseudoreplicated ecological studies is steadily declining, especially in high-quality journals (Hurlbert and White 1993, Heffner et al. 1996, Kroodsma et al. 2001). However, "pseudoreplication is an insidious beast" (Heffner et al. 1996:2558), and this beast is still far from being extinct.

A couple of years ago, when teaching ecological methodology and applied statistics to doctoral students and postdoctoral researchers of the Kola Science Centre (Apatity, Russia), I discovered that the concept of pseudoreplication was unknown to all of them. Further consultations with Russian colleagues revealed that only two research teams (both from Moscow) read and used the monograph by Hurlbert (1984), while about 30 research teams that I questioned had never heard about the pseudoreplication issue. Screening of available Russian textbooks on applied statistics for biologists (some 20 titles published after 1987) demonstrated that none of them even mentioned this problem. Moreover, according to the Science Citation Index (which includes references at least to leading Russian journals), the work by Hurlbert (1984) had never been referred to in any paper published in Russian during 1987–2001.

Thus, it seems that the problem of pseudoreplication had been completely (or almost completely) overlooked by the Russian ecologists. (I define "Russian ecologists" as ecologists working on the territory of the former U.S.S.R. and publishing most of their scientific results in Russian; thus, the group is defined by the language of publications, not by the boundary of the Russian Federation.)

It is therefore interesting to determine how many experimental ecological studies, conducted by Russian researchers during the past years, have been pseudoreplicated, and which kind of pseudoreplication occurs most frequently. Exploration of this topic is important because (1) the international scientific community needs information on the quality of ecological papers published in Russian (which are frequently cited on the basis of abstracts only), and (2) better understanding of the situation may help to decrease the frequency of pseudoreplication.

Methods

I examined the experimental design of recent (1998–2001) ecological papers from six major biological journals published by the Russian Academy of Sciences: *Botanicheskij Zhurnal* [*Botanical Journal*, St. Petersburg], *Ekologia* [*Russian Journal of Ecology*, Ekaterinburg], *Izvestija RAN Serija Biologicheskaja* [*Bulletin of the Russian Academy of Sciences, Biological Series*, Moscow], *Lesoverenie* [*Forestry*, Moscow], *Zhurnal Obstchei Biologii* [*Journal of Fundamental Biology*, Moscow], and *Zoologicheskij Zhurnal* [*Zoological Journal*, Moscow]. The period for which all of the manipulative ecological experiments were included in the sample (Table 1) was determined by the frequency of publication of the experimental papers; I aimed to analyze at least 10 papers of this kind for every journal involved.

I classified the manipulative study as an *ecological* experiment when the researcher modified the environment of some organisms, independent of the character of the outcome variables. Because manipulative studies are relatively infrequent in papers published by Russian ecologists, I included in my sample not only field and mesocosm experiments, but also laboratory experiments. The experimental papers were then scanned in order to determine: (1) if the study was properly replicated, and (2) if inferential statistics were used for data analysis. Calculation of the mean value and standard error (or another index of variability) was considered to use inferential statistics if the author(s) made at least verbal comparisons between mean values.

The papers were evaluated for pseudoreplication following the procedure described by Heffner et al. (1996). If a paper reported more than one experiment, it was classified as a pseudoreplicated study if at least one experiment included this error. Each of these papers was then placed into one or more of the categories defined by Hurlbert (i.e., simple, temporal, sacrificial, or implicit). It should be noted that this classification is partially overlapping; for example, some pseudoreplication can be both simple and implicit. Furthermore, some papers reporting multiple experiments contained more than one type of pseudoreplication.

If the description of experimental design did not allow me to reach a definite conclusion on the presence or absence of pseudoreplication (24 of 86 experimental studies), I contacted the authors in order to clarify the critical details. Because the authors of 10 of 24 articles did not respond to my repeated requests during 3–4 months, these papers were classified as presumably pseudoreplicated. I honestly believe that the majority of these studies are indeed pseudoreplicated: information provided by the authors of 14 presumably pseudoreplicated papers demonstrated that 12 of these papers (86%) contained this type of error.

Table 1. Summary statistics for the ecological papers evaluated for pseudoreplication. All figures indicate the number of papers. Footnote references to *presumably pseudoreplicated* studies are italicized.

Journal name†	Years reviewed	Ecological papers	Manipulative studies	Replication (R) and inferential statistics (S) in manipulative ecological studies: True replic.		Pseudoreplic.		None	Pseudoreplication type‡: Simple	Temporal	Sacrificial	Implicit
				R+S-	R+S+	R+S+	R-S+	R-S-				
Botanicheskij Zhurnal	1998–2000	114	10	5	2	0	0	3	0	0	0	0
Zhurnal Obstchei Biologii (ZOB)	1998–2001	55	14	0	6	3	2	2	1	4	3	2
Zoologicheskij Zhurnal (ZZ)	1999–2000	94	11	0	4	4	3	0	2	1	4	0
Izvestija RAN Ser. Biol. (IB)	1999–2001	82	18	2	6	1	8	1	8	1	2	5
Lesoverenie (L)	2001	61	11	1	1	2	5	2	5	0	2	4
Ekologia (E)	2000–2001	156	22	2	5	3	9	3	8	2	3	0
Total		562	86	10	25	13	27	11	24[a]	8[b]	14[c]	11[d]

† Abbreviations used in footnote references.

‡ One study may include more than one type of pseudoreplication.

[a] *Eremina and Bakanova 1999, IB **0**(3):343–354*; Kargatova et al. 1999, IB **0**(2):152–157; Kulakovskii and Lezin 1999, ZZ 78 (5):596–600; Osadchuk 1999, IB **0**(2):191–200; *Vasil'ev 2000, ZZ **79** (9):1114–1123*; Zyalalov and Avduevskyj 2000, ZOB **61**(2):173–180; Kryukov 2000, E **0**(3):238–240; Lapteva and Solntseva 2000, E **0**(4):295–299; Rudneva and Zherko 2000, E **0**(1):70–73; Pashkova and Korotneva 2000, IB **0**(6):758–761; Rudneva et al. 2000, E (4):304–306; Sidelnikov and Stepanov 2000, IB **0**(5):525–532; *Bobrinev and Ivanova 2001, L **0**(4):58–61*; Grodnitskaya and Gukasyan 2001, L **0**(1):38–42; Yes'kov and Levin 2001, E **0**(1):67–69; Lozhnikova and Kondratieva 2001, IB **0**(2):187–190; *Martinovich et al. 2001, L **0**(3):3–10*; *Mudrik and Vilchek 2001, E **0**(4):267–273*; Orekhova 2001, L **0**(3):46–51; Poletaeva et al. 2001, E **0**(3):231–236; *Popova et al. 2001, IB **0**(2):174–179; Rogozhin et al. 2001, IB **0**(2):165–173*; Smirnov 2001, L **0**(2):46–52; Tatarnikov 2001, E **0**(1):8–13; Trubina 2001, E **0**(1):38–43.

[b] *Berezina 1999, ZOB **60**(2):189–198*; Falzman and Bastakov 1999, ZOB **60**(2):199–206; Gorb and Gorb 2000, ZOB **62**(2): 132–140; Kryukov 2000, E **0**(3):238–240; Nikol'skii 2000, ZZ **79**(3):338–347; Pashkova and Korotneva 2000, IB **0**(6):758–761; *Sokolov and Grechkina 2000, E **0**(5):372–375*; Baskin and Skogland 2001, ZOB **62**(1):78–84.

[c] *Berezina 1999, ZOB **60**(2):189–198*; Zhuzhikov 1999, ZZ **78**(11):1292–1297; Triseleva and Safonkin 1999, ZZ **78**(4): 451–455; Pashkova and Korotneva 2000, IB **0**(6):758–761; Gorb and Gorb 2000, ZOB **62**(2):132–140; Gromov 2000, ZZ **79**(11): 1344–1354; Knorr et al. 2000, IB **0**(1):75–83; Nikol'skii 2000, ZZ **79**(3):338–347; Ruchin 2000, ZZ **79**(11):1331–1336; Safonkin 2000, E **0**(3):224–227; Yes'kov and Levin 2001, E **0**(1):67–69; Markova and Shestakova 2001, L **0**(2):33–40; *Pozolotina 2001, E **0**(2):117–124*; *Rogozhin et al. 2001, IB **0**(2):165–173*; Sedykh et al. 2001, L **0**(5):72–75.

[d] *Berezina 1999, ZOB **60**(2):189–198*; Kargatova et al. 1999, IB **0**(2):152–157; Zyalalov and Avduevsky 2000, ZOB **61**(2):173–180; Pashkova and Korotneva 2000, IB **0**(6):758–761; *Bobrinev and Ivanova 2001, L **0**(4):58–61*; Markova and Shestakova 2001, L **0**(2):33–40; *Martinovich et al. 2001, L **0**(3):3–10*; Lozhnikova and Kondratieva 2001, IB **0**(2):187–190; Orekhova 2001, L **0**(3):46–51; *Popova et al. 2001, IB **0**(2):174–179; Rogozhin et al. 2001, IB **0**(2):165–173*.

Results

Selected issues of six Russian journals contained 562 ecological articles, 86 (15.3%) of which presented results of ecological experiments; inferential statistics were used in 65 publications. I classified 30 (34.9%) of the 86 manipulative studies as pseudoreplicated; 10 studies (11.6%) were presumably pseudoreplicated. The frequency of pseudoreplication for manipulative ecological studies was in the range of 34.9–46.5%, or 46.2–61.5% of studies that used inferential statistics.

Simple pseudoreplication was most common in the surveyed sample (24 of 40 pseudoreplicated studies), followed by sacrificial (14 studies) and temporal pseudoreplication (8 studies); in 11 articles, the pseudoreplication was implicit (that is, authors reported means and standard errors and based their conclusion on "verbal" comparisons, without conducting statistical tests).

The frequency of pseudoreplication was highest (60%) in those articles that reported results of mesocosm experiments (three of five studies), intermediate (48%) in field experiments (12 of 25 studies), and lowest (42.9%) in laboratory experiments (24 of 56 studies). However, these differences between different types of manipulative studies are far from being significant ($G = 0.62$, df = 2, $P > 0.10$).

The six surveyed journals can be split into two categories: *Botanicheskij Zhurnal*, which did not publish pseudoreplicated studies in the selected issues, and all other journals, which published 35.7% (*Zhurnal Obstchei Biologii*) to 63.6% of pseudoreplicated manipulative studies (*Zoologicheskij Zhurnal* and *Lesovedenie*). It should be noted, however, that the absence of pseudoreplicated studies in the *Botanicheskij Zhurnal* resulted not from better planning of experiments, but from the absence of even the simplest statistical analysis in 8 of 10 reviewed papers; the remaining five journals did not differ in the percentage of pseudoreplicated ecological experiments ($G = 2.79$, df = 4, $P > 0.10$).

Discussion

The percentage of pseudoreplicated ecological papers recently published by six journals of the Russian Academy of Sciences was 1.5–2 times as high as the percentage reported by Hurlbert (1984) for the years 1960–1980, and 3–4 times as high as the percentage of pseudoreplicated field studies published in leading international journals in 1991–1992 (Heffner et al. 1996). The high frequency of pseudoreplication in papers by Russian ecologists resulted from the fact that most of the authors had not read Hurlbert's review and seemed generally unfamiliar with issues of experimental design and analysis. However, I cannot attribute this situation to the nonavailability of Hurlbert's publication: the relevant issue of *Ecological Monographs* is present in at least 10 libraries of the Russian Academy of Sciences (data received from the catalogue of the main library in St. Petersburg, Russia).

It seems that a low level of statistical knowledge is the main reason for the high frequency of pseudoreplicated studies published by Russian researchers. This conclusion is supported by the high frequency of sacrificial pseudoreplication, which resulted from the incorrect use of statistics, not from the incorrect design of experiments. Note that sacrificial pseudoreplication did not occur in the sample by Heffner et al. (1996), although Hurlbert (1984) found this type of pseudoreplication surprisingly common.

For a quite a long time in Russia, statistics were taught to biological students as a part of mathematics, without giving proper reference to practical applications. Moreover, almost no attention was paid to the assumptions to be met when selecting the method of data analysis (personal impressions received at Leningrad University in the early 1980s). As a result, quite a number of Russian researchers simply avoid statistical analysis, basing their conclusions on expressions such as "as can be seen from the figure." This practice is both confusing and misleading; sometimes the simplest statistical analysis reveals that conclusions by authors contradict their own data (Kozlov 2001).

To conclude, a high level of pseudoreplication discovered in manipulative studies published by Russian ecologists emphasizes the need for careful revision of the experimental design in papers to be used for reviews and meta-analyses. Citation of the results of Russian researchers on the basis of abstracts only (which are generally available in English, whereas the full text of papers is translated less frequently) should be avoided. Researchers who are cooperating with Russian scientists may help to improve the situation by carefully explaining the pseudoreplication problem to those colleagues and emphasizing the importance of rigorous statistical analysis of the ecological data. From a long-term perspective, some other actions may be needed, such as free distribution of recent statistical textbooks translated into Russian.

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