Research Report on the Influence of the Fire in Isla Isabela of the Galápagos Islands (Ecuador)

Research Report on the Influence of the Fire in Isla Isabela of the Galápagos Islands (Ecuador)

December 1994

Group of Experts
(CONSERVATION of FAUNA and FLORA of the Galápagos Islands)
Japan International Cooperation Agency (JICA)

December 1994

Japan International Cooperation Agency (JICA)

Research Report on the Influence of the Fire in Isla Isabela of the Galápagos Islands (Ecuador)

December 1994

Group of Experts
(CONSERVATION of FAUNA and FLORA of the Galápagos Islands)
Japan International Cooperation Agency (JICA)

List of members of the Group of Experts for the Conservation of Fauna and Flora of the Galápagos Islands

KOHMARU Masaaki

(Charge/Specialty) Chief, Nature conservation management

(Title) Head, Tohoku Area National Park and Wildlife Office, Environment Agency

SHIMIZU Yoshikazu

(Charge/Specialty) Plant ecology

(Title) Assistant professor of Natural Science, Department of Literature, Komazawa University

YANAGISAWA Norio

(Charge/Specialty) Ornithology

(Title) Chief, Investigation Office, Japanese Society for preservation of birds

OHTSUKA Satoko

(Charge/Specialty) Herpetology

(Title) Research staff, Japan Wildlife Research Centre

ITOH Yuhzo

(Charge/Specialty) Veterinarian, Wildlife Management

(Title) Chief, Office of Wildlife Management, Wildlife Protection Division, Nature conservation Bureau, Environment Agency

KAWAI Kohji

(Charge/Specialty) Planning, coordination and management

(Title) Manager, General Affairs Division, JICA ternational Centre

Preface

On April 1994, a big fire broke out in Isla Isabela, the largest island in the Galápagos Archipelago of Ecuador. We heard the news with great attention and anxiety about the influence of the fire on the valuable wildlife, because there had been growing interest in conserving the natural environment in Japan following the registration of the beech forest in the Tohoku region and the cedar forest in the Nansei Shoto as part of the natural heritage specified under the Convention concerning the protection of the world's cultural and natural heritage, the year before, in December 1993.

The Galápagos are an isolated group of islands which lie in the Pacific Ocean on the equator. The nearest mainland country is Ecuador, some 1000 km to the east.

The Archipelago is far from Japan, but its unique and fascinating wildlife is generally well known, as it has been introduced by many students, tourists, photographers and journalists. Formerly, the interesting and curious story of the Galápagos islands wildlife was a matter of another world. In the 1980s when overseas travel was becoming popular owing to the economic development and rapid progress of transport facilities, the Galápagos Islands became easy to access as a tourist resort.

On the other hand, as nature conservation became an important global issue to be tackled, we realized that the Japanese Archipelago as well as the Galápagos Archipelago is an element of the Earth's ecosystem from the global viewpoint.

These circumstances lay beneath our deep concern and the concrete measures addressed by the Japanese Government toward this calamity.

When a bigger fire occurred in 1985, the Japanese Government gave only pecuniary aid. This time, the Government tried to give pecuniary and other technical aid by sending a research group of experts to the scene of the fire in the Galápagos Islands.

Then, the Group of Experts was organized and sent through the Japan International Cooperation Agency (JICA). The purpose was to research the day-after damage from the fire to vegetation and land vertebrates, and to give, if possible, technical advice about ways of restoring or monitoring, including means of proliferation of the Islands wildlife.

Although we could not stay long enough, because of force of circumstance, each member wrote a paper on his field research on the base of information we got on the spot, and I assembled these papers into this Report on the influence of the fire and the future protection of wildlife in Isabela. The contents of this Report do not necessarily reflect the official view of JICA but merely that of the Group of Experts. We sincerely hope that this Report will be helpful in promoting international cooperation for the preservation of Galápagos Islands wildlife.

This field research was carried out thanks to the cooperation and support of a great number of people.

We would like to express our thanks to General Laericio Almeida, Head of the National Department of Civil Defence (DNDC), our counterpart in Ecuador, and to his staff members, especially to Ms. Gloria Maria Roldan, Manager, Environment Department, Technical Division, who always went with us during field research to handle coordination and arrangements. Our research could never have succeeded without her kind and devoted services. We would like to express our thanks also to Dr. Chantal Blanton, Chief of the Charles Darwin Research Station (CDRS), to Mr. Felipe Cruz, Manager of the Galápagos National Park Service (SPNG), and to their excellent staff members, who acted as our guides during our stay in Isabela and Santa Cruz.

Our cordial thanks are due to Mr. Jacinto Gordillo, General Manager of CDRS Isabela Office, and to Mr. Arnold Topiza, Staff, SPGC Isabela Office, who are experts in Isabela. Their appropriate information was indispensable to carry out our short-stay field research efficiently.

Our profound gratitude is also due to the Japanese Embassy in Ecuador, which coordinated and made arrangements for us with the Ecuadorian Authorities and gave us every facility during our stay. We are much obliged to Mr. Matusui Masato, Councilor, and to Mr. Masutome Tokuro, Secretary, for the great trouble they took for us. We are deeply indebted to Professor Ito Shuzo, Nagasaki University, for his kind help and encouragement in all aspects in Japan.

Finally, we express our grateful thanks and deep respect to all concerned in JICA, the Economic Cooperation Bureau of Ministry of Foreign Affairs, and to the Global Environment Department and the Nature Conservation Bureau of Environment Agency, for their endeavor and decision regarding the Group of Experts.

December, 1994
On behalf of the Group of Experts,

Kohmaru Masaaki

The Research Report on the Influence of the Fire In Isla Isabela of theGalápagos Islands (Ecuador)

Contents

List of members of the Group of Experts Preface
I Background and objectives of the assignment of the Group of Experts 1
II Organization and mission of the Group of Experts 2
III Itinerary and summary of the field research 3
IV Research report 6
1. Fire-affected area in 1994 on Isabela 7
1) Location and size of the burnt area, and the cause of the fire 7
2) Circumstances of the burnt area (topography, vegetation) 8
3) Fire fighting and remarks 9
(1) Details from the fire information to the fire fighting 9
(2) Fire fighting 9
(3) Remarks 9
4) Damage to vegetation 10
5) Damage to animals 17
(1) Mammals 17
(2) Birds 18
(3) Reptiles 24
2. Fire-affected area in 1985 26
1) Location and size of the burnt area 26
2) Circumstances of the burnt area (topography, vegetation) 26
3) Fire fighting and remarks 27
4) Damage to the vegetation and the state of recovery 27
5) Damage to the birds and the state of recovery 29
3. Others - the result of site investigation and information collection
except in the afflicted areas 31
1) Vegetation 31
2) Mammals 36
3) Birds 36
4) Reptiles 44
5) Preservation of giant tortoises 48
6) Agroforestry (Useful tree planning project) 49
7) Environmental education 50
V Consideration and proposal 52
1. Evaluation of the influence of the fire on nature
and social environment of Isabela Island 53
1) Evaluation of the influence on the vegetation/flora 53
2) Estimation of the influence on the fauna 55
3) Evaluation of the influence on regional communities 56

2. Suggestions for coping with a future outbreak of fire 58
1) Forecast for the risk of outbreak fo fire 58
2) Determination of priority of fire-prevention and fire-fighting and a plan for conservation by areas 60
3) Propagation and enlightenment on fire prevention 62
3. Suggestion about conservation of nature in Isabela Island 63
1) Special characteristics when considering conservation of nature in Isabela Island 63
2) Carrying out a counterplan by steps in view of local residents and coexistence of alien creatures and primary nature 63
VI Organization of ODA of JAPAN and the future possibility of cooperation 67
1. JICA's scheme that is applicable to assistance to conservation of the Galápagos' nature 68
2. Japan's way to cooperate with the conservation of the Galápagos Islands' nature with the view of international cooperative relationship 69
3. The feasibility of future cooperation 70
1) Conduct ecological research for conservation of the nature of Isabela Island 70
2) The future prospects 72

I. Background and objectives of the assignment of the Group of Experts

On 12 April 1994, a big fire occurred in Isla Isabela, the largest island in the Galápagos Archipelago of Ecuador. Ten days later, on 22 April, every newspaper reported the news distributed by AFP news agency, and said that the fire continued to spread and that precious wildlife was in peril.

At the news of the disaster, the Ministry of Foreign Affairs and the Environment Agency studied what Japan could do for the affected Galápagos islands wildlife, a world natural heritage, and, at the same time, they asked what Ecuador wanted by gathering information through the Japanese Embassy on the spot.

As a result, the Ministry of Foreign Affairs decided to deliver urgently the pecuniary aid of 50 thousand dollars, and at the request of the Ecuador Government, to send experts to the spot, in cooperation with the Environment Agency and JICA, for the purpose of researching the damage, and of giving, if possible, the required technical cooperation for wildlife protection.

II Organization and mission of the Group of Experts

The mission of the experts was to:

•Research the day-after damage to wildlife

•Study and give advice for the preservation and proliferation, if endemic species such as the Giant Tortoise and the Land Iguana and vegetation are severely affected.

•Study and give advice on the monitor program on the wildlife and natural environment in order to understand the change of circumstances and their state of recovery in the fire-affected area and in the surrounding area not affected by the fire.

•Study and give advice for restoration, if necessary.

To carry out the mission, experts were called upon to join the Group. The members of the Group are listed below:

KOHMARU Masaaki
(Charge/Specialty) Chief, Nature conservation management
(Title) Head, Tohoku Area National Park and Wildlife Office, Environment Agency

SHIMIZU Yoshikazu
(Charge/Specialty) Plant ecology
(Title) Assistant professor of Natural Science, Department of Literature, Komazawa University

YANAGISAWA Norio
(Charge/Specialty) Ornithology
(Title) Chief, Investigation Office, Japanese Society for preservation of birds

OHTSUKA Satoko
(Charge/Specialty) Herpetology
(Title) Research staff, Japan Wildlife Research Centre

ITOH Yuhzo
(Charge/Specialty) Veterinarian, Wildlife Management
(Title) Chief, Office of Wildlife Management, Wildlife Protection Division, Nature conservation Bureau, Environment Agency

KAWAI Kohji
(Charge/Specialty) Planning, coordination and management
(Title) Manager, General Affairs Division, JAICA International Centre

III. Itinerary and summary of the field research

1. Itinerary

Itinerary Field research was carried out following the itinerary shown below:

June 3 (Fri.) Tokyo to Miami AA-026
June 4 (Sat.) Miami to Quito AA-967
June 5 (Sun.) Preparation of materials and related equipment
June 6 (Mon.) Preparatory arrangements with the Japanese Embassy in Ecuador, the National Department of Civil Defence (DNCD) and other governmental authorities
June 7 (Tue.) Information-gathering and supply of related equipment
June 8 (Wed.) Quito to Isla Baltra via Guayaquil EQ-191 Isla Baltra to Isla Santa Cruz oat and bus)
June 9 (Thu.) Arrangements with the Charles Darwin Research Station (CDRS) and the Galápagos National Park Service (SNPG)
June 10 (Fri.) Preparatory research, Group meeting and final check for starting
June 11(Sat.) Isla Santa Cruz to Isla Isabela (chartered boat)
June 12(Sun.) to June 16 (Thur.) Field research
June 17(Fri.) Isla Isabela to Isla Santa Cruz (chartered boat) Arrangement with CDRS and SNPG
June 18(Sat.) Collation of collected data and Group meeting
June 19(Sun.) Visit to Isla Santa Fe
June 20(Mon.) Isla Santa Cruz to Isla Baltraoat and bus) Isla Baltra to Quito via Guayaquil EQ-190
June 21(Tue.) Arrangement with the Japanese Embassy in Ecuador and collation of collected data
June 22(Wed.) Seminar/Workshop: Influence of the disaster on the natural environment of the Galápagos Archipelago and its prevention (organized by DNDC)
June 23(Thur.) Oral presentation of the research report in the Seminar
June 24(Fri.) Notification to the Japanese Embassy of the completion of research
June 25(Sat.) Quito to Miami AA-966
June 26(Sun.) to June 27 (Mon.) Miami to Tokyo AA-027

2. Summary of the field research

According to the above-mentioned itinerary, field research, data gathering and exchange of opinions with the concerned Ecuadorian authorities were carried out.

1) Previous arrangements with DNDC (Sun., 6 June)

At the head office of the DNDC, we heard details of the recent fire and former big fires, and studied how to research the day-after damage with the staff concerned in the conflagration on Isabela. Consequently, we planned to first go to the site of the fire by car along the firebreak in order to grasp the situation in its totality, and to undertake careful research by camping out at several points in order to compare the different environmental conditions.

(Participants)

Ecuadorian side (DNDC):

Nelson Vasquez	(Director, Technical Div.)
Magno Rivera	(Manager, Geotechnical Dept., Technical Div.)
Gloria Maria Roldan	(Manager, Environment Dept., Technical Div.)
Mario Cruz	(Staff, Volcan, Geotechnical Dept., Technical Div.)
Carlos Cardelon	(Director, Training Div.)

Japanese side:

Kohmaru Masaaki	(Group of Experts)
Shimizu Yoshikazu	(Group of Experts)
Yanagisawa Norio	(Group of Experts)
Ohtsuka Fusako	(Group of Experts)
Itoh Yuhzo	(Group of Experts)
Kawai Kohji	(Group of Experts)
Sayama Hiroshi	(Research staff in Ecuador, National Personnel Authority)
Masutomi Tokuro	(Japanese Embassy in Ecuador)

2) Preparatory arrangements with CDRD and SPNG (Thur., 10 June)

We went to the SPNG and explained the purposes of our research to Mr. Felipe Cruz, Manager (the General Manager was in Quito on business at the time), and Mr. Chantal Blanton, Chief of CDRS. In answer to our request for their cooperation in collecting data on the fire and the environmental situation in Isabela, and in conducting field research, they willingly offered their support in all aspects and expressed their expectations for this project.

3) Field research in Santa Cruz (Fri., 10 June)

In order to learn about the natural environment of the Galápagos Islands, and to serve as a rehearsal of the research in Isabela, we visited under the CDRS staff's guidance a region where we could see typical natural vegetation, and the tortoise reserve to see Giant Tortoises in the wild. At the breeding field of the agroforestry (a project of useful tree planting) where we stopped on the way, we learned about the project from Mr. Lenin Prado, Research staff of the field.

4) Field research in Isabela

(1) Field research in the site of the fire in 1994 (Sun., 12 June, to Mon., 13 June)

After arrival on the island, we talked over our research project with Mr. Simon Caicedo, General Manager, DNDC Galápagos Office, Mr. German Morillo, SPNG, and Mr. Arnold Topiza, Ranger staff of the island. As a result, in consideration of the bad condition of the road on the firebreak, we decided to go directly to the most interior point we could reach (in the Alemania region), and to research there by camping out.

On 12 June, we started to camp along the firebreak. It was some four hours ride by specially made car (Mercedes Benz truck, Unimok). After setting up the base camp, we started field research in the nearby surroundings of the camp site.

On 13 June, we carried out field research of the site of the fire along the firebreak. We observed vegetation at the site of the fire, and vegetation and birds in its surroundings which were not affected by the fire.

When we went back to the camp, Ms. Roldan advised us to go down the mountain before dark for fear that we could not pass the firebreak in worse condition. So we pulled down the tent and climbed down the mountain with the DNDC team who withdrew from the site.

(2) Field research in the fire-affected area of 1985 (Thur., 14 June)

To observe the state of recovery, we visited the site of the former big fire in 1985 under the guidance of Mr. Jacinto Gordillo, General Manager, CDRS Isabela office, and Mr. A. Topiza, SPNG, along the border line between private land and the National Park, which lies to the west from the main road passing Santo Tomás, and along the former firebreak, and assessed there the state of recovery from damage in comparison to the vegetation in the adjacent area not affected by fire. On the way, we visited the small relic Scalesia forest in the farmland (which CDRS bought to preserve as a forest for environmental education), and on the way back, we visited the Giant Tortoise Reserve Centre.

(3) Research on the vegetation of the littoral zone of Isabela (Feb., 15 June to Thur., 16 June)

On 15 June, under the guidance of Mr. J. Gordillo and Mr. A. Topiza, we landed in the Union region, to the west of Puerto Villamil. It was a one hour trip by boat. We observed there the vegetation in the habitat of Giant Tortoises, the lagoon and its inhabitants.

On 16 June, we observed the vegetation of the arid zone in the Muro de los lamentos region, a 40-minute car ride to the west of Puerto Villamil.

(4) Special meeting with the Head of DNDC (Thur., 16 June)

As the Head of DNDC came to inspect Isabela, a special meeting was held at the hotel where we were staying. We reported the research we carried out, and the DNDC invited us to attend the DNDC seminar on our way home and asked to make a report on this research at the seminar.

The DNDC member of the meeting were:

General Laericio Almeida: Head, DNDC
General Pavon: Chair, National Safety Commission
Mr. Fernando Molina: Director, Foreign Affairs Project Div., DNDC
Mr. Simon Caicedo: General Manager, DNDC Galápagos Office
Mr. Jacinto Gordillo: General Manager, DNDC Isabela Office

IV Research report

Pocket Notebook VI

1. Fire-affected area in 1994 on Isabela

1) Location and size of the burnt area, and the cause of the fire

The fire broke out from the point at about lat. 0°55' S, long. 91°11' W. The point is shown below in fig. 1. The site area was some 36.05 sq km, according to the computer, equivalent to about 0.8 % of the area of Isabela (4.588 sq km), but 32 sq km and 45 sq km, according to the DNDC and the Galápagos National Park Office, respectively.

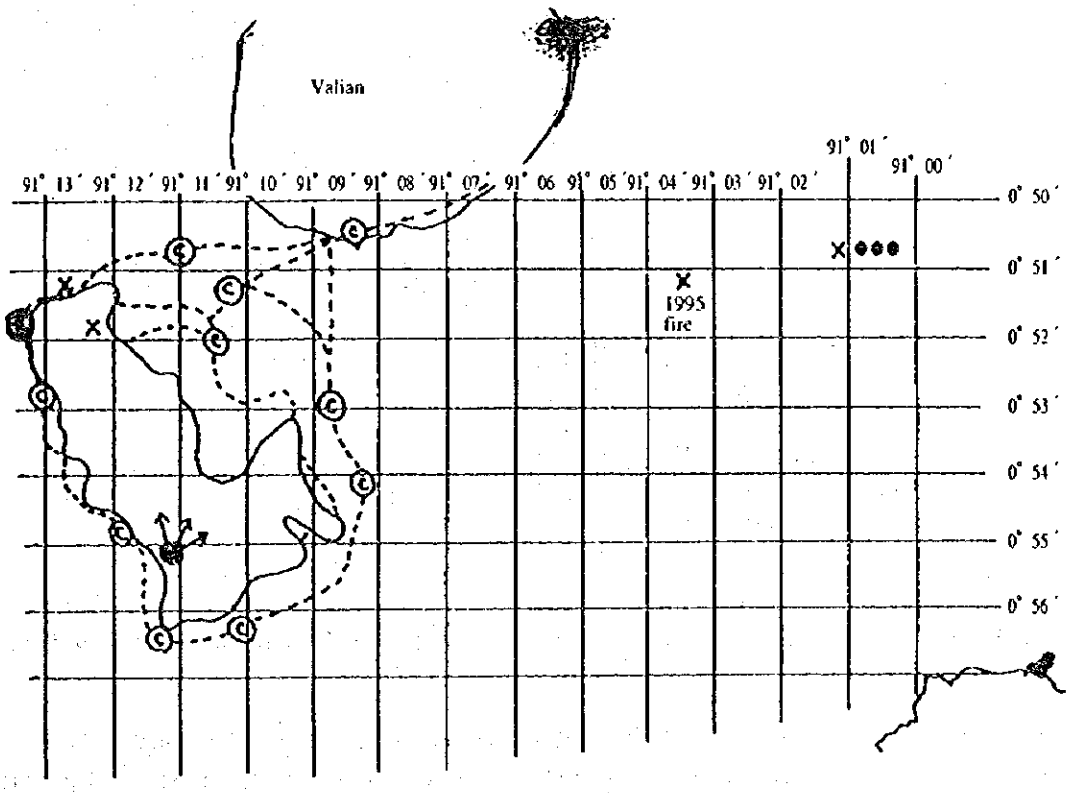


Fig.1 Map of the site of the fire

2) Circumstances of the burnt area (topography, vegetation)

The fire broke out in the hill region between the Volcáns Cerro Azul and Sierra Negra in the south of Isla Isabela. There is a new lava zone lying from the northwest to the southeast, some 6 km to the west from the site. We can find also the lava zone all over the north side of each Volcán. Although we can find some old fumaroles as small hills and craters in this area, the ground surface is almost covered with many species of vegetation without any new trace of volcanic activities.

The vertical distribution of the vegetation on the southwest side of Volcán Sierra Negra is as follows (See the fig.2.): Arid zone (0 to 100 m), Semi-arid zone (100 to 250 m), Scalesia zone (250 to 700 m), Shrub zone (700 to 900 m), Pampa zone (900 to 1100 m). In the Scalesia Zone and higher, where it is always foggy and humid, a cloud forest (mossy forest) type vegetation is seen, that is, the trees are covered with smaller plants such as mosses and lichens.

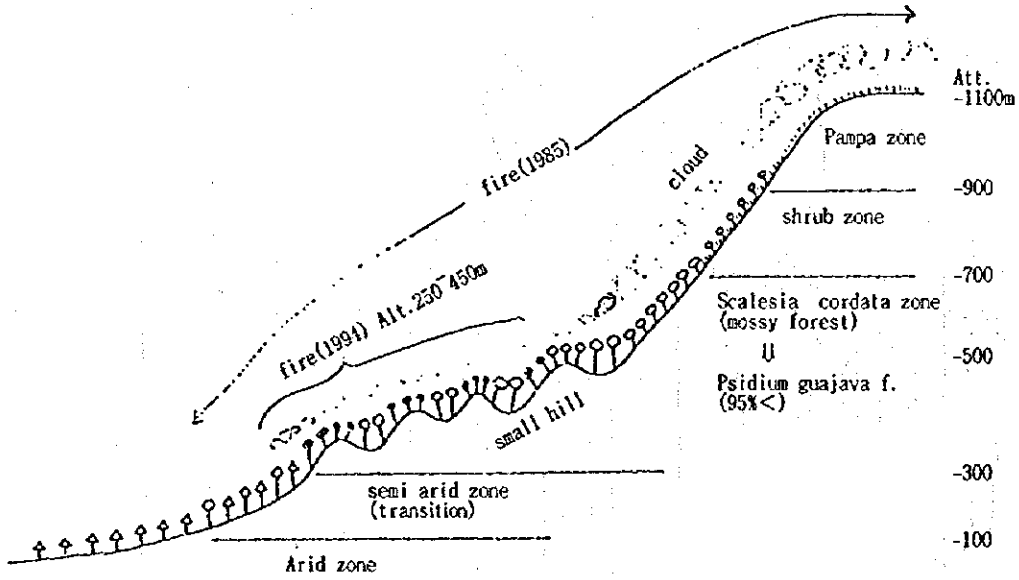


Fig. 2 Vertical distribution of the vegetation of the southwest of Isabela and the fire-affected areas

The Scalesia zone, generally a gentle land with workable soil, has been easily cultured in the large islands. In Isabela, as there were penal colonies before 1945, where the criminals were living a self-sufficient life at Puerto Villamil, Santa Tomás and Alemania regions, we can find fruit trees introduced to cultivation at that time, and domestic animals gone wild that had been initially carried in with colonists from Guayaquil and set free on the island. In the fire-affected Alemania region which is now uninhabited, the Scalesia zone and Shurub zone are almost covered with Guajava trees (Psidium guajava) which was introduced from the mainland in the days of colonization. Domestic species gone wild such as cows, burros and horses have not only destroyed the vegetation of the island, but have also endangered giant tortoises by competing for food resources.

By the late fire, the forests in the lower part of the Scalesia zone, at altitudes of between 250 to 450 meters, were mainly affected. It is well that the fire did not spread to the Shrub zone or to the Pampa zone where

inflammable ferns and grasses grow closely. During the bigger fire in 1985, a vast area from the Scalesia zone to the caldera of Volcán Sierra Negra was affected.

Regarding the cause of the fire, although it may have been a spontaneous combustion by the volcanic activity, in consideration of the location and circumstances, the most likely possibility is that the fire was accidentally caused by a hunter who chased domestic animals gone wild. As cloud forests in the area are always damp, it is thought that a fire is hard to start. Taking into account the fact that the fire in 1985 was caused by abnormally dry weather in the rainy season of the year before, we can say that the long dry weather is considered as an indirect cause of this fire.

3) Fire fighting and remarks

(1) Details from the fire information to the fire fighting

It was before noon on 12 April that the first report of the fire came in from a SPNG staff member on patrol by boat who found smoke rising at the foothills of Volcán Sierra Negra. Received the report by radio contact, Mr. Cruz, Manager of SPNG, knew intuitively that it would get serious because of a long spell of dry weather they had, remembering the big fire in 1985. He lost no time in calling his staff to fight the fire, but he found the required equipment unavailable. At the same time, he reported the fire to Mr. Caicedo, General Manager, DNDC Galápagos office (on Isla San Cristábal), who reported the emergency to the Head office in Quito. Three days after, on 15 April, General L. Almeida, Head of DNDC, and Ms. Roldan, Manager, Environment Dept., DNDC, rushed off to Isabela and inspected the fire by helicopter. As the fire was spreading furiously, they realized the necessity of fire fighting on the national level. By their request of relief under a state of emergency, the President of Ecuador declared, on 19 April, a state of national emergency (a government ordinance) with the approval of the National Assembly.

(2) Fire fighting

Before the declaration of a state of emergency, the SPNG staff fought against the fire. But it was all they could do to open a road of access to the fire with two bulldozers transported from SanCristábal, and to cut undergrowth of fuel load. They could not even carry water, without any means of access to the spot, any available equipment or any channel of command for fire fighting.

After a state of emergency was declared, the army and the navy joined the fire fighting under the command of the DNDC, and built the firebreak which served as the road of access, using the three bulldozers transported by sea from the mainland. At the moment, the special-purpose Unimoc trucks made by Mercedes Benz were most useful for the transportation of goods and workers.

(3) Remarks

The experts in fire fighting who were sent from the U. S. A. to inspect the disaster for five days from 21 April, highly estimated the firebreak and the supporting system and said that it was appropriate to use the big machines in a big fire like that because normal fire extinguishers were too ineffective and would exhaust the workers in vain.

At the site of the fire, we found that the firebreak and the fire stop line were not always the same. It is because the fire fighting was carried out inside the firebreak, or because the fire burnt itself out by changes in wind direction or by the non-inflammability of plants before it reached the firebreak.

At any rate, as the fire did not spread over the firebreak, there is no doubt that the firebreak was effective in controlling the fire.

The firebreak was made by felling trees with bulldozers. It was an open cutover 15 to 20 meters wide with piled logged trees and debris on the edges. (See fig. 3.) On the firebreak, we observed bare lava and soil of volcanic ash which lay 10 to 15 centimeters deep, in places. We also found a mantle community of liana, *Ipomea alba*, already developing on the forest border.

At the DNDC seminar held in Quito on 22 and 23 June, as a person concerned, Mr. F. Cruz, Manager of SPNG, stressed that to rapidly address the disaster with the minimum damage it was indispensable to provide big machines such as bulldozers and Unimoc trucks which were most helpful for the fire fighting in Isabela, to define the channel of command, and to establish a network for contact.

We proposed, at the seminar, the need of preventive measures for disaster by means of forecasts of meteorological conditions, warnings and attention calls for inhabitants and their mutual cooperation. Finally, General Almeida, Head of DNDC, expressed his gratitude to all interests involved in the fire fighting (including our Group of Experts), and expressed that it was important for the natural heritage preservation to ensure the support from international organizations and many other countries, because what one country could do was limited.

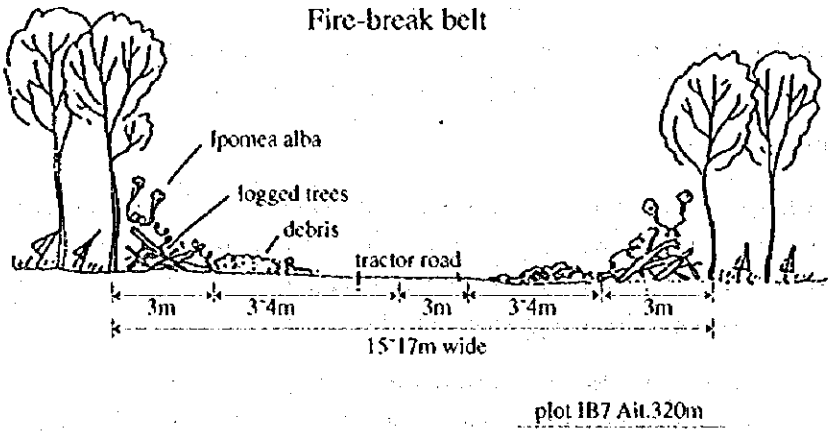


Fig. 3 Cross section of the firebreak

4) Damage to vegetation

(1) Research on vegetation in the fire-affected-area and in the non-affected periphery

We chose as many various plots as possible, according to the extent of influence and the circumstances, and their surroundings, and observed the burnt or remaining species of vegetation. Because of the time limitation, we made only a list of species in places. In the plots where we could conduct adequate research, we carried out a stratification of the vegetation and recorded the species by stratum. We measured also the diameter at breast height (DBH) of the canopy trees and estimated the population density by a spacing method. The seven research plots in Isabela and other islands are shown in fig. 4. As we could not get a detailed topographical map, we calculated the latitude and longitude using the global positioning system

(GPS).

The following is a brief description of the research results.

Research plot IB2: Site of the fire in 1994 (alt. 320 m)

This plot was located in a last fire-affected area, where the fire spread over the firebreak. The stand is almost completely composed of guajava trees, and the crowns and trunks generally remained unburnt. On the trunks to the height of 50 to 60 cm, slight burns are seen without any damage. The organic matters on the forest floor are burned out and only black ash remained. When we dug below the surface, it became clear that only the upper layer of the floor was burned. The crown leaves of the forest are mostly unburned. On the ash layer of the floor, we observed withered leaves which had probably fallen after being affected by the heat of the fire.

Owing to a little rain which had fallen five days earlier, we observed new leaves of the bracken (*Pteridium aquilinum*) shooting forth from the subterranean stem which remained unburned, guajava buds shooting out, and new shoots of *Desmodium cnum* and *Salvia insularis*.

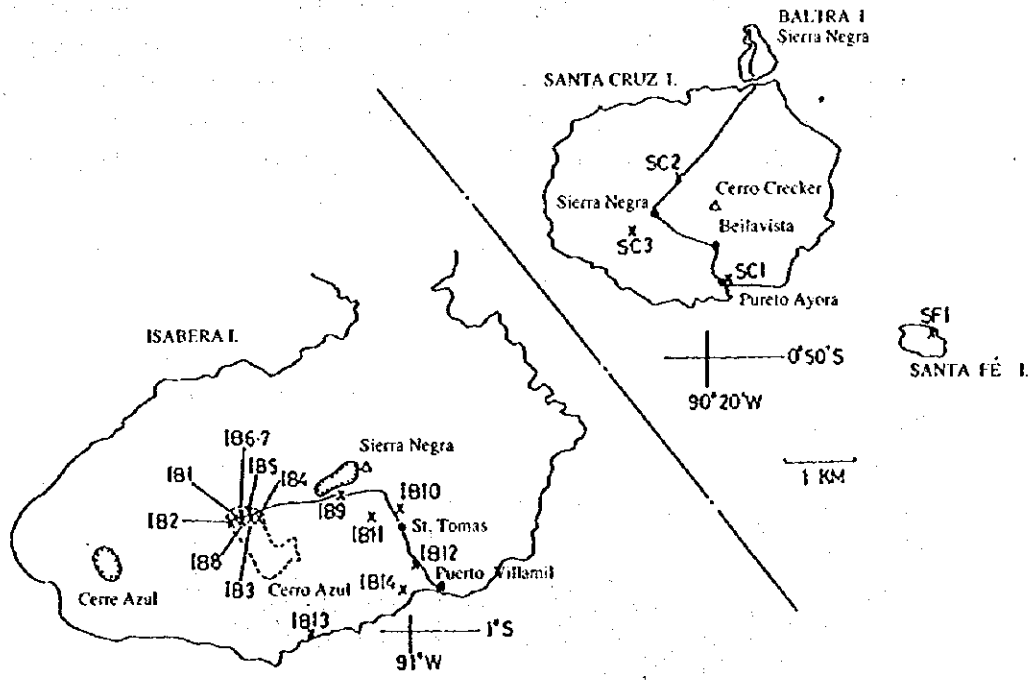


Fig. 4 Research plots

Research plot IB3: Site of the fire in 1994 (alt. 370 m)

This is located in the center of the fire-affected area which lies between the base camp and the Alemania region. At the place most severely affected, we observed charred guajava trunks. We found them on the slope of the rocky spine, facing east-southeast, which was probably once a sunny place with bracken communities and guajava trees of small density. We found black ground with charred organic matter at our feet.

Due to the rain which fell five days earlier, many bracken leaves came out from the subterranean stems, and reached the height of 40 to 50 cm when we observed. The individual density was about 30 to 50 per sq meter, that is, they were rather close there.

Research plot IB4: Near the fire stop line in the Alemania region (alt. 345 m, lat. 0°51'50.1" S, long. 91°12'18.9" W)

As the uninhabited Alemania region was once a colony of settlers before the second world war, many introduced plants are seen there.

On the flat area of the ancient colony, coffee trees, oranges, peppers and or pine communities are grown up under big avocados *(Persea americana)*.

This plot was situated in the transition zone, where the vegetation is both varied and thick, from the ridgy site covered with exposed lava to the flat area covered with soil. The fire stop line is seen at the center of the area. (See Fig. 5.)

On the dry ridgy site the fire-affected forest with guajava trees of 4 meters high was observed (the individual density is 0.14 per s meter). The burned organic matter made a carbonized layer on the floor, but guajava trees remained unburnt with shoots coming out from the trunk. We found unburnt brackens grown up thick to the height of 2 m. So brackens had probably served as the fuel load of the fire. In the lava area, there are tunnels made at the cooling time where we can find roots in places. The fire could spread by burning the organic matter in such tunnels.

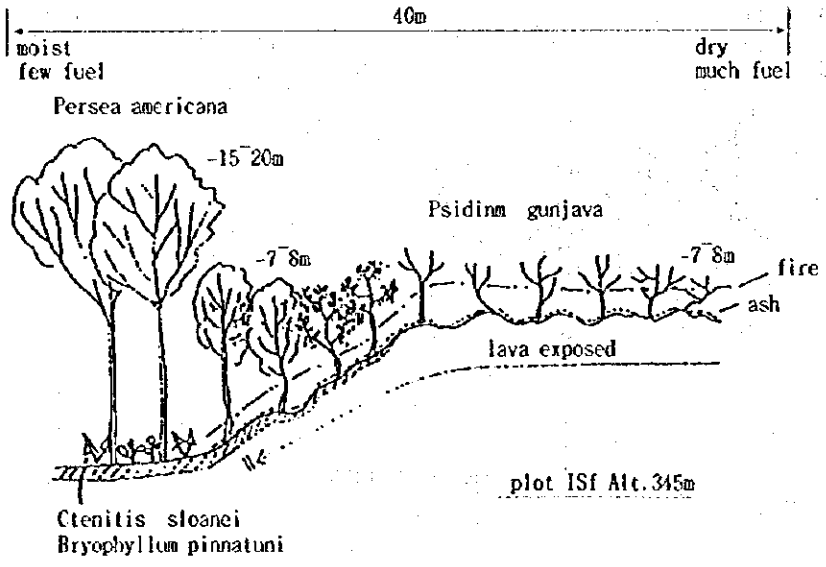


Fig. 5 Aspect of the transition zone around the fire stop line

On the hillside under the ridge, guajava trees are 7 to 8 meters high. Green leaves are seen at the crown, while herbs are burnt away from the forest floor. The flames of the fire must not have reached the crown.

On the flat area, several big avocados of 15 to 20 meters high are seen. Its forest floor is darker and moister than the ridgy site. We cannot find any sun plants such as brackens but pteridophytes (*Ctenitis sloanei*, for example) growing with small density. The herbs on the floor were not affected by the fire.

Research plot IB5: Relic guajava forest in the fire-affected area (alt. 410 m, lat. 0°51'9.9" S, long. 91°12'44.1" W)

A part of the firebreak was made on a saddle. The northwest inside was fire-affected and southeast outside, not affected. As the vegetation was continuous on both sides (the slope inclination is about 20°), its species and structure seemed to be similar. So we set the plot in a relic stand, to research the state of the guajava forest before the fire.

The canopy of the scrub of 4 meters high is composed almost entirely of guajava trees. The individual density is 0.27 per s m^2, and the average diameter at breast height is 6.3 cm. Most stems are thin, of a diameter of less than 10 cm. (See Fig. 6.) Taking the place of a poor bush layer, ferns cover the floor to the height of 1.5 m (cover degree: about 70%). Among the bracken communities, naturalized grasses, *Paspalum conjugatum*, are seen. In the scrub, we found droppings of burros. We can say that this scrub was formed rather recently, judging from the thin guajava individuals and poor bush layer.

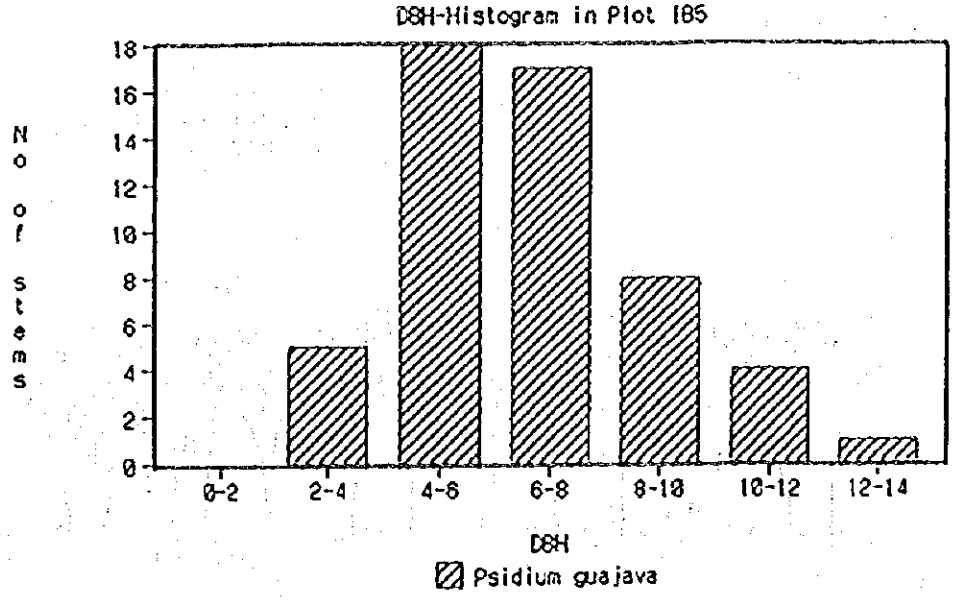


Fig.6 DBH histogram of the guajava trees in a scrub in Plot IB5

Research plot IB6: Relic Scalesia forest in the fire-affected area (alt. 320 m)

We set the research plot in a stand where many relic individuals of scalesia are seen inside the firebreak. This stand on a flat area is 5 meters high, of which the canopy covering is about 80%, composed of three species, *Scalesia cordata*, *Croton scouleri* and *Psidium guajava*. (See Fig. 7.)

The individual density of the canopy is 0.49 per s meter, its average diameter at breast height is 5.8 cm and individuals of more than 10 cm in diameter are not seen. Forests of the scalesia in this area were almost dead owing to much rain caused by El Niáo in 1983, and new seedlings came out after (De Vries & Tupiza 1990). So the forest we observed must be composed of young scalesia individuals. On the other hand, the *average diameter at breast height of guajava trees is 3.5 cm and they are all thin. So the guajava trees* probably invaded more recently than the scalesia trees.

As the canopy is considerably open, the forest is clear but Scalesia saplings are not seen. The bush layer is composed of native species such as *Croton scouleri, Chiococca alba, Psidium galapageium, Zanthoxylum fagara*, and guajava stems. The forest floor, covered closely with moss, is kept moist. We observed there the herbs such as *Desmodium canum, Centella asiatica, Paspalum conjugatum, Doryopteris pedata and Polypodium tridens*. We found few brackens.

In a fire-affected area next to this research plot, we observed Scalesia trees with the barks of the base blackened. We saw resin oozing around the barks. As its cambium is not charred, however, such individuals will survive.

Research plot IB7: Firebreak (alt. 320 m)

The firebreak was constructed around the burning area by felling trees in order to control the spread of fire by the empty area. The trees were cut down by bulldozer and the center was levelled for the vehicles. The debris and logged trees were piled on both sides, then an open space of 15 to 20 meters wide appeared through the forest. (See Fig. 3.)

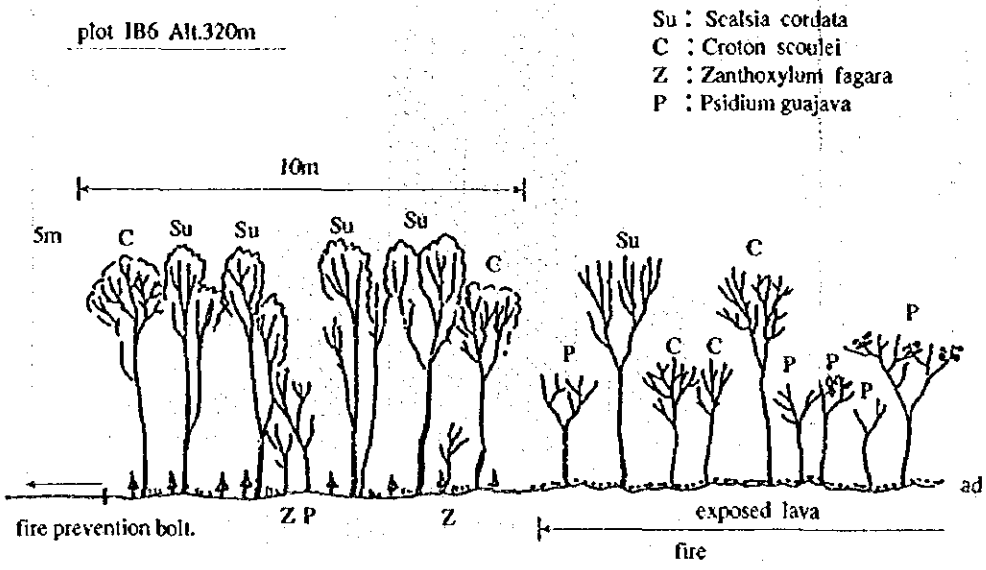


Fig. 7 Aspect of the Scalesia stand that remained unburned and around the fire stop line on Plot IB6

The plot was situated on the firebreak in a ridgy site where lava is exposed on the center part and fine soil lays about 10 to 15 cm deep in places. We observed mantle communities of liana, *Ipomoea alba*, on fallen trees and debris piled on the forest border. At this fire, the Scalesia forest to be protected was also cut down to make the firebreak. As to the firebreak and its effectiveness, refer to paragraphs IV 1 3) and V 2 1).

Research plot IB8: Guajava forest remained unburned around the base camp (alt. 310 m, lat. 0°51'46.9" S, long. 91°13'24.4" W)

The base camp was situated on the flat area covered with relatively rich soil, in the guajava forest of 7 to 8 meters high. The area is outside the firebreak, so it was not affected by the fire. The maximum diameter at breast height of the guajava trees of the canopy is about 30 cm, in contrast to the thin guajava individuals on the ridgy site.

As we found a big avocado of which diameter at breast height is more than 50 cm, the reason why the guajava trees have grown well is not only the soil condition but also the age of invasion of the guajava species. In the canopy, *Zanthoxylum fagara* (maximum DBH: 16 cm) and *Croton sourel* (maximum DBH: 10 cm) are also seen. The individual density of the canopy is 0.16 per m^2. The forest is moist, presenting a cloud forest type vegetation.

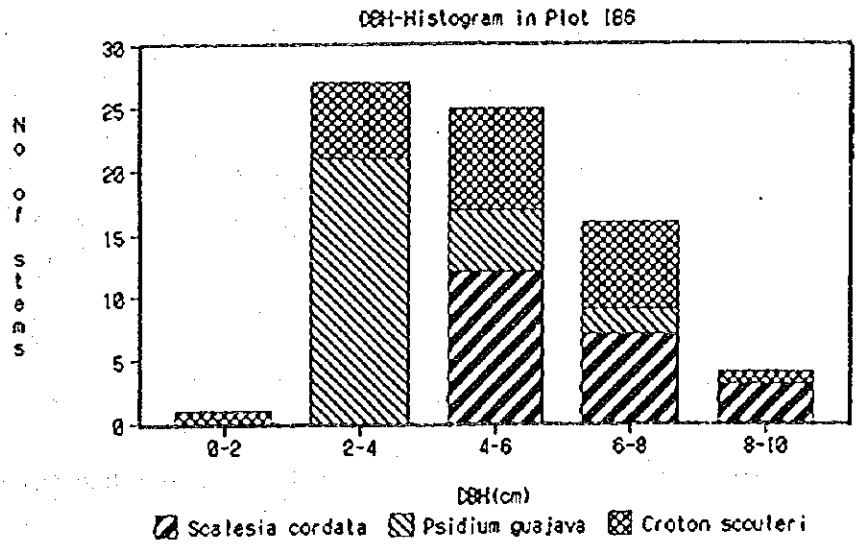


Fig. 8 DBS histogram of the individuals of canopy on the Plot IB6

(2) Conclusion

To keep fire burning, fuel loads are necessary. In the fire of this time, brackens *(Peridium aquilinum)* and herbs under open guajava trees, mosses and lichens on the crowns and stems, and shrubs in bush layer served as the fuel load.

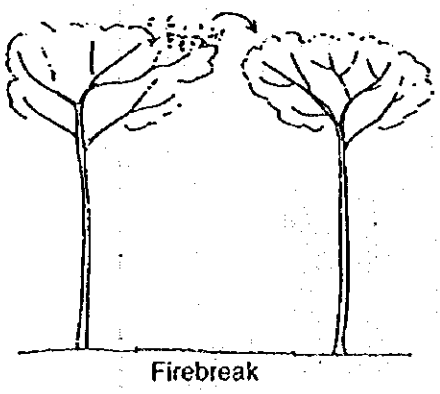
However, as the amount of these plants was not so great, the fire did not stay long in one place but spread all over. According to the staff concerned in the fire fighting, the fire spread at a speed of 10 m/h when the wind fell, 20 m/h when the wind rose.

In this fire, only the light fuel loads were burned and the heavy fuel loads such as the crown, trunk and root of the guajava trees were not burned (except in some places).

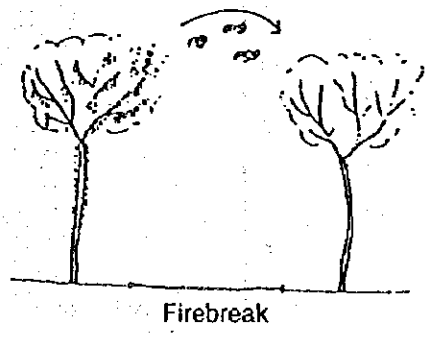
Many crown leaves withered and fell because of the heat of the fire. We observed such withered leaves remaining on the crown in the research.

The litter (Ao layer) was also burned to black ash but the burnt litter was only the upper part of a few centimeters deep. As a result, roots of guajava trees and subterranean stems of brackens remained unburned. We observed many individuals with new shoots which came out by the rain on 8 June, just before the research. As guajava trees have strong regenerative capacity, they can bud from roots remaining unburned even if the canopy is burned. In our research, we observed many shoots at the roots of guajava.

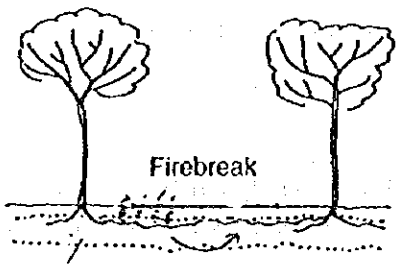
According to the DNDC, the following four types were observed when the fire spread over the breakfire. (See Fig. 9.) (a) Spread of fire from crown to crown to the next tree (b) Leaping flames by epiphytic moss or lichen blown up in the fire (c) Spread of fire through the roots in the lava tunnel (d) Spread of fire through the roots or organic matter on lava. They said that the wide firebreak was effective for the check to the spread of type (a) or (b), but ineffective for the spread of type or (d).



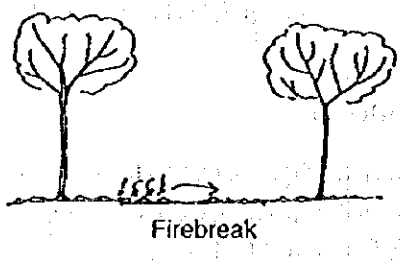
(a) From crown to crown



(b) Leap flames by burning air plants



(c) Through roots in the lava tunnel



(d)Through the roots or organic matter on lava

Fig. 9 Four types of fire spread over the firebreak

The traces of the fire were mainly found on the lava area with poor soil or in the scrub on ridgy site, while we found plants remaining unburned in the forest on gentle slopes or on flat areas. Brackens, a main fuel load, grow thickly on a dry site under clear guajava forest. In such area the fire spread rapidly. On the contrary, sunny plants such as brackens scarcely grow in a moist and dark forest. In such an area without fuel loads such as brackens and grasses, a fire does not spread so rapidly. The research plot IB4 (see Fig. 5) shows how the fire stopped spreading at the transition zone of vegetation from the lava land to the adjacent low land. The guajava forest on the lava land was burned out, but even grasses under the avocado (introduced species) forest on the low land remained unburned. The firebreak must be most effective if it is set between the forest composed of tall trees and that of low trees.

Within the fire-affected area, the guajava trees were mainly affected and some relic native forests including Scalesia trees were also affected. (See Fig. 7.) These relic forests are valuable place where native species including endemic ones such as *Scalesia cordata, Croton scouleri, Spindus saponaria, Psidium galapageium, Zanthozylum fagara, Pisonia floribunda, and Trema micrantho,* are seen. While remaining guajava trees had only a slight trace of fire on the trunk, remaining Scalescia trees had clear black burnt traces on the trunk with resin oozing from them. That is, the former is better able to resist fire than the latter. A fire must accelerate a reduction of relic native forests (that is, a prosperity of guajava trees).

5) Damage to animals

Since animals are different from plants fixed on the ground, the field research required to assess the damage include observing charred bodies, burned traces of eggs or nests as a direct method, or comparing the states of living in the fire-affected area and the non-affected area with similar conditions as an indirect method.

This time, we didn't try to directly find traces of damage. Because firstly any habitat of giant tortoises and land iguanas and any nesting place of shearwaters and boobies which bleed in a colony, were not included in the fire area, secondly it was not the breeding season of the birds in general, and thirdly we could not stay long on the island. Neither did we adopt the indirect method of comparing the living states, because did not have enough time to select appropriate research points for it.

Consequently, we could not carry out research except a census of birds at the plots of vegetation research. We had to do assess the damage to animals by analogy from circumstantial evidence and the information made public.

(1) Mammals

(a) Native species

In the Galápagos, mammals are poorly represented. There are eleven native mammals, of which two are bats, seven are rats, and two are seals, but five species of rats are thought to be extinct because of competition for food resources with the boat rat that invaded with the colonists or by viral diseases brought with them. (See Table I.) In Isabela, three native mammals are seen, that is, the hoary plainnose bat (*Lasiurus cinereus*), the Galápagos fur seal (*Arctocephalus galapagoensis*) and the Galápagos sea lion (*Zalophus californianus wollebacki*). As the latter two species inhabit the littoral zone, the animals which could have suffered from the fire are only the hoary plainnose bats among the native mammals in Isabela.

During our field research, we did not find any evidence of victims of the species in the fire-affected area or any evidence of living animals in its periphery. The species is not endemic in the Galápagos, but well-known in America from southern Canada to central Chile and northern Argentina, and in Hawaii also. As

it is a migrant, its capacity of moving must be high.

From a consideration of the fact that the bats roost alone or small group in the wood, they had a much better chance of surviving even if they inhabited the fire-affected area.

(b) Introduced species

In the Galápagos there are many species gone wild which were initially introduced as domestic animals with the colonists, and they are all seen in Isabela.

They include feral goats, pigs, burros, horses, cows, cats, dogs, rats and mice. They were perhaps inhabiting the fire-affected area, and we are certain that many burros and cows are living there as we heard their calls and found their droppings.

During the field research, we found a cat carcass, which showed that some animals had failed to escape. From considering the fact that the fire spread slowly, however, many animals must have been able to escape the fire.

Table 1. Mammal species in the Galápagos

Order Chiroptera

Plainnose bat family (Vespertilionidae)

Galápagos plainnose bat (*Lasiurus brchyotis*)

Hoary plainnose bat (*Lasiurus cinereus*)

Order Carnivora

Earred seal family (Otaridae)

Galápagos fur seal (*Arctocephalus galapagoensis*)

Galápagos sea lion (*Zelophus californianus wollebaeki*)

Order Rodentia

Rice rats (Cricetidae)

Santa Fe rice rat (*Oryzomys bauri*)

San Cristob bal rice rat (*Oryzomys galapagoensis*) : maybe extinct

Santa Cruz rice rat (*Nesoryzomys narboroughii*): maybe extinct

Fernandina rice rat (*Nesoryzomys narboroughii*)

Santa Cruz rice rat (*Nesoryzomys narboroughii*): maybe extinct

Fernandina rice rat (*Nesoryzomys narboroughii*)

San Salvador rice rat (*Nesoryzomys narboroughii*): maybe extinct

A World List Of Mammals with Japanese Names

Source: Imaizumi Yoshinori "Sekai honyuurui wamei jiten" (1988) (A World List of Mammals with Japanese Names)

(2) Birds

(a) Census in the fire-affected area and on its periphery

We recorded the bird species by a line census and a point census at the research plots of the vegetation. (See Table 2.) As the census was not carried out with enough time and frequency to be used for statistics, we should not form any conclusions from the census.

(b) Conclusion

a) Sea birds

We think that sea birds were not affected. Many sea bird species inhabit and breed in the littoral zone of Isabela, which include the endemic Galápagos penguin (*Spheniscus mendiculus*), the endemic flightless cormorant (*Nannopterum harrisi*), and the brown pelican (*Pelecanus occidentalis*). As the fire fortunately occurred in the inland, the sea birds cannot have been influenced by it. We had been anxious about the nests of true petrels and shearwaters (Procellariidae) which dig a hole in the ground for breeding, but their nesting place was not in the affected area, and neither was the breeding place of the boobies (Sulidae).

b) Land birds

If the fire occurred in the breeding season when they nest and breed (from December to April, mainly from January to March), the nests and young birds which are not able to move could have been greatly affected. As the fire of this time was luckily enough out of season, the land birds must have remained untouched by the fire. The small land birds including Darwin's finches are roughly divided into three groupes as follows:

- Species which feed mainly on hard seeds, such as the Small Ground Finch (*Geospiza fuliginosa*)
- Species which feed mainly on soft seeds or fruits, such as the Small Tree Finch (*Camarhynchus parvulus*)
- Species which feed mainly on insects, such as the Woodpecker Finch (*Camarhynchus pallidus*) and the Warbler Finch (*Certhidea olivacea*)

For species which feed on hard seeds, naked ground is necessary for their foraging. So they are seen on the road or in the open spaces around human habitation, in the arid zone and in the grasslands on the mountain. As their breeding place was not in the fire-affected area, it is thought that they were scarcely influenced by the fire. For the other two species which feed on soft seeds, fruits, or insects, a forest is indispensable as not only the place where they live but also the place where their foods are produced. So the loss of forest by the late fire must have had a great influence on them. But our research could not show clearly how much influence the fire had.

The places where the species which feed on soft seeds and fruits or the species which feed on insects are frequently seen are:

- Forests of native species such as Scalesia (*Scalesia* spp.), where the trees have grown well.
- Forests including relatively many native species, even where the dominant tree is the introduced guajava.

Although we don't know correctly how many areas of such forests were lost in the fire, it must have been small in the Alemania region.

In a forest of low guajavas, the number of birds of the three species which feed on hard seeds, soft seeds, fruits or insects is small. In the fire of 1985, many such forests were damaged.

Though, as we mentioned above, we can say that not so many birds of species which feed on soft seeds, fruits or insects were originally inhabiting the burned-out area, the birds will continue to be influenced somehow over 5 to 10 years or more until the time the area returns completely to its former state.

The population size of birds was small in the burned-out area. We observed only a few birds flying over or down in the forest. We observed some birds of species which feed on hard seeds picking on the ground in the site of the fire. They must have come to the open space which appeared after the vegetation such as ferns growing under the forest was burnt away.

The appearance of large open spaces because of the fire is advantageous to the species which feed on hard seeds, while it is disadvantageous to the species which feed on soft seeds, fruits or insects. We protect the species which feed on insects because these species occupy a higher position than that of the species which feed on hard seeds in the ecosystem. To do that, we must preserve forests composed of native species and forests in which many native species dominate. We suggest the improvement of forests dominated by introduced species like guajava to forests dominated by native species in the future.

Table 2-1 Census (line census) of the birds in the Galápagos islands (Santa Cruz and Isabela)

Species \ Research	Line 1 SC	Line 1 SC	Line 2 SC
	Tortoise house to Hotel	Tortoise house to Hotel	Crater side
Date	Jun. 8	Jun. 9	Jun. 10
Distance, Weather	600 m, Clear	600 m, Clear	400 m, Cloudy
Circumstances	Cactus, shrub, mangrove forest	Cactus, shrub, mangrove forest	Scalesia forest
Vegetation research plot			Plot SC1
Dark-billed Cuckoo *Cocoyzus melacoryphus*			1
Short-eared Owl *Asio flammeus*			1
Vermilion Flycatcher *Pyrocephalus rubinus*			
Large-billed (Galápagos) Flycatcher *Myiarchus magnirostris*		1	
Galápagos Mockingbird *Nesomimus parvulus*	1	2	
Yellow Warbler *Dendroica petechia*	33	29	6
Small Ground Finch *Geospiza fuliginosa*	14	14	1
Medium Ground Finch *Geospiza fortis*	10	11	4
Large Ground Finch *Geospiza magnirostris*	4	6	2
Small Tree Finch *Camarhynchus parvulus*		2	7
Large Tree Finch *Camarhychus psittacula*			1
Woodpecker Finch *Camarhynchus pallidus*	1		3
Warbler Finch *Certhidea olivacea*		1	16
TOTAL (Population)	63	66	43
Population per ha	21/ha	22/ha	21.5/ha

SC: Isla Santa Cruz

IB: Isla Isabela The census range of both sides is 25 m wide.

Alemania ① ~ ⑦ : burnt area, base camp surrounding area

Species	Research	Line 3 IB Alemania	Line 4 IB Alemania	Line 5 IB Alemania	Line 6 IB Alemania
	Date	Jun. 12	Jun. 13	Jun. 13	Jun. 13
	Distance Weather	600 m, Cloudy	1000 m, Cloudy	500 m, Rain	600 m, Rain
	Circumstances	Low guajava forest, burnt area 1985	Road made by cutting guajava forest	Rather tall guava forest	Rather tall guava forest
	Vegetation research plot	Plot IB1	Plot IB8	Plots IB6, IB7	Plot IB5
Dark-billed Cuckoo *Cocoyzus melacoryphus*					1
Short-eared Owl *Asio flammeus*					
Vermilion Flycatcher *Pyrocephalus rubinus*				5	10
Large-billed (Galápagos) Flycatcher *Myiarchus magnirostris*			1	1	1
Galápagos Mockingbird *Nesomimus parvulus*			5	1	
Yellow Warbler *Dendroica petechia*		2	9	6	9
Small Ground Finch *Geospiza fuliginosa*				4	4
Medium Ground Finch *Geospiza fortis*		1	9	4	5
Large Ground Finch *Geospiza magnirostris*			4	4	
Small Tree Finch *Camarhynchus parvulus*			4		
Large Tree Finch *Camarhychus psittacula*			7		
Woodpecker Finch *Camarhynchus pallidus*					
Warbler Finch *Certhidea olivacea*			6		5
TOTAL (Population)		3	45	25	35
Population per ha		1/ha	9/ha	10/ha	11.7/ha

Table 2-2. Census (point census) on the birds in the Galápagos islands (Santa Cruz and Isabela)

Species	Research, Weather / Date / Circumstances / Vegetation / research plot / Time	Point 1 IB Alemania , Cloudy Jun. 12 Low guajava forest, burnt area 1984 Plot IB2 25 min.	Point 2 IB Alemania , Cloudy Jun. 12 Low guajava forest, crater edge 20 min.	Point 3 IB Alemania , Cloudy Jun. 12 Low guajava forest, burnt area 1984 Plot IB3 35 min.
Vermilion Flycatcher *Pyrocephalus rubinus*				
Galápagos Mockingbird *Nesomimus parvulus*				
Yellow Warbler *Dendroica petechia*			4	1
Small Ground Finch *Geospiza fuliginosa*			8	
Medium Ground Finch *Geospiza fortis*			3	1
Large Ground Finch *Geospiza magnirostris*		3 Passage in flying		2
Cactus Finch *Geospiza scandens*				
Small Ground Finch *Camarhynchus parvulus*				
TOTAL (Population)		3	15	4
* Population per ha		1.5/ha	9.6/ha	1.3/ha

* The population per ha is calculated in terms of research time of 40 min. The census radius is 50 m.

** The relic scalesia forest is 0.12 ha in area.

IB: Isla Isabela

Alemania ① ~ ⑦ : burnt area, base camp surrounding area The census range of both sides is 25 m wide.

Species	Research, Weather	Point 4 IB Scalesia forest, Clear	Point 5 IB Cloudy	Point 6 IB Muro de los lamentos, Clear
	Date	Jun. 14	Jun. 14	Jun. 16
	Circumstances	Relic scalesia forest	Low guajava forest, burnt area in 1985	Arid zone vegetation such as cactus
	Vegetation research plot	Plot IB10	Plot IB11	
	Time	20 min.	40 min.	40 min.
Vermilion Flycatcher *Pyrocephalus rubinus*			1	
Galápagos Mockingbird *Nesomimus parvulus*				4
Yellow Warbler *Dendroica petechia*		1		2
Small Ground Finch *Geospiza fuliginosa*			1	12
Medium Ground Finch *Geospiza fortis*				4
Large Ground Finch *Geospiza magnirostris*				
Cactus Finch *Geospiza scandens*				5
Small Ground Finch *Camarhynchus parvulus*		3		8
TOTAL (Population)		4	2	35
* Population per ha		** 44.2/ha	0.6/ha	11.1/ha

(3) Reptiles

For the reptiles, we carried out interviews besides the field research in the fire-affected area. We heard mainly from Ms. Linda J. Cayot, Expert herpetologist, Director in charge of wildlife protection, CDRS, Mr. Felipe Cruz, Manager, SPNG, Mr. German Bo Morillo, Isabela National Park Office, Mr. Arnold Toppiza, and Mr. Jacinto Gordillo, General Manager, Isabela CDRS Office. The research result is as follows:

Although we had heard in Japan that many giant tortoises and land iguanas were influenced by the fire, they were not, in fact, because their limited habitats, caused by their depopulation, were not in the fire-affected area. (See Fig. 10.)

As to the lava lizards, which are also seen in the zone at the height of 300 to 400 meters, they could have inhabited the burnt area. Their habitats, however, are generally in the arid zone or lava zone. So, the land lizard population may not have been reduced by the fire. As to the less often seen Galápagos snakes, which are thought to live in the same region as that of the lava lizards, we could not tell the influence on them because their habitat and their population were unknown. If the snake habitats were in the burnt area, such species with a small population must have been somehow influenced. During our field research, we did not see any dead lizards or dead snakes. As we observed a few crickets prey insect of lava lizards, in the site of the fire, there may have been a place of refuge for insects under the ground in spite of the report that the underground lava got heated. If so, lava lizards might have been able to escape from the fire.

We had heard the news in Japan that giant tortoises were allowed to take refuge from the fire by helicopter. They were not, in fact. As we mentioned above, their habitats are not in the fire-affected area. The fact is that the giant tortoises which had been planned to be moved to the research station, were transported by the helicopter which was permitted to fly for fire-fighting. (See below for further details.)

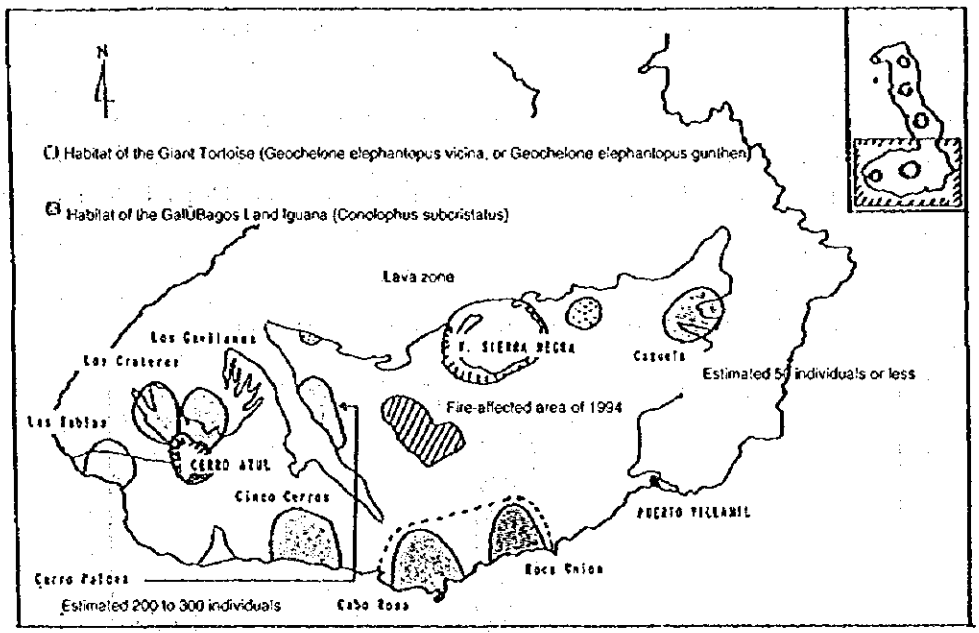


Fig.10 Habitats of the giant tortoise and the Galápagos land iguana

2. Fire-affected area in 1985

1) Location and size of the burnt area

According to Mr. Mario Cruz of DNDC, the area burnt by the fire was located to the west of the area burnt in the late fire, about 120 to 150 km² in area. We have not, however, any correct data.

2) Circumstances of the burnt area (topography, vegetation)

The fire of 1985 spread over an area three or four times as large as the burnt area in the fire of 1994, from the 200-meter-high foothill to the 1100-meter-high caldera of Volcán Sierra Negra (roughly 10 km in diameter, the second largest caldera of the world). (See Fig. 1.) Although the area affected by the fire in 1985 is not correctly known because of insufficient data, it is estimated that the large hillside which lies between the village of Santo Tomás and the burnt area in the fire of this time was fire-affected. According to the interview research, some places were affected twice by the two fires, but, we suppose, such areas were limited. We heard that the inhabitants of Santo Tomás had set fires in order to control the fire direction but in vain without proper wind at the moment.

As to the vegetation zone, Scalesia zone, Shrub zone and Pampa zone were damaged. As we mentioned above, the Scalecia zone and Shrub zone were estimated to have been dominated by the introduced species of guajava for the most part of them. As the affected area was near the human habitation of Santo Tomás, a part of the farmland or pasture was also burnt.

It was said that the fire in 1985 was caused by El Niáo : that is, after the great rains in 1983 caused by El Niáo , which permitted the plants to grow thick and the organic matters to accumulate, a long stem of dry weather followed for two years, 1984, 1985, and this condition might be responsible for the big fire of 1985. (See Fig.11.)

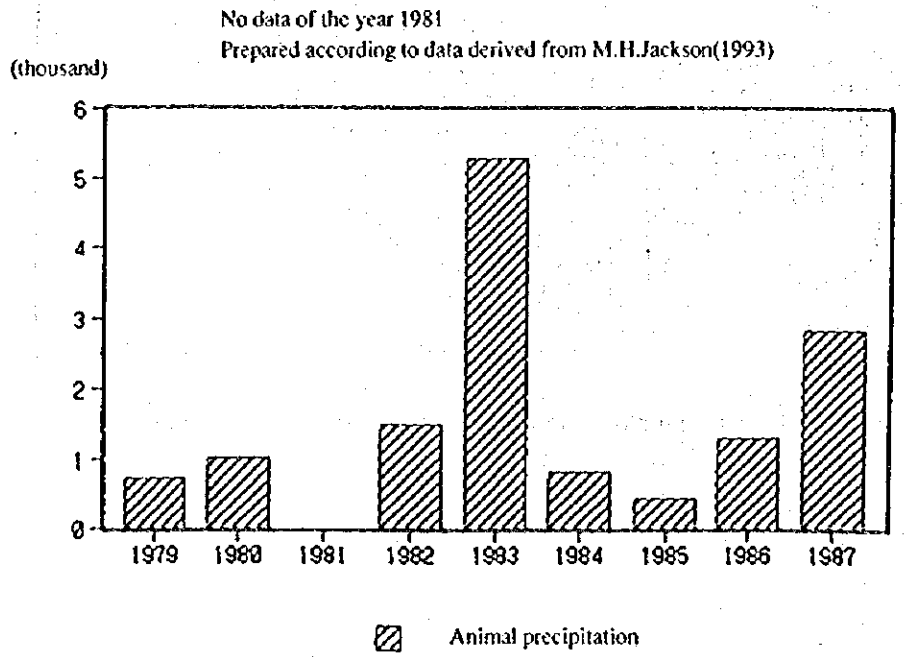


Fig.11 Annual precipitation at Santo Tomás in Isabela

3) Fire fighting and remarks

The fire fighting was carried out by making the firebreak and by setting fires intentionally, but the effort was not effective to control the fire. On the contrary, the fire intentionally started made the fire-affected area increase. In the end, they had to wait till the fire had gone out by itself in the rain.

4) Damage to the vegetation and the state of recovery

(1) Research on the vegetation in the fire-affected area and the surrounding non-affected area

We carried out research at the two plots in the same way as in the burnt area of 1994. (See Fig. 4.) The result is as follows:

Research plot IBI: Guajava forest on the site of the fire of 1985 (alt. 340 m, lat. 0°52'3.4" S, long. 91°13'17.4" W)

This stand which had been damaged by the fire in 1985, near the area affected by the late fire, is a scrub, some 3 meters high, of which the canopy is comprised of an introduced species, guajava. In spite of the canopy covering of 100%, the forest is relatively clear because the leaves are open. The individual density of the canopy comprised of guajavas was 1.41 per m^2. Many saplings of guajava have come out from the stock (average number of stems is 2.6 per stock) and every stem is thin. From these points, we estimate that these trees have regenerated from the surviving roots after the crowns were burnt by the fire of 1985.

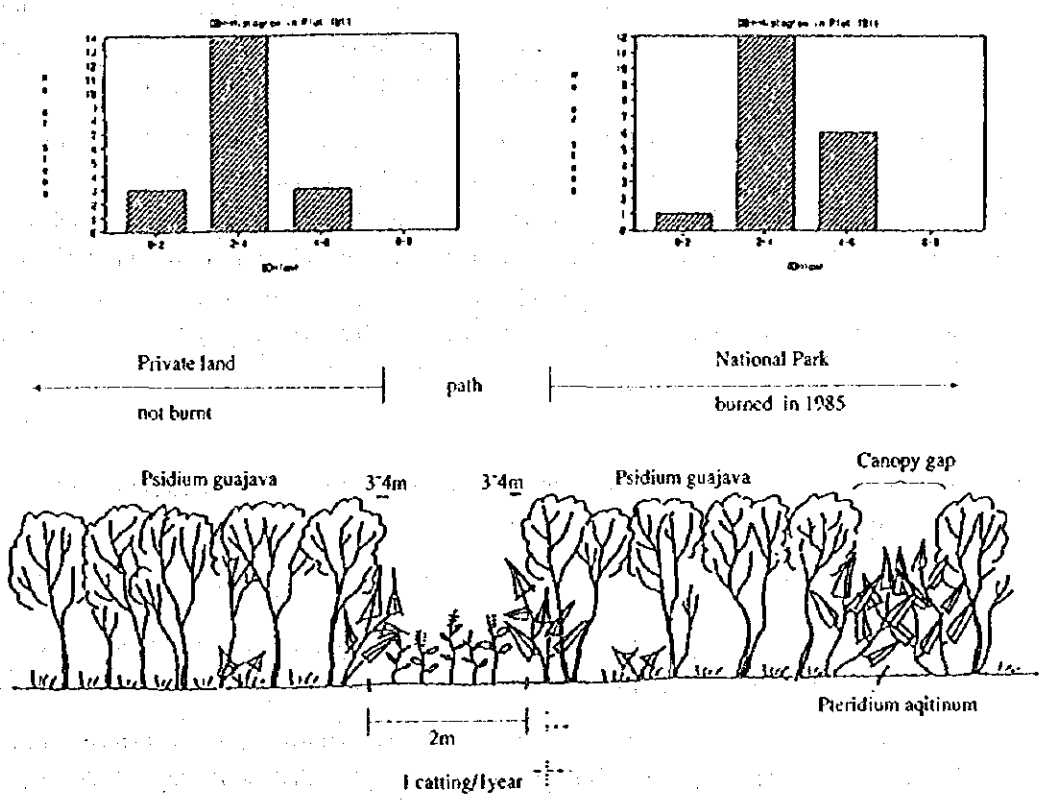


Fig.12 Comparison of the guajava forests in the area affected by the fire in 1985 and in the adjacent non-affected area

In the bush layer, we observed, there are many guajava saplings and a few number of endemic species such as *Darwiniothamnus* sp., and in the herbaceous layer, many *Pteridium aquilinum, Desmodium Canum,* which served as a fuel load in the late fire, as well as *Centella asiatica, Commerina Diffussa, Doryopteris pedata,* and *Polypodium tridens.*

On the forest floor, fallen leaves of guajava and moss plants have formed A0 layer of 5 cm deep. Although the inside of the forest is apparently dry, the forest floor is moist.

Research plot IS11: Comparison of the guajava forests in the area affected by the fire of 1985 and in its adjacent non-affected area (alt. 500 m, lat. 0°51'8.7"S, long. 91°3'25.9" W)

When we walk for a while in a guajava forest of 4 to 5 meters high, to the west from the main road in Santo Tomas, we find the border line between private farmland and the National Park. The border line of 2 meters wide separated in 1985 the fire-affected area of the guajava forest of National Park from the non-affected area of the guajava forest of the farmland. We carried out field research in both stands to compare the forest structure. (See Fig. 12.)

In the stand on the side of the farmland which was not affected by the fire, we observed an almost pure guajava forest. The canopy of 3 to 4 meters high is composed of closed guajava crown of which the covering is almost 100% except the gap. The individual density of guajavas was 0.88 per 1 m² and the average diameter at breast height is 3.1 cm. The floor is covered with mosses, and mosses and lichens are hanging down from the crown: it shows a cloud forest type vegetation. There is no native shrub but guajava saplings. We observed herb species such as *Commelina diffusa, Ctenitis sloanei, Doryopteris pedata, Centella asiatica, Kalanchoe pinnata and Peperomia galapagensis* on the forest floor.

In the stand on the side of the National Park which was affected by the fire, we observed a scrub with a closed crown, of which the canopy was composed of guajava of 3 to 4 meters high. The individual density of guajavas is 0.29 per 1 m². It might be an influence of the fire that the value is smaller than that of the other stand. The frequency and the average diameter at breast height of 3.4 cm are almost the same as those of the other stand. The species in the shrub and the herb species are also the same as those of the other stand. We observed a bracken community of 2 meters high in the canopy gap.

(2) Conclusion

Concerning the recovery of the vegetation affected by the fire in 1985, a follow-up study for two years was conducted by experts including Nowak (1990).

The study said as follows;

(a) In a Semi-deciduous forest (alt. 80 to 250 m), the vegetation has returned to its former state in two years because the crown survival percentage is high and the affected shrub has rapidly regenerated.

(b) In a Closed evergreen forest (alt. 250 to 500 m), 90% of the guajavas were burnt to their crowns but 65% of the guajavas had regenerated to break into leaves. Many individuals of Scalecia were dead and many seedling came out after.But the seedlings were damaged because of diseases and insects. After all, Guajava took the place of Scalecia. Native shrubs have hardly recovered.

(c) In an Open evergreen forest and scrub (alt. 500 to 800 m), as a great number of brackens served as the fuel load, almost all individuals were burnt to their crown, but many guajavas have regenerated to break into leaf.

(d) In a Pampa (alt. 800 to 1100 m), a secondary grassland dominated by Commelina appeared at first, then it is gradually returning to its former state of structure. In places where naturalized grasses took root, the vegetation has changed to be easier to catch fire than before.

Our research was carried out at two areas affected by the fire in 1985.

The research plot IB1 was situated in a pure forest of guajavas of 3 meters high.

The density of the individuals at the canopy is 1.41 per 1 m^2, and although the canopy covering was 100%, the forest is considerably clear because the crown leaves are open. Many individuals have several stems on the trunk (2.6 stems per trunk on average): is it a state of regeneration after the fire?

We observed shrubs such as endemic *Darwiniothamnus tenuifoliius*, besides guajava saplings. As to the herbs, native species such as *Pteridium aquilinum*, *Desmodium canum*, *Centella asiatica* and *Commelina diffusa* grow rather thickly. It is interesting that native species regenerate in the bush layer, under the canopy composed of the naturalized guajavas.

In the research plot IB11, we compared the burnt guajava forest in the National Park with the unburnt guajava forest in the adjacent private land. The grasses on the buffer zone of 2 meters wide which separates the National Park from the private land are cut every year. Each stand is a pure guajava forest of 3 to 4 meters high, and every aspect, such as structure, floor and grasses, is almost the same. (See Fig. 12.) The maximum diameter at breast height frequency per 20 individuals is similar. So we can say that the difference of individual density depends on the micro-environment, rather than the influence of the fire. At the canopy gap we found in places brackens growing in community.

Although the crowns were burnt in the fire of 1985 much more than in the fire of this time, guajavas have regenerated to break into leaf with no trace of fire. As a rule, Scalecias, native shrubs, and native grasses in the Pampa have hardly regenerated, and they are often replaced by naturalized species such as guajava and grasses. However, on the Guajava forest floor, we observed a large number of native grass species.

5) Damage to the birds and the state of recovery

(1) Researches on the birds in a burnt area and in an unburnt area

We carried out field research at the two plots in the same way as at a burnt area of 1994.

The result is shown at the research line 3IB Alemania-(火) (Research plot IB1) and at the research point 5IB (Research plot IB11). (See Tables 2-1 and 2-2.)

At the research line 3IB Alemania-(火), we observed only two Yellow warblers and a Medium ground finch: the individual density is 1 per ha. As they are seen not in a forest but in a firebreak, they might be there for the open space.

We estimate that the bird population in a guajava forest of 3 meters high is rather small.

At the research point 5IB11, we observed only a Vermilion flycatcher and a Small ground finch: the individual density is 0.6 per ha. This point includes the burnt stand in the National Park and the unburnt stand in the farmland, and both stands are composed of guajava forests of 3 to 4 meters high. The border line is a grassland and the grasses are cut every year. A Vermilion flycatcher was seen in the grassland. A Small ground finch was seen in a forest in the burnt area where the individual density is smaller than that in the unburnt area.

In both stands, the bird population is rather small in comparison with that in a tall guajava forest or a Scalecia forest in the unburnt area.

(2) Conclusion

The studies on the damage to the birds from the fire in 1985 were carried out by Carmen (1991) and others. According to their studies, it was the insectivorous species such as Warbler finches, Tylant flycatchers including Warbler finches, Vermilion flycatchers, Large-billed (Galápagos) flycatcher, and Ground finches (Geospiza spp.), that were most affected by the fire, because they lost forests where they were nesting and feeding. The influence was serious because the fire occurred in the breeding season. As the fire reached to the grassy highland in 1985, Galápagos hawks and Short-eared owls, hunters of rodents, were considerably affected by the fire. Also, were Groove-billed anis as the woods near the houses were also burnt.

In our research, we observed two insectivorous Yellow warblers at the research line 3IB, but no Tylant flycatchers. At the research point 5IB11, we only found one Vermilion flycatcher. We cannot say that the insectivorous bird species have recovered.

At the research lines 4IB Alemania-(水) and 6IB Alemania-(金) situated in a relatively tall guajava forest, many Warbler finches and Tylant flycatchers were seen in the open breakfire.

The vegetation has returned to the former state without any trace of fire owing to the regenerative power of guajava species, while the state of recovery is not enough for the birds for nesting or feeding. From a consideration of the fact that rich avifauna is seen in the forest of 7 to 8 meters high, even if its crown is dominated by guajavas, 10 to 20 years may be required till the guajava forest of 3 to 4 meters high has grown up to a double tall forest, although it depends on topographic and atmospheric factors.

3. Others - the result of site investigation and information collection except in the afflicted areas

During our stay on the Galápagos Islands this time we conducted not only investigation related to the fire, but also, using every opportunity, site and hearing investigation on nature and the conservation of nature of the Islands in general to grasp the whole Islands. The following is the result of the investigation.

1) Vegetation

We carried out investigation and observation on the flora and vegetation on Santa Cruz Island (in 3 places), on Isabela Island (in 14 places including the above-mentioned 9 places related to the fire), and on Santa Fe Island (in 1 place). (See Fig.4.) The method of investigation is the same as that in the afflicted areas, etc. The following is a brief description of each area explored.

(1) Santa Cruz Island

Research plot SC1: Vegetation near Puerto Ayora (Altitude: 10m; S0°44'19.3", W90°18'32.4")

Puerto Ayora is a town serving as a base for ecotourism and has a large population, but outside the city area there still remains comparatively primary natural vegetation. First, there is a narrow mangrove forest on the lava coast. Besides four species of mangroves (*Rhizophora mangle, Laguncularia racemosa, Conocarpus erectus, Avicennia germinans*), shrubby *Maytenus octogona*, poisonous *Hippomane mancinella*, climbing *Cryptocarpus pyriformis*, etc. are relatively widely met. As for herbs, *Sesuvium portulacastrum, Sesuvium edmonstonei, Heliotropium curassavicum*, etc. form a community, covering the surface of the earth.

When setting foot in an inland area apart from the forest on the coast, the vegetation of the Arid zone appears. Prickly pears (*Opuntia sp.*) and (*Jasminocereus sp.*) are peculiar to this vegetation, but parosant dropping leaves in the dry season (*Bursera graveolens*), matasarno, a useful tree (*Piscidia carthagenensis*), *Parkinsonia aculeata* having leaves of strange form, *Erythrina velutina* distinguished by red flowers, etc. are met as trees. As shrubs, thorny *Scutia pauciflora, Castela galapageia* having leaves like Ilex crenata Thunb., *Acacia rorudiana* having fine leaves, *Altenanthera filifolia, Altenanthera echinocephala* having unique aggregative inflorescence, half-climbing Plumbago scandens, etc. are often met.

On the Okinawa and Ogasawara Islands there are many cases where naturalized weeds have made invasion and grown thick along the roadside, but here we got an impression that naturalized weeds were very small both in kind and quantity. Is it because the severe dry condition refuses their invasion or because it has not been long since the latter half of 1980s when the number of tourists increased rapidly?

Research plot SC2: Forest of *Scalesia pedunculata* (Altitude: 600m; S0°37'21.4", W90°22'55.2")

Forests of *Scalesia pedunculata* remain relatively well in the place over the watershed where the roadway connecting the airport and Puerto Ayora divides the north and south slopes of Santa Cruz Island. The place where twin craters exist was chosen as an area to be explored.

Table 3 shows the composition of each layer. The height of trees of a forest is 4 to 5m and almost 100% of the tree layer consists of *Scalesia pedunculata* being tree Scalesia. Many of the trunks of Scalesia are thin, 10cm or less in diameter, and generally they have a form of bean sprout. The coverage of canopy is about 90%, but it is relatively bright in the forest as leaves of tree crowns are sparse. In spite of that, there are almost no natural young growth or seedling of Scalesia (sun tree) seen in the forest. Mosses and lichens grow thick on trunks and the forest floor, looking like a foggy forest.

As for the shrub layer, *Psychotria rufipes* and *Tournefortia rufo-sericea* are often met, and besides them, *Psidium galapageium, Zanthoxylum fagara, Chiococca alba, Cordia leucophlyctis*, etc. are met. As for herbs, *Altenanthera halimifolia* grows in colonies here and there, and *Commerina difusa* is widely spread. There are many kinds of fern. To trunks adheres *Peperomia galapagensis* and *Passiflora suberosa*, a climbing plant, was in bloom.

Cinchona succirubra, an exotic tree, has invaded in the neighborhood, which has aroused fear about influence on the forest of Scalesia.

Table 3 The composition of each layer of Research plot SC2

SC1	
Tree layer	N=30
Scalesia pedunculata	
100%	
Sthrub layer	N=59
Psychotria rufipes	35.6%
Tournefortia rufo-sericea	27.1%
Psidium galapageium	11.9%
Zanthoxylum fagara	8.5%
Chiococca alba	5.1%
Cordia leucofhlyctis	3.4%
Malvastrum sp.	
Herb layer	
Alternanthera halimifolia	
Asplenium cristatum	
Asplenium auritum var. auriculatum	
Asplenium praemorsum	
Blechnum occidentale var. puberulum	
Commelina diffusa	
Ctenitis sloanei	
Doryopteris pedata var. palmata	
Hyptis rhomboidea	
Polypodium sp.	
Thelypteris quadrangularis	
Passiflora suberosa (vine)	
Peperomia galapagensis (epiphyte)	

N: The number of individuals investigated

Figures show the percentage of individuals of each species.

Table 4 The composition of each layer of Research plot SC3

SC2	
Tree layer	N=20
Trema micrantha	35%
Pisonia floribunta	30%
Psidium galapageium	20%
Scalesia pedunculata	15%
Shrub layer	
Zanthoxylum fagara	
Tournefortia rufo-sericea	
Chiococca alba	
Clerodendrum molle	
Herb layer	
Salvia occidentalis	
Blechnum brownei	
Paspalum conjugatum	
Thelypteris quadrangularis	
Passiflora edulis (vine)	

N: The number of individuals investigated

Figures show the percentage of individuals of each species.

Research plot SC3: Vegetation around the protected area for giant tortoises (Altitude: 210m; S0°40'16.5", W90°25'59.1")

There is a protected area established for giant tortoises in a place about 1.5-hour walking in farmland from Community of Santa Roza. There is a native semideciduous forest consisting of *Trema micrantha, Pisonia floribunda,* and *Psidium galapageium* around the hollow where puddles are formed in the rainy season. *Scalesia pedunculata* is also mixed, though in small numbers, and this is considered to be transitional vegetation from the Scalesia zone to the Arid zone. Table 4 shows the species composing each layer.

As for the shrub layer, species are met which appear both in the Arid zone and the Scalesia zone such as *Zanthoxylum fagara, Tournefortia rufo-sericea, Chiococca alba. Paspalum conjugatum* (a grass weed) and *Passiflora edulis* (a climbing fruit tree) known as a passion fruit are often met, which may be caused under the influence of farmland nearby. On the way to the protected area *Caesalpinia bonduc* with sharp prickles repelling browser forms a large community and the scale of damage to vegetation caused by domestic animals having become wild is expected to be large.

(2) Isabela Island

Research plot IB9: Vegetation of the Pampa zone

There spreads grassland consisting of plants with length of about 50cm on the slope of the outer wall of the caldera of Sierra Negra. There as a heavy fog over the grassland at the time of investigation and we observed only a part of it. The grassland basically consisting of bracken (*Pteridium aquilinum*) and *Paspalum conjugatum* has many kinds of grass (*Centella asiatica, Equisetum begotense, Lycopodium, Cyperus spp., Gnapharium purpureum, Euphorbia sp., Labiatae, etc.*) mixed as if in a flower garden. Most of the flowers are,however, of sober color and this flower garden is somewhat different from that in the alpine zone on the mainland. It is interesting that most of herbaceous plants are common to those appearing on the floor of the forest of Scalesia located in places of lower altitudes. As for the shrubs, *Pernetya howellii* belonging to *Ericaceae* is met which is considered to be derived from a species of the same genus appearing in the alpine zone of the mainland of Ecuador. *Cyathea weatherbyana,* tree fern, is also a species peculiar to this zone. *Darwiniothamnus* sp. being an endemic genus of the *Compositae* was also in bloom.

Research plot IB10: Remaining forest of Scalesia of Santo Thomas(Altitude: 340m; S0°50'41.1", W91°1'11.7")

In the middle of the farmland a little east of the trunk road in the area of Santo Thomas is a remaining stand of *Scalesia cordata.* CDRS bought this stand which was private land to preserve it as a historical sample of a forest of Scalesia and to pursue a plan to use it as a material for teaching inhabitants (especially children) of the Islands the contents and value of the native forest. At present this stand (30m x 50m) is fenced to exterminate exotic species such as guava and to protect and propagate Scalesia. Mr. Jacinto Gordillo, the head of the branch office of CDRS on Isabela Island, is responsible for this project. Investigation was conducted in places with relatively high density of Scalesia (0.77 /m^2). Most of the trees composing the canopy with tree height of 7m are Scalesia and the average diameter at breast height was 7.8cm (Fig.13). Individuals with fine trunks of 5cm or less in diameter were distinguished by death due to self-thinning. Since the crown of Scalesia is small, there is a gap between crowns; the coverage of the canopy is about 80%. Species reaching the canopy besides Scalesia are *Zanthoxylum fagara* and guava

and the latter has individuals 17cm in diameter (Fig.14). There are parts greatly invaded by guava in the fenced place. As for the shrub layer 3 to 4m high the natural young growth of guava was predominant, but native shrubs and natural young growth (*Psidium galapageium, Psychotria rufipes, Chiococca alba, Tournefortia rufo-sericea, Cordia leucophlyctis, Zanthoxylum fagara, etc.*) were also met in relatively great numbers. Mosses and lichens grow thick on trunks and the forest floor, looking like a foggy forest. Since bottom grass is mowed, herbs are poor, and fern was met in great numbers such as *Doryopteris pedata, Poripodium tridens*, etc. In gaps *Pteridium aquilinum* formed a community.

Research plot IB12: Vegetation of the Arid zone with *Scalesia affinis* (Altitude: 60m)

We observed the vegetation of the Arid zone along the main road connecting Puerto Villamil and Santo Thomas. This is a dry location with exposures of lava in places and the coverage of vegetation is about 60%. There grows shrubby Scalesia (*Scalesia affinis*) whose height reaches 2m. According to Mr. Jacinto Gordillo, *Scalesia cordata* appears at an altitude of 70m or higher in the same Arid zone and there is an intermediate area where neither species is met. There is also *Darwiniothamnus tenuifolius var. galbriusculus*, the endemic genus of an arbor of the Compositae. Other ascertained species are Alternanthera echinocephala, *Alternanthera halimifolia, Lycopersicon cheesmanii, Bursera graveolens, Chiococca alba, Waltheria ovata, Cordia leucophlyctis, Clerodendrum mole, Plumbago scandens, Croton scouteli, Meytenus octogona, Passiflora foetida*, etc. Many species have sharp prickles, which may be remains of their coping with eating by giant tortoises and land iguanas which had once lived.

Research plot IB13: Vegetation in habitats of the area of Union (Altitude: 0 to 10m; S1°0'26.1", W91°5'48.3")

We landed on the coast about 1.5-hour ride in a boat to the west from Puerto Villamil. According to Mr. Jacinto Gordillo, giant tortoises were found 2 to 3 years ago around here, but recently they have not been seen. On the coast was a small-scale littoral forest, where *Rhizophora mangle, Avicenia germinans, Conocarpus erects, Hibiscus tiliaceus, Hippomane mancinella*, etc. were met. In particular, *Hibiscus tiliaceous* also grows in the interior part about 5km from here and serves as an indicator of spring water.

From the very inside of the littoral forest spreads the vegetation of the Arid zone. Not only *Opuntia* sp., but also *Croton scouleri, Scutia pauciflora, Cryptocarpus pyriformis, Acasia rorudiana, Clerodendrum molle, Maytenus octogona, Chamaesyce viminea, Vallesia galbra, Plumbago scandens, Lysium minimum*, etc. were met. Here we also saw dung of donkeys. It is said that they partially compete with the food of giant tortoises. Along the coast a little backward to the east from this landing spot are a vast sandy beach and back marsh. On the coast *Ipomea pescaprae* grew its tendrils, *Scaevala plumieri* was in white bloom, and *Lysium minimum* formed a large community covering the surface of the earth.

Research plot IB14: Vegetation in the Arid zone around "the Wall of Grief" (Altitude: 10m; S0°57'39.9", W91°0'38.4")

There is a place with traces of stone masonry called "the Wall of Grief" about 40-minute ride in a car to the west from Puerto Villamil. According to Mr. Jacinto Gordillo, it had been a US military base from

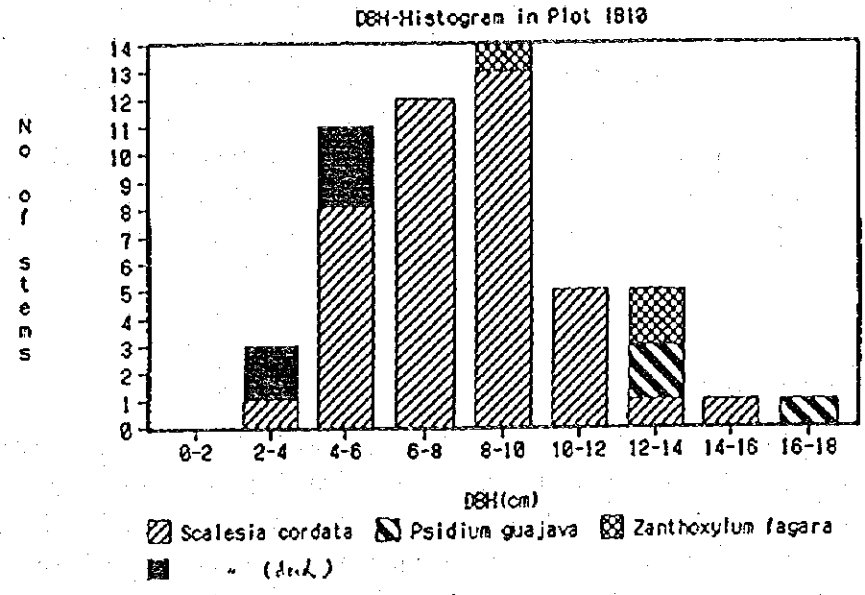


Fig.13 Histogram of diameter at breast heights of individuals composing the canopy of Research plot IB10

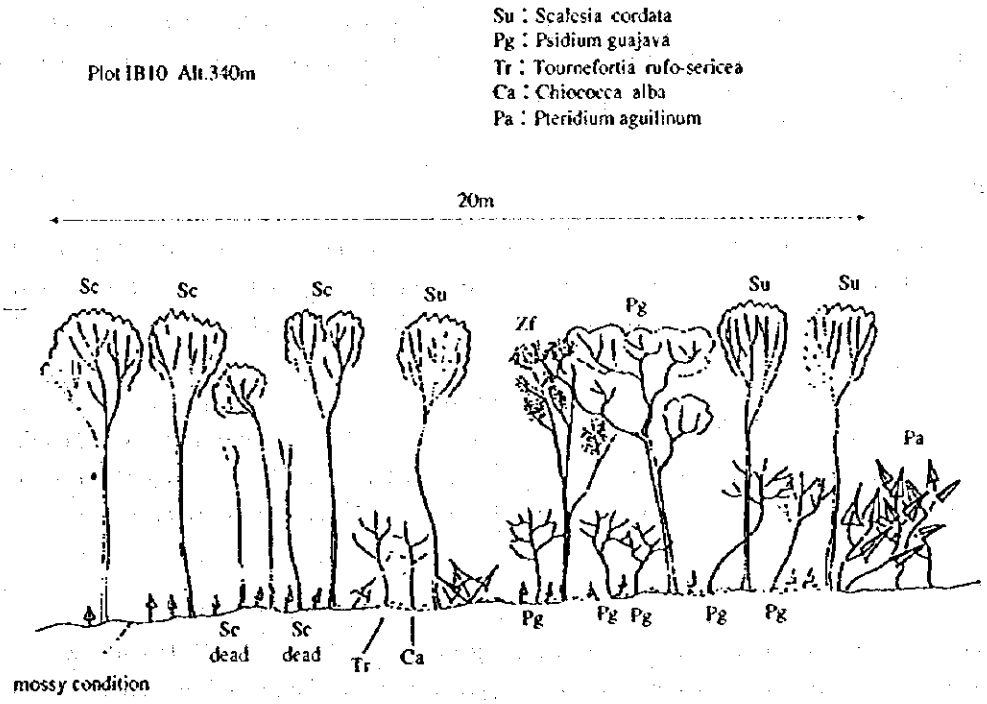


Fig.14 Remaining forest of Scalesia (protected forest) in Reserch plot IB10

1941 to 1945, and prisoners had been made to construct a stone wall since 1946.

The vegetation of the Arid zone with *Opuntia* sp. is met around there. *Scalesia afinis* is also met here; the basic constituent species are common to those of Area explored IB12. Around parent plants of *Opuntia* are many prickly young individuals which have grown from fallen propagules formed on the edge of the thalluses of parent plants. We saw flowers of *Lantana peduncularis*, an endemic species. Though this is a place greatly affected by human beings, as was mentioned above, only some naturalized species are met such as *Sida* sp.; the surrounding native vegetation does not seem to be greatly damaged. Does the severe environment of the Arid zone prevent naturalized species from invading? It is an interesting phenomenon.

(3) Santa Fe Island

Research plot SF1: Vegetation in the Arid zone of the habitat of land iguanas

Santa Fe Island is a small island with an area of 24km² located to the southeast of Santa Cruz Island. The highest altitude is 259m, and the whole island belongs to the Arid zone. On this island goats having become wild propagated and caused great damage to the vegetation. In 1971, however, all the goats were exterminated and the vegetation was recovered. Part of the coast of the island is one of the landing spots for eco-tours and a course is provided for tourists to observe hair seals on the beach and land iguanas in the interior part.

In a 30-m-wide zone from the coast where the landing spot is provided continues a community of *Cryptocarpus pyriformis* 1 to 2m high. Though this species grows like a liane on Santa Cruz Island, here it grows like shrubbery, which is interesting. Beyond it is scrub mainly consisting of *Bursera glaveolens* and *Croton scouleri* having shed their leaves and *Opuntia* sp. and *Scutia pauciflora* grow in places. It is difficult to presume the former damage by the goats on the basis of the present vegetation, but is it due to this that shrubs seemed to be small in quantity?

2) Mammals

The native mammals of the Galápagos Islands are poor; there are only 2 species of bats, 7 species of rats, 2 species of hair seals. Five out of the above-mentioned seven species of rats are considered to have been exterminated through competition with black rats having invaded the Islands with the settlement of human beings and viral diseases brought by them. (Refer to Table 1.)
However, investigations on land small mammals seem to be insufficient. For example, rice rats are considered to be exterminated on Santa Cruz Island, but we saw rats obviously different from black rats on the forest floor by the roadside when we got off to see the twin craters (Refer to the frontispiece), which suggests that rice rats are still living. This is a field needing detailed investigations on rats as well as on bats.

3) Birds

About 120 species of birds are registered on the Galápagos Islands (Harris, 1974). Twenty-six of them are peculiar to the Galápagos Islands. In addition, 53 species including the endemic ones inhabit all the year round on the Islands as resident birds. Others are sea birds having a breeding area on the Islands, sea birds making seasonal migration, snipes and plovers stopping in on the way of migration or going down to pass the winter there, and birds straying into the Islands at rare intervals. Recorded are only 26 species of the

sparrow order generally recognized as small birds, 18 species of which are resident birds. Most of the others are sea and water birds. All these show clearly the features of the isolated islands in the ocean no less than 1000km to the east of the mainland of South America.

In such avi-fauna, we recorded 57 species in total during our stay from June 8 to June 20 on three islands: Santa Cruz, Isabela, and Santa Fe Islands. (Refer to Table 5.)

We conducted the census made in investigations on the influence of the fire also in other places, the result of which was already shown as part of Table 2.

This result shows that most of the resident birds inhabiting the three islands and more than half of the migratory birds have been recognized. Out of the resident birds, ten plus species including Galápagos penguins (*Spheniscus mendiculus*), flightless cormorants (*Nannopterum harrisi*), large cactus finches (*Geospiza conirostris*), etc. are not recorded because we did not go to islands or areas where they inhabited. The following is a brief description of birds recorded.

• Albatross

We saw two-three waved albatrosses above the ocean between Santa Cruz and Isabela Islands when we sailed between them. This is the only one species of Diomedidae.

• Shearwaters

Above the ocean between Santa Cruz and Isabela Islands and between Santa Fe and Santa Cruz Islands we saw Hawaiian dark-rumped petrels and Audubon's shearwaters. Audubon's shearwaters are often met also between Baltra and Santa Cruz Islands.

Hawaiian dark-rumped petrels have breeding areas in the Hawaiian Islands and the Galapagos Islands. In the Hawaiian Islands, however, the environment has remarkably changed and they are almost extinct there.

In the breeding areas of the Galapagos Islands they are also decreasing in number and their protection is being watched with keen interest.

• Storm petrels

They were often met above the ocean between Santa Cruz and Isabela Islands, between Santa Fe and Santa Cruz Islands, and between Baltra and Santa Cruz Islands. In addition, on Santa Cruz, Isabela Islands, etc. they were seen to take wing from the beach. We saw 4 species in total. In all cases they were flying individually.

• Tropicbirds

We saw two red-billed tropicbirds flying above the ocean between Santa Cruz and Isabela Islands. Only one species is recorded on the Galapagos Islands.

• Pelicans

This sea area is inhabited by only one species, brown pelicans. They are often met everywhere, on the beach and above the ocean. On Isabela Island we saw them propagating in the mangrove forest on the coast.

• **Boobies**

They can be seen everywhere, on the beach and above the ocean. Blue-footed boobies were the largest in population. Masked white boobies were small in number. Red-footed boobies and brown boobies were seen only five, respectively. Of the boobies propagating in the Islands, red-footed ones are the largest in population, and then masked white ones and blue-footed ones. The record of boobies is extremely limited; they are considered to be a retrograding species in the Islands.

• **Frigatebirds**

They can be seen everywhere, on the beach and above the ocean. Since the Islands are surrounded by the sea, they can sometimes be seen in the sky above the land. There are two species: large frigatebird and american frigatebird. It is rather difficult to distinguish them while they are flying. It is said that the number of individuals propagating in the Islands is larger for large frigatebirds.

• **Egrets**

Eight species are recorded in the Islands and we saw six out of the eight species.

Cattle egrets were often seen with domestic animals on arable land and grassland.

Common egrets were seen on the beach and grassland of a mountainous region.

They may be advancing into the non-waterside environment.

Great blue herons were seen on the beach and lakes near the coast only in very small numbers.

Lava herons are often seen on the lava beach; they are considered to be a variety of striated heron. Not a few individuals are located in the middle of them.

Yellow-crowned night herons sleep in the forest of mangrove by day and are active by night. We saw a small number of them on the beach of Santa Cruz Island.

• **Flamingoes**

Only one species, greater flamingo, is recorded in the Islands. We saw about 110 greater flamingoes on lakes and marshes of Isabela Island in total.

• **Wild ducks**

We saw only white-checked pintails on lakes and marshes of Isabela Island; the number of them was about 20.

• **Hawks In the Islands is recorded only one species peculiar to the Islands,**

Galapagos Hawk. On Isabela Island we saw flying individuals several times.

• **Water rails**

There are species peculiar to the Islands, but we saw only common gallinules on lakes and marshes of Isabela Island.

• **Snipes and plovers**

In the Islands are recorded 31 species, but we saw only ten species:

oystercatcher, black-bellied plover, semipalmated plover, ruddy turnstone, wandering tattler, semipalmated sandpiper, western sandpiper, sanderling, whimbrel, common stilt. Of these species, oystercatchers and common stilts act in pairs and we think they are propagating. Semipalmated plovers are in rivalry over

territory and they are expected to propagate. Other young individuals seemed to spend time till they reached reproducing age.

• Sea gulls and terns

In the Islands are recorded 9 species, and we saw four of them. Lava gulls and brown noddies are often seen on the beach and above the sea, but they were hardly to be seen offshore. Swallow-tailed gulls and royal terns were seen on the beach of Isabela Island only in small numbers.

• Doves

In the Islands is recorded only one endemic species, Galapagos dove. We saw a few of them on Santa Cruz and Santa Fe Islands. They were seen in dry land with space on the surface of the earth where cactuses grew.

• Cuckoos

In the Islands are recorded 3 species, and we saw two of them. Dark-billed cuckoos were often seen in woodlands in the interior part and groove-billed anis - in forests taken care of by people and near human habitations.

• Owls

In the Islands are recorded 2 species: barn owl and short-earred owl. They also propagate. We saw only short-earred owls; they were often seen in grassland located on the upper part of a mountainous region both on Santa Cruz and Isabela Islands.

• Tyrant-flycatchers

Vermilion flycatchers were often seen in woodlands in the interior part of Santa Cruz and Isabela Islands. They prefer to inhabit on the border with a forest and space.

Large-billed flycatchers, an endemic species, were often seen in the dry zone and woodlands above it.

• Swallows

In the Islands are recorded 4 species, but we saw only one species. We saw one Galapagos martin flying in the sky above the dry land of Isabela Island.

• Mockingbirds

Four endemic species are known in the Islands. Most of the mockingbirds of the same species inhabit in the same island. Only Galapagos mockingbirds, however, inhabit three islands: Santa Cruz, Isabela, and Santa Fe Islands.

• Wood warblers

In the Islands is recorded only one species, yellow warbler. However, the population of this species is large, and besides, they are widely distributed from the beach to grassland in the upper part of the island. We think this is a species of land bird having the largest population in the Islands.

• Finches

In the Islands are known 13 species, all of which are resident birds and peculiar to the Islands. This is a

Table 5-1 List of birds bred in the Galapagos Islands and species of birds recorded (June 8 to June 20, 1994)

under line	→	endemic species
under line	→	resident birds
**	→	regular migrant
	→	regular migrant in small numbers
no mark	→	accidental birds

1. Jun./8 10:SANTA CRUZ IS.
2. Jun./11 SANTA CRUZ IS. ISABELLA IS. Cruising
3. Jun/12-16 ISABELLA IS.
4. Jun./17 ISABELLA IS. SANTA CRUZ IS. Cruising
5. Jun./17-20 SANTA CRUZ IS.
6. Jun./19 SANTA FE IS.

		1	2	3	4	5	6
SPHENISCIDAE							
Galapagos Penguin	*Spheniscus mendiculus*						
PODICIPIDAE							
Pied-billed Grebe	*Podilymbus podiceps*						
DIOMEDIDAE							
Waved Albatross	*Diomedea irorata*		o		o		
PROCELLARIIDAE							
Cape Pigeon (Pintado Petrel)	*Daption capense*						
Hawaiian (Dark-rumped) Petrel	*Pterodroma phaeopygia*		o		o		
Parkinson's Petrel	*Procellaria parkinsoni*						
Wedge-tailed Shearwater	*Puffinus pacificus*						
Flesh-footed Shearwater	*Puffinus carneipes*						
Sooty Shearwater	*Puffinus griseus*						
Audubon's Shearwater	*Puffinus therminieri*	o	o		o		
HYDROBATIDAE							
White-vented (Elliot's) Storm Petrel	*Oceanites gracilis*		o				
White-faced Storm Petrel	*Pelagodroma marina*						
White-bellied Storm Petrel	*Fregetta grallaria*						
Band-rumped (Madeiran) Storm Petrel	*Oceanodroma castro*	o	o		o		
Leach's Storm Petrel	*Oceanodroma leucorhoa*						
Wedge-rumped (Galapagos) Storm Petrel	*Oceanodroma tethys*	o	o		o		
Markham's Storm Petrel	*Oceanodroma markhami*		o		o		
PHAETHONTIDAE							
Red-billed Tropicbird	*Phaethon aetherous*		o		o		
PELECANIDAE							
Brown Pelican	*Pelecanus occidentalis*	o	o	o	o	o	o
SULIDAE							
Blue-footed Booby	*Sula nebouxii*	o	o	o	o	o	o
Masked (white) Booby	*Sula dactylatra*		o		o		o
Brown Booby	*Sula leucogaster*				o		
Red-footed Booby	*Sula sula*		o				
PHALACROCORACIDAE							
Flightless Cormorant	*Nannopterum harrisi*						
FREGATIDAE							
Great Frigatebird	*Fregata minor*	o	o	o		o	o
Magnificent Frigatebird	*Fregata magnificens*	o	o	o		o	o
ARDEIDAE							
Great Blue Heron	*Ardea herodias*	o		o			
Common Egret	*Casmerodius albus*	o		o		o	
Snowy Egret	*Leucophoyx thula*						
Cattle Egret	*Bubulcus ibis*	o		o		o	
Lava Heron	*Butorides sundevalli*	o		o		o	
Striated Heron	*Butorides striatus*	o		o		o	
Yellow-crowned Night Heron	*Nyctiocorax violacea*	o				o	

Table 5-2 List of birds bred in the Galapagos Islands and species of birds recorded
(Continued from the previous page)

		1	2	3	4	5	6
ARDEIDAE (continued)							
Black-crowned Night Heron	*Nycticorax nycticorax*						
PHOENICORTERIDAE							
Greater Flamingo	*Phoenicopterus ruber*			o			
ANATIDAE							
Black-bellied Tree Duck	*Dendrocygna autumnalis*						
White-cheeked Pintail	*Anas bahamensis*			o			
Blue-winged Teal	*Anas discors*						
ACCIPITRINIDAE							
Galapagos Hawk	*Buteo galapagoensis*			o			o
PANDIONIDAE							
Osprey	*Pandion haliaetus*						
FALCONIDAE							
Peregrine Falcon	*Falco peregrinus*						
RALLIDAE							
Galapagos Rail	*Latelallus spilonotus*						
Paint-billed Crake	*Neocrex erythrops*						
Common Gallinule (Moorhen)	*Gallinula chloropus*			o			
Purple Gallinule	*Porphyrula martinica*						
HAEMATOPODIDAE							
Oystercatcher	*Haematopus ostralegus*			o			
CHARADRIIDAE							
Black-bellied (Grey) Plover	*Squatarola squatarola*			o			
Golden Plover	*Pluvialis dominica*						
Semipalmated Plover	*Charadrius semipalmatus*			o			
Thick-billed Plover	*Charadrius wilsonia*						
Killdeer	*Charadrius vociferus*						
Ruddy Turnstone	*Arenaria interpres*			o		o	
Black Turnstone	*Arenaria melanocephala*						
Surfbird	*Aphriza virgata*						
SCOLOPACIDAE							
Solitary Sandpiper	*Tringa solitaria*						
Lesser Yellowlegs	*Tringa flavipes*						
Greater Yeellowlegs	*Tringa melanoleucus*						
Spotted Sandpiper	*Actitis macularia*						
Wandering Tattler	*Heterscelus incanus*			o			o
Willet	*Catoprophorus semipalmatus*						
Knot	*Calidris canutus*						
Least Sandpiper	*Calidris minutilla*						
Semipalmated Sandpiper	*Galidris pusillus*			o			
Western Sandpiper	*Calidris mauri*			o			
Baird's Sandpiper	*Calidris bairdii*						
White-rumped Sandpiper	*Caalidris fusciocllis*						
Pectoral Sandpiper	*Calidris melanotos*						
Sanderling	*Crocthtia alba*			o			
Stilt Sandpiper	*Micropalama himontopus*						
Whimbrel	*Numenius phaeopus*	o		o		o	
Marbled Godwit	*Limosa fedoa*						
Short-billed Dowicher	*Limnodromus griseus*						

Table 5-3 List of birds bred in the Galapagos Islands and species of birds recorded (Continued from the previous page)

		1	2	3	4	5	6
RECURVIROSTRIDAE							
Common Stilt	*Himantopus himantopus*	o		o		o	
PHALAROPODIDAE							
Northern (Red-necked) Phalarope	*Lobipes lobatus*						
Red (Grey) Phalarope	*Phalaropus fulicarius*						
Wilson's Phalarope	*Steganopus tricolor*						
STERCORARIIDAE							
Great Skua	*Catharacta skua*						
Pomarine Skua (Jaeger)	*Stercorarius pomarinus*						
LARIDAE							
Swallow-tailed Gull	*Creagrus furcatus*			o	o		
Lava Gull	*Larus fuliginosus*	o	o	o	o	o	o
Franklin's Gull	*Larus pipixcan*						
Laughing Gull	*Larus atricilla*						
Royal Tern	*Sterna maxima*			o			
Common Tern	*Sterna hirundo*						
Sooty Tern	*Sterna fuscata*						
Fairy Tern	*Gygis alba*						
Brown Noddy	*Anous stolidus*	o	o	o	o	o	o
COLUMBIDAE							
Galapagos Dove	*Zenaida galapagoensis*	o					o
CUCULIDAE							
Dark-billed cuckoo	*Coccyzus melacoryphus*	o		o			
Black-billed cuckoo	*Coccyzus erythrophthalmus*						
Groove-Billed Ani	*Crotophaga sulcirostris*	o		o		o	
TYTONIDAE							
Barn Owl	*Tyto alba*						
STRIGIDAE							
Short-eared Owl	*Asio flammeus*	o		o			
CAPRIMULGIDAE							
Common Nighthawk	*Chordeiles minor*						
ALCEDINIDAE							
Belted Kingfisher	*Ceryle alcyon*						
TYRANNIDAE							
Vermilion Flycatcher	*Pyrocephalus rubinus*	o		o		o	
Large-Billed Flycatcher	*Myiarchus magnirostris*	o		o			o
HIRUNDINIDAE							
Galapagos Martin	*Progne modesta*			o			
Purple Martin	*Progne subis*						
Bank Swallow (Sand martin)	*Riparia riparia*						
Barn Swallow	*Hirundo rustica*						
MIMIDAE							
Galapagos Mockingbird	*Nesomimus parvulus*	o		o		o	o
Charles Mockingbird	*Nesomimus trifasciatus*						
Hood Mockingbird	*Nesomimus macdonaldi*						
Chatham Mockingbird	*Nesomimus melanotis*						

Table 5-4 List of birds bred in the Galapagos Islands and species of birds recorded
(Continued from the previous page)

		1	2	3	4	5	6
PARULIDAE							
Yellow Warbler	*Dendroica petechia*	o		o		o	o
THRAUPIDAE							
Summer Tanager	*Piranga rubra*						
ICTERIDAE							
Bobolink	*Dolichonyx oryzivorus*						
FRINGILLIDAE							
Small Ground Finch	*Geospiza fuliginosa*	o		o		o	o
Medium Ground Finch	*Geospiza fortis*	o		o		o	
Large Ground Finch	*Geospiza magnirostris*	o		o			
Sharp-beaked Ground Finch	*Geospiza difficilis*						
Cactus (Ground) Finch	*Geospiza scandens*	o		o			
Large Cactus Finch	*Geospiza conirostris*						
Vegetarian (tree) Finch	*Platyspiza crassirostris*	o		o			
Small Tree Finch	*Camarhynchus parvulus*	o		o		o	
Medium Tree Finch	*Camarhynchus pauper*						
Large Tree Finch	*Camarhynchus psittacula*	o		o			
Woodpecker Finch	*Camarhynchus pallidus*	o		o			
Mangrove Finch	*Camarhynchus heliobates*						
Warbler Finch	*Certhidea olivacea*	o		o		o	

group well-known as a sample of speciation. Ten species have a distribution and inhabit Santa Cruz and Isabela Islands. We saw 9 out of the ten species.

Since ground finches such as small ground finches collect food mainly on the ground, they were often seen in the dry zone, grassland in the upper part of an island, on roads near human habitations. Small ground finches have the largest population, and then medium ground finches. The number of large ground finches was small.

Cactus ground finches were often seen in the dry zone, but compared with small ground finches, they were much smaller in number.

Medium tree finches and large tree finches were seen in forests and bushes, but their population is not large.

The population of warbler finches was large in woodlands, but it was small in bushes and near human habitations.

The population of woodpecker finches is not large in the forest of Scalesia in woodlands, but they were often seen. This species is famous as a bird using tools; it pecks out insects inhabiting holes bored in trees by using a twig. We did not see it in the forest of guava or near human habitations; we saw it in the forest of mangrove only once.

4) Reptiles

(1) The present state

As for giant tortoises (*Geochelone elephantopus*) which receive most attention of all reptiles in the Galapagos Islands, a technique for their propagation has already been established with the cooperation of CDRS and SPNG. In some areas their population has been recovered by reintroduction to habitats after propagation. On the other hand, even now there are areas where their population is small and they are in danger of extinction due to the influence of hunting and immigrants, and besides, there are areas where their present situation is not clear, such as populations in distant places hard to get to (the northern part of Isabela Island, etc.). In addition, their classification is not a final one, which holds the key to the solution of the problem of propagation. The system of their classification is now investigated from a genetic viewpoint, and it is expected that the classification of populations will be clear and propagation potency will be increased in the near future.

As for land iguanas (*Conolophus* spp., the system for their propagation is arranged following giant tortoises and retransfer is also conducted, but a complete technique of their propagation is not yet established, and there is the danger that the number of their wild individuals may be decreased by the influence of wild dogs and cats.

Lava lizards (*Tropidurus* spp.) inhabit lowlands in great numbers (on Santa Cruz, Isabela, and Santa Fe Islands a considerable number of their individuals were seen in the cleared dry zone in lowlands (in the lava zone and on the coast)), and it is not necessary to immediately take measures to cope with the present situation. CDRS has also judged that at present they are not in danger of extermination, giving them low priority of investigation. Only outside scientists conduct their own investigations.

It is feared that native and exotic geckos (*Phyllodactylus* spp.) compete with each other and that Galapagos snakes (*Alsophis* spp., *Philodrysa* spp.) are adversely affected by exotic mammals, but detailed investigations are not yet conducted. In particular, the classification of snakes has been changed (formerly 3 species of *Dromicus*), with the result that it is not completely known what islands what species (subspecies) inhabit. In addition, there are few individuals whose inhabitation is confirmed. Judging from this situation, considerable investigations will be necessary in the future.

As for marine iguanas (*Amblyrhynchus cristatus*), a respectable number of them can be seen on the beach (craggy place), and there is no fear of their extermination, but they receive some influence from exotic species. Marine iguanas can receive influence from the change in climate and it is necessary to further conduct detailed investigations to determine what factors have influence on them.

The reptiles list of the Galapagos islands will be shown in Table 6.

Table 6 The Reptiles of the Galápagos Islands

Cheloniidae (sea turtle family)
Chelonia mydas
Testudinidae (land turtle family)
Geochelone elephantopus
G.e. abingdoni Pinta: Only in Lonesome George where it is being grown
G.e. becki Isabela: (Volcan Wolf)
G.e. chathamensis San Cristobal
G.e. darwini Santiago
G.e. ephippium Pinzon
G.e. galapagoensis Floreana: extinct
G.e. guntheri Isabela (Volcan Sierra Negra)
G.e. hoodensis Espanõla
G.e. microphyes Isabela (Volcan Darwin)
G.e. phantastica Fernandina :extinct
G.e.porteri Santa Cruz
G.e. vandenburghi Isabela (Volcan Alcedo)
G.e. vicina Isabela (Cerro Azul)
G.e. subsp. Santa Fe: extinct (only bone specimens existing)
(*G.e.wallacei* Rabida: Said not to live, but not known concerning subspecies)
Gekkonidae (gecko family)
Phyllodactylus tuberculosus
Phyllodactylus bauri
Phyllodactylus barringtonensis
Phyllodactylus galapagoensis
Phyllodactylus gilberti
Phyllodactylus leei
Gonatodes caudiscutatus: introduced species
Phyllodactylus reissi: introduced species
Lepidodactylus lugubris: introduced species

Iguanidae (Iguana family)
Conolophus (land lizard)
Conolophus subcristatus
Conolophus pallidus
Amblyrhynchus (sea lizard)
Amblyrhynchus cristatus: 7 subspecies
Tropidurus
Tropidurus albemarlensis
Tropidurus bivittatus

Tropidurus delanonis
Tropidurus duncanensis
Tropidurus grayi
Tropidurus habeli
Tropidurus pacificus

Colubridae (Snake family)
Philodryas sp.
Alsophis sp.

The above classification was compiled using Write (1983) and Jackson (1993) as reference, but a reconsideration of classification is taking place at present by means of genetic investigations.

(2) Problems of reptiles in the Galapagos Islands

(a) Poaching

Hunting by human beings gave a serious impact to the population of giant tortoises in the past, and even now poaching seems to have the greatest influence on them. The purpose of poaching is to get their meat (especially, meat of female ones), but natives say that they ate the meat of giant tortoises in the past, but now they seldom eat it. This is different from the remark of the staff of CDRS that even now inhabitants in some regions eat the meat of giant tortoises; it is not clear whether natives catch them to eat their meat or to sell them to outside people as sea slugs. But in the Galapagos Islands there is a fact that giant tortoises were killed after sea cucumber fishery had been prohibited, though it is not clear whether the killing had relation to the resistance to the prohibition of sea cucumber fishery. We are worried about inhabitants' low awareness of the preservation of giant tortoises.

(b) Exotic species

It is pigs which have become wild that have the greatest influence on giant tortoises of all the exotic species. They prey on the eggs of giant tortoises, exerting a remarkable influence on them in the breeding period. Besides direct predation, pigs tread on nests insensitively, causing damage to them. In the natural condition without exotic species hawks are considered to be predators of young giant tortoises. In addition, the experience of the CDRS propagation center has shown that even exotic rats prey on young giant tortoises. There is a history that on Pinta Island goats propagated in wild condition (goats were expelled from Pinta Island and there are no goats on it) and ate up the plants of giant tortoises, with the result that giant tortoises were exterminated. But it is said that generally when the island is large, competition of giant tortoises with exotic species for plants does not have such a strong influence on them compared with direct influence of poaching by human beings or exotic species. This is because the plants of giant tortoises

is diversified, that is, they eat arboreous plants such as leaves of *Acacia macracantha*, etc., cactuses such as Opuntia, etc., fruit of *Hippomane mancinella* (Manzanillo) (poisonous to human beings), gramineous plants, etc. Though exotic animals exert influence on trees, they have not yet done so much damage as to extremely decrease the population of giant tortoises.

Dogs and cats which have become wild have influence also on marine iguanas and snakes small in number, especially with cats doing a lot of damage to snakes. On islands where cats have not immigrated a certain number of snakes can be seen, but on islands where cats have immigrated it is very difficult to confirm the inhabitation of individuals, though such detailed investigations as mentioned above have not been made on snakes and it is not clear whether or not there exist factors other than cats which have influence on them.

As for geckos, there is the possibility of competition between native species and exotic ones. At present exotic geckos expand their habitat in the village (private houses), but are not in competition with native ones outside the village. Extension of the sphere of influence of exotic plant species on the reptiles of the Galapagos Islands has not caused so great a problem so far.

Expanding of the forest of guava, however, seems to have some influence on the inhabitation range of giant tortoises.

(3) Measures against problems and problems to be solved

Exotic animals are expelled by hunting from islands where human beings do not live. There are some cases of complete expulsion of exotic animals, such as expelling of goats from Santa Fe and Pinta Islands. On islands where human beings live, however, complete expulsion is thought to be difficult. In the investigation conducted this time we saw horses equipped with reins which had been raised by human beings in a herd of wild horses. As long as the raising of domestic animals continues, and as long as inhabitants exist who insist on property in domestic animals, complete expulsion is thought to be difficult. In spite of that, SPNG does hunting of exotic animals two-three times a year.

To prevent poaching inhabitants are given education in environmental conservation, but insufficient materials and facilities make enlightenment of inhabitants insufficient. In addition, arrested giant-tortoise poachers are to be imprisoned for one month or fined 20000 sucres, which is said to be not so heavy.

(4) Reptiles of Isabela Island

In the southern area of Isabela Island explored this time (area of Cerro Azul and Volcan Sierra Negra) the population of giant tortoises and land iguanas has considerably decreased due to poaching in the past. As for giant tortoises, there are only 8 habitats confirmed. (Refer to Fig. 10 for habitats and population.) Formerly it was thought that giant tortoises in the southern area were of subspecies inhabiting around respective volcanos.

According to recent investigations, it is not clear in which of the 8 habitats 2 subspecies (*G. elephantopus vicina, G. elephantopus guntheri*) inhabit owing to division of habitats by lava flows from the volcanos. For example, it is confirmed that in the area of Cinco Cerros two different forms of giant tortoises live together and the conclusion of classifying investigation is now being looked forward to. At present in habitats near the coast a certain number of giant tortoises inhabit. Though exotic species such as donkeys inhabit, there is no particular change in vegetation seen and the habitats are kept almost in a natural state.

In habitats in highlands, however, the population of giant tortoises has decreased and we are worried about their extermination.

It is known that except in the southern area giant tortoises inhabit in considerable numbers the area of Volcan Alcedo, but those in the areas of Volcan Wolf and Volcan Darwin are not investigated sufficiently because the areas are hard to get to. It is possible that goats, donkeys, etc. in the area of Volcan Alcedo have moved to the northern part and exerted influence. Expulsion of donkeys from around Volcan Arcedo has already been started and a plan is being made to start investigations on the state of giant tortoises and exotic species in the areas of Volcan Wolf and Volcan Darwin next year.

Habitats of land iguanas are also limited. Only two habitats are confirmed in the southern area of Isabela Island. Their population, etc. has not been grasped yet, which makes it necessary to conduct investigations in the future.

5) Preservation of giant tortoises

(1) Establishment of a preservation area for giant tortoises

In the southern part of Santa Cruz Island is established a preservation area for giant tortoises. Here they inhabit in wild condition. A considerable number of domestic animals such as cows also get in this area. The significance of the preservation area established is not clear because anyone can get in this area and periodical investigations are not conducted either.

(2) The giant-tortoise propagation center on Santa Cruz Island

It is thought that 4 male giant tortoises are necessary for at least 12 females to keep an adequate reproductive rate. The maintenance of the population under propagation in wild condition depends on the area and ecological system. for example, on Espanola Island there inhabit about 50 males, which is said to be adequate for propagation in natural condition.

As for islands or habitats with small populations, CDRS moves giant tortoises inhabiting there to the Propagation center established on Santa Cruz Island to propagate them and raises young produced from eggs about 5 years followed by retransferring them to the original habitats, thus recovering the population. At present about 600 giant tortoises are raised in the Propagation center. There was a period when propagation did not go well, not knowing that it was necessary to fix the top and the bottom of an egg. The propagation technique is now established, and about 1670 giant tortoises have been retransferred (to Espanola Island, Pinzon Island, Santiago Island) from 1975 to 1993. On Espanola Island the population was very small before propagation: 2 males and 10 females. Now more than 300 giant tortoises have been retransferred, and the population has recovered to such a degree as to enable to reproduct in natural condition. The fact that giant tortoises hatched in the Propagation center have propagated in wild condition attests that they will be able to mature to reproduct in natural condition in 20 to 30 years. Naturally they make it a rule to make investigations on the balance mechanism of population corresponding to the ecological system of the habitat before retransfer and determine the number of individuals to be retransferred.

The giant-tortoise propagation technique has already been established, but it has some problems. The last giant tortoise named Lonesome George discovered on Pinta Island in 1972 has female giant tortoises (*G. elephantopus becki*) in the area of Volcan Wolf on Isabela Island which are thought to be taxonomically

nearest to the subspecies (*G. elephantopus abingdoni*) on Pinta Island as the mate. One of the problems is whether it is possible to retransfer giant tortoises there even if propagation goes well, as the vegetation on Pinta Island has changed because herbivorous animals do not exist. Another problem of whether propagation with a different subspecies is adequate for avoiding extermination is left unsolved.

(3) The giant-tortoise propagation center on Isabela Island

As for giant tortoises in the southern area of this island, the population, especially that inhabiting around Volcan Sierra Negra is small, and a plan is being made to propagate them in the Propagation center followed by retransferring them to the island. After the fire in 1985, the construction of the Propagation center was started in Puerto Villamil in 1987 with the use of aid from foreign countries. This center is managed by the National park bureau. It was in 1990 when the construction of the breeding farm was completed that the first giant tortoises were carried in. But the hatchery (utilizing solar heat) is not completed because of an insufficient state budget, and they seem to be expecting aid for the fire this time. This propagation center has now 55 individuals (15 mature individuals; 3 males and 12 females) and 10 individuals (5 mature individuals; 4 males and 1 female) brought from the area of Cazuela and the area of Cerro Paloma respectively. Of these mature individuals, five from the area of Cerro Paloma and nine from the area of Cazuela (2 males and 7 females) were carried with the use of a helicopter at the time of the fire this time.

Other giant tortoises have been carried by the staff of SPNG, donkeys, horses, etc. from the fire in 1990 to the fire this time. Most of them were small and few reached maturity. The nesting period of giant tortoises is from June to December. Most of the individuals carried from the area of Cazuela to this center are female and they already show mounting and copulation, which indicates the possibility of egg production within this year. In the Propagation center they are given as food grass leaves of a plant called *Xanthosoma violaceum* (Otoy in the native language) similar to taro three times a week. This plant is an exotic one raised by islanders originally for food for pigs, and now it is grown for giant tortoises raised in the Propagation center. We are worried about the influence of the food plant they eat which cannot be eaten by them in natural condition when they are retransferred.

6) Agroforestry (Useful tree planting project)

The following description is based on the on site explanation by Lenin Prado, a research worker of CDRS.

In the Galapagos Islands plants brought by human beings from outside the Islands have become wild and are a big menace to native species. In particular, farmland and pastures outside the park area have become a hotbed of naturalized plants, which invade the surrounding park area. For example, *Cinchona succirubra* introduced in 1946, one of the rare trees highly valued as a certain medicine in the mainland, is invading the forest of Scalesia at an altitude of 450 to 700m on Santa Cruz Island. On the other hand, *Piscidia carthagenesis*, one of the limited number of useful native trees, has been used for a long time as a material for ships, houses, furniture, etc., and it has remarkably decreased in population on Santa Cruz and San Cristobal Islands. In the managed park area only felling of dead trees is permitted, but in fact, illegal felling of live trees continues even now. Since Piscidia carthagenesis grows slowly, it is in danger of extermination when left as it is. To solve these problems CDRS and SPNG started a joint project of agroforestry in 1990. First they selected five species of trees capable of use as timber in the future and

ecologically not actively invading native forests (with low capability of seed dispersion): *Tectona grandis, Piscidia carthagenensis, Switenia macrophylla, Juglans neotropica,* and *Centrolobium paraense*, and two species for feed: *Gliricidia sepium* and *Erythrina poepihiana*. (Of these species, only Piscidia carthagenensis is a native one.)

In the nursery center established in the area of Villavista on Santa Cruz Island, they gather seeds from good parent trees in the Island (in the case of seeds already introduced in the Island in the past) or bring seeds from the mainland and grow nursery trees. They say propagation by cuttage has recently been well under way. There are 2-m-wide buffering zones on the border between the park area and private farmland, and proper trees are selected from the tree species mentioned above and planted on the farmland side (in the farmland) with the cooperation of the farmers concerned. The farmers not only grow these trees, but also expel harmful naturalized species in the farmland, thus preventing naturalized plants in the farmland from invading the park area, and besides, utilizing produced timber for their own use or sale. There will be no need of importing timber from the mainland, which will prevent exotic species from invading at the time of import. The annual budget for this project is 20 to 30 thousand dollars. At present this project has a staff of only 3 including the manager hired on the spot.

College students of the Ecuador mainland voluntarily take part in this project by turns. This year three thousand nursery trees are to be planted. We want to advance enlightenment of farmers and spread this project, but there is no car for the exclusive use of the staff, and it is also difficult to prepare printed matter due to a budgetary deficit. We also encourage the village authorities and organizations such as an agricultural cooperative to engage in this project as their own. We intend to spread similar projects to San Cristobal and Isabela Islands where people settle like on Santa Cruz Island.

7) Environmental education

The organs and groups concerned have a common awareness that one of the most important factors for further advancing nature conservation in this area is an increase on the part of people living in the Galapagos Islands and people going there to see the sights of the understanding of the following points and to bring them to concrete action: (1) geological and biological history of the Islands and its invaluable value; (2) how fragile it is and how it has been disturbed by human beings; (3) what efforts have been made to preserve it; (4) why it is necessary for people on the earth, the Ecuadorian people, and inhabitants of the Islands to preserve nature on the Galapagos Islands; (5) how they act in their own position to preserve nature, etc.

The Galapagos Islands, almost the whole area of which is the National park and which are registered as one of the World's natural heritages, are visited by many tourists from various foreign, mainly western, countries. The system of using this national park is well known as typical eco-tourism. Not only the lodging and accessing method is limited, but also a tour is required to be accompanied by an authorized guide, which makes it possible to give tourists an opportunity of receiving environmental education as well as to control the number of tourists and their behavior.

The visitors center and the giant-tortoise propagation facilities in CDRS on Santa Cruz Island are open to the public and it is possible to hear a detailed lecture on them. The facilities are in the course of the tour.They are the only place where extensive information can be obtained. Places in the course of the eco-tour are limited from the viewpoint of nature conservation, and places having the essence of nature of the Galapagos Islands are selected in consideration of the iciency of the tour. Places not arousing public

interest or whose nature is disturbed are not selected. It

is indispensable to show people pictures and other materials to supplement their on-site experience and make them understand the menace to nature of the Galapagos Islands, and aid ofthe Sasagawa Foundation to this field such as video apparatus is highly estimated.

On the other hand, we observed some cases of environmental education of on-site experience type for islanders, especially for children, not for tourists, on Isabela Island.

This is given exclusively by Mr. Jacinto Gordillo, the head of the branch office of CDRS on Isabela Island. This is intended to teach the necessity of preserving forests of Scalesia through work related to preservation (such as expulsion of exotic plants and cleaning) of the forest of Scalesia remaining in one corner of the farmland a little east from the trunk road in the area of Santo Thomas bought for this purpose and surrounded with a fence. (Refer to 3-(2) for details.) Better effects might be achieved if the neighborhood of the protected forest were bought, recovery were promoted, and an educational exhibition facilities combined with the management facilities were established, but a rapid expansion of the project is not expected for financial reason.

It was said that camping was also performed by Mr. Jacinto Gordillo for the purpose of giving environmental education, but equipment was insufficient, so we gave the camping apparatus carried by the research group for the purpose.

V. Consideration and proposal

V. Conclusion and Prospect

1. Evaluation of the influence of the fire on natural and social environment of Isabela Island

1) Evaluation of the influence on the vegetation/flora

Each of the vegetation zones in Fig.2 consisted of species of native plants of the Galapagos Islands, but a remarkable number of naturalized plants have now invaded the Islands as a result of past and present human activities. In particular, forests of Scalesia being the original vegetation of the Scalesia zone have almost been replaced with guavas (*Psidium guajava*), fruit trees brought by human beings.

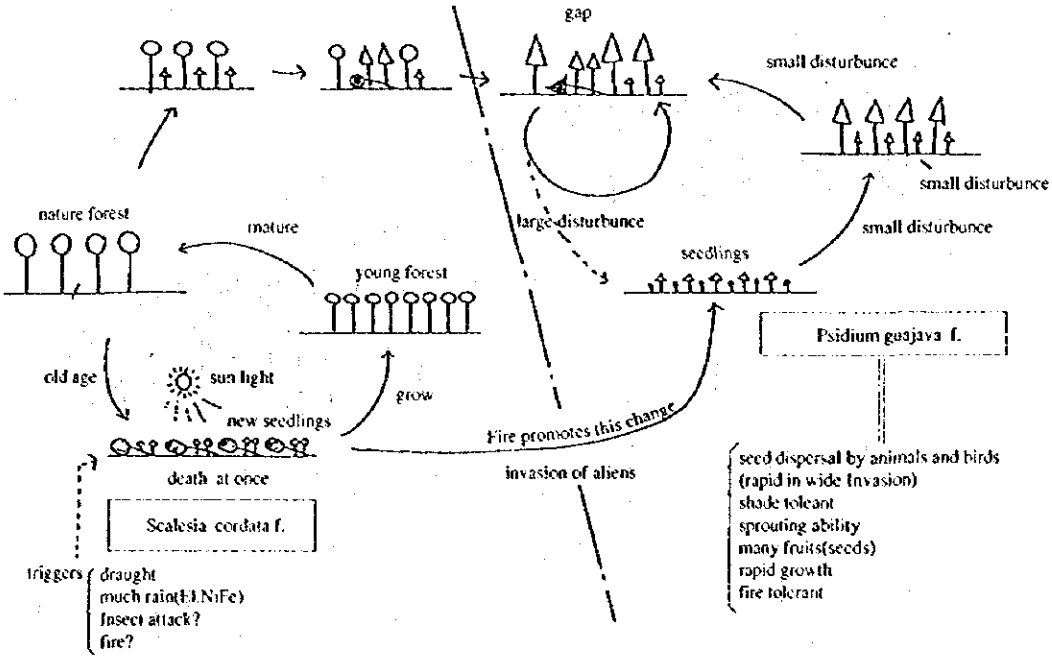


Fig.15 Competitive relationship between a forest of Scalesia and a forest of guava

Fig.15 schematically shows the manner of renewal of a forest of Scalesia and the mechanism of its transition to a forest of guava. According to the study made so far, Scalesia is a sun tree and it sprouts and settles only in bare ground with sufficient light. Generally, in the mainland with high biological diversity shade trees replace sun trees in the course of succession of the vegetation. In the environment of ocean islands with no shade trees, however, there are cases where sun trees form climax forests as they are. When Scalesias die of various causes such as extremely dry conditions, a lot of rain related to El Niáo, vermin damage, etc. all at once and their top layer is opened, seedlings of Scalesia grow all at once and its forest regenerates. There were probably cases where forests of Scalesia burned in a fire caused by a volcano eruption in the past, but

it is thought that as long as there remained forests of Scalesia capable of supplying seeds nearby, regeneration was easy.

However, guavas have relatively high shade tolerance and it is easy for their natural young growth to settle under the canopy of a forest of Scalesia. In addition, at present domestic animals having become wild disperse a large number of seeds in various places and when bare ground such as a fire-ravaged area appears over a wide area, guavas easily invade the area and occupy it. On the other hand, Scalesia has wind-dispersing seeds, but its attached organ for dispersion has atrophied and its dispersing potency is inferior to that of guava. There now remain few forests of Scalesia serving as a seed supplying source, and this tendency is more and more strengthened. Even if a forest of guava has its canopy burnt, it can maintain individuals by active sprouting and renewal if their roots survive. Scalesia, however, hardly shows such potency. Scalesia probably has a certain degree of fire resistance, but there is no doubt that guava is superior also in fire resistance.

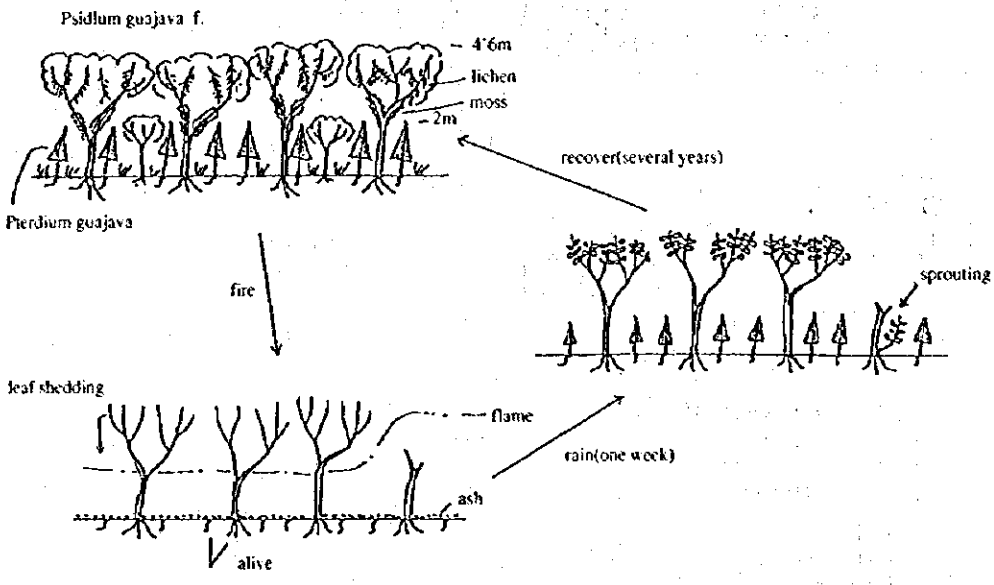


Fig.16 The manner of burning of a forest of guava and the process of its recovery

Judging from the above, guava increases its prepotency each time the forest is disturbed, and the fire this time is thought to further increase the prepotency of guava. Repeated disturbances by burning and accidental fires at the time of settlement in the past probably formed a vast forest of guava as is now seen. It is estimated that more than 95% of the trees composing the canopy burnt in the fire this time are occupied by guavas. Fig.16 schematically shows the aspect of burning of a forest of guava in the fire this time and the process of regeneration. Since guavas themselves survive almost without any damage, they soon bud when conditions becomes good after rain. In addition, bracken on the forest floor can also develop new leaves from underground stems. It will take some time for grass on the forest floor except bracken and bushes to recover, and original forest physiognomy will probably be recovered in several to ten years.

2) Estimation of the influence on the fauna

(1) Recoverability as an evaluation criterion and a method of its calculation

The influence of fire, more generally of natural disasters, artificial impacts, on the fauna can be evaluated by whether populations of various species and habitats supporting them can recover as they were before being affected and how long it will take them to recover, that is, by recoverability.

This recoverability depends on how the population of each animal species shows its recovery potency in given conditions. The recovery potency includes propagation potency peculiar to the population of each species (concretely speaking, the difference between the fecundity and the number of deaths because of predation, etc.), migration and dispersion potency enabling immigration from other populations, adaptability to the environmental change, etc., which are shown depending on the population size left as a source, the size of the population existing around as a source supplying individuals and the degree of isolation showing the distance from it, the rate of restoration of the environment (habitat), etc. In this case a habitat offering animals food, a place for propagation and rest, a refuge, etc. is mainly based on a plant community or vegetation, and it is possible to replace the rate of restoration or recoverability of a habitat with that of vegetation.

Animal communities in the afflicted area are to be recovered with constituent elements interacting with each other, but at the present time we have a poor knowledge of interspecific relations, and we cannot help making an independent evaluation for each species. But when interspecific relations are clear in the aspect of food chain and competition, it will be necessary to evaluate the influence exerted on the relations.

At the present time it is difficult to handle these elements quantitatively and calculate the time necessary for recovery to the original state, and we cannot help handling them qualitatively and relatively as shown in Table 6. Anyway, presenting recoverability as a model in the form of a table will have some effect in expecting and monitoring the process of recovery and taking conservation measures.

Table6 shows the following tentative five ranks of recoverability with the time scale taken into account.

Rank I:	Recovery to the original state is possible in very short time (within 2 to 3 years). (Slight)
Rank II:	Recovery to the original state is possible in relatively short time (in about 10 years). (Minor)
Rank III:	Recovery to the original state is possible, but in considerably long time (in decades of years). (Medium)
Rank IV:	Recovery to the original state is impossible if left untouched; if possible, in extremely long time (more than 100 years). (Major)
Rank V:	There is no possibility of recovery. (Terrible)

(2) Evaluation from the viewpoint of nature conservation

Evaluation of the influence of the fire made uniformly from the viewpoint of recoverability for the populations of all the species must be based on the assumption that all of them are equivalent, but in consideration of the purpose of this research we cannot exclude the viewpoint of the conservation of nature of the Galapagos Islands.

Nature of the Galapagos Islands is characterized by poor diversity, a large number of endemic species, and pressure on them by exotic species. From the standpoint of conservation of nature of the Galapagos Islands based on the idea that it is necessary to conserve existing original nature as far as possible and restore it to a more natural state, exotic species are existences to be actively excluded. With this viewpoint taken into account, endemic species and exotic ones have adverse evaluation of recoverability.

(3) Comprehensive evaluation

Our worry about the influence of the fire on Galapagos giant tortoises having triggered this research proved groundless, because the afflicted area was a long way from the isolated habitats. This is true of land iguanas. Animals directly affected by the fire were endemic ones such as bats, birds, snakes, mollusks, arthropods, etc. which seemed to be widely distributed in the Island, probably uniformly distributed in forests of guava in the foggy zone and domestic ones having become wild.

As is shown in the evaluation of recoverability in Table 6, animals with poor migration potency are strongly affected, but it was judged that endemic animals could recover to their original state in a certain time. On the other hand, it seems that some exotic animals, taking advantage of this fire, expanded their influence. It was judged that the fire had generally been more convenient to exotic species also in fauna, as was seen in vegetation.When estimated from the viewpoint of nature conservation, the fire has put more pressure on endemic species than on exotic ones, which will stimulate the expansion of inhabitation of exotic species and may affect populations of giant tortoises and land iguanas in the future which were saved from direct influence of this fire.

In addition, if such a fire is repeated in a relatively short time, the fauna will be more and more simplified. Fires caused by man shall be prevented as far as possible from the viewpoint of nature conservation.

3) Evaluation of the influence on regional communities

The fire having occurred this time was a long way from communities and areas where agriculture and stock raising are admitted, thanks to which there was no direct influence on them and there was almost no indirect influence found on the natural environment either.
However, in the period from occurrence to extinguishment of the fire a lot of people came to Isabela Island to fight the fire, and it is obvious that it stimulated the economy of communities. This is a temporary influence, but there are also various kinds of unseen influence which are continuously and considerably exerted on communities with enhanced interest such as increase in number of eco-tourists, acceleration of the construction of an airport to improve poor access having disturbed fire fighting this time.
Naturally, this has something to do with nature of Isabela Island, which shall be remembered.

Table 7 Table of comparative estimation of the influence of the fire based on recoverability

Population of species	*(a) Size of remaining population	*(b) Propagation potency	*(b) VS *(c)	*(c) Competition pressure, predation pressure	*(d) Migration potency, dispersion potency	*(d) VS *(e)	*(e) Degree of isolation	*(f) Size of surrounding population	*(g) Adaptability to the environment	*(h) Evaluation of the influence of the fire based on recoverability
Bats	9/10	Medium	>	Weak	Great	>	Medium	Medium	Medium	II (Minor)
Domestic animals having become wild	9/10	Medium	>	Weak	Great	»	Low	Large	High	I (Slight)
Land birds, herbivorous	9/10	Medium	>	Weak	Great	»	Low	Large	High	II (Minor)
Land birds, carnivorous	9/10	Medium	>	Weak	Great	»	Low	Large	Medium	II (Minor)
Giant tortoises	1/1	Medium	<	Strong	Small	«	High	Small	Medium	Status quo/gradually decreasing
Giant tortoises *1	1/10	Medium	<	Strong	Small	«	High	Small	Medium	V (Terrible)
Land iguanas	1/1	Medium	<	Strong	Small	«	∞	0	Medium	Status quo/gradually decreasing
Land iguanas *2	1/10	Medium	<	Strong	Small	«	∞	0	Medium	V (Terrible)
Galapagos snakes	2/5	Medium	≤	Ordinary	Small	>	Medium	Medium	Medium	III (Medium)
Flying insects	3/5	Great	»	Ordinary	Medium	>	Low	Large	High *3	II (Minor)
Epigean insects	1/5	Great	»	Ordinary	Small	≥	Low	Large	High	II (Medium)
Epigean insects	1/5	Great	»	Ordinary	Small	≥	Low	Medium	High	III (Medium)
Scalesia	2/5	Low	<	Strong	Small	≤	High	Small	-	IV (Major)
Guava	2/5	Great	»	Weak	Small	>	0	Large	-	II (Minor)

a) Temporarily determined on the presumption that 4/5 of the ground of the afflicted area was burnt with the survival rate based on migration potency (in the case of plants, those having escaped the fire) taken into account; numbers mean the percentage to the population having existed in the afflicted area.
(b) Judged to be "Medium" for vertebrates and "Great" for invertebrates; relatively determined for competitive species of the plant.
(c) "Weak (=low)" for endemic vertebrates without exotic predators or competitors, "Strong (=high)" for those with exotic predators and competitors, "Ordinary (=medium)" when it is not certain whether they have predators or competitors, and for invertebrates.
(d) With the migration potency of individuals and the dispersion potency of seeds integrated.
(e) "Low" when animals inhabit a wide area in a relatively large number, "Medium" when they inhabit a wide area, but at relatively low or unknown density, "High" when there exist a plural number of isolated populations in the Islands, "∞" when there are no other populations (nor measures to cross the sea), and "0" when they inhabit a wide area at high density.
(f) The size of the closest population; generally "Large" for invertebrates, "Medium" for animals of an unknown group.
(g) Item especially intended for animal groups; "High" when animals can inhabit at considerably earlier stage than the time when the environment (=vegetation) is restored to the state at the time of affliction, "Medium" when they cannot inhabit unless it becomes similar to that at the time of affliction, "Low" when they cannot inhabit except in the former state of vegetation.

*1 On condition that habitats are included in the afflicted area.
*2 The same as above.
*3 The possibility of peculiar adaptation to endemic plant species is not considered.

2. Suggestions for coping with a future outbreak of fire

1) Forecast for the risk of outbreak of fire

We collected factors in a fire and issues of fire prevention as shown in Fig. 17. First of all, we can mention that there are some direct factors and indirect factors in a fire. As direct factors, volcanic activity (eruption, extravasation of lava) and an accidental fire caused by man can be mentioned. Judging from circumstances, there is not much doubt that disasters both in 1985 and this time were caused by accidental fires. It is hard to prevent volcanic factors, however, an accidental fire could be prevented in some degree with inhabitants' everyday educational movement, intensive patrols, and so forth.

As indirect factors, we can mention long-term arid conditions. Fundamentally speaking, cloud forest does not catch fire easily and we can assume that it does not burn easily unless unusually arid weather lasts. Both in 1985 and this time, the main reason for the outbreak of those fires was that there was not much rainfall and thus the drought continued long. Also, according to a research into forest fires in Japan, the very day after a long drought, which is especially hot, arid, and windy, is pointed out as a day when a fire would be most likely to happen. As we can obtain such data by continuously making meteorological observations, it is necessary to organize a network of such meteorological observations. Whenever any condition of combustibility is indicated, we can prevent a fire by issuing a warning to inhabitants, strengthening patrols, and so forth.

Another indirect factor is accumulation of organic matter which could be fuel for a fire. It is indicated that the damage from the fire in 1985 became serious due to increase of organic matter. Much rain caused by El Niáo had greatly stimulated vegetation and produced such fuel. It is also possible for us to monitor such accumulation of organic matter. If we equip fixed plots at certain points and keep measuring the amount of organic matter, we will be able to forecast the scale (burnability) of fire and put it to good use for prevention.

In case of fire, early detection and early fire-extinguishing are important. For that, inhabitants' cooperation in reporting and emergency fire fighting are indispensable. However, when a fire is unfortunately spread, fire fighting should be undertaken rapidly and for that, we must not neglect advance preparations. As one of these preparations, we can mention practical fire fighting matters, such as fire-extinguishing equipment, camping goods, storing of foodstuffs and water, rapid transportation and arrangement of heavy machines and personnel, cooperative system among the authorities concerned in Ecuador (coordination of command system, unification of information), requests for international cooperation, organizing the emergency refuge system for wild animals. Also, another preparation, we must previously clarify what we should protect first. We should protect residential areas, farmland and pastureland, habitats of elephant tortoise and land iguana, and so on from the spread of fire. Also, at the same time, as the first priority, we must protect the area where the Galápagos's native ecosystems remain. In order to do so, we have to clearly grasp in advance where those areas are located. If those preparations would be completed, we can make an effective plan for establishing a firebreak and also conduct rapid fire-fighting.

As for the fire-fighting of this time, the establishment of the firebreak worked effectually for the control of the fire, however, we can point out following problems also. First, at the time of establishing the firebreak, species to be cut down were not decided, and in some case, indigenous species which should have been conserved such as Scalesia were cut over along with other woods. In addition, such wide open space promoted luxuriant growth of guajava and that probably made feral livestock penetrate into backwoods easily. There is a report that the firebreak which was established in 1985 and has been left alone since then reproduced

guajava and now it is hard to tell the border with surrounding woods of guajava. Furthermore, the firebreak became a pass which makes it possible for people to access this area often, and this may cause some bad effect on nature.

The present policy is that we leave such firebreaks as is and let nature restore and still utilize the part of the firebreak for the future prevention of fires. But, considering the above issues, we have to review the clearance of such firebreaks. According to circumstances, we may also consider planting seeds of Scalesia for protection and expansion of the Scalesia forest.

Lastly, after extinguishing, we should estimate the effect of the fire on nature scientifically and in order to examine more effective countermeasures against future fires, we need to conduct monitoring research on the restoration process of flora and fauna in the burnt area. It is desirable that we establish fixed plots at the site and periodically observe and measure them. Also, aerial photos taken every 5 or 10 years would be very useful for research on the restoration process in a wide area. In addition, to look at changes on the whole, the use of satellite photos will be also effective. According to future considerations, it is possible to actively promote the project to protect and increase Scalesia forest by utilizing burnt sites.

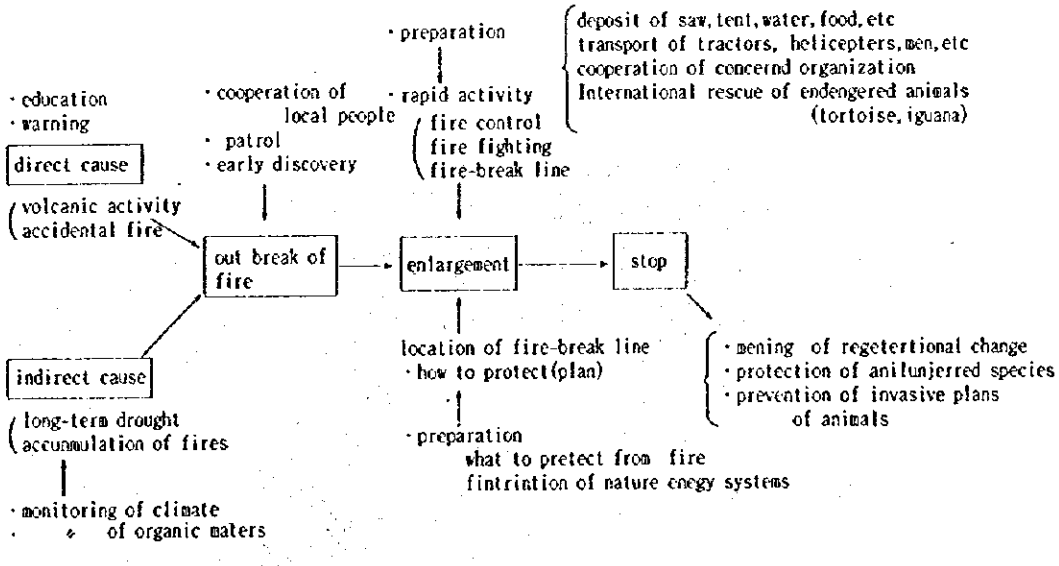


Fig. 17 Factors of fire and prevention of disasters

2) Determination of priority of fire-prevention and fire-fighting and a plan for conservation by areas

This time, with research on higher plants, birds and reptiles, it is assumed that when compared to Scalesia forest, Guajava forest is scientifically less worthy. For the future, it is necessary to conduct research on lower plants, insects, land shellfish, soil creatures, etc. to study scientific details of Guajava forest more minutely, and also necessary to evaluate Guajava forest among the nature of the whole Galápagos. Taking all of these into account, we should review how to cope with fire. Even though we postpone fire-fighting against Guajava forest, we should concentrate equipment and personnel on important places to be protected in the case that scientific status of Guajava forest is evaluated lower.

Although sometimes it depends on a shift of wind, a fire generally tends to crawl up a slanting surface. It is assumed that the fire this time also broke out at the lower part of Scalesia zone and crawled up a slanting surface, then spread all over. At the lower part of the Scalesia zone there are a semi-arid zone and an arid zone, where it is always dry and catches fire easily. At an area where lava is exposed, there are some openings between individual plants, and this structure prevents the easy spread of a fire, however, many other places are thickly grown with shrubs and the possibility of spread is potentially high. The arid zone is adjacent to a residential area on the coast, therefore, this area, for the future, should be protected against fire as well as the Scalesia zone.

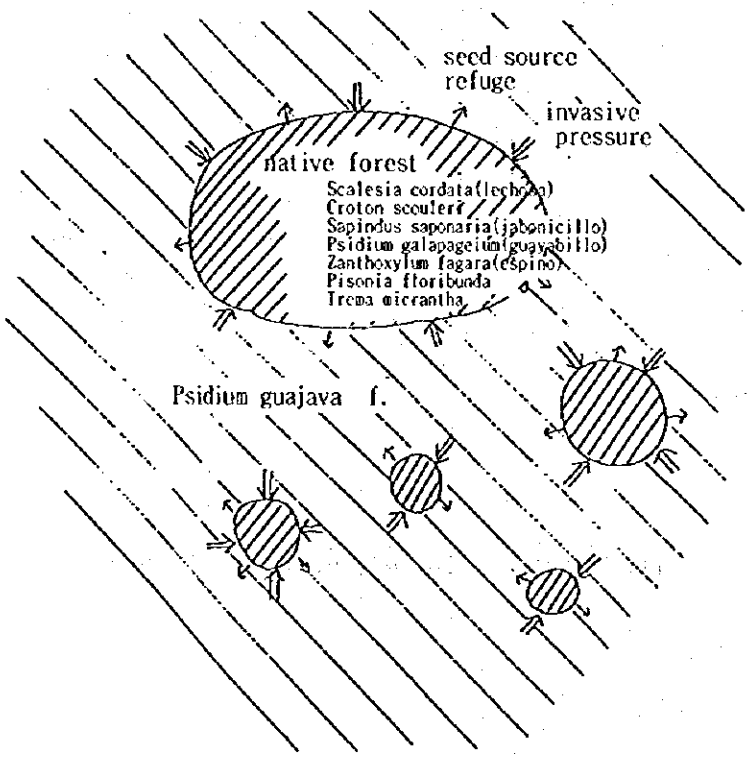


Fig.18 Conceptual chart of the distribution of relic Scalesia forest

Fortunately, the fire this time damaged mainly the Guajava forest, which is a introduced species, and did not reach the habitat of the elephant tortoise. Also, the time was not a breeding season for birds. Therefore, we can assume that the effect on native creatures in the Galápagos was not so serious. However, in the afflicted area, relics including Scalesia and some other native species lie sporadically. Fig. 18 shows the relation between Guajava forest and relic Scalesia forest at the burnt area typically. Relic Scalesia forest which lies scattered in Guajava forest becomes a refuge for native species and has an important meaning as a base for advancing again into surroundings. In that case, the larger relics hold more kinds of plants and animals and can exhibit desirable attributes.

We may say that the fire this time will reduce further the size of relics. If we let it alone, such relics will also disappear someday, therefore, we have to make the geographic distribution of relics in this area clear and prepare for future fires. To know the distribution of relics, reading aerial photos should be effective. We have to arrange firebreaks in order to conserve such relics and also be careful not to cut over these relics to establishing firebreaks in any way.

Lastly, we would like to emphasize that the most valuable matter for protecting nature in the Galápagos, which we should protect with first priority, is the Galápagos Islands' native ecosystem (Fig. 19). Indeed, to conserve rare species such as the elephant tortoise and the *Scalesia cordata*, which are on the way to extinction, should be appreciated as only a symbol of conservation. The most important matter is to protect the whole environment where the elephant tortoise or the *Scalesia cordata* can survive along with other coexisting animals and plants. In the native ecosystem, various creatures are connected each other with a unique partnership which in the world can be seen only in the Galápagos. It is important to protect the whole ecosystem without ruining this relationship. In this sense, the invasion of alien plants and animals must be checked and the ones which have already invaded should be excluded as much as possible by our efforts.

If a map (the whole of the Galápagos) which indicates where and how much the native ecosystem remains today is available, it is useful to consider the future conservation of nature.

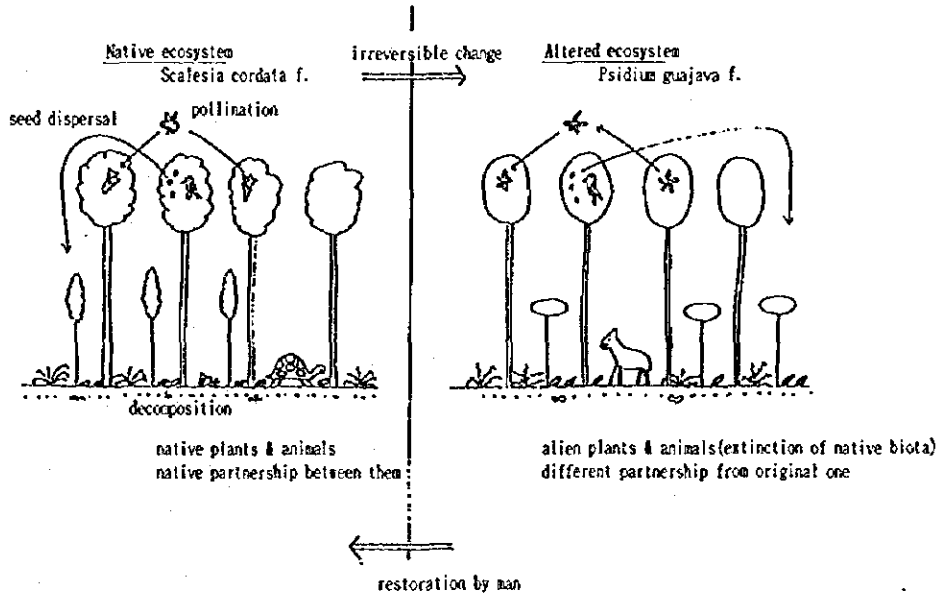


Fig. 19 Native ecosystem in the Galápagos and altered ecosystem

3) Propagation and enlightenment on fire prevention

We mostly consider that the fire of this time was caused not by natural phenomenon but by man. Furthermore, judging from the point where the fire broke out, the fire was most likely an accidental fire caused by a hunter who was hunting feral livestock.

The coast where the residential area lies is arid zone, and plants are sparsely grown. Also, on the ground, there is not an accumulation of fallen leaves or fernery leaves which become fuel. Therefore, even if a fire breaks out, the risk of spreading is almost zero and we cannot expect much of an effect even if we ask people, who are within the sphere of the residential area, to cooperate in fire prevention. People whom we should ask for cooperation may be farm workers who live in settlement areas and have a great potential at times to get into the park area.

Concerning those farm workers, to propagate and enlighten them about fire prevention is necessary, as a matter of course, but it would be more effective to positively involve them into the conservation system.

With regard to stamping out feral livestock which have spread within the park area, we should allow them not only for hunting purposes, but also for other benefits. We have to enlighten them that the extermination is profitable and that grazing cattle, on the other hand, can cause destruction of nature; then, we should appoint, for example, "Eliminators of feral livestock and fire guards", and make the most of this system.

3. Suggestion about conservation of nature in Isabela Island

1) Special characteristics when considering conservation of nature in Isabela Island

With our research this time, we could observe not only burnt sites in the Isabela Island but also other environments of this island and also partial circumstances of other islands. And we recognized that a fire is an important factor but only one of the effects on the indigenous nature of the Galápagos Islands and it is necessary for us to consider fire prevention from the standpoint of the whole of Isabela Is.'s conservation.

The nature of the Galápagos is composed of several taxa of which ancestors had a chance to reach these volcanic islands which appeared in the Pacific Ocean, 1,000 km away from South America and have accomplished adaptive radiation after a long period of several million years.

But, for these several hundred years, nature has been threatened by man's intervention - the slaughter of the elephant tortoise, bringing in and spreading of cattle and other plants /animals along with domiciliation.

Right after its designation as a national park, the Ecuadorian Government established CDRS and SPNG as its main operating organizations, and has conducted conservation and restoration of surviving nature mainly through control of alien creatures and artificial breeding / increase endemic threatened species. Extermination of feral livestock started from smaller islands and they have achieved dramatic success, however, in larger islands where people have settled down, they get behind in realization. The reason for that is in those larger islands, to carry out the extermination plan costs a lot of money and labor compared to the case of smaller islands. Also, there is the problem that the livestock which inhabitants keep acts as a potential supply source, and that makes the effect of such a extermination plan trivial.

Human activities including "eco-tours" are allowed under strict control, however, it is very difficult to realize conservation of nature without the understanding and cooperation of the inhabitants in islands where people have settled.

Considering that Isabela Island is an aggregate of some volcanic islands and they are ecologically isolated by coulees, and people have settled down there, and its vegetation has been replaced by alien plants over an extensive area and feral livestock extensively inhabit only the southern part, we may consider that the issue of the conservation of nature in the main land can be concluded in the southern part.

In this area, it is difficult to apply the means used in smaller uninhabited islands, that is a simple method of extermination of alien species, and we first have to recognize that it is necessary to adopt another approach.

2) Carrying out a countermeasure by steps in view of local residents and coexistence of alien creatures and primary nature

(1) Conservation of primary natural environment and ecosystem

First of all, judging from the viewpoint that we should not reduce primary nature any further, we need to strictly conserve primary natural environment which are becoming fragmentary.

In order to do so, it is necessary to conduct research from the air and the ground and thoroughly mark the existence of surviving natural environment and designate them as reserves. When man threatens the object to be protected, it is possible to control the threat in some degree through propagation by designating reserves and establishing signs, however, in case creatures other than man threaten the object, a physical

barrier is needed to prevent their invasion.

As a physical barrier, we can think of a combination of a fence and a firebreak and in case the size of a reserve is several hundred hectares, it is not impossible to establish such a barrier. If the reserve is surrounded by Guajava forest, we should cut it over to function as a fire zone adjacent to a boundary and set up a fence outside to prevent the invasion of cattle or donkeys so that we may prevent the spread of seeds of guajava caused by those cattle and accelerate the advance of native species into this open space.

In case the object to be prevented is a small animal such as a pig, dog, or cat, according to its size, we have to change the size of the mesh of fences or the width of stockades. Also, in case of the elephant tortoise which moves to lay its eggs, we ought not to block their route with fences and so forth.

With regard to establishing reserves, without limiting them to Isabela Is., we also have to establish typical reserves on each island or in each vegetation zone all over the islands and with concentration on studies in respective fields we will be able to improve the efficiency of these studies and integrate the results of respective fields.

(2) Promote ecological study for conservation

On the second stage, as a base for planning a policy of conservation with a viewpoint of coexistence with alien creatures, we need to promote the ecological study of them.

Guajava took the place of Scalesia forest covering a wide area and it supplies fruit as feed among inhabiting feral livestock such as cattle and donkeys, and these animals eliminate and spread seeds with solid wastes. In this way, this biotic community built up the relationship that gives them mutual benefit and the community is given a position of dominant at the misty zone in the south of Isabela Island.

For this Guajava forest, which native plants and animals that used to adapt to the native Scalesia forest succeeded in its readaptation and which ones did not? It is necessary by efforts to eventually bring up the difference of both ecosystems' structure and function compared to the ecosystem of the native Scalesia forest.

Considering the result, for example, of whether we will restore it to the native vegetation or not, whether we will leave it alone or not, whether we positively use it or not- it is desirable to determine basic policies on how to treat those above subjects.

Also, it is necessary to grasp the size, the home range, and the breeding ratio with regard to feral livestock populations, and to prepare for the utilization or the enforcement of effective control.

Researchers in the Galápagos used to tend to have an interest as a matter of course in the remarkable native nature of these islands, however, from now on, we have to promote studies of certain fields where we still can find an absense of basic information such as invertebrate , and on the other hand, we should promote applied ecological and conserved biological research more and more with the aim of conservation of natural environment. These types of research and study need to involve specialists from various biologic groups and the project should not be a mere mixture but should be mutually cooperative.

Concerning research activities of CDRS which offer a scientific base for conservation of the Galápagos's nature, one of these activities is conducted by the institute itself and another one by permitted researchers from around the world. At the Galápagos Islands, which are blessed with unique and outstanding nature and interest to scientists of the world, we appreciate that the latter research system is excellent in

supplementing its research activities conducted by limited staff and budget and in bearing its educational effect on domestic students.

However, this system forces a considerable economic burden upon permitted visiting researchers, therefore, we may say that it is very difficult to induce respective researchers who hold their own research field other than conservation biology or restoration ecology to research activities in the field with an aim of conservation. In order to do so, we should make a plan for comprehensive research to provide a scientific base for a conservation policy. And, it is necessary to promote a research system that, on the condition that if they intend to share a part, they will be given facilities and lightening of their economic burden, we should collect researchers who join a concerned project.

(3) Planning and operation of Isabela Island's own conservation and utilization project

As the third step, we would rather say it should be promoted along with the second step, however, we develop planning and operation of Isabela Island's conservation and utilization project which treats the conservation of nature as the main subject.

At present, people are living there and immigration is not regulated. In this situation, if it moves as it is in Isabela Island, the permanent population is mounting steadily, agriculture-forestry-fishery development and tourist development are advancing gradually, and along with it, expectations and requests for construction of infrastructure will increase among residents.

Regulation of human activities in the Galápagos Islands is based on the fact that settlement and production are limited to a certain area; however, as mentioned earlier, it is difficult to effectively confine either man or creatures only by an ideal barrier such as zoning of area.

In Isabela Island, the increase in the permanent population in the residential area, if we leave it, will cause the enlargement of drainage and waste and produce burdens mainly on the coast and the littoral area. And it will also threaten marine and coastal animals such as the sea lion, the sea turtle, and the sea iguana and an increase in activities at the settlement will cause the spread of alien plants and the increase of feral livestock.

So far as we can anticipate such a situation, it would be prudent to take some action as soon as possible in order to prevent it. In this case, it is desirable to consider whether the residential areas should be maintained as an isolated closed system from nature of the island as far as possible, that is to say, we let the supply of food basically depend on outside the island and the treatment of drainage and waste not involve the cycle of nature, or as an open system where human life assimilate into the cycle of nature. Environmental pollution arose from our life style where we obtain food, water, energy, etc. from a far distant place and drain discharge wastes within our surroundings.

Now, as this island depends on rainwater in natural condition, it is quite difficult by the latter system to afford water to only the present population and the establishment of a complete cyclic system needs extraordinary technique experimented with only in Biosphere projects on a small scale at present.

Therefore, it is more realistic to reach a "hybrid" conclusion that we should rapidly grasp the environmental capacity and sustainability and in order not to exceed them, we socially and technically control output as much as possible. If the limit of the burden to the environment is prescribed, the population-carrying capacity will be determined as a matter of course and if we try to enlarge such capacity, we have to

reduce the burden.

Rational and scientific calculation of environmental capacity will be realized by comprehensive research and study. At present, it is necessary to establish a provisional criterion, even if it holds some arbitrariness, and in order to achieve such a criterion make a blueprint for the local community such as a local conservation management project.

On the other hand, it is desirable that systematic research and study will advance in order to scientifically calculate the environmental capacity, to farm in misty zones and to establish a rational control policy, and also the result of those will be fed back to the conservation management project.

(4) System to carry out the project

The national park system, which acts in a leading role for the conservation of the Galápagos Islands' nature, takes the measure that excludes man's residential area and farming area from its formation, however, in order to plan a local conservation and utilization project involving human activities suggested in clause (3) and then carry it out, we have to involve the part which has been excluded also. To do so, cooperation with administrative offices concerned (ex. INGALA: Institute of Galápagos) in the part related to inhabitants' life.

(5) Necessity of creating incentives to realize the project

To realize all kinds of policies, as long as human life is involved with them, understanding and agreement of all concerned are indispensable. In case of Isabela island, we have to show the effect obtained by the conservation of nature, or incentive, along with promoting an understanding of the importance of this island's nature, that is,environmental education. In the case of the Galápagos, they made a considerable success in "eco-tourism" and also in Isabela Island, it might be difficult to find an incentive other than that. In this case, it may be a good idea to endeavor to gain tourists' attention to plants, especially Scalesia species, which is ecologically, or evolutionarily, just as important as the elephant tortoise while they are not so conspicuous neither atractive.

We are deeply impressed by Isabela's conservation of Scalsia forest which is very small, and the practice of activities on environmental education utilizing the forest. It must be largely effective that they will systematically exhibit Scalsia group which have evolved in various ways and also will combine the development facilities and the explanation facilities.

VI Organization of ODA of JAPAN and the future possibility of cooperation

IV

1. JICA's scheme that is applicable to assistance to conservation of the Galápagos' nature

In order to support developing countries' economic development and welfare improvement, the Japanese Government conducts Official Development Assistance (ODA) which is organized with 3 functions of (1) donation between two nations, (2) lending between two nations, (3) investment and contribution to international organizations. Japan International Cooperation Agency (JICA) is in charge of investigation/ facilitation of the operation of technical cooperation and financing cooperation by free gifts which holds the most part of donations between two nations. 6 members of the research group of this time are dispatched from the Dispatch Project Department of JICA as short-term specialists.
In order to contribute to the conservation of nature in the Galápagos, JICA will be able to utilize the following scheme.

1) Dispatch long-term specialists:

A specialist who is dispatched for one year or more is called a long-term specialist (usually his term of service is 2 or 3 years) and dispatched for the purpose of advising technical experts of the Government authorities (in case of Ecuador, INEFAN, SPNG, etc.) and transferring technique. If necessary, it is possible to furnish equipment (single equipment furnishing) in the sum of about 50 million yen linking with the dispatch.

2) Project type technical cooperation

This is also technical cooperation given by long-term specialists as 1). A team formed by several specialists is dispatched to the party and the amount of equipment to be furnished is quite extensive. According to Record of Discussions(R/D) which states subjects of discussions about the purpose, transferred technique, items conducted by both Japan and the other party, this type of technical cooperation is carried on. Training in Japan is also given to technical staff of the party's government office concerned. Usually, for 5 years, 3-5 specialists, equipment worth 100-200 million yen, training in Japan: about 5-6 persons.

3) Development investigation

To cooperate in making a public development plan, dispatch an investigation team formed mainly by consultants and blueprint a development plan.

4) Dispatch of members of Japan Overseas Cooperation Volunteers

Living and working together with local people, for the purpose of making a contribution toward social and economic development of the area along with putting individual techniques to practical use, members of JOCV are dispatched according to the volunteer spirit for 2 years. For example, belonging to an office of the National Park, a member engages in managing and investigating plants and animals native to the Galápagos. This may be considered as an example.

All schemes such as those above will be carried on after the Ministry of Foreign Affairs, JICA and other authorities concerned discuss and determine the necessity and feasibility according to the request of the Government.

2. Japan's way to cooperate with the conservation of the Galápagos Islands' nature with the view of international cooperative relationship

International cooperation to the Galápagos in checking the advance of nature destruction and to restore the nature has been started with Dr's study and its report and request to IUCN according to the study. Then, the fruit of their efforts has been produced with the establishment of the Charles Darwin Institute and now is our day. It is not too much to say that the international network of scientists with the Institute as the central figure and system and result of research and study have given a determination to us of decision making and enforcement for the conservation and management of the nature of the Galápagos.

Therefore, even though the Galápagos Islands belongs to the territory of Ecuador, conservation management of its nature is under international cooperation and supervision. On the other hand, a few researchers from Japan are involved only with study at the individual level and the management of CDRS, therefore, it is notable that our involvement with international cooperation system is behind.

When Japan is going to contribute to the conservation of the Galápagos nature, the buildup and repletion of research and study, we must do so in the framework of an already-established international cooperation system which has a history and has obtained great results and performance.

Considering the limitation of the ODA scheme in Japan and the above circumstances, the most realistic way is to position CDRS as a partner of the Japanese side and to accept CDRS's suggestions and requests, to start the JICA scheme cooperating with a counterpart on Ecuador's side.

3. The feasibility of future cooperation

With regard to concrete subjects on cooperative projects for conservation of the Galápagos Islands' nature, assuming that we treat CDRS as our partner, we will suggest the following. The contents of the following part do not reflect the official view of JICA but merely that of the members of the Group of Experts.

1) Conduct ecological research for conservation of the nature of Isabela Island.

(1) Necessity

We can say that Isabela Island, the largest one in the whole island group, is an island which holds the most serious issues in view of the conservation of nature because large-sized fires happened twice including the one this time, which was obviously caused by man, and by artificial effects piling up, an ecosystem that introduced species dominate native species can be seen over a wide area, and is still vigorously spreading. The island holds a tendency that the number of both inhabitants and visitors is increasing. In order to solve those issues, as suggested earlier, a comprehensive ecological research and study with the purpose of conservation is sought after.

We can say that the SPNG/CDRS system, which can realize conservation management on the basis of scientific research and study, is ideal in view of the management of a national park, however, neither the budget nor the staff is sufficient, and at this present stage, we think it is not ready for seriously coping with Isabela Island's issues to be solved.

In the field of research / study, a balance of budget and staff is important and this tendency is remarkable in the field of conservation of nature which holds field research, in particular, as a main subject. As mentioned in our suggestion, considering a number of potential research staff from all over the world who are interested in the Galápagos, if the fund is enough, it should be possible to organize a research /study project team with the aim of conservation which CDRS itself holds up. However, as this project should be realized by donation or contribution to CDRS, it is difficult to say how things will turn out, and therefore, a scheme of dispatching JICA specialists is considered appropriate as a more positive way.

(2) Formation of a specialist team to be dispatched

Concerning the scheme of dispatching JICA specialists, if short-term specialists are combined, the same project will be realized earlier by itself. In other words, 1 or 2 long-term specialists, who conduct planning of the whole program of research and study taking into account the planning of conservation/utilization program, and coordinate, manage and adjust the enforcement of research based on the above planning, will be combined with a investigation team formed by short-term specialists.

As a matter of course, the said operation should be conducted under close tie-up with SPNG/CDRS.

The reason that we put short-term specialists into the core of the investigation team, their specialties are various, and even if we try to get long-term specialists in respective fields from universities or other institutes, we might get only a few staff because most of them cannot respond to our request of a long visit because of limitation of their own study or business schedule. On the other hand, if their term is as short as 2-3 months or a half year, we can expect a number of leading researchers to join the project and we will be able to form a sufficient team to realize comprehensive research and study.

Long-term specialists take charge of making this project, coordinating with the authorities concetned of the other party to realize the project, managing and completing actual research and advancing to the next step. In this case, it is desirable to make the combination, such as an administrative official in the nature-conservation field and a younger researcher who intends to learn conservation biology or a researcher of the same rank at a private institute. If a cooperative relationship with counterpart of the other is established enough and good communication can be made, it may be possible for short-term specialists to treat with this.

As for the specialties of short-term specialists, we can mention the following:

Plant ecology
Plant taxonomy (vascular plant, mosses, lichen)
Animal ecology (mammal, birds, reptiles, insects)
Animal taxonomy (small mammal, reptiles, insects, other arthropod, soil animals, mollusk)
Ocean zoology (fishes, crustacean)
Topography, Geology, Pedology
Climate, Meteorology
Environmental education, museology

Appointment of these specialists can be appropriately done through the specialist network which the Environmental Agency holds.

(3) Equipment needed for investigation

At investigation, we need transportation on the scene and a base, and equipment for investigation. To be concrete, as transportation, we can suggest 4-wheel vehicles which make it possible to travel (extremely) off-road (the ultimate way may be by donkey, horse or foot), and as an investigation base, we might need a hut where we can cook simply, stay, and do some easy work.

In addition to these, if we are able to supply SPNG/CDRS an investigation ship which functions as sleeping accommodations, field experiment facilities, after consideration of the difficulty of access to Isabela Island and the necessity of visits to other islands for comparative investigation, research and study of the Galápagos Islands and conservation of nature will make rapid progress. As we saw distinctly at the fire this time, a helicopter worked very well for investigation and transportation of personnel, equipment and also elephant tortoises. But, to possess one on the scene will be difficult in maintaining and managing. Therefore, it should be appropriate to charter one when necessary.

(4) The result expected

(a) Contribution to the basic study of the Galápagos Islands' nature

By committing leading researchers to the field where so far no good chance has been given to carry out an investigation, we can expect the discovery of many new facts and anticipate that they will largely contribute to explicate the ecosystem of Isabela Island on the level of a basic study.

(b) Basic data for planning conservation/utilization program

The result which comes from research and study conducted with keeping close tie-ups under a unified aim (conservation of Isabela Island's nature) will be expected to be utilized as basic data when we

conduct planning of a conservation/utilization program which sufficiently reflects natural and social conditions of Isabela Island.

(c) Feasibility of establishment of techniques for restoration of the native ecosystem

In this research and study, mechanisms of vegetation renewal and competitive mechanisms in the process are also its subject and there is some possibility to find a technique whereby we can control alien vegetation and restore native vegetation through them; if the technique is established, construction of vegetation restoration facilities should be realized.

(d) Training the staff of the party

At the on-site investigation, it is desirable to have a support of counterpart staff. In this case, a technical staff who are given certain education can master techniques to investigate, make samples, supplement, exhibit, make reports and so on in assistance of research and study.

(e) Contribution to environmental education

In order to effectively realize the conservation of nature, the inhabitants' understanding and cooperation are indispensable and it is recognized that environmental education is the most effective means to do so. However, facilities, equipment, software, etc. are not sufficient in the Galápagos, especially Isabela Island.

From the result of this research and study, much available information and a number of exhibits are derived. In view of the necessity of environmental education, by involving persons who are experienced in environmental education or museology from an early stage, we can expect to make a systematic and effective exhibition program. Also, we have to consider the arrangement of exhibition facilities which hold field practice/experiment facilities along with vegetation restoration facilities (c.)

2) The future prospects

(1) Involvement and cooperation in conservation policy of wider range

In the Galápagos Islands, it is likely that their understanding that they have to conduct comprehensive conservation including management of permanent residents' activities as well as the management of the national park, is getting stronger.

Even if it is realized, the existing key note that conservation of Galápagos's nature has priority will be maintained firmly. If we seek to maintain residents' standard of living by sticking to the policy, we must carefully consider the native environment in the enforcement of every measure. In this case, we will be strongly demanded to transfer our advanced technique from environmental assessment to construction of infrastructure. If research and study for conservation of native environment is steadily conducted prior to this, and if we, Japan play a leading role in the operation, we will be able to contribute a lot while making the maximum use of our experience and result.

(2) Contribution to the establishment of the Pacific network of islands ecology study organization

Islands in the ocean isolated far from a continent such as the Galápagos, Hawaii and the Ogasawara Islands are all unique in the evolutionary aspect and their ecosystems are very fragile. Therefore, careful measures for conservation should have been taken, however, in the history of past settlement, people did not pay attention to it and precious nature which we should call the heritage of human being vanished or almost did.

The above 3 islands are situated in between the equator and 27' North Latitude and hold a position respectively in the east, the center, and the west of the Pacific Ocean, and all more or less experienced destruction by man. At present, most or part of them are designated as national parks under the systems of each country to be conserved.

An "island" is an isolated ecosystem surrounded by sea and each has a different characteristic, by size, distance from land or other islands, time isolated, etc., and has become a very important subject in the field of study. In these days, even in a mainland, an isolated ecosystem caused by environmental development can be seen often (ecological islands), and island ecology is becoming significant in the field of the conservation of nature.

Broadly speaking, Japan, in particular, itself is an archipelago which is composed of thousands of islands. The importance of native scientific knowledge about islands is very large in every aspect besides conservation of nature. However, though in the Galápagos, Charles Darwin Institute, and in Hawaii, Bishop Museum, each has been established as a investigation base of biology of the island and attracts researchers from all over the world, in Ogasawara, we don't have such institute. Even though only 20 years have passed since retrocession by the U.S., we cannot deny our backwardness. Realization of cooperation for conservation of the Galápagos Island depends on the future measures to be taken. We can promote the development of personnel, internationalization of research/ study fields, arrangement of study bases and maybe get a great chance to sweep out our backwardness.

With regard to internationalization, we can start by making the Ogasawara Islands one of the training places for our practice of technical cooperation. Further development depends on whether facilities are arranged or not. If training facilities of JICA, the wild life center of the Environment Agency, research facilities affiliated with Tokyo Metropolitan University, or either one of them is arranged, initial steps of establishing the Pacific network of islands conservation ecology research organization will be taken through operation of JICA project.

At this stage, it would be one line crossing the Pacific rather than a network, however, at the next stage, the circum-pan-Pacific network will be formed including Okinawa, Iriomote, Micronesia, New Zealand, etc..

JICA