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ON THE EQUILIBRIUM OF LIVING BEINGS BY MEANS OF RECIPROCAL DESTRUCTION

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[Translated by Claudia M. Jacobi. Edited by Joel E. Cohen.]

The building of the world is held together by the forces of hunger and love.
Schiller

The recent history of Zoology, starting some time before the middle of this century and still continuing, is principally characterized by many researches on both the utility and the damages to man due to animals. Applied zoology, in a word, was born in this period of development of the zoological sciences.

Much has been written about animals that are useful and harmful, in various ways, to mankind. Practical results have been, up to now, very scarce.

The reasons for this are many, starting with the tremendous difficulty presented by this type of studies but, above all, because of an inclination to hasten to applications while disregarding data from pure science.

This not only does not produce the expected results but also - more seriously - frequently gives rise to erroneous theories about phenomena related to living animals and plants, theories which hinder the development of science.

One of the most debated issues these days is that of animals which are useful and those harmful to crops. [394]

This issue is one of the most complex regarding animals and about which there are no very clear and conclusive ideas. This probably comes mostly from separately studying the relations between animals and plants, that is, without taking into account the many and very important relations among the different groups of animals which, as I will now explain, influence very importantly the relations between animals and plants.

1 [Page numbers in the original appear here in brackets]

* [CAMERANO, LORENZO. 1880 Dell'equilibrio dei viventi mercè la reciproca distruzione. *Atti della Reale Accademia delle Scienze di Torino* 15:393-414. 8º 24 pp. 4 plates.]

To give an idea of the main current theories on the abovementioned issues I will briefly discuss the case of insectivorous birds and insects harmful to crops, and the relations between these groups of living beings.

Naturalists are divided on this topic, as is well known, in two categories.

One category admits the usefulness of birds since these destroy insects which damage crops, and believes that by promoting increase of bird numbers the number of insects and the extent of the damage they do could be reduced.

The other category, on the other hand, believes that the effect of birds is of little importance concerning the destruction of insects harmful to crops, and that the development of birds would not prevent the development of insects.

Naturalists belonging to the first category reason in this way: the number of insects which cause damage to crops increases; that of birds, on the other hand, decreases. Now, birds feed to a great extent on insects; so if we increase the number of birds, the number of insects will decrease.

The second category of naturalists think differently: the number of birds is high particularly in those places where insects are very abundant. When the number of insects decreases, so does the number of birds. Regions with low insect abundance also have few birds. The amount of insects in a region depends essentially on the amount of plant food found in it: the [395] total number of insects in a given locality is quite constant; what changes is the number of species and of individuals belonging to each species (1) [*see end-notes*]. Hence, they conclude: birds play only a small effect in destroying insects which damage crops.

Well-known naturalists have argued in favor of either one of the theories mentioned.

However, the number of naturalists who support the first theory is decreasing every day, while those in favor of the second one increase. What has been said for the special case of insects and insectivorous birds may be applied more generally to many other groups of animals.

To have an exact and clear idea, I repeat, of the relations between, for example, insectivorous birds and phytophagous insects, and between these and plants, these groups cannot be studied [396] separately. Rather it is necessary to study each in relation to all other animals to see the general laws governing the equilibrium of animal and plant species.

I will now leave aside the special cases and will consider comprehensively all animals.

Before continuing, nevertheless, it is useful that I explain the meaning of some expressions which I will frequently employ hereafter.

I say that a species is in *equilibrium* when the number of individuals is not significantly above or below what is usually observed in a given locality.

I say that a species is *increasing* when the number of individuals is higher than what is usually observed in a particular place.

I further say that a species is *decreasing* when the number of individuals in a given area is reduced beyond what is usually observed in that place.

These observations apply to both animal and plant species.

Considering all animals, we can divide them in two broad groups:
1) phytophagous animals;
2) carnivorous animals.

Animals of the first group take their nourishment directly at the expense of the plant kingdom.

Animals of the second group feed on phytophagous animals.

It is a fact accepted by all that animals and plants develop in direct proportion to the available food.

From this it follows that no species, be it carnivore or herbivore, can develop beyond a certain limit which, if surpassed, would destroy the source of its own nourishment. Equilibrium, broken by the excessive growth of either kind of animal, would again be reestablished.

To make clear the law I have just stated, let us look at a practical example. Let us consider a portion of unploughed land, in which a great number of herbs and wild plants grow. [397] If we visit this site, we will find a great number of insects, some phytophagous, which feed on the various kinds of plants that grow there, some carnivorous, feeding on the phytophagous species. Let us suppose that, for some reason, the number of carnivores increases extraordinarily, thus soon consuming the herbivores almost completely. This in turn will benefit the plants upon

which this last group was feeding. But this effect would be temporary, for, once the herbivores are destroyed, a great proportion of carnivores will have either to migrate or to die for lack of food. Moreover, it would be almost impossible that not a single individual of the phytophagous species would survive the slaughter. Now, these few individuals, thanks to the extraordinary fecundity of insects, will soon repopulate the place with herbivores. Carnivores being very scarce for the moment, herbivores will quickly develop and soon the plants which they feed upon will suffer greatly and also die. The herbivores will thus be deprived of food and so these too will have to die for the most part. Furthermore, the great number of herbivores will have already fed the carnivores, which will have again started to increase in number, and in turn will resume the destruction of herbivores, and so on.

The equilibrium of species, which is disturbed every now and then due to the abnormal growth of some component, is reestablished naturally without the action of man.

From what we have said we can conclude that if carnivores are absent from a certain area, herbivores will not multiply indefinitely, and that carnivores are not indispensable to prevent the development of phytophagous species.

From what I have said above, it follows that:
1) the number of phytophagous animals depends directly on the vegetation;
2) the number of carnivorous animals depends directly on the number of phytophagous animals and indirectly on the vegetation. [398]

It can be seen that the immense quantity and variety of animals are strictly related to the vegetation, and that the different animals are related among themselves through feeding relations.

Carnivorous animals can be divided, in a very general way, essentially in two categories which are:
1) carnivores which feed on phytophagous animals;
2) carnivores which feed on other carnivores.

I must mention that many species of carnivores feed indifferently on these both categories.

Carnivorous animals may also be subdivided in two groups, taking into account their life history and their relations with the animals upon which they feed:
1) carnivorous predators;
2) carnivorous parasites.

Carnivorous parasites may in turn be divided into:
1) carnivorous parasites of herbivores;
2) carnivorous parasites of predatory carnivores;
3) carnivorous parasites of other parasites of herbivores or carnivorous predators.

I believe it would be useful for greater clarity to put together in a table the divisions of animals mentioned, taking as a point of departure their feeding habits.

ANIMALS
- Phytophagous
- Carnivorous
  - predators
    - of phytophagous animals
    - of carnivorous animals
    - of phytophagous animals and carnivorous animals
  - parasites (endoparasites) (ectoparasites)
    - of phytophagous animals
    - of carnivorous animals
      - predators
      - parasites

[399]

I do not intend to elaborate on the various kinds of parasitism or of predation of animals. It is enough to say that the phenomenon of parasitism is one of the most widespread in the animal kingdom and that virtually no animal is free of parasites. The number of cases of parasitism grows every day as animals continue to be studied.

There are parasites of herbivores or carnivores which are themselves parasitized by other animals, just as carnivorous animals preying on herbivores or carnivores are themselves preyed on by other carnivores, which in turn can be preyed on by other carnivores.

Most animals are at the same time the prey of other animal and subject to varied sorts of parasites.

A great number of animals can be at the same time prey of other animals and subjected to various kinds of parasites, and also predators or parasites of other animals which can be predators or parasites of others, etc.

I have graphically displayed in Plate I the relations which exist among the various categories of animals from the point of view of their nourishment. [*Plates follow the text.*]

Vegetation serves as food to herbivores upon which carnivores feed.

Carnivores that feed on herbivores are divided in two groups, carnivorous predators and carnivorous parasites. Each of these groups is in turn devoured by other predators and other parasites, etc. up to those groups which are not preyed upon by other predators but are essentially subject to endoparasites, which are in charge of preventing their growth.

I have considered a special case in Plate II. I have pictured the enemies of phytophagous Coleoptera and the enemies of those enemies, etc. This plate is constructed analogously to the preceding.

Phytophagous Coleoptera eat vegetation and are decimated by other predators and parasites. [400] These in turn are decimated by other animal predators and animal parasites and so on.

For example, phytophagous Coleoptera are in part eaten by certain mammals. These mammals are prey of various reptiles, birds and larger mammals, and are subjected to all manner of parasites. These birds, reptiles and mammals are themselves prey of other mammals, birds and reptiles, and are also variously parasitized.

Phytophagous Coleoptera, besides being eaten by mammals, are parasitized by several Hymenoptera. These Hymenoptera can be devoured by amphibians, reptiles, birds, mammals, Orthoptera, other Hymenoptera, arachnids, etc., and these are themselves subject to other parasites, etc.

Plate II shows the complexity of the causes affecting the enemies of phytophagous Coleoptera, that is, Hymenoptera, Orthoptera, carnivorous Coleoptera, arachnids, amphibians, reptiles, birds, mammals, Diptera and parasitic spiders.

Now that we have seen the feeding relations between animals and plants, and among animals, let us see how the law stated above applies to an increase in animal numbers: that animals develop in direct proportion to their available food.

Essentially two categories of causes act to increase or diminish animal numbers. One could be named extrinsic and the other one intrinsic. The extrinsic causes come from the outside world and act directly or indirectly on animals. Included in this category are climatic, physical, and geological conditions from the locality in which the animals live.

Suppose, for example, that the forest of a certain area is cut, and this is done at very large scales in our days. It is evident that the climatic conditions in that region will change, more or less quickly and [401] more or less profoundly. Cutting down a forest frequently modifies the nature of the soil, favoring river overflow and flooding of the neighboring plains, on which they deposit different sorts of material which can directly affect the animals that live in those regions, or have an indirect effect by preventing the development of many kinds of plants.

Cutting the forest also reduces the number of animals: first because it directly affects the animals that lived on the felled plants; second because plants which grew in the shadow of the trees cut and that served as food to many groups of animals can no longer develop; third because it has a direct effect on animals by modifying climatic and physical conditions in the area.

An example of what I have said just now can be seen in the surroundings of Turin.

Insects that were abundant some thirty years ago along the forested banks of the rivers Po, Dora and Stura have nowadays become quite scarce, and many species have completely disappeared or are rapidly disappearing.

A very important extrinsic cause is also that which comes from climatic variations.

Continuous and abundant rains, for example, long-lasting droughts, and also intense and prolonged cold weather, can cause decreases in animal numbers.

In a word, it can be said that animal numbers tend to vary according to any cause (climatic, physical or geological) that alters normal conditions in a given area.

These changes have almost always an indirect effect on animals, while they affect vegetation more directly.

Damages caused directly to animals by these factors are relatively small, and are certainly not enough effectively to prevent their development in great numbers.

The intrinsic causes directly affect [402] the animals and originate from their feeding relations.

For example, the growth in number of a species A, predator of another species B, is an intrinsic cause directly affecting the latter by reducing its number of individuals.

On the other hand the development of a large number of individuals of a species C, predator of species A, is a direct cause of decrease of individuals of species A, while indirectly preventing the destruction of species B by species A.

More generally, we can say that considering a species A which affects another species B, that is, feeds on it either by preying upon it or parasitizing it, we have (2) [*see end-notes*]
$A \rightarrow B = - B$

If a third species C acts on species A we have: $C \rightarrow A = - A$
resulting in: - A and + B.

Let us suppose that a fourth species D affects species C, then: $D \rightarrow C = - C$
resulting in: - C and + A
so that we will again have + A
and hence - B.

Suppose a fifth species E affects species D,
then: $E \rightarrow D = - D$
and so + C and - D
[403] and again + C and - A
and consequently + B.

If we now suppose that a sixth species F affects species E, we will have the same pattern:
$F \rightarrow E = - E$
which will result in: - E and + D
and hence + D and - C
resulting in - C and + A and
again - B
and so on.

It is seen from the preceding that a cause acting directly on a species is in most cases an indirect cause for the reduction of another species, and that a direct cause of increase in a species can be an indirect cause of increase of another species. Or even, a direct cause of decrease in a species can be indirectly a cause of either increase or decrease of other species.

The result of this series of intricate relations between living beings with regards to their nourishment is the struggle for life. This comprises essentially two series of actions, that is, a series of actions that the animals perform to obtain their food, and another series that animals perform to avoid being themselves food for other animals.

The struggle for life, understood in its broadest sense, is itself a very important intrinsic cause and exercises a major influence on the equilibrium of beings.

For greater clarity, I will now put together in a table the main causes that modify the equilibrium of living beings. [404]

CAUSES	extrinsic	direct	climatic, physical, and other conditions that act directly on the animal species	
		indirect	climatic, physical (geological, etc.) conditions that directly affect the plants which are food for phytophagous animals and thus indirectly affect the animals	
	intrinsic	direct	predators	struggle for life
		indirect	parasites	

Now that the main causes for change have been pointed out, let us see what effects these produce on the equilibrium of living beings and in which way equilibrium can be explained in spite of the action of these forces, which tend to alter the reciprocal relations between the various groups of animals.

Examining a given locality, we see that the various animal species have for a certain time an almost constant amount of individuals, and the relations between phytophagous species and vegetation and between phytophagous species and carnivores are also substantially constant. When this occurs we will say that in that locality the animals are in equilibrium.

It might happen that in the same area a certain species increases suddenly and extensively, or that a given species decreases suddenly, or even that a species is increasing or decreasing gradually but significantly.

When any of these things happens we say that the equilibrium of the animals of that place is broken, and we will be able to distinguish a period of growth or reduction according to the species under consideration.

If we continue observing the animals of the same place, it will be frequently observed that those species which have grown extraordinarily, as well as those which have undergone gradual reduction will eventually return sooner or later to constant levels. [405]

Equilibrium is thus reestablished without the intervention of man.

Examples of these phenomena are many and can be taken from any group of animals. Insects, however, are the animals which provide us with the most outstanding and easily studied ones.

It is frequent, for example, that in a particular area an insect species develops in such a way as to cause damage to some particular plant species for one, two, three years or more. It can later disappear almost completely from the place, only to reappear some time later. The grapevines from several places in Astigiana were damaged some years ago by a great number of *Anomala vitis*, a Coleopteran which although not new in the region, usually occurred in low abundance. Nowadays the insect is again found in small numbers.

Also in this case human interference was very small, even if in a few places, not very extensive, some action was taken to destroy the species named.

This localized development of some species can be observed in very restricted areas. A species may be very abundant in a garden or a field while this is not seen in other gardens or fields which are apparently subjected to the same conditions.

An example of this nature can be easily seen in the surroundings, or rather, within the city of Turin itself. There are years in which the poplars from the old main square are entirely devastated by thousands and thousands of *Liparis ṣalicis* caterpillars, while the poplars in Queen's Avenue, not far from there, remain almost immune.

Also in this case we see that periods of great abundance of individuals are followed by periods of less but constant activity and by periods of scarcity of the same individuals.

Also in this case the part played by man is negligible.

How can these facts be explained? How can the practically always constant quantities of many categories of animals be explained, etc.? [406]

There is no doubt that these phenomena are a product of the various causes mentioned above.

To explain the very complex facts I believe that it is possible to resort to a reasoning analogous to that which serves to explain the propagation of sound waves in a generic cylinder, or better still, in a generic medium. This may seem rather daring but the concept will become clearer after I have exposed some general considerations.

Although the ideas can be applied to the majority of cases, I will use here for simplicity and clarity the example of the relations between the reciprocal actions of vegetation and herbivores, carnivorous animals which prey on herbivores, carnivores which parasitize predators, those which prey on parasites and finally endoparasites of parasite predators.

Suppose that for some reason the vegetation in a given locality happens to grow abnormally. This increase in vegetation will necessarily result in an increase in phytophagous animals, following the rule already noted which states that animals grow in direct proportion to the available food. This increase in phytophagous animals will, for the same reason, promote an increase in carnivores who prey upon herbivores. This in turn will promote the development of animals which parasitize those predators. The increase of parasites will cause an increase of animals which prey on these parasites. Finally, this will increase the endoparasites of these predators.

Now, an increase of endoparasites will tend to reduce the number of animals in which they live, that is predators, resulting in the growth of their prey.

In our case, this will increase the number of parasites, and this will again result in a decline of other predators. Consequently, the number of phytophagous animals will increase, which in turn will diminish the quantity of vegetation. [407]

Assuming that other causes have not changed, this decrease of the vegetation will result in a decrease of herbivores; this will reduce the predators; this, the parasites; this in turn the other predators and then their endoparasites.

Now the decrease of endoparasites will cause an increase of their prey and hence the number of predators will increase. This will result in a decrease of parasites, promoting growth of other predators, which will reduce the number of herbivores. The decrease of phytophagous animals is one of the causes of increase in the quantity of vegetation.

If the same causes continue to exist, increase in vegetation will cause the increase of herbivores which in turn will increase the number of predatory carnivorous animals, etc. The same cycle will be repeated again.

Figure 1 in Plate III represents graphically what is stated above.

The lines that rise from the horizontal line indicate an increase in growth of a given category of animals; the lines that go down from the same horizontal line indicate decrease in development of a given group of animals.

The signs + and - indicate these facts.

Equilibrium is represented by the horizontal line 0 already mentioned.

The arrows show the directions in which the causes for disturbance are acting.

This notation serves for all figures in Plates III and IV in this work.

The case just mentioned is the simplest, and assumes that a complex of causes affects the vegetation and that the results of this disequilibrium is slowly propagated successively to the different categories of animals. When equilibrium is broken by the increase in [408] vegetation, it starts a reaction which propagates in a given direction and brings about certain determinate changes in the equilibrium of other categories of animals. While this first impulse proceeds, a second one is produced as a direct consequence of it which will modify the action produced by the first one, as I will explain better soon.

Let us first consider what occurs between vegetation and herbivores, and between predatory animals and endoparasitic animals.

The increase in vegetation increases the number of herbivores. Now, while on the one hand this will increase the number of their predators, it is also on the other hand cause for vegetation reduction. Thus the great increase in vegetation is overwhelmed as a direct consequence of this increase, by the great development of herbivores. This decrease in vegetation produces a decrease in the number of herbivores, so that in this case too the increase in herbivore numbers is overwhelmed by its consequences. This decrease of herbivore numbers will again make vegetation thrive, and this in turn will make the number of herbivores grow, and so on.

The same occurs with predatory animals and endoparasites. A great development of endoparasites will result in a decrease in predators and this will produce a reduction of endoparasites. This will increase the number of predators. The increase in predators will cause an increase of endoparasitic animals. This will again reduce the number of predators and so on.

This is depicted graphically in Figures 2 and 3, Plate III.

It follows from what has been said thus far that there are two centers of disturbance which vibrate continuously, which are vegetation on the one hand and endoparasites on the other.

These are not, however, the only sources of disturbance that can be observed in the animal series mentioned above. [409]

It may happen, for example, that for some of the reasons already stated the number of predators or parasites either increases or decreases abnormally. What will then happen to the other categories?

Suppose that the predatory animals increase (Plate III, fig 4). Then, on one side the number of parasites of these predators will grow, and hence the number of other predators, and lastly of endoparasites; on the other side we would see a decrease in herbivores, whence an increase in vegetation.

If we now suppose that predators decrease (Plate III, fig. 5), parasites will decrease. This will reduce on the one hand the number of predators and of their endoparasites, but on the other hand will increase herbivores which will result in less vegetation.

What I have conjectured for carnivorous predators can be applied to carnivorous parasites etc.

It is now clear that besides these two disturbance centers at the extremes of the animal series considered, every other group within the series can become in its turn a center of disturbance.

Examining one of the ends of the series of living beings, for example vegetation, we see that an increase in vegetation will promote an increase in phytophagous animals, that is, a pulse or cause of disequilibrium that moves forward and is felt by the other categories of living beings. Increasing numbers of phytophagous animals will immediately reduce the amount of vegetation, and this will be a second cause of disequilibrium which continues in the direction of the first one, canceling the effects of the first one.

In this way, the balance broken at any point of the series of living beings is reestablished by the relations between them and are based on food, in other words, on reciprocal destruction (Plate III, fig. 6).

The same reasoning may be repeated starting from any of the disturbance centers just mentioned. [410]

Figures 7 and 8 in Plate III show the effects of considering other centers of disturbance.

What has been said for two causes of disequilibrium that are generated in a given point can be also said for any number of causes of disequilibrium that rise successively from the same point.

Let us suppose (Plate III, Figure 9) that the amount of vegetation increases. This will make the number of phytophages increase and will be a first cause of disequilibrium that will move forward along the series. The increase in phytophages will produce a second cause of disequilibrium - less vegetation and less phytophagous individuals - which will proceed in the same direction as the first. But the decrease of phytophages will again favor an increase in vegetation and this again will promote an increase of herbivores, creating a third cause of disequilibrium. The increase in herbivores will produce a fourth cause of disequilibrium, as it decreases the amount of vegetation, and this again reduces the number of herbivores. In this particular case we then have four causes of disequilibrium which rise from the same points of propagation, vegetation and phytophages, that tend to suppress each other alternately. What has been said for four causes of disequilibrium can be repeated naturally for any number of causes and for any starting point.

Let us consider now, for simplicity, what happens when a single cause of disequilibrium originates in the vegetation and arrives at the endoparasites (Plate IV, Fig. 1). This category reacts, so to speak, causing another disequilibrium which will return to affect the vegetation.

It can be thus said that the cause of disturbance produced by the vegetation which has reached the endoparasites is reflected and modifies its own effects, either by increasing it or suppressing it.

In the case of Figure 1, both the first cause of [411] disequilibrium and the second one - which is but the consequence of the reflection of the first one - would produce equilibrium among predators, increasing instead the parasites which would again produce the equilibrium of predators, increase phytophages and finally produce the equilibrium of the vegetation.

This case - I repeat - is one of the simplest: things are much more complicated in nature.

Figures 2, 3, 4 and 5 in Plate IV show the consequences when the causes of disturbance rise from any of the points of propagation and are later reflected.

Figure 6 in Plate IV shows the consequences of four causes of disequilibrium that are reflected in pairs.

In nature, the various causes of disequilibrium do not act in isolation, as I have supposed here for clarity. Instead they superpose, intertwine, at times canceling one another, at times increasing, at times decreasing.

In Figure 7, Plate IV, I have considered the case in which eleven causes of disequilibrium rise from all the points of propagation already mentioned and go in various directions, sometimes reflecting on themselves and sometimes not. The directions of the arrows and their color [*color is omitted in the reproductions of the plates*] clearly show the development of the causes of disequilibrium so that there is no need to repeat here the explanations given for the various special cases of disequilibrium. In Figure 7, I have indicated the final result produced by the action of the causes of disequilibrium considered. To obtain this curve it is enough naturally to make the algebraic sum of the causes above (+) and below (-) the line of equilibrium (0) for each category of living beings.

The case I have considered is one among many that are observed in nature. It will suffice to change the number of causes of disequilibrium and the numbers of propagation points to obtain many others.

It is now clear that:

1) the categories that constitute the animal series have an indefinite number of disequilibrium [412] centers, and each group of animals is a potential center of disequilibrium for the other groups of animals;

2) all the causes of disequilibrium produced by single groups of animals ultimately reflect at one end on the vegetation and at the other end on the endoparasitic animals.

These two categories of living beings reflect, though modified, the causes of disequilibrium themselves;

3) all these causes of disequilibrium tend either to suppress each other, or to increase and to decrease one another alternately.

From what was said it is clear that the propagation of causes of disequilibrium can be very well compared to the propagation of sound waves from any center of disturbance along a radius. In the same way as there are sound interferences when waves coming from two or more centers of disturbance meet, it is also frequent to see cases of interference among the causes which govern various groups of living beings and tend to modify their equilibrium.

In a word, we could compare the different groups of living beings to a set of diapasons which vibrate together generating a series of waves which interfere with one another, with well-known effects.

From what has been said it can be concluded that:

1) the equilibrium between vegetation and animals, and among the various groups of animals is maintained by the animals themselves;

2) the causes of disequilibrium produced by man in any animal group, such as deforestation, agriculture, etc., have many times insignificant effects because they are counterbalanced by other causes coming from the various groups of animals themselves;

3) the complete extinction of any animal group may produce either light effects or very pronounced ones. In any case, even when the disequilibrium caused by disappearance of an animal group is severe, this is eventually compensated by other causes generated by the animals themselves. [413]

4) the part played by man is very small regarding changes in the equilibrium of the various groups of living beings, and hence in the destruction of certain species, or the abnormal development of others. In any case the momentary effects produced by these factors tend to stop by the effects of other factors coming from the various groups of living beings themselves.

Anybody could, nevertheless, object concerning this last conclusion that man can very easily destroy completely many species of living beings. This is true and there are many examples of species now extinct by human action. Man destroys especially big animals, but has not been successful in destroying directly those small species of animals which are so frequently harmful to humans.

The destruction of a big mammal species, for example in a given area, by man, is certainly not a small cause of disequilibrium, but this disequilibrium is momentary, and balance is reestablished without the action of man. It is useful that I mention on this topic what happened in the region of

Piedmont. Professor Michele Lessona in his account on the *Snakes of the Piedmont* (3) [*see end-notes*] speaks about the gathering of snakes that took place in the Lanzo valleys between the end of the past century and the beginning of ours. He refers to a passage in the book by Count Luigi Francesetti di Mezzenile, entitled *Lettres sur les vallées de Lanzo*, in which the gathering of snakes is discussed. From this passage it is evident that in the valleys of the Lanzo alone many thousands of snakes were caught for pharmaceutical uses.

Snake gathering ceased entirely in the Lanzo valleys and also in other places some twenty years ago. It could be deduced, from the original number of snakes, that their actual number would be enormous. But this is not so. Stopping the snake hunt must have broken the equilibrium of many [414] categories of living beings in the Lanzo valleys. The numerous snakes must have greatly decreased the number of frogs and small mammals of these valleys. Lower numbers of frogs and small mammals must in turn have been a cause of lower numbers of snakes. The reasoning from the general cases can be applied here.

What is important to notice is that the equilibrium which comes from the relations among the animals in the Lanzo area disappeared in a relatively brief time, due to the animals themselves without any action of man.

END NOTES

(1) Also consult on this topic, among other works, Camerano, *The Insects*, Turin, E. Loescher, 1879, p. 26, etc. I have treated the main questions concerning the relations between insects and agriculture in a passage of this book: "Let us consider a portion of unploughed land, in which a large number of herbs and wild plants grow. If we visited this place, we would find a large population of insects; some phytophagous, which feed on the various kinds of plants available, some carnivorous, feeding on the phytophagous species... Suppose that the area is now tilled. The farmer, by plucking out the plants that filled up the place and turning over the soil with the plough, destroys a large number of insect species which either lived on the uprooted plants or metamorphosed there."

"Following the seeding, only one or two species of plants will take the place of the many more that the farmer took away. Very few insect species will remain, and these will precisely be those which feed on the cultivated plants. Since these plants are in great number, the number of insects will soon grow to such an extent as to cause great damage to the plants."

"This does not mean, as is the general belief, that the total number of insects has increased. Before the tillage the area was populated with many types of insects. After the tillage the number of species is reduced, and instead the number of individuals from the remaining species has increased."

(2) The direction of the arrows shows the direction in which one species acts on the other one. I use the symbol = to indicate the result of the action of one species on the other one, the symbols - when this action reduces the number of individuals of a species, and + when the action of a species does not reduce the number of individuals of a second one.

(3) *Atti della Reale Accademia delle Scienze di Torino*, vol. XII, 1877.

Plate I
vegetazione = vegetation
predatori = predators
parassiti = parasites
endoparassiti = endoparasites
carnivori = carnivores

Tavola IX

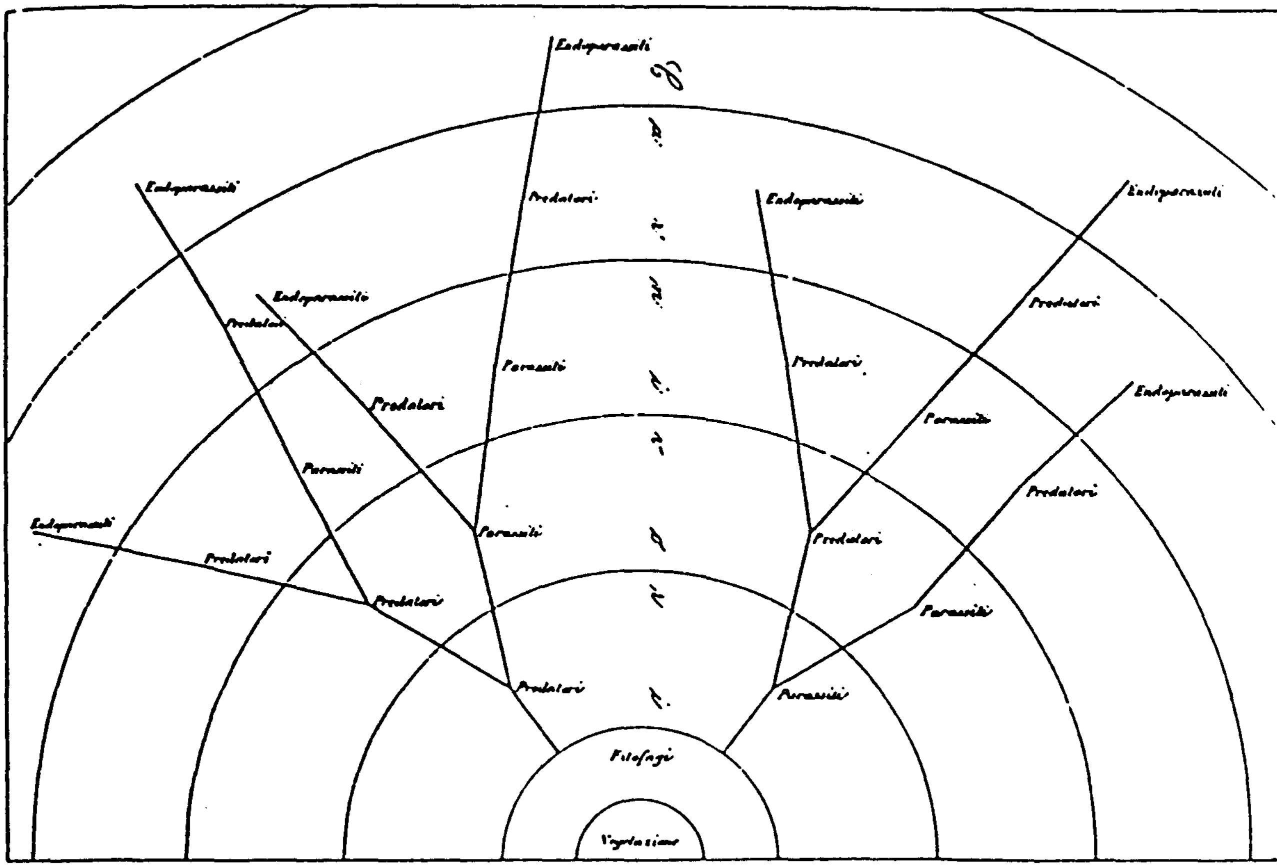
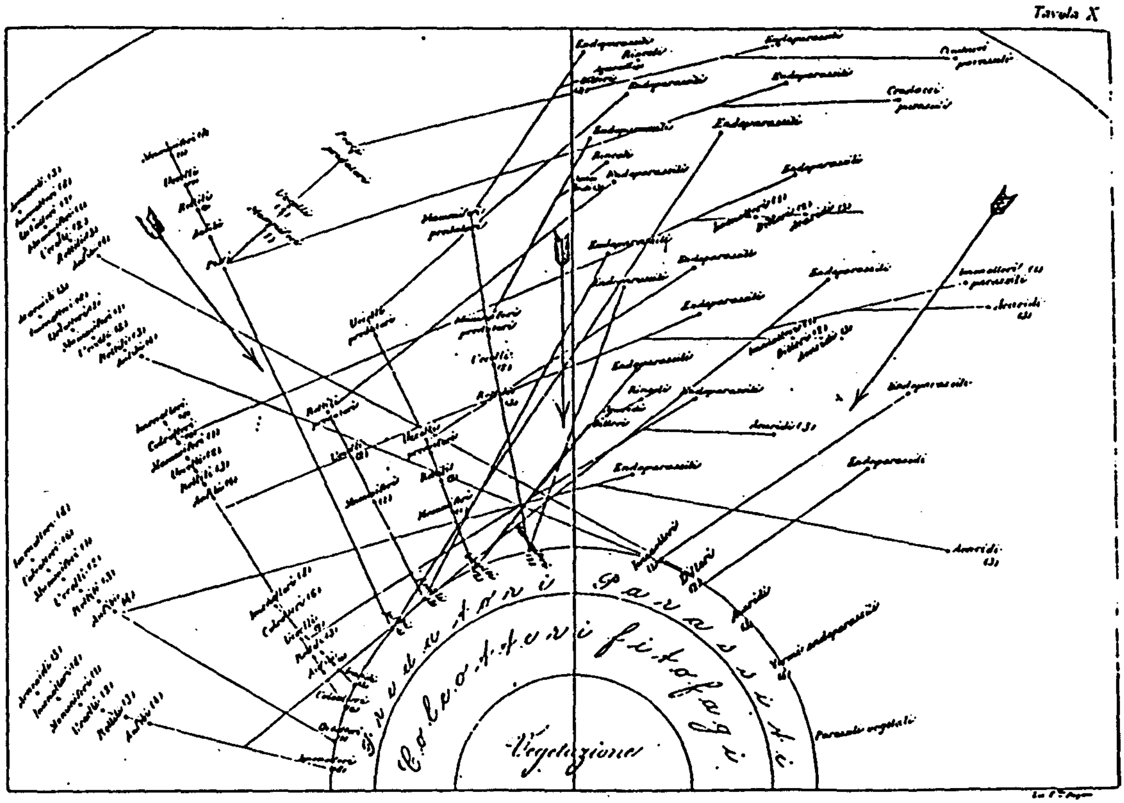


Plate II
coleotteri fitofagi = phytophagous Coleoptera
imenotteri = Hymenoptera
ortotteri = Orthoptera
acaridi = mites
anfibi = amphibians
rettili = reptiles
uccelli = birds
mammiferi = mammals
ditteri = Diptera
vermi endoparassiti = endoparasitic worms
parasiti vegetali = parasitic plants
rincoti = true bugs (Hemiptera)
aracnidi = arachnids
pesci predatori = carnivorous fish
crostacei parassiti = parasitic crustaceans



<u>Plate III</u>
aumento = increase
equilibrio = equilibrium
diminuzione = decrease
[In the originals of plates III and IV, a grid of Cartesian coordinates is printed in red. Various arrows are printed in red, green or black, but no explanation is given for the different colors.]

Tavola XI.

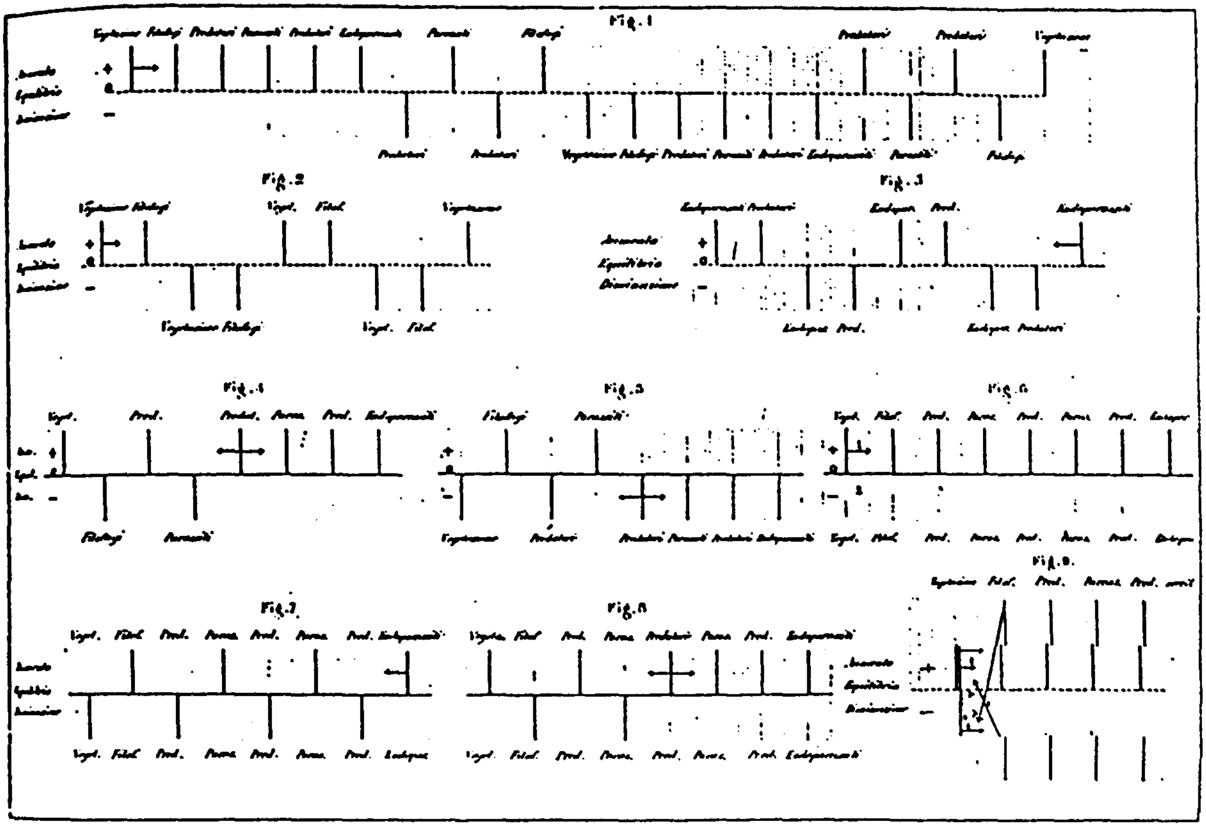


Plate IV
[no new words]