Fishes Killed by the 1950 Eruption of Mauna Loa
I. The Origin and Nature of the Collections

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THE GREAT VOLCANO MAUNA LOA plays many parts in the Hawaiian community. We are here concerned with its role as a fish collecting apparatus. The present paper, which is the first of a series that will deal with the the fishes made available to us by the 1950 eruption, is limited to an account of the general nature of our collections.

The Mauna Loa lava flows of June, 1950, reached the sea on the Kona coast of the Island of Hawaii at three main points (Fig. 1). The first two of these flows dwindled to almost nothing a short time after entering the water on the morning of June 2. The third flow has far greater significance for us. It entered the ocean somewhat to the south of the other two (at 19°16′N., 155°55′W.) on the afternoon of the same day. Surges of lava from this flow continued to pass into the sea in quantity through June 4 and in lesser amounts through June 7.

Whenever a heavy surge of lava hit the sea, a large amount of steam rose from the surface (Fig. 2). Between the peaks of the surges, at least during the later stages of the flow, the moving column of lava entered the sea quietly, unexpectedly resembling an escalator disappearing through the floor of a department store (Fig. 3). Apparently the failure to cause surface steam at such times was due to the cooling and hardening of the outer layer of the lava column into a water-impervious shell through which the rest of the lava flowed. (Such conduits, now hollow and sometimes extending for distances of more than a mile, are well-known features of the Hawaiian terrestrial landscape.) Since the molten material flowed continuously without ever filling this shell, it can be assumed that the lava was breaking out somewhere below. Such outbreaks presumably produced steam explosions which could be felt even in a skiff anywhere near the flow. However, no steam from these assumed outbreaks ever reached the surface, nor was this to be expected unless they had been very large or very near the surface.

The total amount of lava entering the sea from the 1950 eruption was estimated by Macdonald and Finch (1950: 1) at over 100 million cubic yards.

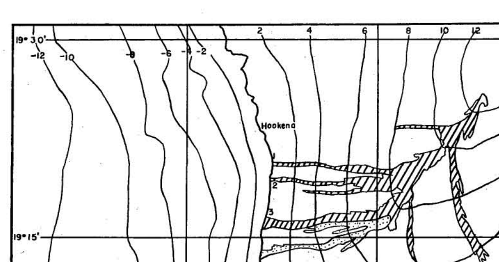

FIG. 1. Land areas covered by the Mauna Loa lava flows of 1919 and 1950. Heights above and below sea level given in thousands of feet. Diagonally hatched areas: 1950 flows; those that entered the sea are numbered in the sequence with which they reached sea level. Stippled area: 1919 flow. Redrafted in part from Macdonald and Finch.

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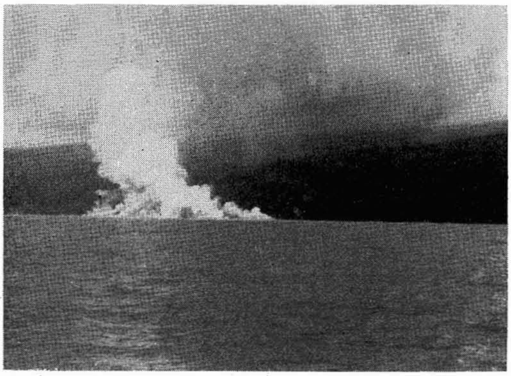

FIG. 2. Third lava flow reaching sea level on June 3.

Concerning sea conditions around the lava flow on June 2, Finch and Macdonald (1950: 6) state:

> By 5:00 P. M. a line of steaming water, marking the sub-sea course of the flow, extended to sea for about half a mile from the point where the . . . flow entered the ocean. Close to the shore and directly over the submerged flow, the water was boiling, and a semicircular area of hot turbulent water extended for a mile offshore. Many fish were killed and were seen drifting or were washed up on shore during succeeding days. The prevailing currents drifted the area of hot water southward.

On the morning of June 3 there was a "windrow" of dead fishes, 2 to 6 feet wide and extending as far as the eye could see, about 2 miles offshore from the flow. Inside this windrow, which marked a border between murky green and deep blue oceanic water, were other smaller, linearly arranged aggregations of dead fishes. At approximately half a mile from the point of entry of the lava, the water-cooled engine of the boat from which these observations were made became overheated.

By the afternoon of June 3 the windrows of fishes had broken up.

On June 6 the water in a roughly semicircular area several miles in radius around the point of entry of the lava was discolored and of dirty appearance. The relatively rare and scattered fish carcasses were found mostly toward the periphery of the disturbed area. Water a quarter of a mile from the flow was hardly warm, though a slick of upwelled hot water was still being formed closer in. The molten lava was still pouring into the sea continuously (Fig. 3), but in surges of greatly varying volume. The average width of the column entering the water at this time was perhaps about 30 feet.

On June 7 lava was entering the sea in greatly decreased volume and more or less intermittently, ceasing completely on this day or the next.

Four collections were made of the fishes brought to the surface of the sea by the 1950 lava flows. On the morning of June 2 Brock flew over the area where the lava was entering the water and made arrangements for collecting. In the afternoon of the same day Eugene Burke and Homer Hayes of the Territorial Division of Fish and Game took a small number of fishes. On June 3 the U. S. Fish and Wildlife Service vessel "Henry O'Malley," with Moore as scientist in charge, sent into the area a small boat from which collections were made in both the morning and afternoon. On the morning of June 6 Yamaguchi collected from a skiff. That afternoon Gosline, Homer Hayes, and Ed Keen took specimens from a sampan owned by Keen. On June 7 Hayes and Gosline returned to the area but found almost nothing.

Circumstantial evidence is rather strong that most of the fishes taken were brought to the surface during the early middle stages of the third flow. We know that the first stages of all three flows killed mostly inshore fishes, and we saw few of these. On the other hand, by June 6 relatively few fishes were coming to the surface, though live specimens were still occasionally seen. Furthermore, specimens in the June 6 collections often showed signs of more or less advanced decomposition.

Some of the fishes in these collections, particularly those taken on the first two dates, are in excellent condition. Others are not. Some of the latter were parboiled, some were partially decomposed, and some were both. The myctophids collected on June 6 gave the impression that if one looked at them intently their scales would fall off. Nevertheless, the specimens in these four collections are probably in a better state of preservation than is most deep-water fish material.

Certain highly desirable data concerning our collections are unobtainable. For one thing, little can definitely be said about the depth from which these fishes came. Some of our specimens, such as the brotulids, are deep-water bottom forms. Others like the myctophids are bathypelagic. A few probably normally inhabit the surface layers of the open ocean. A very few are obviously inshore forms which had drifted into the area where we were collecting. The maximum depth at which our fishes were killed is likewise unknown. The most that can be said is that the known depth records for such fishes as *Opisthoproctus*, of which we took five specimens, indicate that at least some of our material is from rather deep water, presumably greater than half a mile.

We also do not know how representative our collections are of the total fish fauna living in the area. Four types of selectivity have probably restricted the representativeness of our sample. Two of these are due to our collecting methods and can be taken into account. First, we made no effort to collect the obviously inshore forms. Second, small fishes were almost completely missed because we took only what we could see and catch with a dip net from a boat. The other possible selective factors are: differential decimation

FIG. 3. The third lava flow entering the water several days later. Photograph by Jack Matsumoto.

among the species in the area and differential flotation among the species killed. These last two factors are impossible to evaluate, and the best that can be done is to point out their possible effects.

Death of these fishes may have been brought about by one or more of four causes: (1) the fishes may have been killed by simple overheating; (2) the lava entering the water may have introduced some directly or indirectly lethal chemical; (3) fishes with an air bladder may have been carried upward so rapidly by the upwelling water as to have caused overexpansion of this organ; and (4) the underwater explosions, caused by the breaking out of the molten lava from the conduits, may have caused some mortality. We do not have evidence that would make profitable a discussion of any of these possible causes of death. With any of them, however, it would seem likely that large fishes would be better able than smaller ones to move out of the way in time to avoid harm. The differential in decimation between large and small fishes may have been increased by the possibility that the water moving in to replace that which had upwelled carried with it small, weak swimmers from the surrounding region into the outbreak area.

Concerning the possibility of differential flotation, our only evidence is from the specimens we collected. With regard to these, two questions arise. What brought them to the surface, and, once there, why did they not sink back to the bottom? As to the first, one might suspect that the water heated by the lava would make its way through the water column above it to the surface, where it would spread out as a thin layer. Under such a hypothesis only the fishes from the area around the outbreaks would be brought to the top. Actually our collections contain epipelagic and a large number of bathypelagic fishes, as well as bottom forms. The presence of these pelagic species can best be explained by hypothesizing considerable mixing between the rising water and that around it. It does seem apparent that, regardless of the amount of mixing, fishes with a high specific gravity would be less readily transported to the surface than those with lighter bodies. Likewise, among fishes with the same specific gravity, those with a higher surface-volume ratio, e.g., small fishes, would be more easily carried in the upwelling water than those with a lower surface-volume ratio. It is possible, however, that not all the fishes we collected were originally brought to the surface by upwelled water, but rather that some of them were forced up after death by gases of decomposition.

This possibility leads into the question of why fishes were at the surface when we got there. Evidence from some of our specimens indicates that their air bladders became overexpanded and remained so after death, serving as floats. However, others show no expansion of an air bladder, and a large number of our specimens presumably do not even possess this organ. The presence of such fishes at the surface can best be explained by hypothesizing the formation of gases in parts of the body other than the air bladder. For example, the two brotulids we took on June 6 had the belly (but not the air bladder) greatly distended and empty. Most of our specimens, however, showed no abdominal distension. Whether decomposition gases and air bladder expansion can explain the presence of all our fishes at the surface seems open to question. Whatever the full explanation is, it must take into account the fact that, with the exception of two jellyfishes, we found no organisms other than fishes at the surface.

Our four collections together probably total 300 to 500 specimens distributed among more than 20 families. Perhaps a third of the individuals are myctophids. Except for the Myctophidae, and to a lesser extent the Sternoptychidae, none of the families is represented by more than a few specimens. Among groups unrepresented in our collections are sharks, flatfishes, and angler fishes.

In number of species our material would

seem to be much richer than the number of individuals might indicate. For example, each of the five brotulid specimens represents a different species. Such a representation indicates the variety of fish life that must exist in the deeper waters around Hawaii. Another piece of evidence bears on this same point. In 1922 Jordan reported on seven species collected from the sea around the point of entry of the 1919 lava flow (Fig. 1), six of which he described as new. Of these seven species, at least three and probably six were not taken by us.

There appear to be only two extensive reports on the deep-water fishes of the Central Pacific (Gilbert and Cramer, 1896; Gilbert, 1905). Both of these are based on dredge hauls made by the "Albatross" in Hawaiian waters. In the later paper, which summarizes the results, Gilbert recognizes 111 species taken below the 100-fathom line. Since 1905 occasional deep-water forms, mostly taken by fishermen, have been added to the Hawaiian fauna from time to time. The only previous paper based on Hawaiian fishes killed by a lava flow is that by Jordan (1922) mentioned above.

After the "Albatross" material, the 1950 lava-flow collections constitute the most important deep-water fish material yet taken in the Central Pacific. Their value is enhanced by the fact that, though there is some overlap, the 1950 collections by no means duplicate those taken by the "Albatross." For example, we took five species of brotulids whereas Gilbert did not record any; conversely, in another bottom-fish group—the flatfishes—Gilbert reported 13 species and we did not take any. Such examples, though extreme, again indicate the tremendous size of the fauna from which our samples were drawn.

It is planned to publish reports on the various groups in our collections in this journal as they are completed. The section on brotulids has been finished and appears elsewhere in this issue. Specimens of certain groups have been sent out to be worked up by others: the zeoids by Dr. George Myers, the myctophids and gonostomatids by Dr. R. L. Bolin, both of Stanford University, and the sternoptychids by Miss Janet Haig, of the Allan Hancock Foundation.

For constructive criticism and help in preparing the present paper we wish to thank Dr. R. L. Bolin, Dr. C. K. Wentworth, Mr. T. Cromwell, and various members of the University of Hawaii faculty.

REFERENCES

FINCH, R. H., and G. A. MACDONALD. 1950. The June 1950 eruption of Mauna Loa. Part 1. Narrative of the eruption. *The Volcano Letter* (Honolulu) 508: 1–11.

GILBERT, C. H. 1905. The aquatic resources of the Hawaiian Islands. Part II. Section II. The deep-sea fishes. *U. S. Fish Comm., Bul. for 1903*, 23(2): i–xi, 577–713, pls. 66–101.

——— and F. CRAMER. 1896. Report on the fishes dredged in deep water near the Hawaiian Islands, with descriptions and figures of twenty-three new species. *U. S. Natl. Mus., Proc.* 19: 403–435, pls. 36–48.

JORDAN, D. S. 1922. Description of deep-sea fishes from the coast of Hawaii, killed by a lava flow from Mauna Loa. *U. S. Natl. Mus., Proc.* 59: 643–656.

MACDONALD, G. A., and R. H. FINCH. 1950. The June 1950 eruption of Mauna Loa. Part II. Special features. *The Volcano Letter* (Honolulu) 509: 1–6.