**Biological Control Efforts in the Early 19th Century**

A number of articles appeared during the first half of the 19th Century that lauded the beneficial effects of entomophagous insects. *Erasmus Darwin* (1800) recommended protecting and encouraging syrphid flies and ichneumonid wasps because they destroyed considerable numbers of cabbage-feeding caterpillars. *Kirby & Spence* (1815) showed that predaceous coccinellids controlled aphids. *Hartig* (1827) recommended the construction of large rearing cages for parasitized caterpillars, with the ultimate aim of mass release. *Ratzeberg* (ca. 1828) called particular attention to the value of parasitic insects with publication of a large volume on the parasitoids of forest insects in Germany. He did not believe that parasitic control could be augmented by humans. *AgustinoBassi* (1834) first demonstrated that a microorganism, Beauvariabassiana, caused an animal disease, namely the *muscardine* disease of silkworms**.***Kollär* (1837) writing an article for farmers, foresters and gardeners pointed out the importance of entomophagous insects in nature's economy; studied parasitoid biologies and was the first to report the existence of egg parasitoids. *Boisgiraud* (1843) reported that he used the predaceous carabid beetle, Calasomasycophanta, to successfully control gypsy moth larvae on poplars growing near his home in rural France. He also reported that he had destroyed earwigs in his garden by introducing predaceous staphylinid beetles.

**Biological Control in the Late 19th Century**

Beginning in 1850, events associated with the westward expansion of agriculture in the United States paved the way for the further development of the field of biological control. During and following the "Gold Rush" in California, agriculture expanded tremendously in California especially. At first the new and expanded plantings escaped the ravages of arthropod pests. Predictably, however, crops soon began to suffer from destructive arthropod outbreaks. Many of these pests were found to be of foreign origin, and were observed to be far more destructive in the newly colonized areas than in their native countries. Consequently, the notion grew that perhaps these pests had escaped from some regulatory factor or factors during their accidental introduction into America.

**Asa Fitch** (1855) was the State Entomologist of New York who is recorded as the first entomologist to seriously consider the transfer of beneficial insects from one country to another for the control of an agricultural pest. Fitch suggested that the European parasitoids of the wheat midge*, Sitydiplosismesellana*, be sent into the eastern United States.

**Benjamin Walsh**supported Fitch's suggestion and in 1866 he became the first worker in the United States to suggest that insects be employed in weed control. He proposed that insects feeding on toadflax, *Linaria vulgaris*, be imported from Europe to control invaded yellow toad flax plants. The first actual case of biological control of weeds was, nevertheless, in Asia, where around 1865 the cochineal insect *Dactylopiusceylonicus* was introduced from southern India into Ceylon for prickly pear cactus control (Opuntia vulgaris). Originally*, Dactylopius* had been imported to India from Argentina in 1795, in the mistaken belief that it was the cochineal insect of commerce, D. cacti.

**Louis Pasteur** (1865-70) studied silkworm diseases and saved the silk industry in France from ruin [not really biological control].

**Charles Valentine Riley** (1870) has been named the father of modern biological control. He shipped parasitoids of the plum curculio from Kirkwood, Missouri to other parts of that state. In 1873 he became the first person to successfully transfer a predator from one country to another with the shipment of the American predatory mite, *Tyroglyphusphylloxerae* to France for use against the destructive grapevine *phylloxera*. The results were not particularly successful, however. In 1883, Riley directed the first successful intercontinental transfer of an insect parasitoid, *Apantelesglomeratus*, from England to the United States for control of the imported cabbageworm. He was Chief Entomologist of the U. S. Department of Agriculture. In 1872, 11 years before the importation of A. *glomeratus*, Riley began his interest in the cottony-cushion scale, *Iceryapurchasi*, which was considered the most important citrus pest in California. He correctly located its point of origin in Australia. [Doutt's account of this biological control program on p. 31-38 of the DeBach (1964) text is particularly colorful. Read this, paying particular attention to the following:

a. the roles played by Riley, Albert Koebele and D. W. Coquillet.

b. note the species of insects involved (the vedalia beetle, *Rodoliacardinalis*, and the dipterous parasitoid, *Cryptochaetumiceryae*), their source, numbers imported, and their activities relative to the cottony-cushion scale.

c. note the method of colonization, and be able to describe the spectacular results of these introductions, which changed the status of the pest to an insect of no economic importance in only four years time.

The successful biological control effort against the cottony-cushion scale spirited many biological control attempts in many countries, resulting in over 200 biological control successes (see Chapter 24 of the DeBach (1964) text and other hand-outs).

The cottony-cushion scale success admittedly harmed overall pest control in California for quite some time because growers thought that the vedalia beetle would also control other insect pests. Consequently, they neglected other mechanical and chemical control methods.

**George Compere** (1899) became the first state employee specifically hired for biological control work. He worked as a foreign collector until 1910, during which time he sent many shipments of beneficial insects to California from many parts of the world. Harold Compere his son, also devoted his entire career to the search for and identification of natural enemies of scale insects.

**Harry Scott Smith** (1913) was appointed superintendent of the State Insectary in Sacramento. In 1923, biological control work was transferred to the Citrus Experiment Station and Graduate School of Subtropical Agriculture of the University of California, Riverside. Biological control work at Riverside was first conducted in the Division of Beneficial Insect Investigations, and was changed to the Division of Biological Control with Smith as chairman in 1947. Personnel were stationed at Albany and Riverside. Under Smith, importation of *Chrysolina* beetles from Australia for Klamath weed control marked the beginning of biological weed control in California in 1944.

**Edward Steinhaus** (1947) established the first laboratory and curriculum in insect pathology at the University of California, Berkeley. Later he transferred to the newly opened Irvine campus of the University and attempted to further insect pathology there. His untimely death in 1968 precluded this goal.

The Division of Biological Control became the Department of Biological Control at UC Riverside and Berkeley in 1954. In 1969 Biological Control was dropped as a department, becoming a Division of Biological Control within the Department of Entomology, against the wishes of the entire biological control faculty, numbering over 24 academics at Riverside and Berkeley at that time. The Berkeley faculty created their own separate Division of Biological Control with guaranteed privileges and minimum control by the Department of Entomology. At Riverside, the Division of Biological Control gradually became dominated by chemical control oriented faculty in the Department of Entomology. In 1989 the Division was abolished, against the wishes of 85% of the faculty in the Division. Ignorance and pecuniary control among the ranks of University of California bureaucrats is believed to be the principal cause. Although the dissenting faculty in the Division each wrote a personal plea to the then Chancellor Rosemary S. J. Schraer to discuss the matter, in not one case was a reply received.

**Decline of Biological Control in the University of California**

The biological control unit at the new campus of the University of California in Riverside was by 1962 the most renowned research entity for that discipline in the world. It served as a World Center for students and scientists devoted to the practice of classical biological control, where natural enemies were sought worldwide for importation and establishment. Although this unit's headquarters was at Riverside, about 1/3rd of the faculty resided at facility in Central California at Albany, just five miles north of the UC-Berkeley campus. By 1961, UC-Riverside and the Albany facility had a total of about 18 full-time professional biological control faculty plus several emeriti; about 10 Research Associates, and graduate students that varied from 10-20 until the 1980's. Members of this statewide department interacted with other similar organizations in various parts of the world, especially the Commonwealth Institute of Biological Control, that had established laboratories worldwide, and the U. S. Department of Agriculture. On the world scene, it is estimated that there were more than 300 scientists engaged in Classical Biological Control (= The search for, importation and propagation of new species of natural enemies). This does not include investigators engaged only in fundamental research. The harmony amongst these scientists was exceptional and admired, and was spirited most likely from a realization that cooperation accelerated achievements in a field that required extensive knowledge of arthropod biology and breeding habits.

However, a feud developed among some of the top administrators in the University of California and within the Department of Biological Control itself that ultimately contributed to the demise of this outstanding unit. The basis was involved, but especially referred to unprofessional conduct, the hiring of new faculty that was not supported by a majority of the Department, and animosities developed in previous years when current administrators had previously served as technical staff. The then Dean of Agriculture, Dr. Alfred Boyce, operating through departmental administrators, organized a voting block among the younger faculty against one Dr. Robert van den Bosch who was very vociferous in denouncing what he perceived to be administrative inadequacy. This ultimately led to van den Bosch being asked to leave the unit, especially after his rebellion extended to a denunciation of the scientific integrity of several active faculty.

A pervasive gloomy atmosphere followed, especially among the newly hired faculty. Van den Bosch left the Riverside campus for the branch laboratory in Albany, California, taking with him some highly skilled technical personnel, and a while later a new faculty member, Dr. George Poinar, Jr. Other faculty and staff at Riverside that were disturbed by the politics of these events then joined the separate Department of Entomology.

The feud had far reaching consequences in the University of California that persisted into the latter part of the 20th Century. One Riverside professor who had sympathy for the Albany group tried on two occasions to have a faculty member fired whom the Riverside group had supported. This even though his first attempt presumably banned him from the fellow's promotion committee. Another especially malevolent incident involved a Korean graduate student, where a junior member of the Qualifying Committee who had been a student at Albany contrived a scheme to deny the Korean student his PhD Degree. Teaming up with another faculty of the Biology Department the two failed the student and refused to grant him a second Qualifying Examination even though other members of the committee deemed his performance on the examination excellent. The incident was especially illogical and sordid because the two dissenting faculty had given the student high passing grades in their courses, and no indication of inadequacy was ever made to the major professor whom they obviously despised for his support of Dean Al Boyce in the earlier Interdepartmental conflicts. The Korean student had gained high grades in all his courses and established an excellent rapport among Public Health organizations in California while performing his thesis research. As a credit to the integrity of the University of California, wisdom prevailed as the two dissenters were removed from the student's committee. He gained the PhD Degree following a successful reexamination and later became Head of the Department of Public Health in Seoul, Korea.

Dr. Boyce later expounded on matters that further revealed more of the nature of the feud (Boyce 1997/98) and personal communications). He was especially distraught when Dr. Paul DeBach and associates at Albany ignored his contribution to the discovery of the citrus red scale parasitoids*, Aphytismaculicornis* and *Coccophagoidesutilis* that parasitized olive scale in Pakistan and Iran. He also maintained that he had made the original discovery of *Aphytismelinus* that attacks red scale (*Aoidinellaauranti*) in Pakistan, although it is unclear whether he was able to send a viable culture to California [Personal communication to Dr. E. F. Legner]. The living cultures that he did obtain from that region that was typically undergoing intense political unrest exposed him to "a hail of bullets" as he once described to Dr. E. F. Legner. Yet, not one mention of his involvement in the discovery or acquisitions of these parasitoids was ever made by DeBach or his associates who later were credited with their discovery. A disregard of the honor process among scientists in recognizing each other's contributions may have far reaching effects. Yet these failures continue and may be widespread as shown by the recent description of Biosteressublaevus Wharton that ignored mention of original specimens donated from years of effort in securing them from the wild (Legner&Goeden1987 ).

Being weakened as it was, by the loss of highly capable and productive scientists, and lacking in political adeptness, the Riverside unit fell victim to the one Riverside Campus President who had the power to do a coup de graz. It may be debated that his professional background in Political Science certainly did not justify his making unilateral decisions concerning the Biological Control discipline. By this time, DeBach had become dismayed at the politics and rather accepted the final triumph of the Al Boyce lobby. DeBach, because of his international renown in the field of Biological Control, should have been the logical choice to lead the Department as Chairman. However, against the wishes of most of the faculty, Dr. Boyce hired Dr. Don Chant of Ontario, Canada to head the Department. Chant had a very positive influence on the younger faculty especially by helping them to attain the research funds that are needed to do this highly sophisticated and time-consuming research. However, he then gradually became increasingly dismayed at the politics of the higher administration and after three years returned to Canada to head the Department of Zoology at the University of Toronto. Boyce then, against the wishes of the entire faculty, unilaterally abolished the Department of Biological Control, and forced it to reorganize as a subsidiary Division of Biological Control within the Department of Entomology, that was on the whole devoted to the use of pesticides to control agricultural pests. Later the Division itself was abolished through the intense efforts of Dr. Boyce and against the objection of 90% of its faculty. In the meantime, the Albany faculty continued relatively autonomous from the pesticide-oriented fraction, but ultimately lost critical numbers who were devoted solely to the classical biological control approach.

Another contributing factor to Riverside’s decrease in classical biological control activity is related to a reduced ability to interact with professionals overseas. To illustrate this it should be considered that classical biological control successes have relied heavily on the interaction with other international organizations, especially the Commonwealth Institute of Biological Control with headquarters in Curepe, Trinidad. Various permanent and temporary laboratories of this organization existed in all parts of the world. Researchers there would host, assist and otherwise interact with those of the United States Department of Agriculture and the University of California to obtain beneficial species. As independence from the British Commonwealth developed among the different countries that maintained laboratories, local support for their continuance diminished, and in many cases ceased entirely. This has resulted in a greater than 90% decrease in classical biological control activity worldwide.

**Strange Mortalities of Biological Control Specialists**

There have been four known suicides among the ranks of biological control scientists. These were Owen Smith and Irv Newell of the Untied States, GiuseppiiZinna of Italy, and David Annecke<PHOTO> of South Africa. Smith was found by technician Louis Dawson, hanging from a tree in the biological control orange grove on the University of California, Riverside campus. This just after his success in classical biological control of the grape leaf skeletonizer. The caterpillars possess urticating hairs that can interfere with the health of persons in close contact with them. Zinna had just been hired by the Division of Biological Control in Riverside as chief systemiatist: the position that was later filled by Gordon Gordh. Zinna returned to Italy, presumably to gather his personal effects, when he, unprovoked, jumped from an eight-story building. Annecke killed himself in South Africa, also without known provocation. Newell killed himself with a shotgun at his home in Riverside. Rumors were that he suffered from cancer, but he also was known to suffer constant severe pain in the facial area, which may have been an allergic reaction to the mites with which he so diligently worked.

Robert van den Bosch died from a heart attack while jogging in the Berkeley, California area. He had been ardently pursuing the Pesticide Industry (van den Bosch 1978) for unscrupulous activities in pest control, gaining the animosity of many dedicated to chemical pest control. There seemed to be no generally known history of cardiac illness. Paul Messenger, who took up the struggle against pesticides after van den Bosch's death, also died mysteriously from a heart attack. Blair Bartlett died in his hospital bed immediately after having heart bypass surgery in San Bernardino, California. He had been studying the effects of pesticides on beneficial organisms, and just concluded that almost all available materials had severe detrimental effects on an array of species in many important families (Bartlett 1964\*-- 1966). Harry Shorey, working with insect pheromones as a substitute for chemical insecticides in the Coachella Valley, was killed when the automobile that his student was driving collided with a truck transporting produce from Mexico.

**Major Crops with their Common Pest and their Natural Enemies**

**Beans**

Common Pests: aphids, whitefly, bean bugs, beetle, red spider mite, bollworm, bean stem maggot,

**Onion**

Common Pests: onion thrips, liriomyza leafminer

**Tomato**

Common Pests: African bollworm, armyworm, whitefly, leafworm, Tomato Semi Looper, red spider mite

**Potato**

Common Pests: aphids, cutworms, potato tuber moth, armyworm, semi-looper, whitefly

**Tobacco**

Common Pests: aphids, budworm, cutworm, stinkbugs, lace worm, termites, whitegrubs, tuber moth

**Sorghum**

Common Pests: African bollworm, armyworm, green stink bugs, aphids, sorghum shootfly

**Cabbage**

Common Pests: cutworm, cabbage aphids, bagrada bug, webworm, moth, Liriomyza

**Corn**

Common Pests: bollworm, chafer beetles, cutworms, pink stem borer, stalk borer, grain moth, maize caterpillar, white grubs, rootworm, aphids, armyworms

**Peanut**

Common Pests: aphids, false wireworms, groundnut hopper, African bollworm, leafworm, termites, whitegrubs

**Population Attributes**

**Density**

**Population density** (in agriculture **standing stock** and [standing crop](http://en.wikipedia.org/wiki/Standing_crop)) is a measurement of [population](http://en.wikipedia.org/wiki/Population) per unit area or unit volume. It is frequently applied to [living organisms](http://en.wikipedia.org/wiki/Living_organisms), and particularly to [humans](http://en.wikipedia.org/wiki/Human).

Population density is population divided by total land area or water volume, as appropriate.

Low densities may cause an [extinction vortex](http://en.wikipedia.org/wiki/Extinction_vortex) and lead to further reduced fertility. This is called the [Allee effect](http://en.wikipedia.org/wiki/Allee_effect) after the scientist who identified it. Examples of the causes in low population densities include:

* Increased problems with locating sexual mates
* Increased [inbreeding](http://en.wikipedia.org/wiki/Inbreeding)

Different species have different expected densities. [R-selected species](http://en.wikipedia.org/wiki/R/K_selection_theory) commonly have high population densities, while [K-selected species](http://en.wikipedia.org/wiki/K-selection) may have lower densities. Low densities may be associated with specialized mate location adaptations such as specialized pollinators, as found in the [orchid](http://en.wikipedia.org/wiki/Orchid) family (*Orchidaceae*).

**Dispersion**

Individual members of populations may be distributed over a geographical area in a number of different ways including:

(i)      Clumped distribution (attraction)

Clumping may result either from individual organisms being attracted to each other, or individual organisms being attracted more to some patches within a range than they are to other patches; the net effect is that some parts of the range will have a large number of individuals whereas others will contain few or none

(ii)     Uniform distribution (repulsion)

A uniform distribution means that approximately the same distance may be found between individual organisms; uniform distributions result from individual organisms actively repelling each other

(iii)     Random distribution (minimal interaction/influence)

A random distribution means that where individual organisms are found is only minimally influenced by interactions with other members of the same population, and random distributions are uncommon; "Random spacing occurs in the absence of strong attractions or repulsions among individuals of a population."

**Natality**

**Natality** is the reproductive output of a population ( birth, reproduction). Natality in population ecology is the scientific term for [birth rate](http://en.wikipedia.org/wiki/Birth_rate). Along with [mortality rate](http://en.wikipedia.org/wiki/Mortality_rate), natality rate is used to calculate the dynamics of a population. They are the key factors in determining whether a population is increasing, decreasing or staying the same in size. Natality is the greatest influence on a population’s increase. Natality is shown as a crude birth rate or specific birth rate. [Crude birth rate](http://en.wikipedia.org/wiki/Crude_birth_rate) is used when calculating population size (number of births per 1000 population/year), whereas specific birth rate is used relative to a specific criterion such as age. By calculating specific birth rate, the results are seen in an age-specific schedule of births.

* Natality Rate – number of births per 1000 individuals per year.
* Absolute Natality – the number of births under ideal conditions (with no competition, abundance of resources such as food and water, etc.).
* Realized Natality – the number of births when environmental pressures come into play.

**Animal natality**

Specific birth rate is used when calculating animal natality. The criterion used is age. Animal natality is expressed as an age-specific schedule of births. This is represented by the quantity of young/unit of time by females in various age classes. The age-specific birth schedule will count females that have only given birth to females. Showing the number of females that have been born relative to the previous generation will show how much of that generation may have the ability to reproduce. To construct the age-specific schedule, the average number of females born must be calculated. A survivorship column must also be included to construct a fertility table. Taking the survivorship column and the mx values from the life table, the number of offspring will be shown, giving us the natality rate.

## Plant natality

Plants’ natality is more difficult to determine than animals. The factors that make it difficult to measure are:

* Seed production of individual plants varying year to year.
* Seed production will also vary age class to age class.
* The seeds will become dormant for long periods of time before germinating

Plant natality is an uncertain factor to measure. The time it takes for a plant to germinate its seeds may be extended over too long of a time period for accurate measurement.

**Calculations where natality is a factor**

* Natality rate: number of births/unit of time/Average Population
* For wildlife management: N1 = N0 + (B − D) + (I − E) Where:
	+ N1 = number of individuals at time 1
	+ N0 = number of individuals at time 0
	+ B = number of individuals born
	+ D = number of individuals that died
	+ I = number of individuals that immigrated
	+ E = number of individuals that emigrated between time 0 and time 1.
* Intrinsic rate of increase: (dN/dt)(1/N) = r
	+ r= intrinsic rate of increase
	+ (dN/dt) = rate that population increases
	+ N = population size

**Fecundity**

 Fecundity refers to the average birth rate associated with a population

* The greater a population's fecundity, all else held constant, the faster a [population](http://www.mansfield.ohio-state.edu/~sabedon/campbl52.htm#population) will increase in size
* Note that fecundity typically varies with the age of individuals

**Fertility**

Fertility is the ecological concept based on the no of viable offspring produced during a period time

**Sex ratio**

Sex ratio can have important effects on population dynamics.  We will consider some of the forces that act to change sex ratios as well as broad patterns of sex ratio variation n the animal kingdom.

Sex ratio is the proportion of males relative to the proportion of females. It can be expressed in several ways, some of which are shown in the table of equivalents below:

|  |  |  |
| --- | --- | --- |
| Ratio        Male: female | Proportion males | Percentage males |
| 50:50 | 0.5 | 50% |
| 2:1 | 0.67 | 67% |
| 3:1 | 0.75 | 75% |

As we move *across rows* in the table we are expressing the same sex ratio in different ways. As we move *down the columns* we are changing the sex ratio (toward more males) but using the same notation. Another, verbal way of expressing the sex ratio is to say that it is "male-biased" (more males than females) or "female-biased" (more females than males).

Ernst Mayr classified sex ratios according to the stage in the life cycle:

**Primary sex ratio**: sex ratio at conception (the point at which the sperm fertilize the eggs). This is usually near 50:50 in natural populations, though a few cases exist where parasites can change the primary sex ratio by for example, having lethal effects on sperm.

**Secondary sex ratio**: sex ratio at time of hatch or birth. Often nearly 50:50 but more examples exist of skewed secondary sex ratios than of skewed primary sex ratios.

**Tertiary sex ratio**: sex ratio at some later stage of life such as at age of first reproduction or "adult" stage. Skewed sex ratios are most often observed at this stage.

**Mortality**

Mortality is the death of organisms in a population. Mortality is also sometimes inappropriately used to refer to the number of deaths among a set of diagnosed hospital cases for a disease or injury, rather than for the general population of a country or ethnic group. This disease mortality statistic is more precisely referred to as "[case fatality rate](http://en.wikipedia.org/wiki/Case_fatality_rate)" (CFR).

**Mortality rate** is a measure of the number of [deaths](http://en.wikipedia.org/wiki/Death) (in general, or due to a specific cause) in a population, scaled to the size of that population, per unit of time. Mortality rate is typically expressed in units of deaths per 1000 individuals per year; thus, a mortality rate of 9.5 (out of 1000) in a population of 1,000 would mean 9.5 deaths per year in that entire population, or 0.95% out of the total. It is distinct from [morbidity rate](http://en.wikipedia.org/wiki/Morbidity_rate), which refers to the number of individuals in poor health during a given time period (the [prevalence rate](http://en.wikipedia.org/wiki/Prevalence_rate)) or the number of newly appearing cases of the disease per unit of time ([incidence rate](http://en.wikipedia.org/wiki/Incidence_rate)).