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N O U V E L L E S   D E S   G A L A P A G O S

Publicado por

la

FUNDACION CHARLES DARWIN PARA LAS ISLAS GALAPAGOS

Creada bajo los auspicios de la UNESCO

Con ayuda económica de la Organización de las Naciones Unidas
para la Educación, la Ciencia y la Cultura (UNESCO)

N° 11 Abril de 1.968

N O T I C I A S   D E   G A L A P A G O S ,   N° 11

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NOTICIAS DE GALAPAGOS - 1 rue Ducale, BRUXELLES-1, Belgium.

OBSERVACIONES SOBRE LAS AVES FRAGATAS, *Fregata minor* Y *Fregata magnificens* EN LAS ISLAS GALAPAGOS

por

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La Coexistencia de las Dos Especies en el Archipiélago

El Archipiélago de Galápagos ha venido a ser un laboratorio natural para el estudio de la presión selectiva sobre poblaciones que han colonizado nuevas áreas y sobre especies emparentadas, ocupando nichos ecológicos similares. Las aves marinas han ofrecido menos oportunidades para un estudio productivo que las dadas por los pinzones de Darwin y otras aves terrestres. Varias especies son peculiares de las Galápagos; otras están representadas por razas locales. En general, sin embargo, las relaciones ecológicas entre aves marinas están bien establecidas. Las tres especies de petreles de tempestad de la subfamilia Hydrobatinae que residen en el archipiélago se conocen muy poco; sin embargo, las dos especies de fardelas, *Pterodroma phaeopygia* y *Puffinus lherminieri*, están bien separadas con respecto a la nidificación. De igual modo, diferencias en modo de alimentación y nidificación permiten que los piqueros *Sula sula*, *S. dactylatra* y *S. nebouxii* puedan coexistir en el archipiélago. Además, la coexistencia de todas estas especies no se encuentra sólo en las Galápagos.

Sin embargo, las dos especies de aves fragatas *Fregata minor* y *Fregata magnificens* (también conocidas como tijeretas o rabihorcados) se encuentran juntas sólo en las Galápagos. Su ecología es tan similar que cuando se realizó la expedición de la Academia de Ciencias de California a comienzos de este siglo, las dos especies no fueron distinguidas.[1] Las características que les han permitido vivir juntas, por lo mismo, están por ser determinadas. De aún mayor interés es el problema de si estas características de ecología y comportamiento también están presentes en otras partes de la distribución de estas especies, o si han sido influenciadas por presiones selectivas resultantes de una interacción o "competencia" después de un contacto secundario entre las dos especies en las Galápagos.

La danza nupcial del ave fragata macho es una de las más espectaculares que se encuentran en las aves. Con un saco inflable grande y rojo en la garganta, con gorjeos musicales, con plumas iridiscentes y con aleteos, el macho trata de atraer a la hembra. En esta danza el rasgo principal es el saco rojo en la garganta. Aunque algunas especies de cuervos marinos (cormoranes) tienen sacos gulares de color; que se usan en danzas nupciales, ninguna otra ave pelecaniforme los tiene tan desarrollados como la fragata. Evidentemente, éstos son una "palabra" importante en el lenguaje de la especie, por la cual un individuo se comunica con su pareja, con otras fragatas, y con otras especies.

Se hicieron observaciones en las Galápagos en 1962 y comienzos de 1963. El autor pasó cuatro días en Genovesa en la última parte de noviembre, dos semanas y media en Española en diciembre, seis semanas en Genovesa en enero y febrero, y ocho días en Seymour en la última parte de febrero. Debido a varias circunstancias este estudio no ha podido ser completado con un nuevo viaje a las Galápagos. Por lo mismo, el presente trabajo deberá ser considerado como preliminar.

Quiero particularmente hacer llegar mis gracias a los Drs. Ernst Mayr, André Brosset y David Snow y a los Srs. Edgar Pots y Jeremy Hatch por su asistencia. Una parte del apoyo financiero para el estudio vino del fondo Chapman, del American Museum of Natural History en la ciudad de Nueva York, y de la sociedad Sigma Xi. Además, agradezco al Sr. Fernando Ortiz-Crespo y a la Srta. Consuelo Butler por su ayuda en la traducción de este artículo.

Las cinco especies existentes de aves fragatas son notablemente similares en su morfología y se distinguen principalmente en su tamaño y en ligeros cambios de coloración. Todas parasitizan otras aves marinas, en especial piqueros, que las fragatas persiguen y obligan a regurgitar el alimento, pero son también capaces de obtener su propio alimento. En varias áreas del mundo dos especies de fragata también coexisten en cercana vecindad : en Trinidad del Sur, en el Atlántico, y en Aldabra en el Océano Indico *F. minor* se encuentran con *F. ariel*. En la Isla de Navidad en el Océano Indico *F. minor* ocurre junto con *F. andrewsi*. *F. minor* es más grande que *ariel* pero es casi del mismo tamaño que *andrewsi* y más pequeña que *magnificens*, con la cual está presente en las Galápagos.

F. magnificens se encuentra en el Caribe, las Islas del Cabo Verde, la costa Atlántica del Africa y la costa Americana del Pacífico tropical. Las aves fragatas do esta especie en las Galápagos, como el pelícano café, el flamenco, y otras especies han venido evidentemente del Oriente. *F. minor* se halla alrededor del mundo en mares tropicales, pero las poblaciones más cercanas a las Galápagos se encuentran al oeste y al norte.

Las poblaciones de ambas especies en las Galápagos son clasificadas actualmente como subespecies diferentes de las del resto del mundo.[2] *F.m. magnificens* de las Galápagos es más grande que las aves del continente, y Murphy considera que esta raza es válida. El mismo autor ha indicado que la raza de Galápagos *F. minor ridgwayi* no está bien definida. Es importante que se estudie de nuevo la validez de ambas subespecies. Si ambas están bien definidas, las especies evidentemente han vivido juntas por un tiempo considerable. Una comparación detallada de las aves de las Galápagos con las poblaciones de *F. magnificens* residentes en la costa del continente y de *minor* en otras islas del Pacífico arrojaría mucha luz sobre su coexistencia ecológica. De esta manera sería posible determinar si las razas locales han evolucionado de manera que la competencia entre ellas se haya reducido.

Ambas especies están distribuidas en todo el archipiélago.[3,4] Lévêque cuenta cuatro colonias de _magnificens_ en Genovesa, Daphne, Seymour, y Bahía Elizabeth (Isabela). La mayor de estas colonias es la de Bahía Elizabeth que tiene de 150 a 200 parejas.[3] Una población total en Genovesa de cerca de 100 parejas fue estimada en febrero de 1963. Genovesa es la única isla donde ambas especies han sido halladas nidificando. _F. minor_ es mucho más numerosa : Lévêque cuenta nueve colonias y otras dos áreas de probable nidificación. El estima que es cinco veces más numerosa que _magnificens_. Grandes colonias de cerca de mil parejas se encuentran en Genovesa y Wolf.

Se ha sugerido que diferencias en el período de reproducción podrían reducir la competencia entre las dos especies. Las observaciones de Lévêque parecen sugerir que _magnificens_ anida más tarde que _minor_. Durante las visitas del autor a Genovesa, Española y Seymour no se hicieron observaciones que permitiesen suponer que el tiempo de reproducción es un factor importante en las relaciones interspecíficas. Machos de _magnificens_ en celo, huevos y jóvenes de toda edad estaban presentes en Genovesa a fines de noviembre, en enero y febrero y en Seymour a fines de febrero. Estas observaciones, consideradas juntas a las de Lévêque y Brosset, muestran que la reproducción de esta especie es continua durante el año. No hubieron machos de _minor_ en celo, ni huevos o jóvenes en plumón de esta especie en Genovesa a fines de noviembre, ni se encontraron huevos o jóvenes en plumón en Española en diciembre. El período de reproducción, sin embargo, es largo. Individuos jóvenes estaban todavía siendo alimentados por adultos en Española en diciembre y en Genovesa en febrero. _F. minor_ por lo mismo tiene un ciclo reproductivo y durante una proción del año permanece sin demostrar actividades reproductivas. Los ciclos, sin embargo, no son necesariamente uniformes de isla en isla. Danzas nupciales eran muy frecuentes en Española en diciembre, y tanto formación de parejas como copulación se observaron. Actividades comparables no aparecieron en Genovesa hasta febrero. Puesto que los pescadores locales eran de la opinión de que cada año en febrero se ven danzas nupciales en Genovesa, el ciclo parece ser anual, con el comienzo asociado con los primeros días de tiempo despejado.

Existe una correlación entre la presencia o ausencia de un ciclo reproductivo y el comportamiento de los machos danzantes. Todos los machos danzantes de _magnificens_ observados eran solitarios. Las danzas de _minor_, sin embargo, son más comunales; casi siempre los machos se encuentran en grupos. Un macho danzante solitario atrae a otros machos a la vecinidad, que también empiezan a danzar, aunque frecuentemente con menos intensidad. También machos juveniles, todavía con algunas plumas blancas, toman parte en las danzas con movimientos de la cabeza similares a los de los adultos. Invariablemente un observador juvenil estaba presente en las danzas de _minor_. La tendencia de danzar juntos se correlaciona entonces con la reproducción sincrónica de la especie.

Las dos especies están bien separadas en el sitio de los nidos. _F. minor_ invariablemente anida en matorrales bajos o en una elevación pequeña del suelo. Algunos nidos estaban solitarios o se encontraban en grupos dispersos, pero en Genovesa y Española la mayor parte estaban en colonias más grandes y mas compactas. En otras regiones de su distribución, _minor_ anida en árboles grandes,[5] en matorrales,[6] y en el suelo en la isleta Dom Pedro Segundo de las Islas Martín Vas, en el Océano Atlántico, donde no hay ni árboles ni matorrales.[7] _F. magnificens_ anida invariablemente encima del suelo, en _Opuntia_ en Daphne, en mangles u otros árboles en otras partes. La altura sobre el suelo puede ser hasta de un metro como mínimo. Ocasionalmente machos de _minor_ danzaban en arboles y al menos un par se constituyó y comenzó a construir un nido en el lugar de la danza, sobre un árbol. Machos danzantes fueron vistos en árboles a lo largo del borde del cráter de Genovesa pero no se sabe si se construyeron nidos allí. Si ésto sucedió, los nidos habrán estado immediatamente junto a varios nidos de _magnificens_. A corta distancia de dos nidos ocupados por _magnificens_ una hembra de _minor_ bajó hacia un macho danzante de su especie. Más tarde, sin embargo, la pareja de _minor_ se fué. La mayor parte de los machos que danzaban al principio del período de reproducción no atrajeron compañeras y algunas parejas que se formaron se rompieron sin procrear.

El tamaño considerablemente mayor de _magnificens_ probablemente le impide ocupar los sitios de anidación de _minor_. _F. magnificens_ sufriría una dificultad algo mayor en levantar el vuelo desde el suelo o desde matorrales muy bajos. En Genovesa no hay árboles grandes y los nidos de _magnificens_ están de ordinario solitarios, o en grupos de 2, 3 o 4. En otras partes del archipiélago donde hay grupos de árboles más grandes, los nidos de esta especie están reunidos cerca y en mayor número.

En Genovesa _minor_ es más abundante que _magnificens_, en aproximadamente una relación de 10 à 1, y por tanto, parecería ser la especie dominante. Sin embargo, a pesar de su mayor abundancia, no se vieron adultos de _minor_ en las costas de Genovesa. Casi todos los adultos vistos durante un viaje alrededor de la isla con pescadores visitantes fueron de _magnificens_. Cuando el bote venía a Bahía Darwin, donde estuvo cade noche durante varias semanas, se hacía la limpieza del pescado. Una bandera de fragatas se reunía en la popa para alimentarse de los desperdicios. Estas aves fueron siempre _magnificens_, aunque jóvenes de _minor_ llenaban el cielo arriba. Similarmente, cuando se arrojó desperdicios al mar desde la playa, sólo _magnificens_ bajaron a tomarlos, aunque una colonia grande de _minor_ estaba situada a sólo unos metros de distancia. Frecuentemente los piqueros _Sula sula_ fueron perseguidos por fragatas sobre Bahía Darwin. Se supuso al principio que puesto que casi siempre las fragatas eran machos, éstos eran de _minor_, pero siempre que fue posible identificarlas positivemente, las fragatas resultaron ser _magnificens_. Sin embargo, se ha descrito casos en que _F. minor_ ha parasitizado a _Sula sula_ en otras partes de sus respectivas distribuciones.[6] En las Islas Plazas, Santa Fe, y Santa Cruz se ha observado que las fragatas alimentándose a lo largo de la orilla siempre eran _magnificens_. En la vecindad de las Galápagos, por lo mismo, _minor_ debe alimentarse a considerable distancia de la orilla. Durante la travesía desde Guayaquil, un macho de _minor_ fue visto cerca de 350 kilómetros al este de San Cristobal. Tal comportamiento alimenticio podría resultar en que el cambio de adulto incubando de _minor_ sucede sólo después de varios días mientras que el de _magnificens_ es revelado por su pareja al menos una vez al día. En su relación sobre las aves fragatas, Murphy[2] ha acentuado su naturaleza relativamente sedentaria y su ausencia en alta mar. Sin embargo, durante el Programa de Exploración Biológica del Océano Pacífico llevado a cabo recientemente por el Instituto Smithsoniano, se reunieron mas de 40 casos de observaciones de minor a distancias mayores de 350 kilómetros de tierra; de éstas, 9 fueron a 800 kilómetros o más de la tierra mas próxima.[8] Durante el programa se anillaron muchos jóvenes de F. ariel. Los datos recobrados mostraron que éstos se dispersan ampliamente y que viajan frecuentemente a mas de 400 kilómetros de tierra. Si las aves minor que anidan en Wolf y Darwin o en otras isletas en el Archipíelago de Galápagos se alimentan cerca de la orilla, parecería que en Genovesa responden directamente a la competencia con magnificens.

Brosset ha observado la gran diferencia en mansedumbre demostrada por las dos especies.[4] Machos danzantes de minor pueden ser tocados con la mano, mientras que machos danzantes de magnificens no permiten ninguna aproximación, y una vez molestados, no vuelven de ordinario al mismo sitio. Aunque Brosset concluyó que magnificens debe ser una especie comparativamente recién llegada, la raza de minor residente en Laysan tambíen ha sido citada como muy mansa.[6] Aunque minor no tiene miedo de la gente en las Galápagos, la bandada de machos danzantes en Española invariablemente levantaban el vuelo si un halcón llegaba a la vecindad.

De que manera; sobre la base de la información disponible, pueden las dos especies ser consideradas como preadaptadas a la coexistencia ? La capacidad de minor para anidar en lugares bajos y abiertos, mostrada por su selección de tales áreas en la isla de Dom Pedro II en el Atlántico, resulta en competencia reducida con magnificens. El tamaño más grande de magnificens le da una ventaja indiscutible al escoger áreas de alimentación. No está todavía claro, sin embargo, si los hábitos alimenticios mas pelágicos de minor resultan de competencia directa con magnificens, o si es que éstan comprendidos dentro del comportamiento alimenticio normal de la especie. Los datos recientes de minor en alta mar en el Pacífico Central sugirieron que la especie es mas pelágica de lo que se suponía previamente. Si es así, esta característica resultaría en competencia reducida entre las dos especies cuando en contacto secundario.

F.m. magnificens es la más grande subespecie de la especie mas grande de aves fragatas, y parecería que una presión selectiva producida por competencia ha favorecido esta tendencia de tener mayor tamaño. Está todavía por determinarse si presiones selectivas comparables han actuado sobre minor para producir características morfológicas o de comportamiento determinadas genéticamente que podrían justificar la validez de la raza F. minor ridgwayi de las Islas Galápagos.

References

1. GIFFORD, E.W. 1913. The birds of the Galapagos Islands, with observations on the birds of Cocos and Clipperton Islands (Columbiformes to Pelecaniformes). Proc. Calif. Acad. Sci. (4) 2, pt. 1 : 1-132.

2. MURPHY, R.C. 1936. Oceanic Birds of South America. Macmillan Company, New York.

3. LEVEQUE, R. 1964. Notes sur la Reproduction des Oiseaux aux Iles Galapagos. Alauda 32 : 5-44.

4. BROSSET, A. 1963. La Reproduction des Oiseaux de Mer des Iles Galapagos en 1962. Alauda 31 : 6-109.

5. MURPHY, R.C. 1939. Man-o'-War. Nat. Hist. 44 : 132-143.

6. DILL, H.R. 1916. The Mating and Nesting Habits of *Fregata aquila*. Wils. Bull. 28 : 153-157.

7. SIMMONS, G.F. 1927. Nat. Geogr. Mag. 52 : July, no. 1 : 1-75.

8. SIBLEY, F.C. and R.B. CLAPP. 1967. Distribution and Dispersal of Central Pacific Lesser Frigatebirds *Fregata ariel*. Ibis 109 : 328-337.

BEHAVORIAL STUDIES OF THE SWALLOW-TAILED GULL

by

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The primary purpose of my visit to the Galapagos in November and December 1962 was to gather information about the behavior of the Swallow-tailed Gull, Larus (Creagrus) furcatus. My companion, Dr. Jeremy J. Hatch, concentrated his studies on the various forms of mockingbirds, and he remained on the islands some months after I left. We were also able to make a few notes on other species (e.g., Hailman, 1963a; Hatch and Hailman, 1967), but in general our research aims were quite specific.

One of the first facts evident in the breeding behavior of the Swallow-tailed Gull was the local synchrony of breeding (Hailman, 1964a). In documenting this phenomenon I pointed out that although there was a high degree of synchrony in local breeding groups, different groups were not well synchronized with one another. I interpreted this to mean that gross environmental stimuli (say, availability of food supply, rainfall, etc.) were not responsible for synchronizing the birds, since these stimuli would effect all birds on a given island similarly. Furthermore, the environmental changes during the year are not so dramatic in the equatorial Galapagos as they are in north-temperate habitats where I have studied other gull species. Using these two lines of evidence, I argued that one could make a much better case for social stimuli playing an important role in synchronizing pairs of Swallow-tailed Gulls than in north-temperate species, where the concept of social stimulation was first proposed.

Dr. David Snow was able to gather further evidence concerning breeding synchrony of the Swallow-tailed Gull, and his evidence (Snow and Snow, 1967) indicates that local differences in environmental characters (wind, wave action, etc.) render local nesting sites differentially vulnerable at various times. Thus it would appear that, despite the reduction in magnitude of environmental triggering stimuli compared with north temperate habitats, local factors in the Galapagos can also act to synchronize local groups of birds. There has been (in litt.) some misunderstanding concerning my conclusions with regard to breeding synchrony, and it might be well to state here that (so far as I know) Dr. Snow and I are in no disagreement concerning this matter. His study strengthens my primary point that it is very difficult to provide a completely uhambiguous case for social stimuli acting as the main cause of breeding synchrony.

The next point to become apparent in my studies was confirmation of Gifford's (1913) suggestion that the Swallow-tailed Gull is nocturnal.

I documented this fact with direct observations of the birds at all times of day (Hailman, 1964b), and found the birds to be active mostly at night, when they go to sea to feed. Social displays occur mainly at dawn and dusk, or during nest relief in the middle of the night, and young are fed by parents returning from the sea in the middle of the night or towards dawn. Perhaps Moynihan (1962) describes relatively few of the displays of this species because his observations were confined to daylight hours.

Some of the characteristics of the species seem to be possible adaptations to nocturnal life : for instance, the white tuft of feathers at the base of the bill, the white tip to the bill, and the white plumage of the prefledged young. These areas might provide better signals at night than would the more drab or less contrasting plumage of most other gull species. The eye of this species is enormous, a complicated but well known adaptation to nocturnal vision in many kinds of animals. The eye also appears to have a tapetum-like reflecting surface, and the bird exhibits eye-shine (which the diurnal gulls I have tested do not); this is also a well-known adaptation to night vision. Finally, the pecten is very slowly-developing in the chicks of the Swallow-tailed Gull; since reduced pectens are known from other nocturnal birds, this too, appears to have some relation to nocturnality.

A corollary of the noctural feeding flights is the diet of squids, found to be almost the sole regurgitated prey in birds banded by Dr. A. Brosset on Tower Is. during our visit there in November. These squid rise to the surface of the ocean at night, and thus become available prey for nocturnal predators. I have also suggested that of nocturnality in these birds may have been evolved by selection pressures promoting staying at the nest during the day, when Man-o-war birds constantly patrol the breeding colonies. All these observations on nocturnality cast doubt upon the meaning of the report of Streets (1912) that the species flies towards the Galapagos in the evenings and away in the mornings.

A third major portion of the study concerned a comparison of the cliff-nesting adaptations of this species with those of the Kittiwake studied so creatively by E. Cullen (1957). The Swallow-tail is not an obligatory cliff-nester, nor are its nesting cliffs as high or as steep as those of the Kittiwake. Of some 30 behavioral and morphological characters unambiguous enough to use for comparison, the five related to situations shared by ground-nesting gulls were all like the characteristics shown by ground-nesters. Of seven characters related to situations intermediate between ground-nesting and cliff-nesting, five resembled characters of ground-nesters and two were intermediate between ground-nesters and Kittiwakes. Finally, of 18 characters related to cliff-nesting directly, 11 were like the Kittiwake's characters, one was intermediate and six were like ground-nesters. On the whole, then, this comparison strongly supports Dr. Cullen's hypothesis that the characters investigated are a response to cliff-nesting habits.

Some of the adaptations solve the same problem as faced by the Kittiwake, but in a different way. For instance, to prevent eggs from rolling out of the nest, the Kittiwake builds a deep mud cup, whereas the Swallow-tailed Gull utilizes a shallow nest of stones and sea urchin spines. Some characteristics are no doubt the result of multiple selection pressures (e.g., the reduced clutch size of one egg).

I also performed visual-cliff experiments on incubator-hatched Swallow-tail chicks, using a simple model of the standard psychological apparatus. I found the chicks to move to the shallow, rather than deep, side of the cliff. However, recent tests (Hailman, 1967b) with surface-nesting gull species show that their chicks do likewise, so that this response cannot be considered a special adaptation to cliff-nesting.

A fourth part of the study was concerned with the display behavior and social/sexual interactions of the species. Although much data were gathered, very little has been published (except in popular form : Hailman, 1966) because I learned that yet more detailed studies were being carried out by Drs. Snow and J.B. Nelson. One strikingly "ungull-like" display seen and photographed was one in which the bill and head are pointed vertically upward, somewhat as in the Erect display of terns. Since the Swallow-tailed Gull is rather tern-like in other respects (flight, morphology of tail and wings, and perhaps feeding methods), this may be a case of convergent evolution of a whole complex of characters, or (less likely) it may indicate a relationship between this gull and the terns.

Finally one of my chief aims was to see how the young chicks begged food from parent, in order to compare the feeding with other species I have studied. The releasing stimuli of the bill (dark gray with a white tip, rather than red bill or red patches shown by most gull species) were the most puzzling, until I learned that the species was nocturnal. It would appear that the primary releaser for the chick's begging is merely the white tip, which is quite visible at night. Some experiments using models of the parent and incubator-reared chicks (Hailman, 1967a) showed the Swallow-tail chicks to be far less responsive to movement of the stimulus than are chicks of other species. The Swallow-tailed Gull responds mainly to contrast, to which other species respond also. This situation provides an interesting connection with the reduced pecten in the chick's eye, for other studies have shown the pecten to be best developed in species that are keen in detecting movement. Psychological experiments have also shown that interposing a pecten-like grid in front of the human eye enhances movement-detection at certain light intensities. The gull studies, then, have provided another piece of indirect evidence that involves the pecten in the perception of movement.

It might also be added to this report that I was personally very impressed with the importance of preserving the Galapagos and its fauna as a natural laboratory of evolution. To this end I have attempted to make public (e.g., Hailman, 1963b, 1966) the urgency of the conservation effort for the Archipelago.

The Galapagos research was sponsored by U.S. National Science Foundation Grant GB98 to P.H. Klopfer. I am endebted to D.H. Morse for reading the manuscript of this report.

R e f e r e n c e s

CULLEN, E. 1957. - Adaptations in the Kittiwake to cliff-nesting. Ibis, 99 : 275-302.

GIFFORD, E.W. 1913. - The birds of the Galapagos Islands -- expedition of the California Academy of Sciences, 1905-1906. Part VIII. Proc. Calif. Acad. Sci., 2 : 1-132.

HAILMAN, J.P. 1963a. - Why is the Galapagos Lava Gull the color of lava ? Condor, 65 : 528.

HAILMAN, J.P. 1963b. - Two views on conservation in the Galapagos. II. Phila. Herp. Soc. Bull. 11 : 72-74.

HAILMAN, J.P. 1964a. - Breeding synchrony in the equitorial Swallow-tailed Gull. Amer. Nat., 98 : 79-83.

HAILMAN, J.P. 1964b. - The Galapagos Swallow-tailed Gull is nocturnal. Wilson Bull., 76 : 347-354.

HAILMAN, J.P. 1965. - Cliff-nesting adaptations of the Galapagos Swallow-tailed Gull. Wilson Bull., 77 : 346-362.

HAILMAN, J.P. 1966.-Strange gull of the Galapagos. Audubon Mag., 68 : 180-184.

HAILMAN, J.P. 1967a.-The Ontogeny of an instinct : the pecking response in chicks of the Laughing Gull (*Larus atricilla* L.) and related species. Behav. Suppl. 15, 196 pp.

HAILMAN, J.P. 1967b.-Visual-cliff responses of a surface nesting gull. MS.

HATCH, J.J. and J.P. HAILMAN. 1967. - Golden Plovers in the Galapagos. Condor, 69 : 320.

MOYNIHAN, M. 1962. - Hostile and sexual behavior patterns of South American and Pacific Laridae. Behav. Suppl., 8, 365 pp.

SNOW, D.W. and B.K. SNOW. 1967.-The breeding cycle of the Swallow-tailed Gull, *Creagrus furcatus*. Ibis, 109 : 14-24.

STREETS, T.H. 1912. - The Fork-tailed Gull (*Xema furcatum*). Auk, 29 : 233-234.

PALEOLIMNOLOGICAL INVESTIGATIONS IN THE GALAPAGOS ARCHIPELAGO[1]

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I have searched the Galapagos Archipelago for lakes, seeking an environmental history of the islands in the records of their sediments. There are lagoons along the coasts and a few small ponds in the forested uplands. Other lakes occupy volcanic craters. Two craters hold freshwater lakes : Fernandina (Narborough), whose main cone holds a lake which has fluctuated to a maximum size of several kilometers but which spans only a short history easily measured in decades, and the crater lake known as El Junco on San Cristobal (Chatham), which appears to be ancient. Beagle Crater on Isabela (Albemarle) holds a young saline lake about two kilometers across, and containing no more than half a meter sediment in its deepest part. Brine lakes, precipitating rock salt, exist at Tagus Cove on Isabela and on Santiago (James), where the salt deposit is thick enough for commercial mining. An ephemeral lake in an unnamed crater yielded a core of four meters of sediment. The magnificent collapse crater on Genovesa (Tower) has a deep saline lake containing nearly five meters of finely banded sediment. My studies of drill cores and limnic collections from nearly all the Galapagos lakes are only just beginning. The following is an account of some preliminary investigations into cores from El Junco and the Genovesa crater.

El Junco : Isla San Cristobal (Chatham)

The lake occupies a small cone at nearly 900 meters elevation. It is essentially a flat-bottomed disk of water, 270 meters across by 6 meters deep. There is a tiny overflow outlet, but no inlet. The sixty meter high sloping rim of the crater comprises the entire catchment area for the lake and is the only source of run-off water and inwashed sediments.[2] The lake is apparently nearly always in the clouds, which explains how a small closed basin should persist in an equatorial region

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1 The Galapagos study is supported by grant GB-4654 from the U.S. National Science Foundation to the Ohio State University. This paper is contribution number 88 from the Charles Darwin Foundation for the Galapagos Isles.

2. The appearance of the crater is strikingly similar to an Arctic crater lake on the Pribilof Islands (illustrated in COLINVAUX, 1967).

of low rainfall. Water analyses[3] show the lake to contain even less dissolved matter than does Lake Baikal (KOZHOV, 1963), with the exception of chloride (7.0 mg/liter). I cored the sediments to bedrock in three places, finding them to be 15.35 meters thick in the middle of the lake.

I have so far only examined the longest core. The top two meters are of brown gyttja (Munsel no. 10YR 3/2), but most of the rest of the core is of reddish clay (commonest color 5YR 3/3 or 3/4). The transition in the third meter is of alternating broad bands of red clay and blackish (5YR 2/1) organic layers. The lowest thick black band at 2.8 meters has a radiocarbon age[4] of 8230 +/- 140 years before present (I-2868). I found a similar alternation of red and black bands in a short incomplete core I raised from the edge of the lake. These black layers were largely composed of sedge stems and leaves. A sample roughly judged to come from between 3.5 and 4.0 meters has a radiocarbon age of 5980 +/- 120 years before present (I-2427). These data suggest that the black bands may be continuous through the sediments, representing periods when the lake was shallower than now, so that a sedge marsh spread over much of the present basin.

Below the 8000 year black band there are 12.5 meters of the reddish clay-rich sediment. Fossils such as pollen are scarce in this material and attempts to combust a sample for radiocarbon dating produced only a negligible yield of gas from about 100 cc of sediment. There are numerous concretions, two of which have been shown by X-ray diffraction[5] to be mixtures of gibbsite and hematite. Such concretions suggest oxidizing conditions, conditions which should also explain the dearth of fossils. X-ray diffraction analysis of a clay sample[6] shows distinct but weak lines for kaolinite and quartz, but no trace of the 10 Å and 14 Å diffraction clays, such as montmorillonite and illite. There is some suggestion of a terrestrial environment here. A series of samples of the clay material is being examined by Professor W.L. Kubiëna in thin-section for micromorphological evidence of soil-forming processes.

The 8000 year date at 2.8 meters and the isolation of the lake basin from most external sources of sediment together suggest an unusually slow rate of sedimentation. It is likely that a long period, perhaps a signi-

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3 Water analyses performed by the U.S. Geological Survey, Water Resources Division, Colombus, Ohio.

4 Radiocarbon dates performed by Isotopes Incorporated of Westwood, New Jersey.

5 X-ray diffraction of the concretions by Dr. Duncan McConnell of the Department of Dentistry, Ohio State University.

6 X-ray diffraction of the clay sample by Dr. Larry Wilding of the Department of Soils and Crops, Ohio State University.

ficant portion of the Pleistocene, is represented in the El Junco cores. Further evidence for the age of the sediments is being sought by potassium/argon dating of rocks from the crater rim. Subtle textural banding affords hope that it will be possible to reconstruct an environmental history for the basin, even in the early stages, on the basis of chemistry, mineralogy, and micromorphology. Fortunately, also, some thinly polleniferous mud has been found near the bottom of the long core.

The Crater Lake on Isla Genovesa (Tower Island)

Genovesa is a low, dry island some ten kilometers across, a flat disk of lava only sixty meters high fronting the sea on all sides by steep cliffs. Close to the center of the island there is a circular collapse crater containing a lake and with nearly vertical walls sixty meters high. The lake is a kilometer across, thirty meters deep, and has a chloride content of 27,900 mg/liter[7]. The lake is thus much saltier than the sea, but the salinity is well short of the level needed to precipitate rock salt. Marine algae assigned to the genera Ulva and Enteromorpha, genera noted for their tolerance of unusual salinities, grow in the lake, and carid shrimps, but not brine shrimps, are present. The water level must be close to sea level, though there is no evidence that there is a direct contact between the lake and the sea. Numerous sea birds nest in the fringing mangroves and the scrub vegetation on the crater walls.

I raised two cores to bedrock from close to the middle of the lake in thirty meters of water, finding the sediments to be about four and a half meters thick. The core which I have examined is spectacularly color banded over most of its length with white, green, brown, and yellow bands. Banding of the intensity occupies about half the core, the remaining intervals being of bands up to several centimeters thick.

Such beautiful banding at once suggests an annual rhythmn of deposition, a possibility which needs to be checked by independent dating of the sequence. The following radiocarbon ages have been determined[8] :

371 - 383 cm	5,080 +/- 120 years before present	(I-2665)
414.25 - 426 cm	5,070 +/- 120 years before present	(I-2666)

If we accept the extreme dates allowed by the stated errors, and also

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7 Water analyses by the U.S. Geological Survey, Water Resources Division, Columbus, Ohio. An average figure for sea water is 19,400 mg/lt Cl. The lowest chloride content for a Galapagos rock-salt precipitating lake is 44,000 mg/lt, for the Tagus Cove crater.

8 Radiocarbon dates by Isotopes Incorporated of Westwood, New Jersey.

accept each determination as applying to the middle of the sampled core segment, we have 44 cm being deposited in 230 years, or roughly 2 mm per annum. The most distinct bands of this segment are each about one millimeter thick, suggesting that an annual cycle consists of two bands- which is in accord with common experience of banded sediments. Unfortunately, this confortable result was only achieved by an extreme interpretation of the radiocarbon measurements, a proceeding which throws doubt on the result's validity. Further doubts appear when we apply the sedimentation rate of 2 mm per annum.to the upper part of the core, a not unreasonable proceeding, since the incidence of banding appears roughly constant throughout the core. We have 376 centimeters of sediment deposited at 2 mm per annum, giving an age of 1880 years for material shown by radiocarbon to be about 5000 years old. Probably more radiocarbon assay and cross correlation with the second core will help to resolve this difficulty.

Microscopic and analytical investigation of a few bands has shown that some appear silica rich and some carbonate rich. An extreme example of a silica rich band is provided by a hard white layer about one millimeter thick at the 376 cm level. This material is unaffected by dilute NaOH, dilute HCl, or concentrated HNO_3. X-ray diffraction[9] of a sample previously ground with distilled water gave a diffuse band at 4 Å, conforming to crystobalite and consistent with glass shards or biogenic opal (SiO_2). No other bands were present in the diffraction photograph. Microscopic examination reveals a number of distinctive diatoms and a mass of frustule-like objects which may be diatoms or siliceous tests. Shards are very rare. The material thus appears to be opaline fossils comented by amorphous silica.

A second apparently siliceous material is a translucent green jelly, the sample examined coming from between 59 and 60 cm. Infrared spectroscopy[10] revealed no peptide or saccharide absorption bands but suggested silicon. These results indicate that the material is inorganic and possibly a silica gel. D.C. arc emmision spectrography[11] found the jelly to be rich in silicon as well as sodium, calcium, and magnesium. That the calcium, sodium, and magnesium are not present as microcrystals is indicated by the fact that no points of biafringence can be detected when the jelly is viewed with crossed polarizers at 500x magnification. The results of spectroscopy thus suggest a silica gel hydrated with saline water like that of the modern lake. X-ray diffraction photographs[9] show only intense halite lines, even on material soaked in distilled water before drying. Any silica bands

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9 X-ray diffraction by Dr. Duncan McConnell.

10 Infrared spectroscopy by Dr. Robert Jacobsen of Battelle Memorial Institute, Columbus, Ohio.

11 D.C. arc emmission spectrography by Dr. R.E. Heffelfinger of Battelle Memorial Institute.

present would be masked by the halite, but such distinctive bands as carbonate should still be visible, if present. Microscopy reveals a few scattered diatoms in a transparent matrix structured into refracting lines, ellipses and double concave shapes. This appearance of the jelly is unchanged by 24 hours of soaking in concentrated nitric acid, but several days immersion in glycerine granulates the material. Probably the jelly is a silica gel, hydrated with saline lake water, and in which diatom frustules and other siliceous fossils are embedded. It is tempting to think that dessication of this gel would produce a hard dry deposit similar to that at 376 cm, but there is no direct evidence to support this hypothesis.

Carbonate crystals are present in various band types. A hard white layer at 119 cm is superficially similar to the silica band at 376 cm, but is totally soluble in dilute HCl. Standard qualitative chemistry gave positive results only for carbonate. X-ray diffraction[12] showed that the material was aragonite with no detectable inclusion of calcite. The source of this aragonite has not yet been determined. A carid shrimp of the modern lake yielded X-ray diffraction lines of calcite, but none of aragonite[12]. There are numerous spherical fossils, some 30 to 50 microns across, present in the mud, fossils having thick biafringent walls which effervesce and dissolve in dilute HCl. These fossils are thought to be of coccolithophorids. They are normally considered to deposit calcite but WILBUR and WATABE (1963) found that Coccolithus huxleyi deposited both aragonite and vaterite when grown in nitrogen-free culture. I did not find aragonite-depositing benthic algae, such as the Galaxaura or Padina which are common in the Galapagos (TAYLOR, 1945). Ostracods are present, but they are not known to deposit aragonite (CHAVE, 1962). Identifying the source of aragonite bands should yield useful environmental information, and the bands themselves may be used for paleotemperature determinations by the oxygen isotope method.

Carbonates may also be responsible for some of the other color banding, for varying quantities of carbonate crystals (identified microscopically by biafringence and effervescence with dilute HCl) have been found in some of the brown organic bands.

It seems likely that the banded Genovesa crater deposits will reveal a strikingly detailed history of this lake, and provide much information about the environmental history of the Galapagos Islands over the last five thousand years. This can be compared with lagoon cores and cores from various ponded deposits on larger islands. The long El Junco core should enable this record to be extended well into the Pleistocene.

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12 X-ray diffraction by Dr. Duncan McConnell.

References

CHAVE, K.E. 1963. Factors influencing the mineralogy of carbonate sediments. Limnology and Oceanography 7(2) : 218-223.

COLINVAUX, P.A. 1967. Bering Land Bridge : evidence of spruce in Late-Wisconsin times. Science 156(3773) : 380-383.

KOZHOV, M. 1963. Lake Baikal and its life. W. Junk, The Hague. 344 p.
Munsell Soil Color Charts. 1954. Munsell Solor Co., Inc., Maryland.

TAYLOR, W.R. 1945. Pacific marine algae of the Allan Hancock Expeditions to the Galapagos Islands. Rep. Allan Hancock Pacific Expeditions 12 : 1-528.

WILBUR, K.M. and N. WATABE. 1963. Experimental studies on calcification in molluscs and the alga Coccolithus huxleyi. Ann. N.Y. Acad. Sci. 109 : 82-112.

ON THE INFLUENCE OF INTRODUCED ANIMALS ON THE NATURAL VEGETATION OF THE GALAPAGOS ISLANDS

by

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Much has been written and discussed about the influence of introduced animals on the indigenous flora and fauna of the Galapagos Islands. Recently my wife and I spent nine months of plant-collecting in the archipelago. During this time we had many opportunities to realize the very serious threat to the existence and survival of several endemic plants that introduced animals, especially free-ranging goats, constitute. In this paper I will mention a few examples of endemic plants which - in my opinion - are seriously threatened by extinction because of animals which are not natural on the islands.

James (San Salvador) is one of the islands where this problem has become particularly great. Goats are very numerous over the largest part of the island, especially in the western part, here being present all the way from the shore to the top at about 900 m altitude. Their influence on the vegetation is enormous, I would say incredible. We found several Opuntia stems about 5 dm thick which had fallen to the ground and some which would soon fall because goats had practically eaten through the stem. Near the shore we saw Cryptocarpus bushes, the branches of which had been browsed as high as the goats could reach. On two occasions we found goats which had climbed to a height of 2 m in bushes of Clerodendron, eating the upper branches.

The range of the endemic Composite genus Scalesia seems to be steadily decreasing, no doubt mainly because of the activities of feral goats. Four species of this genus are indigenous to James, three of these constituting a taxonomically natural group endemic to the island. Of the three species, only one, S. stewartii, is still not rare, growing on the islet Bartolomé and on a lava field on the adjacent coast of James. There are no goats on Bartolomé, where this Scalesia is quite common. The fact that the species grows on a relatively fresh lava field on James has probably saved it from browsing animals. The animals seem disinclined to cross young lava fields, at least as long as there is enough to eat in other areas. The two other species of the group are however, seriously threatened. We sought in vain for S. darwinii, which was previously known from the neighbourhood of James Bay and was earlier reported to occur at an altitude of about 300 m. It would not be surprised if this species is already extinct. The third species, S. atractyloides, was found growing beyond the reach of goats on the side of a steep cliff north of the old salt mine at James Bay. Only three small trees were seen and I fear that these specimens are the only surviving individuals of the species.

The fourth Scalesia species on James is S. pedunculata (var. pedunculata). It is a tree-forming species, reaching at least 10 m in height. At the beginning of this century these trees were abundant on James, forming true Scalesia-forests at elevations above 400 m. Today, forests of this kind no longer occur. We found only a few scattered full-grown specimens at altitudes between 500 and 900 m. No young individuals were seen, a fact that is rather alarming. I believe that the young plants are eaten by goats at an early stage. The plants simply do not get the opportunity to grow tall enough to survive the attacks of the animals. For this reason S. pedunculata var. pedunculata is threatened with extinction in the near future, unless measures are taken to eradicate the goats.

Another problem on James is the pigs, which are common, especially in the higher parts. The pigs grub out the ground and undermine the root systems of the trees which soon fall to the ground. The result of the activities of goats, pigs and donkeys on the top of James constitutes an example of how lack of planning and conservation can lead to the uncontrollable and meaningless destruction of whole ecosystems.

On Barrington (Santa Fe), where goats are numerous, Scalesia helleri is found only on cliff-sides. There is no reason why the species should not grow also in other localities if there were no goats. We visited Barrington in November and December (1966). The vegetation is very poor at this time of the year and the goats have to eat anything that can possibly be eaten. It is quite understandable, therefore, that a Scalesia growing within the reach of goats has no possibility to survive; it will be eaten practically as soon as it grows. Also on the southern side of Indefatigable (Santa Cruz), S. helleri, apart from a population at Puerto Nunez, is entirely restricted to steep cliff sides. Between Puerto Ayora and Punta Nunez we found a beautiful specimen of S. helleri growing in a steep coastal cliff far beyond the reach of goats. The plant was about 2 m high. On the flat lava plateau a few meters above this site, another specimen was growing, within the reach of goats. This plant was about 5 cm high, severely bitten, and will certainly have no opportunity to grow up and survive.

Calandrinia galapagosa is a very rare species, known only from Sappho Cove on Chatham (San Cristobal). It has been collected only twice. The first collection was made by Alban Stewart in 1906 (it was then mistaken for a Portulaca). The second collection was made by my wife and myself in 1967. We searched a large area at Sappho Cove and found about 20 small bushes of this species. However, all the plants were sterile and severely browsed. The succulent stems seem to be attractive to browsing animals. Some of the cut stems had a diameter of 3 - 5 cm. I consider this species to be threatened by extinction if no measures are taken to prevent continuous browsing.

Portulaca howellii is a characteristic endemic species which is distributed over a large part of the archipelago. However, it is noteworthy that it seems to grow only on small islands. We noted it on Abingdon (Pinta), Bartolomé, Jervis (Rabida), Daphne major, Eden, North Seymour, Plaza Islands, Brattle (Tortuga), Onslow, Champion, Enderby, Caldwell and Gardner near Charles (Floreana); but we never saw it on the adjacent larger islands, James, Indefatigable, Albemarle (Isabela) and Charles. The influence of introduced animals is a possible explanation of this peculiar distribution. The species might have occurred earlier on the larger islands but have been eradicated or become very rare. P. howellii has fleshy succulent stems which are probably attractive to browsing animals. The species has leaves and flowers only during a few weeks, it passes the rest of the year as semi-dormant naked stems. A large part of the nutriment must then be stored in the stems. Consequently, if the stems were eaten away every year the plant would quickly be exterminated. All the small islands mentioned above, except Abingdon, are free from browsing animals. On Abingdon two goats were set ashore in the nineteen fifties. Now there are hundreds of them. On this island we saw only two small specimens of P. howellii close to the shore and it seems likely that the plant will become extinct on Abingdon very soon.

The Galapagos Archipelago has already provided very important material for biological research, but still much remains to be done. It is desirable and also necessary that the original animal and plant communities should be altered and disturbed as little as possible. Very much has already been ruined and can never be restored, but it must be possible to slow down and eventually stop this continuous destruction. The Galapagos Islands are too unique not to be saved. The eradication of introduced animals, at least from islands where there are no settlements, is a difficult task. Yet it must be done, and it must be done soon.

During our stay in Galapagos our headquarters was the Charles Darwin Research Station on Indefatigable. The existence of this institution facilitated our work in many ways. We owe a great debt of gratitude to the staff of the station for their very valuable help and good advice.

FUNDACION CHARLES DARWIN PARA LAS ISLAS GALAPAGOS

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Créée sous les auspices de l'Organisation des Nations-Unies pour l'Education, la Science et la Culture (UNESCO)

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L'Association propose aux autorités compétentes toutes mesures propres à assurer, dans l'archipel des Galapagos et dans les mers qui l'entourent, la conservation du sol, de la flore et de la faune, et la sauvegarde de la vie sauvage et de son milieu naturel. Elle arrête le programme de recherches de la Station biologique et la charge de toutes études scientifiques en rapport avec les objets ci-dessus.

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