TABLE III

Milk Yield					Egg Production				
		A	B	C			A	B	C
Class limits in gallons	Observed absolute frequency	Per cent. which mid-point is of mean	Absolute frequency per one per cent. of mean	Per mille frequency per one per cent. of mean	Class limits (number of eggs)	Observed absolute frequency	Per cent. which mid-point is of mean	Absolute frequency per one per cent. of mean	Per mille frequency per one per cent. of mean
6.50– 6.99	2	48.8	0.6	0.4	0– 14	1	6.3	0.08	0.3
7.00– 7.49	6	52.4	1.7	1.2	15– 29	1	18.8	0.08	0.3
7.50– 7.99	7	56.0	1.9	1.3	30– 44	4	31.4	0.32	1.2
8.00– 8.49	7	59.6	1.9	1.3	45– 59	10	44.0	0.80	2.9
8.50– 8.99	5	63.2	1.4	1.0	60– 74	21	56.5	1.67	6.1
9.00– 9.49	24	66.8	6.6	4.6	75– 89	23	69.1	1.83	6.7
9.50– 9.99	28	70.4	7.8	5.4	90–104	35	81.6	2.79	10.1
10.00–10.49	35	74.1	9.7	6.7	105–119	46	94.2	3.66	13.3
10.50–10.99	56	77.7	15.5	10.8	120–134	40	106.8	3.18	11.6
11.00–11.49	68	81.3	18.8	13.0	135–149	35	119.3	2.79	10.1
11.50–11.99	70	84.9	19.4	13.5	150–164	25	131.9	1.99	7.2
12.00–12.49	107	88.5	29.6	20.5	165–179	19	144.4	1.51	5.5
12.50–12.99	118	92.1	32.7	22.7	180–194	8	157.0	0.64	2.3
13.00–13.49	124	95.7	34.3	23.8	195–209	6	169.6	0.48	1.7
13.50–13.99	119	99.3	32.9	22.8	210–224	1	182.1	0.08	0.3
14.00–14.49	133	103.0	36.8	25.5	.....	.....	.....	.....	.....
14.50–14.99	87	106.6	24.1	16.7	.....	.....	.....	.....	.....
15.00–15.49	102	110.2	28.2	19.6	.....	.....	.....	.....	.....
15.50–15.99	78	113.8	21.6	15.0	.....	.....	.....	.....	.....
16.00–16.49	76	117.4	21.0	14.6	.....	.....	.....	.....	.....
16.50–16.99	43	121.0	11.9	8.3	.....	.....	.....	.....	.....
17.00–17.49	43	124.6	11.9	8.3	.....	.....	.....	.....	.....
17.50–17.99	28	128.2	7.8	5.4	.....	.....	.....	.....	.....
18.00–18.49	20	131.9	5.5	3.8	.....	.....	.....	.....	.....
18.50–18.99	22	135.5	6.1	4.2	.....	.....	.....	.....	.....
19.00–19.49	14	139.1	3.9	2.7	.....	.....	.....	.....	.....
19.50–19.99	5	142.7	1.4	1.0	.....	.....	.....	.....	.....
20.00–20.49	6	146.3	1.7	1.2	.....	.....	.....	.....	.....
20.50–20.99	3	149.9	0.8	0.6	.....	.....	.....	.....	.....
21.00–21.49	2	153.5	0.6	0.4	.....	.....	.....	.....	.....
21.50–21.99	2	157.1	0.6	0.4	.....	.....	.....	.....	.....
22.00–22.49	.....	160.8	.....	.....	.....	.....	.....	.....	.....
22.50–22.99	1	164.4	0.3	0.2	.....	.....	.....	.....	.....
Totals.....	1441	.....	.....	.....	.....	275	.....	.....	.....

The greater relative variability in egg production is apparent.

The general principle here developed for the graphic representation of frequency distributions may, of course, also be applied to regression diagrams.

RAYMOND PEARL

THE BIOLOGICAL RELATIONSHIPS OF THE LAND, THE SEA AND MAN

UP to the present time life in the sea has always been treated and considered as quite separate and distinct from the more familiar life on land. But this idea can no longer be maintained. The life of all the world is one vast unit, dependent for existence on the same sources of supply. The ocean life, though to most of us so strange and unfamiliar, is but the aquatic fringe of the life on land, and for the most part is supported by the same materials which, washed into the sea, no longer are available for the support of the land creatures.

Heretofore we have been led astray in our contemplation of sea life by the interesting fact that about three times as many major types of animals live in the sea as are found upon the land; indeed, of the major types of animals no less than ten, nearly half again as many as all land living types together, are exclusively marine.

This great variety in the form and structure of sea animals obscures another interesting fact. About three fourths of all known kinds of animals live on the land, and only one fourth in the sea.

The reason for these curious contrasts is not far to seek. All land animals have one thing in common. They must seek their food; it will not come to them. Therefore land animals are almost wholly of those types, arthropods and vertebrates, which are best adapted for locomotion, with representatives of some others of fair locomotor powers.

In the sea food substances not only lie upon the bottom, but they float everywhere suspended in the water, drifting back and forth and up and down. While useful, powers of locomotion are not essential for the creatures of the sea; if they can not seek their food it will be brought to them.

On land all creatures have to seek their food, but in the sea the food relations of the animals are of three kinds instead of one. Some, like the crabs, go after it, as do the animals on land; some, like the corals, attach themselves to firm supports, or, like the clams, burrow in the mud and let the water do the work of bringing food to them; and some, like jellyfishes, simply float about suspended in their food supply.

Three possible ways of securing food instead of one means a corresponding diversity in the fundamental structure of the animals involved. But the relative uniformity of conditions in the sea, especially in regard to the most essential substance, water, permits the existence of the numerous major types with relatively slight subdivision, in startling contrast to what we find on land where infinite variation in conditions has resulted in infinite variation in those few major types fitted to meet the exigencies of terrestrial existence.

The sea is commonly regarded as the place of origin of all animal life. But there is no real evidence that this is true. The reason for the supposition is to be found in the greater diversity of sea animals as contrasted with the animals on land and in fresh water.

Just as for many years we have commonly looked upon the sea as the place of origin of life, so also have we regarded it as the region where the primitive germs of life by an evolutionary process expanded into the forms we know to-day.

But very much of what biologists consider as the result of the evolution of the animal form is really nothing more than the necessary response to the physical restrictions of environment.

If you take the various forms of animal life and subtract from each those structural peculiarities which are immediately due to these physical restrictions imposed by their environment, you will see at once that the whole subject of the interrelationships of the major animal types takes on an entirely new aspect.

There is a most important trinity of factors affecting life in general that is not sufficiently appreciated. Life will be most abundant where there is a maximum of water permanently in the liquid state, a maximum of air and a maximum of food.

Thus on the land the optimum conditions for both plants and animals are in the moister regions of the tropics, where the rains are not so heavy as to be destructive by the weight of water falling, and the temperatures are high, but not too high, and constant.

But in the sea these factors find their most perfect balance in a region wholly different. For the colder water gets, the greater the amount of air and other gases it will hold in solution, and the longer will the organic matter in suspension or lying on the bottom be preserved. Thus in the sea the optimum conditions for both plants and animals are in the coldest oceans, in the polar seas in the summer time when the sun is at its highest, and in the cold currents flowing out from these.

Water, air and food are the three prime requisites for all organic life. The first two need not concern us further. Let us take up the last.

Our knowledge of the origin of the substances on which the plants and animals of the sea depend for their existence is very vague indeed. But the evidence seems to indicate that for the most part life in the oceans is dependent on foods brought down from the exposed land areas.

On land the frosts of winter and the heat of summer and the intermittent action of the rain by its mere weight alone as well as by the power of fresh water of dissolving solid substances, are continually wearing down the rocks. The products of this process of disintegration form our soils, and partly are delivered to the sea in the form of sands and muds and of various substances in solution.

On the soils grow plants of all descriptions, sometimes in great abundance, forming huge forests and extensive grassy plains, sometimes in less abundance.

All the animals on the land are of course supported by the plants, since only plants are able to form organic out of inorganic substances.

But there is a curious relationship between land plants and the animals that feed upon them that is commonly overlooked. In order to grow a plant must have a relatively large amount of green leaf surface exposed to the action of the sun's rays. If this be reduced below a certain minimum the plants will die. At the same time most plants produce more leaf surface than they really need. In the delicate balance of nature the difference between the actual necessities of the plants in leaves (or other structures) and the whole amount produced represents the food supply of the insects and plant-feeding creatures generally, and the things that feed on them.

Nature is so adjusted that plant-feeding creatures, held in check by predators and parasites, never deprive the plants of more leaves than they can spare; and curiously certain plants when raised in the absence of their insect or other normal enemies grow better if their surplus leaves be cut away.

At the beginning of the winter or of the dry season the green leaves cease to function; they are of no further value to the plants. In most of our plants and in many in the tropics they wither and fall off.

The dying and falling of the leaves in autumn and at the beginning of the dry season, and more or less constantly at other times as well, means the accumulation of a vast reservoir of foodstuffs for anything capable of making use of it.

Bacteria and fungi thrive on this detritus, and earthworms, many kinds of snails and insects, as well as other creatures, feed either on this decaying vegetable matter, or on the bacteria and fungi in it, or on the living things that feed on them.

Much of this material is consumed where it lies upon the ground; but a vast amount is washed into the rivers, especially by the floods of spring and at the breaking of the rains, and goes into the sea. Much of this is still in a condition to be eaten by detritus-feeding animals. Much more, especially in the form of organic substances in suspension or solution, is available for food for the marine plants.

From the land there is thus delivered to the sea through the erosive action of the elements and the growth of plants a constant stream of foodstuffs.

Now, turning to the sea, we note at once two interesting facts. In the first place, sea life becomes scarcer with increasing distance from the land and toward the middle of the oceans almost completely disappears. The central south Pacific is a region far more barren than any desert area on land. No life of any kind has been detected in the surface water, and there is none whatever on the bottom. Manganese nodules, ear-bones of whales, and quantities of sharks' teeth are all that the dredge brings up. There is nothing living. Some of the sharks' teeth are four or five inches long and belong to a kind of shark that flourished in the Miocene, tens of thousands of years ago. Since the Miocene all the land areas have undergone great changes in their shapes and in the details of their surface sculpture; yet all this time these sharks' teeth have lain quite undisturbed on the sterile red clays of the ocean floor beneath the sterile sea.

Another interesting fact is that sea animals are largest and most abundant on those shores which have a copious rainfall, especially on rugged and on cold coasts where it may be assumed that material from the land would reach the sea unaltered in the greatest quantity.

As an illustration, the poverty of the sea life on the shores of the island of Barbados is most striking. As a detail, you at once remark the absence of those enormous starfishes so characteristic of the Caribbean region. Yet on the shores of the islands of St. Vincent and St. Lucia, to the west about one hundred miles, sea life of all kinds is abundant.

Barbados is low and flat, with a small rainfall and a small runoff. St. Vincent and St. Lucia both are very high and rugged with a very heavy rainfall, especially in the higher regions. Both support great forests in contrast to the cultivated sugar cane which covers most of the surface of Barbados.

In the East Indies also the large high islands of the Malayan archipelago, which are well wooded and have a heavy rainfall, support along their shores a wonderfully rich and varied fauna, while the fauna of the Polynesian coral islands remote from the great land masses is very scanty.

These facts would seem to demonstrate in a conclusive manner that life in the sea is dependent to a very large extent on the material derived from the exposed land surfaces. What other explanation is there to show why life decreases in abundance with distance from the land, becoming very scanty or quite absent in midocean, and why sea creatures are more abundant and of larger size on the shores of continents and of the large high rainy islands than on the shores of the small dry low-lying islands in the same latitudes?

But here we find an apparent paradox. In the Antarctic continent we have an exposed but frozen land mass which, so far as we can see, is not delivering food materials, especially organic food materials, to the sea in appreciable quantities. Yet along the shores of the Antarctic sea life is most extraordinarily abundant. This fact would seem to negative the inference just drawn.

Let us look more closely into this. The Antarctic Ocean water seems to be identical with the waters in the great depths of the other oceans, and the Antarctic seas thus seem actually to be simply a portion of the abyssal waters of the earth which here come to the surface, circulate about the Antarctic continent, run in great currents up the west coasts of South America (Humboldt current), Africa (Benguela current) and Australia (West Australian current), which currents turn gradually toward the west and sink beneath the warmer and lighter surface waters.

From such information as we have we believe the waters of the seas of the Antarctic to be the same as and continuous with the waters of the greater depths in all the oceans elsewhere, and quite distinct from all the other surface waters.

What is the significance of this? Let me recall that plants require sunlight for their vital processes and that effective sunlight can not penetrate the water to a depth greater than at most six hundred feet under the most favorable circumstances.

But the substances washed from the land into the sea would not all remain above six hundred feet; they would become diffused at every depth down to the very bottom. Thus on the lee side of the West Indies the dredge brings up tree trunks and branches from many hundred feet beneath the surface. Much of the material washed into the sea, such as the finely ground and partially decayed remains of leaves, is in a form to be consumed directly by detritus-feeding animals. But much of it is in a form fit only to serve as food for plants living in sunlight. This material, falling below the thin illuminated surface layer of water into the dark and cold abysses, would there be preserved indefinitely. There it is useless for the support of life; but if that abyssal water should by any chance rise upward high enough to become illuminated, immediately this reservoir of food is made available for the consumption of the plants and through them for the support of animals.

In the Antarctic seas the cold abyssal water rises to the surface and the light. Here the substances it contains are immediately utilized by free floating plants, mostly the diatoms, which flourish in incredible abundance and support a vast array of animals of all kinds and sizes.

Thus the Antarctic marine life appears to be supported not by any local richness of the sea but by wash from the land masses in the temperate and tropical regions to the northward.

There is a curious difference between the diatom flora of the Antarctic and that of the Arctic seas. In both regions diatoms are amazingly abundant. But the Arctic diatoms are few in species and simple in structure, while in the Antarctic we find one of the most varied and elaborately ornamented diatom floras now existing. There the cruder and simpler naviculoid group so characteristic of the Arctic is in the decided minority, circular, polygonal and other symmetrical shapes being more common, and usually adorned with complex sculpturing and a variety of horns, spines and other ornamental appendages.

This superior richness, though not abundance, of the diatom flora of the Antarctic as compared with the Arctic must have some explanation, and I can not help believing that it has to do with a much more varied organic content of the water.

In the Arctic the substances transported from the land into the sea by the rivers and the runoff are relatively slightly variable in their composition. All of them come from much the same general type of vegetation, and all of them are transported by cold fresh water.

If we are right in our assumption that the Antarctic sea derives its water from the abysses of the other oceans, it is easy to see why the organic content of Antarctic waters should be much diversified. It would consist of materials derived from all types of vegetation, transported by cold and by warm waters, and delivered to the abyssal refrigerator in all stages of bacterial and other alteration. It would also contain much material of animal origin similarly diversified.

Conditions comparable to those in the Antarctic are found wherever abyssal water rises to the surface, as in those regions where there are seasonal upwellings.

From this it would appear that after all the Antarctic seas offer no obstacle to the assumption that the food substances in the seas are for the most part of land origin.

Now let us turn again to conditions on the land. An uncultivated area on land is so nearly balanced between the minimum requirements of plant life on the one hand, and the constant losses through the depredations of the insects and other plant-feeding creatures on the other, that human life can only be supported by subsisting chiefly on an animal, including insect, diet. The earliest human inhabitants of the earth must have been very few in numbers, and they must have fed chiefly on the destroyers of the plants, that is to say, plant-eating animals and birds and insects.

But we have learned to cultivate the land. Cultivation of the land may be described as the destruction of the original vegetation, the planting in its stead of those types of plants which yield us food and clothing, and, most important, the protection of these useful plants from their normal depredators.

We do this last instinctively to a large degree. For instance, we never bring an area under extensive cultivation until the large plant-eating animals have mostly been killed off.

At the present day there are far more human beings on the earth than there ever were before. Each one of us represent the forcible displacement and suppression of our equivalent in life of other types, the normal primitive predators upon the plants by which we live. The grasses are our most important crops. The grasses are the normal and the usual food of most of the hoofed animals, and of many rodents. These we have killed off and we flourish in their place.

Our existence at the expense of the hoofed animals, the rabbits, rats and mice and similar other creatures, is nearing the saturation point; we are beginning keenly to feel the competition of the insects. Our further increase in the not distant future will be measured by the success we may attain in the displacement of the insects from their normal food which we shall ourselves consume.

Our future increase is dependent on the ability we may show to cut deeper and deeper into the ranks of those plant-feeding things that are competing with us for our food supply. The ability of our grandchildren to live will be measured by their ability to suppress their equivalent in insects.

What has the sea to offer for the future? Much less than is commonly supposed. In the sea the huge annual surplus of vegetable material so characteristic of the land does not exist. Except for a few flowering plants growing in shoal water near the coasts and the abundant sexual products of some algae, no sea plant bears special organs like the leaves of land plants which are discarded at the end of the growing season. There is no need for them to do so, as the humidity does not vary and the changes in the temperatures, if any, are very slight and gradual.

Life in the sea is a continuous cycle without the enormous annual waste of organic substance that characterizes life on land. In the sea when the minute plants called diatoms increase in numbers this phenomenon is promptly followed by an increase in those small creatures, especially the copepods, that feed on them. Increase in the copepods is followed by an increase in the number of the copepod consuming fishes, and these serve to attract predaceous fish and mammals that feed on them. When, owing to changed conditions, the numbers of the diatoms fall off, the copepods in their turn become less numerous. The fishes, however, swim away and seek their food elsewhere, followed by the predaceous fishes, dolphins, porpoises, etc. The annual cycle in the sea is a cycle of continuous, though changing, life, and there is almost no organic waste. If a large creature dies, it is soon consumed by the other creatures of the sea. On the bottom muds live many scavengers that feed upon whatever falls down from above, many swallowing the mud and digesting out of it the half-decayed remains of diatoms and copepods and other things.

Probably the extensive ooze deposits on the bottom of the seas mostly represent the shells of shell-bearing animals, diatoms, etc., from which the organic matter largely had been eaten or digested before they fell. Were this not so we should expect to find upon the oozes much more abundant life than there exists.

Of the products of the sea we eat plant feeders, predators of plant feeders, scavengers and detritus feeders. We eat sea plants only in wholly negligible quantities. Our relations with the sea to-day are just the same as those of the most primitive of mankind were with the land. Just as primitive man found the uninhabited lands the most productive, so we find the uninhabited coasts the most productive. Any large increase in sea products must come mostly from the exploitation of new areas. By the elimination of the present waste and by proper conservation the amount of food drawn from the sea can be more or less increased in the populous regions, but the possibility of increasing the productivity of sea areas already being utilized is infinitely less than the possibilities of similar efforts on the land.

The interrelationships of the land and sea as set forth above are not yet proved, but all the evidence seems to point in that direction. On our utilization of the land depends the productivity of our adjacent seas. For instance the unrestricted use of streams for industry by the pollution of the water not only kills off such aquatic life as they contain, but, more important still, decreases the value of the substances brought down for the support of marine life.

Intensive cultivation of extensive areas on land not only greatly lessens the amount of vegetable detritus washed into the sea, but also permits the washing off from the land surface of quantities of mud and sand. Such detritus as goes down a very muddy river is largely buried when the sand and mud sinks to the bottom on the ocean floor, or is so diluted with mud particles as to make it unavailable for use by detritus feeding animals. Furthermore, in a muddy river mouth only a small part of the available material can be used by plants, since the sunlight in effective quantities can only penetrate for a few feet through the clouds of mud.

For centuries the land areas have been subject to intensive study. The similarly intensive study of the seas is yet to come. We see our way to an increase in the products of the land. We see at present no such simple way of increasing the products of the sea.

We can not escape the inference that at the present time and in the future we should especially devote ourselves to the problem of displacing the competing insects on the land, and to an intensive study of the seas, especially with a view to ascertaining what it is that feeds the life in them, the nature, extent and quantity of that life and how we may conserve and utilize it to the best advantage.

Smithsonian Institution Austin H. Clark

NOTES AND REFLECTIONS ON ISOSTASY

If the earth's materials were sufficiently plastic to allow of a condition of perfect equilibrium, these materials would arrange themselves in concentric strata according to density, and there would be no