

Food webs and feeding habits on the Revillagigedo Islands, Mexico

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Abstract

Food webs on oceanic islands are often markedly different from continental food webs due to low species diversity and the absence of key components of mainland ecosystems. Food webs and feeding habits are described from observations and scat, pellet, and gut analysis on the four islands of the Revillagigedo Islands, Mexico, when in their near original state. Changes in food habits after the introduction of exotics are described. Food webs increase in complexity with an increase in island size, but this is largely a function of the increase in habitat diversity seen with an increase in island size. Seabirds are the major components of the food webs on the smaller two islands while reptiles, passerine birds, hawks, owls, parrots, and doves are more important on the larger two islands. Some island vertebrates have food habits similar to their mainland counterparts while others have become food specialists (e.g., the Socorro Red-tailed Hawk, in the absence of small mammals eat mostly lizards and land crabs). Other birds have seasonally or permanently switched food (ravens and owls on Clarion eat cactus, towhees eat insects, red-tails eat plants). Some of this food switching may be due to the presence of a harsh dry season and/or to the unique fauna and flora of the islands. The insectivorous birds on Socorro apparently reduce competition by utilizing different foraging heights, habitats, and feeding methods. Sheep introduced onto Socorro in 1869 have destroyed some vegetation but while their population numbers fluctuated over the years, they have now been eradicated. Exotics introduced as part of military bases and an airfield may have major effects on the ecosystem of these islands in the future.

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This **early view** paper has been peer-reviewed and accepted for publication in *Pacific Science*. However, it has not been copy-edited nor has it undergone typesetting for *Pacific Science*. The final published paper will look different due to formatting changes, but scientific content will remain the same.

INTRODUCTION

The Revillagigedo Islands consist of a group of four volcanic, oceanic islands rising independently from the ocean floor (about 4 km deep) along the Clarion Fracture Zone some 350-650 km south and southwest of Baja California, Mexico (Fig. 1). The islands are, in order of increasing size, Roca Partida, San Benedicto, Clarion, and Socorro. First discovered in 1533, the islands have been the subjects of numerous scientific investigations (see Richards and Brattstrom, 1959, for the history of exploration, maps, and a bibliography of the scientific work to that date). Since 1994 the archipelago has been protected as a Biosphere Reserve. Renewed interest in the islands developed after the violent eruption of Bárcena Volcano on Aug. 1, 1952, on San Benedicto Island. That volcano and its effect on San Benedicto Island and its biota have been the basis of numerous geological (Richards 1959, 1965, 1966) and biological investigations (Brattstrom and Richards, 1959; Brattstrom, 1963). I have previously published on the cacti, reptiles, and birds (Brattstrom, 1953, 1955, 1982a, b, 1990, 1998; Brattstrom and Howell, 1956) of the islands. In this study I report on notes I took of what animals ate (by observations and examination of scats, pellets and guts) and I construct food webs for each of the islands, adding to our knowledge of food web complexity on oceanic islands. I also examined feeding behavior and report on changes in avifauna, food and extinctions as the result of the introduction of exotics and new arrivals.

The islands

Roca Partida is a small rock 30 X 100 and 50m high, the throat of an old volcano, with steep sides (fig. 2). It has no plants on it and its fauna consists only of sea birds, (Red-tailed Tropicbird, *Phaethon aethereus*, Masked Booby, *Sula nebouxi*, Red-footed Booby, *Sula sula*, Brown Booby, *Sula leucogaster*). The steep sides descend into the ocean 40m with no rocky

intertidal area (Brattstrom and Howell, 1956; Richards, 1964). With continuous strong wave action, only the most tenacious invertebrates occur on the sides of the island (Richards, 1956).

San Benedicto, the youngest of the four islands, is 6.4 km long and 3.2 km wide (fig 3). The island consists of several old coalescent and partly eroded volcanic cones. The border of the island contains at least one discontinuous submerged Pleistocene erosion shelf. On August 1, 1952, Bárcena Volcano was born with the highest recorded index of explosiveness of any oceanic volcano in the eastern Pacific Ocean (Richards, 1959, 1965). Within about 20 minutes the entire island was covered with a cloud of ash, hot gases and pumice killing an estimated 20,000 sea birds within hours (Brattstrom and Howell, 1959; Brattstrom, 1963). By August 2, a cone 335m high had developed and on December 8, a lava flow had broken through the side of the cone and formed a delta of lava, which eventually extended nearly 8km out to the sea. The original fauna consisted of sea birds and an endemic subspecies of rock wren, *Salpinctes obsoletus exsul*. A few of the wrens survived the volcanic activity but have not been seen since December 1952, and this race is considered extinct (Brattstrom and Howell, 1956; Brattstrom, 1963; Jehl and Parks, 1982). The original vegetation (grasses and low herbs) consisted of 11 species; six survived the volcanic activity and re-sprouted from roots or seeds. Of these six, three have subsequently become extinct and three new invasions have occurred (Brattstrom, 1963, 1990, in prep.). The island is thus largely barren with low vegetation, mostly on the northern half, and occupied by a large population of sea birds (Wedge-tailed Shearwater, *Puffinus pacificus*; Townsend's Shearwater, *Puffinus auricularis* (no longer breeding on this island, Águirre-Muñoz, et al. 2009); Red-tailed Tropicbird, *Phaethon aethereus*; Blue-footed Booby, *Sula nebouxi*; Masked Booby, *Sula dactylatra*; Red-footed Booby, *Sula Sula*; Brown Booby, *Sula leucogaster*; Great Frigatebird, *Fregata minor*; and occasional land bird vagrants, warbler, redstarts, swallows, and occasional visitors from nearby Socorro, Osprey, Socorro Red-

tailed Hawk, etc.). Land crabs, insects and spiders also occur on the island (Brattstrom and Howell, 1956; Jehl and Parkes, 1982, 1983).

Clarion Island (6.4 X 9.7km) is the western most of the islands, and apparently the oldest (perhaps early Pliocene based on marine fossils, Brattstrom, 1990). It attains a height of a little over 305m (Fig. 4). It is covered with grass and thick clumps of morning glory (*Convolvulus*) covering prickly pear cactus (*Opuntia*, but see below) plus large areas of low shrubs and occasional small trees to 2.5m high. An extensive coral filled bay occurs on its south side. Two temporary ponds occur on the low flat southern portion (Brattstrom, 1953, 1955, 1982a, b, 1990). The vertebrate fauna consists of nesting sea turtles (*Chelonia mydas*), an endemic snake, the Clarion Island Racer, (*Masticophis anthonyi*), the endemic Clarion Island lizard (*Urosaurus clarionensis*), (Brattstrom, 1953, 1955, 1982a, b, 1990; Wanless and Angel, 2007), sea birds, (Townsend's Shearwater, *Puffinus auricularis*; Masked Booby, *Sula dactylatra*; Red-footed Booby, *Sula sula*; Great Frigatebird, *Fregata minor*; as well as an endemic mourning dove, *Zenaida macroura clarionensis*; burrowing owl, *Athene cunicularia rostrata*; raven *Corvus corax clarionensis*; and wren *Thryomanes tanneri*, Brattstrom and Howell, 1956; Jehl and Parkes, 1982). Insects, spiders, land snails and crabs also occur on the island, but the arthropod fauna is poorly studied (Aldrete, et al. 1992). A permanent Mexican Naval Garrison was established in 1979. By 1988 an airstrip that had been recently constructed was overgrown and its use discontinued (Howell & Webb, 1989). Sheep (*Ovis aries*), pigs (*Sus scrofa*) and European rabbits (*Oryctolagus cuniculus*) had been introduced over the years and except for the rabbits, eradicated (Wanless, et al. 2009; Águirre-Muñoz, et al. 2009). According to Everett (1988), an extensive fire in 1984 burned the western two-thirds of the island. This may account for the low, grassy vegetation encountered by him over most of the island, in contrast to the

extensive dense vine-covered cactus (*Opuntia*) described by Townsend (1890) and Anthony (1898).

Harvesting by humans and predation by pigs may reduce the small population of green sea turtles (*Chelonia mydas*) which nest at Bahia Sulphur (Aubrey et al. 1984). Ground-nesting birds such as Townsend's Shearwater and Masked Booby were especially vulnerable to predation by pigs. Massive reduction of vegetation by the fire and rooting by pigs has dramatically reduced habitat for the endemic land-bird fauna by 1986 (Everett, 1988). By 1990 the *Opuntia* cactus was mostly eliminated (Santaella and Sada, 1991). Pigs and sheep had been eradicated by 2002, but rabbits persist (Wanless, et al. 2009). At least 46 pairs of Laysan Albatrosses (*Phoebastria immutabilis*), first recorded in 1999, bred for first time in 2002/2003 (Wanless, et al. 2009). Numerous migrating and accidentals are reported for the island (Wanless, et al. 2009, record 55 visitors). While some Shearwaters (*Puffinus*) live on the island, the local population of Townsend's Shearwater is presumed to be extinct on Clarion. The burrowing owl's population was apparently greatly reduced by pigs but has recovered since the pigs have been eradicated (Wanless, et al. 2009). Population numbers of other species on the island are given in Brattstrom and Howell, (1956); Jehl and Parkes, (1982); Everett, (1988); Howell and Webb, (1989); Santaella and Spada, (1991).

Socorro Island is the largest (15 X 15km) and most diverse of the four islands in topography and vegetation (Fig. 5). It reaches 1130m, has some occasional sulfur fumerolic activity near its summit, and is probably early Pleistocene in age, based on the existence of Pleistocene erosion shelf (Richards, 1959; Richards and Brattstrom, 1959). The island consists of one high central volcanic peak, Mt. Evermann, and numerous large basaltic flows, which descend to sea. Numerous small to large cinder cones occur especially on the southern slopes of the island (Richards and Brattstrom, 1959). A few temporary (July to February) lakes exist on the south

end of the island and temporary and permanent ponds and water seeps occur on the north and west ends of the island. The dominant vegetation of the west, south, and east sides of the island consist of thick masses of the shrub, *Croton masonii*, with large occasional patches of *Opuntia* sp. cactus (Brattstrom, 1953, 1955; Levin and Moran, 1989). Broad leaved tropical plants, some deciduous, including *Prunus capuli*, *Ficus continifolia*, *Guettarda insularis* and some bromeliads and orchids occur on the north side of the island, the higher elevations and a few canyons descending to or near the sea (Levin and Moran, 1989). In some of the northern canyons this vegetation is sometimes so dense it prevents walking. The flora (Johnston, 1931) has been revised (Levin and Moran, 1989).

The native fauna of Socorro includes sea birds, (Wedge-tailed Shearwater, *Puffinus pacificus*; Townsend's Shearwater, *Puffinus auricularia*; Red-tailed Tropicbird, *Phaethon aethereus*; Blue-footed Booby, *Sula nebouxi*; Masked Booby, *Sula dactylatra*, Red-footed Booby, *Sula sula*; Brown Booby, *Sula leucogaster*; Great Frigatebird, *Fregata magnificans*). Magnificent Frigatebird, *Fregata magnificans*; migrating and accident shore birds, several endemic terrestrial birds (Socorro dove, *Zenaida graysoni*; Elf Owl, *Micrathene graysoni*; Socorro Mockingbird, *Mimodes graysoni*; Red-tailed Hawk, *Buteo jamaicensis socorroensis*; Green Parakeet, *Aratinga holochroa brevipes*; Ground Dove, *Columbina passerina socorroensis*; Rufous-Sided Towhee, *Pipilo erythrophthalmus socorroensis*; Socorro Wren, *Troglodytes sissonii*; Tropical Parula, *Parula pitiayumi graysoni*), an endemic lizard (*Urosaurus auriculatus*), nesting sea turtles, (*Chelonia mydas*), land crabs, land snails, spiders, scorpions, centipedes, and numerous kinds of insects (Aldrete, 1994; Aldrete, et al. 1992; Brattstrom, 1955; Brattstrom and Howell, 1956; Hogue, 1978; Jimenez, 1991; Palacios and Vargas, et al. 1980; Vazquez, 1958). There are also seasonal transients, visitors and temporary residents.

Sheep were introduced to Socorro in 1869. I estimated the population to be about 1000 animals in the 1950s. Levin (1989) estimated a population at of 3000 sheep. They were mostly on the southern and eastern sides of the island and were common up to about 600m on the eastern plateau region. They had extensively over grazed the eastern section of the island. By 2010 with the support of various Mexican agencies these sheep (n=1,350) were eradicated (Águirre-Muñoz, et al. 2011).

In 1957 the Mexican Government established a garrison on the southern most portion of the island. In 1978 a large military jet airport was constructed on the upper (300m) plateau region of the eastern half of the island. As a result numerous exotic plants and animals were introduced. These include Acacias, Papaya, Coconut, palms, flowers, vegetables and weeds as well as domestic animals, pets and house mice, *Mus musculus*, (Jehl and Parkes, 1982, 1983; Brattstrom, 1990). In 1971 I saw cats (reported wild over most of the island), 10 horses, 20 burrows, chickens, pigeons (wild type and domestic), and no dogs. In 1978 I saw no pigeons, 1 cow, a few chickens, and cats; in 1981 I saw chickens and turkeys in pens and a black and white cat. No cats were seen by Santaella and Sada (1991) in 1990 and they reported that there was an effort to eliminate the cats. Most of these animals have subsequently been eliminated or caged except for the cats and house mice (see discussion of the effects of the cats on the birds in Jehl and Parks, 1982, 1983).

In April of 1978, I observed house mice (*Mus musculus*), under fig trees in Grayson's cove on the west side of the Island. They had never been seen there before. They were active even during the day. Whether people brought them there from the garrison or whether the mice have escaped from the garrison area and extended their range 8km to Grayson's Cove is not known. None were seen there in 1981.

The Socorro Mockingbird (*Mimoides graysoni*) is unique to Socorro. From being the most abundant and widespread species of land bird on Socorro (McLellan, 1926), *Mimodes* has declined to near extinction, most likely due to the depredations by feral cats (Jehl and Parkes, 1982, 1983; Rodríguez-Estrella, et al. 1991). In 1978, Jehl and Parkes (1982) found only a few *Mimodes*, mainly in the vicinity of large fig groves (*Ficus cotonifolia*) near the coast. In 1981, a party from the University of Mexico found 20 individuals in a relatively inaccessible part of the island, and in early 1990, 16 were found by a group from the Centro de Investigaciones biológicas (C.I.B.) of La Paz, B.C.S. (H. Walter, pers. Comm.). Santaella and Sada (1991) found a family of four *Mimodes* at about 600m elevation on the way to the summit of Cerro Evermann in mixed open woodland consisting of *Ficus contonifolia* and the endemic trees: *Bumelia socorrensis*, *Ilex socorrensis*, *Guettarda insularis*, and *Psidium socorrensis*. Castellanos and Rodríguez-Estrella (1993), found Socorro Mockingbirds breeding and fairly common (est. 50-60 pairs) in thicker vegetation on Socorro. Gomez and Curry (1995) marked 215 Socorro Mockingbirds and described their eggs and nests.

The Northern mocking bird (*Mimus polyglottos*) is a recent invader (Jehl and Parkes, 1982, 1983) that was very common throughout both open and wooded areas of Socorro and behaved exactly like its congeners on the mainland (Santaella and Sada, 1991; Castellanos and Rodríguez-Estrella, 1993).

The Socorro Dove (*Zenaida graysoni*) was once common on Socorro, it was not found in 1958, 1978, 1981, (Jehl and Parkes, 1982) and is presumed extinct in the wild. Breeding colonies occur in Europe, Canada, and California (Baptista, et al. 1983). Apparently attempts at re-establishing the species on Socorro will be made in the future (Baptista, et al. 1983; Baptista, 1983; Johnson and Clayton, 2000; Yanga, et al. 2011). The Morning dove (*Zenaida macroura*)

has invaded Socorro since 1958 and in 1978 was an abundant breeder on the island (Jehl and Parkes, 1982)

In summary, the vegetation of the four islands ranges from nothing (Roca Partida), to limited (San Benedicto), to grass cactus and scrubs (Clarion), to complex (Socorro). The vertebrate fauna consists of two endemic lizards (Clarion and Socorro), an endemic snake (Clarion), sea turtles (Clarion, Socorro), sea birds, shore birds, and several endemic terrestrial birds (Clarion and Socorro) some of which are rare or extinct. All the islands except Roca Partida have land crabs. San Benedicto has insects and spiders. Clarion and Socorro have insects, spiders, and land snails; Socorro also has scorpions (Palacios-Vargas, et al. 1982), though the arthropod fauna of the islands is poorly known. Recent introduced animals and plants have impacted populations and caused extinctions, some of these exotics have been eliminated on the islands.

Temporary ponds occur on Clarion, temporary and permanent ponds and seeps occur on Socorro. There are no primary freshwater fish, amphibians, or native mammals on any of the islands (though cetaceans occur around the islands). Little is published about the weather (though the hurricane season is in the summer months and heavy clouds and fog form almost daily about Mt. Evermann on Socorro). Most of the terrestrial fauna and flora had its origin in the Sonora, Sinaloa, Nayarit region of western Mexico and not from Baja California (Brattstrom, 1953, 1955, 1990; Brattstrom and Howell, 1956). Most of the marine biota is of Indo-Pacific or Panamanian affinity (Brattstrom, 1990).

METHODS

I made six trips to the Revillagigedo islands by ship in March/April, 1953; November, 1953; April, 1955; November, 1971; April, 1978; and April, 1981. I visited Clarion and passed

Roca Partida on only three of those trips, (1953, 1955, 1971). I have spent approximately 915 hours on Clarion, San Benedicto and Socorro. I flew over San Benedicto and Socorro in October 1954 and August 1961. Current vegetation can be seen on Google maps.

The data for this report on food habits and feeding behavior is based on detailed observations of behavior (recording in my field notes every time I observed an animal eating something), scats, feces, hawk and owl pellets, and examination of the digestive tract (lizards and birds), observations by others, (especially colleagues on the various trips, including Jehl and Parkes), and from the literature. Every heavy line in the food web figures is a verified link. The invertebrate fauna of the islands is poorly known, so I have had to lump most of the species of insects together except where specific information is available.

There was no garrison (which started in 1979) or exotics on Clarion on my last trip to Clarion (1971). The data in these food webs therefore represents the ecological interactions on the island before obvious human impacts.

Roca Partida can be observed only from the sea. San Benedicto was walked over completely and circumnavigated from a close distance. I have walked over most of Clarion, except the northeastern most portions. I landed and traveled inland on Socorro at many places and many times. I made observations, counts, collections, and took photographs. On the 1978 and 1981 trips, data were collected on feeding heights and habits of the birds. Several dozen scats, pellets, and digestive tracts were examined in the laboratory under a dissection microscope and identifications, were made by other scientists when I was in doubt.

In 1978 on Socorro, I tallied feeding heights and feeding strategies of the smaller terrestrial birds at four locations. Unless I was engaged in other observations, all birds seen feeding were tallied. Some of these observations were for concentrated periods, while others were casual throughout the day. Data were tallied on April 10, all day, at Grayson's Cove on the

wren, warbler, towhee, and ground dove; on the morning of April 11 at Playas Blancas on the wren, warbler, towhee, ground dove, and Socorro Mockingbird' at 300m on the east side of Socorro for two hours, April 12, on the warbler, towhee and Socorro Mockingbird; and at Academy Bay for four hours, April 14, 0700-1100 hours on the wren, warbler, and towhee. Data were not collected for such obvious birds as the parrots eating *Ficus* and *Prunus* fruit in the trees of Grayson's Cove or the red-tail and osprey flying above the vegetation. Limited data collected on feeding strategies at heights in 1981 did not differ from 1978 data and thus are not included.

Scientific names for the birds are found in Brattstrom and Howell (1956) and Jehl and Parkes (1982), and herein in the introduction to the Islands. Cohen, et al. (1993), Pimm, et al. (1991) and Goldwasser and Roughgarden (1997), Cohen (1978) have discussed the problem of the grouping or lumping of kinds of organisms. I have grouped (in Figs. 6-9) animals (e.g., sea birds) when they all ate the same food items and separated them when one or more species ate additional food items (e.g., frigate birds additionally preying on young of other sea birds on San Benedicto).

RESULTS

Since the biota of Roca Partida (Fig. 6) consists only of sea birds (usually less than 100), the food web is extremely simple. The sea birds (boobies and frigate birds) eat fish (though the frigate birds may eat nestlings of the other sea birds on the island) and contribute nutrients to the marine ecosystem nutrients in excreta and presumably dead bodies. San Benedicto, the site of Bárcena Volcano, has a limited biota (fig. 7). The presence of even the limited number of species and abundance of plants and the larger size of the island has allowed for a slight increase in the complexity of the food web over that seen on Roca Partida. The plants provide food for insects and land crabs. The former provides food for transient insectivorous birds (and did for the now-extinct wren present prior to Bárcena) and the plants provide occasional food and

nesting material for the sea birds. Frigatebirds and perhaps transient hawks occasionally consume unprotected young of other sea bird species on this open, essentially barren island. Sea birds also feed on fish disturbed by dolphins, sharks and whales (Brattstrom, personal observations; Pitman and Balance; 1990, 1992) and by kleptoparasitism (Vickery and Brooke, 1994; LeCorre and Jouventin, 1997). Almost 90% of the sea birds, especially the boobies, travel daily, largely to the southeast, to feed. Tropicbirds and Frigatebirds travel also, but also feed about the island (Brattstrom, in prep.).

The larger size and more complex flora of Clarion Island has provided habitats and food potentialities for an even more complex food web than seen on San Benedicto (Fig. 8). The food web includes two endemic reptiles, nesting sea turtles (Brattstrom, 1955, 1982b; Awbrey, et al. 1985; Frazier, 1985), and the endemic birds. The extensive southern bay and beach allows for the presence of nesting sea turtles. Both the Clarion Island Racer and the burrowing owl take advantage of this by occasionally consuming baby sea turtles. The racer eats primarily the Clarion Island Lizard, *Urosaurus clarionensis* but also eats chicks of the newly established (2002) breeding population of Laysan Albatrosses, *Phoebastria immutabilis* (Wanless and Angel, 2007).

With its large size and altitude, its complexity of landforms, and its vertical exposure, slope zonation and habitat differentiation, Socorro has the most diverse biota and most complex food web of the four islands (Fig. 9). The lizards eat insects and other arthropods (mites, centipedes, sowbugs) and the Socorro Red-tailed Hawk eats lizards, land crabs, and occasionally doves, carrion and baby sea turtles and in dry seasons also eats plants. It appears that it is the large number and diverse species of birds in addition to habitat diversity and island size, which is largely responsible for the complexity of the food web on Socorro. Populations of sea birds rarely nest on Socorro but feed in bays, inlets, and the surrounding water. The Townsend

Shearwater, *Puffinus auricularis*, is rare on Socorro (Martínez-Gomez and Jacobsen, 2004 report 1,100 individuals above 600m); it feeds at sea (Santaella and Sada, 1991). The rocky intertidal regions on Socorro are, however, much more complex and extensive and hence shore birds play a larger role in the ecosystem. I never observed the elusive elf owl. The introduced sheep have had a disastrous effect on some portions of the island but are now eradicated (Álvarez-Cárdenes, et al. 1994; Águirre-Muñoz, et al. 2011). I have not included in Fig. 9 the domestic animals at the Garrison, but have included the house mouse because of its presence in the “wild” at Grayson’s Cove. For clarity I have in Fig. 8 and 9 only included a few lines as indicting excrement nutrients (sea and shore birds are essentially the only providers of these nutrients on Roca Partida and San Benedicto). It is clear, of course, that all of the organisms contribute excrement nutrients.

Food specialists and food switching

One of the first things that I observed about the feeding habits of the vertebrates on these islands was some of the peculiarities of food eaten due to the limited number of prey species and perhaps in part due to the long dry season and the temporary unavailability of some prey. For example, since there are no native mammals on the islands, the Socorro Red-tailed Hawk eats mostly the endemic Socorro Island Lizard (but see below). In contrast to the high soaring hunting of red-tails on the mainland, these hawks soar and fly slowly along exposed rocky ridges in search of lizards. The Socorro lizard is extremely wary and is usually found in and around lava cracks and crevices or in thick brush. The males are brilliant blue and are very obvious when seen in full sun. But they seem to be largely in places where it would be difficult for hawks to catch them, except for the exposed ridges (Brattstrom, 1955). It was difficult to assess the number of hawks on the islands, but my estimate, for several trips up to 1981, was less than 10 pairs. Jehl and Parkes, (1982), estimated the population at 15-25 pairs and Walter (1990)

considers the population stable. I have also seen the hawks scan turtle beaches as young were emerging, but have no data on predation. In 1971, I saw a Red-tail at the garrison area, perhaps looking for escaped domestic animals. One gut content of a hawk collected at Academy Bay in April 1978 contained, besides intestinal parasites, nothing but a white mash which appeared to be crushed fruit, perhaps *Ficus* or *Prunus*. Perhaps the hawks switch to fruit during the dry season.

In 1981 the contents of several hawk pellets contained nothing but land crabs. McLellan (1926) described a pair of hawks feeding on a young lamb (carrion?) and also found a Socorro Dove in the gut of one hawk. Villa (1960) described the capture of ground doves by Red-tailed Hawks. The sheep are now eradicated and the Socorro Dove may be near extinction (Jehl and Parkes, 1982; but see Santaella and Sada, 1991), but Mourning Doves, new arrivals on the island, are abundant.

In contrast to the wary behavior of the Socorro lizard, the bright green Clarion Island Lizard is extremely conspicuous as it sits and displays on the exposed lava boulders. Its major, if not only predator on that island, is the Clarion Island Racer. By being exposed on top of boulders it can apparently easily see the approach of the snake. The snake occasionally eats baby sea turtles and (young?) birds (Ortenberger, 1928; Brattstrom, 1955). Wanless and Angel (2007), report the snake eating a hatchling of the newly established (2002) breeding population of Laysan Albatross.

The raven on Clarion eats insects, land snails, and occasionally young birds, but based on observations and ejecta from raven roosting sites, its food consists largely of seeds, flowers and cactus fruit.

When available, insects provide the major food for the endemic race of burrowing owl on Clarion Island. In 1971, for example three large pellet samples contained 95-99% crickets along with a few beetles (*Tenebrionidae*), and flies. I have also found a shore bird, Long Billed

Dowitcher's (*Limnodromus scolopaceus*) feathers and the skull of a young raven, and baby sea turtle (*Chelonian mydas*), remains around the entrance and pellet areas of owl burrows. I also found remnants of a sea turtle eggshell. I do not know if the owl may have dug for it, whether it was exposed as baby turtles escaped from their nest, or if the owl placed it there.

Observations and ejecta indicate that during the dry season, the major food of the burrowing owl switches to cactus pads, flowers and fruit. While seasonal changes in food taken have been reported for this species, in several studies on the mainland (see Zarn, 1974; Jaksic and Marti, 1981), no mention has been made of them consuming plants. Perhaps, as with the ravens of Clarion, there is no alternative during the dry season.

The Socorro Towhee, (*Pipilo erythrophthalmus socorroensis*), consumes seeds as does its mainland counterpart. Yet five digestive tracts collected in 1978 contained largely insects (beetles, beetle larvae, unidentified small insects, as well as small seeds). Thus, during the breeding season this seedeater, like many passerine birds, consumes insects.

The Yellow-crowned Heron (*Nyctanassa violacea gravirostris*) an endemic race on Socorro, apparently largely eats land crabs (*Aegecarcinus planatus*). It may also take young and small shore birds, as I have found several dead birds on beaches with their heads pierced in typical heron feeding fashion (also see Jehl and Parkes, 1982; Watts, 1988). Numerous land crabs are found around the edge of lava flows and under fig trees with their carapaces or undershells pierced and eaten by herons. The herons do not seem to be able to pierce the large claws of these crabs. Ortiz-Alcaraz (personal communication), reports observation of night herons feeding on crabs at night near the Navy base in the *Ficus* forest. This night heron also feeds at night on the Bahamas and elsewhere (Clayton, 1985). No nocturnal observations were made on the Revillagigedo Islands due to the hazards of landing and walking. Dead crabs decay, and flies (mostly muscids) lay eggs in the decaying flesh. The Socorro Wren (*Thryomanes sissoni*) visits

the carcasses and examines and pokes its bill into the dismembered legs removing fly larva and emerging adult flies. For 30 minutes I watched and photographed one wren make the same circuit of some 20 crabs about 12 times, often in a stereotypically repeated pattern. The wren is the most diversified in its feeding methods and habitats of all the terrestrial birds (see below). In addition, to this unique food source the wren also feed on supratidal beach insects.

The insect eating Socorro or Parula Warbler, *Parula pitiayumi graysoni*, was also observed eating at a spider's web, either on the spider or it's captured insects (Charles Hogue, personal communication).

The Green Parakeet, *Aratinga holochlora brevipes*, was observed by Rodriguez-Estrella, et al. (1992), feeding on *Bumelia* (51.0%), *Guettarda* (19.5%), *Ilex* (16.7%), and *Psidium* (12.7%) seeds and fruit pulp (N = 251 observations). The birds typically were observed feeding on ripe and unripe fruits. *Bumelia* and *Ilex* fruit production probably occurs throughout the year: *Guettarda* fruit was found in February and November, but its phenology is unknown, *Psidium* produces fruits from January to April. Thus the principal food sources for parakeets are present throughout the year on the island. *Opuntia sp.* and *Ficus* fruits may be another alternate food in the dry season (Rodriguez-Estrella, et al. 1992).

Land bird feeding habits

Feeding heights of foraging birds varied by species (Fig. 10). While all land birds occasionally fed on the ground, the ground dove was exclusively a ground feeder. The wren and towhee fed closest to the ground and since the towhee is at least a seasonal insectivore this would presumably place it in potential competition with the wren, if they ate the same types of insects. The warbler fed in the upper canopy of trees and shrubs (Fig. 11). Since tree and shrub height varied at each of the locations studied, the average foraging height for this species was probably a low figure because of the low vegetation at two locations.

Feeding locations utilized by each species also differed (Fig. 11). The ground dove feeds in the open or under cover of trees and shrubs. The warbler was largely a canopy feeder and the Socorro Mockingbird fed throughout the trees and shrubs. The towhee feeds on the ground, under cover or in the inner portion of trees. The wren used the greatest variety of habitats from supra-tidal feeding in the open to occasionally feeding in the canopy. The four insect feeding birds appear to feed largely in different habitats. The wren may occupy some of these habitats (Fig. 11), but also fed in more specialized habitats. The various birds seemed to be quite diverse in their use of height and habitat and by the methods used by each species to obtain prey (Fig 12). All of these methods may allow the insectivorous birds to consume different size and/or species of prey, thus reducing competition, but the small number of digestive tracts examined are inadequate to indicate if this is so (one mockingbird: soft-bodied insect parts; seven wrens: small beetles, ants, miscellaneous insect parts; five towhees: beetles, beetle larvae, small insect parts, seeds; three warblers: ants, small beetles, hymenopteran, larvae).

DISCUSSION

I have described who eats whom and what on each of the four islands as far as I could determine. The invertebrate and plant biota of the islands is so poorly known as to prevent a more complete analysis. Some studies have been published on insects (Aldrete, 1994; Aldrete, et al. 1992; Vasquez, 1958). The spiders have been surveyed by Jiménez (1991), and Levins and Moran (1989) have published a flora of Socorro. These studies will hopefully aid in future food web studies. The rugged topography of the islands and the difficulty of landings, however, will continue to make studies hazardous and incomplete.

The food web data presented herein was collected from 1953 to 1981. Since then more exotics have been introduced and some were eliminated, but since the islands are now a

Biosphere Reserve, the Mexican Government and researchers from several countries are trying to restore the biota (Águirre-Muñoz, et al. 2009, 2011; SEMARIVAT. 2004). In any event, the information presented herein hopefully will provide a baseline which can be compared to food webs that emerge following human-caused alterations, including the arrival of exotics and climate change.

Differences among these four islands are clear, but because of the lack of similar data for other islands in the eastern Pacific, little comparison can be made between these islands and others. An ecosystem analysis was made by Wolda (1975) for Malpelo Island, Columbia, , but that island is so different in climate, size, topography, plants, biota, and the invertebrate fauna of the Revillagigedo Islands so poorly known that comparison at this time seems difficult.

Because of the lack of many of their normal foods and perhaps due to the marked dry season, food specialization and food shifting has been a common occurrence on these islands. This is as would be predicted (Murdoch, 1969; Keast, 1970).

Some of the predators on the island are clearly opportunistic feeders. This is especially seen in the utilization of hatchling sea turtles as food by the Clarion Island Owl and racer, and perhaps the Socorro Red-tail and the Clarion Raven. The emergence of these young in the daytime enhances their probability of being eaten. Opportunistic predation on hatchling sea turtles has been noted by others (see, for example, Mrosovsky, 1971).

While the sheep introduced on Socorro in 1860 have destroyed some vegetation, they apparently are unable to penetrate the densely covered northern slopes of the island. Seasonal starvation from overgrazing (my observations on the east side of the island) coupled with hunting by visitors and men from the military base, seems to have kept the sheep population at a relatively constant number up to my last visit in 1981. The sheep were eradicated by 2010 (Ácuirre-Muñoz, 2011). The house mice found at Grayson's Cove may have been released there

or dispersed from the military base. The introduced pigs on Clarion have been eliminated but the rabbits have not. What effect these species will have on the island ecosystem in the future is unknown. Control efforts have reduced the number of exotic (domestic) animals around the Garrison. Designated in 1984 as a Biosphere Reserve, the unique island ecosystems described here hopefully will be preserved through continuing conservations efforts.

ACKNOWLEDGEMENTS

Early investigations of the geology, biology, and oceanography of the islands, with special reference to San Benedicto Island, were carried out by the Scripps institution of Oceanography under the leadership of Dr. Adrian R. Richards. The Office of Naval Research and the Bureau of ships under contracts with Scripps provided financial support. The Janss Foundation under the leadership of Mr. Ed Janss sponsored the 1971 expedition. The Carnegie Museum of Natural History and Sea World of San Diego sponsored the 1978 trip under the joint leadership of Dr. Joe Jehl and Dr. Kenneth Parkes. Tom and Doroty Hawthorn of San Diego, Clifornia and the Carnegie Museum of Natural History sponsored the 1981 trip. I wish to thank those individuals and their institutions for the support of these expeditions. Special note and thanks should also be given to the seamen who safely landed and returned us from many precarious and sometimes very dangerous landing places on the islands and to the cooks who always provided a pack lunch and a big meal after a long, often hazardous day.

I wish to also thank all those who provided photographs, observations or identifications. Of those not previously acknowledged (Richards and Brattstrom, 1959; Brattstrom, 1953), I wish to thank Dr. Charles Hogue, Dr. George Linsey, the late Dr. Earl Herald, the late Dr. Thomas Howell, Dr. Joe Jehl, the late Dr. Reid Moran, Dr. Bob Lavenberg and Dr. Robert Pitman.

Shipboard discussions were usually very stimulating with the sharing of experiences, observations, data and ideas. Of the many, I especially remember and appreciate those I had with Dr. G. Dallas Hanna, Dr. Herbert Mason, D.E. Yale Dawson, Dr. Reid Moran, Dr. Joe Jehl, Dr. Kenneth Parkes, Mr. Milton C. Shedd, Dr. James Warren, Dr. Robert Pitman, Dr. Earl Herald, Dr. Richard Rosenblatt, Dr. Adrian Richards, and Mr. Ed Janss. I hope they, and others, benefited also from my observations, data and insights.

Paula McKenzie Allen and Mark Zolle did the drawings under support from the Department of Biological Science and the Office of Research, California State University, Fullerton, California. Dr. Joe Jehl, Dr. Kenneth Parkes, and several anonymous reviewers kindly read earlier drafts of this paper and I thank them for their comments and corrections.

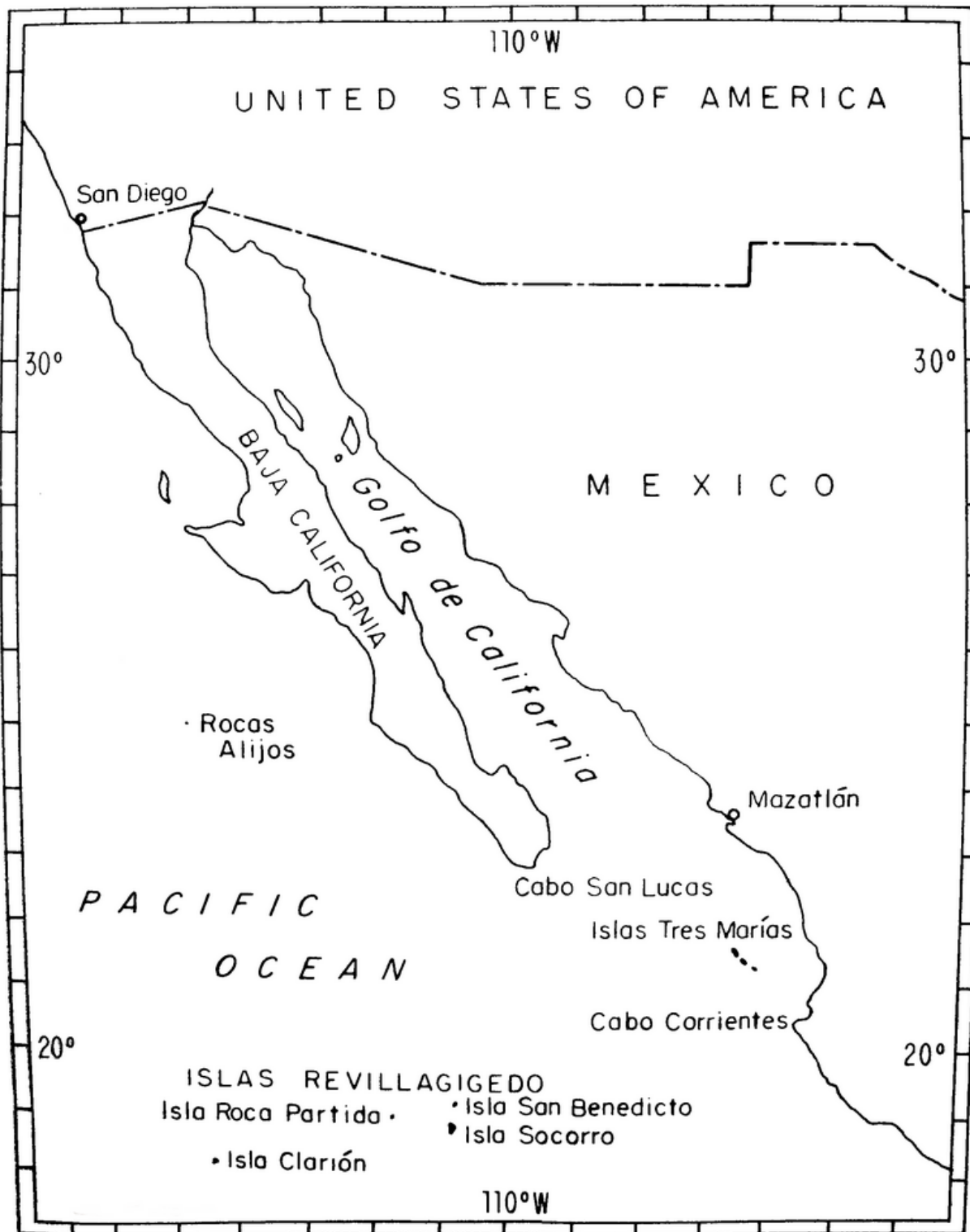


Fig. 1. Map showing the location of the four islands of the Revillagigedo Islands, Mexico.

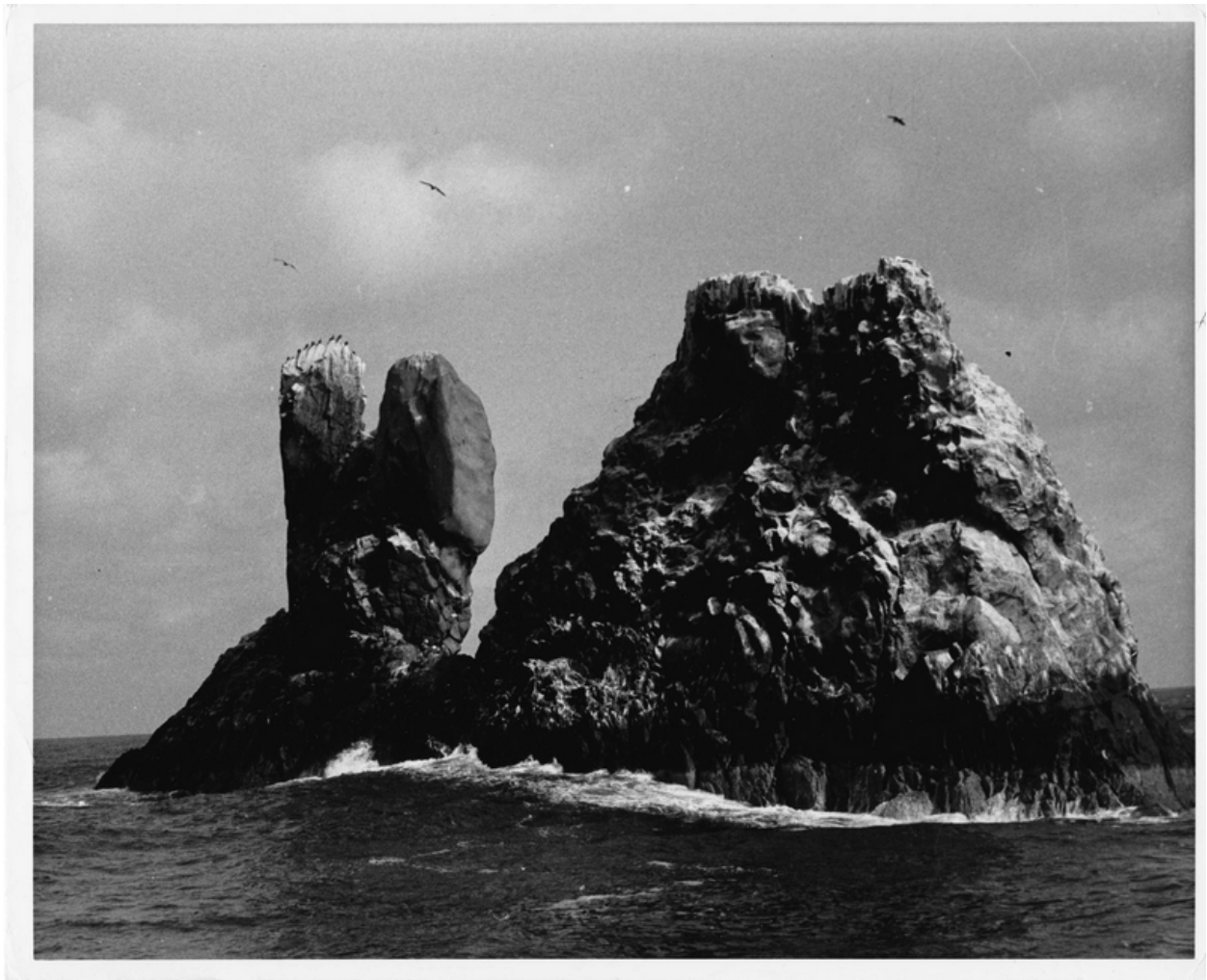


Fig. 2. Photograph of Roca Partida.



Fig. 3. Photograph of San Benedicto Island taken in 1953, (U.S. Navy Photo).



Fig. 4. Photograph of Clarion Island.



Fig. 5. Photograph of Socorro Island taken in 1951, (U.S. Navy Photo).

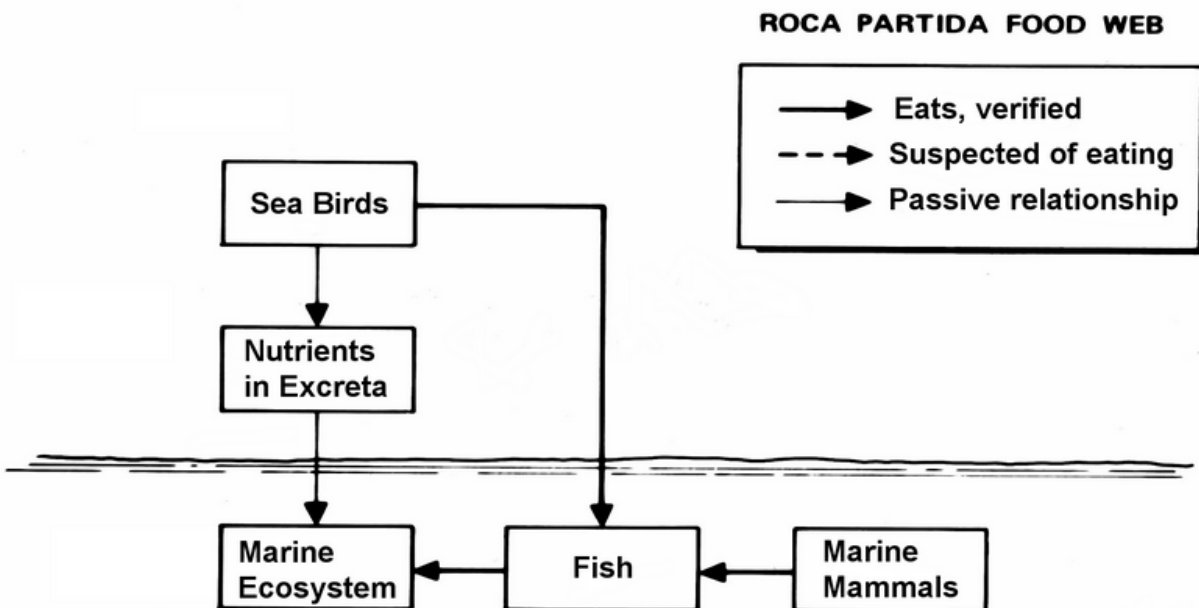


Fig. 6. Diagram of food web for Roca Partida. Solid lines represent one or more observations on actual feeding or data from guts, feces, pellets or

food caches. Dotted lines are conjecture or suspicions.

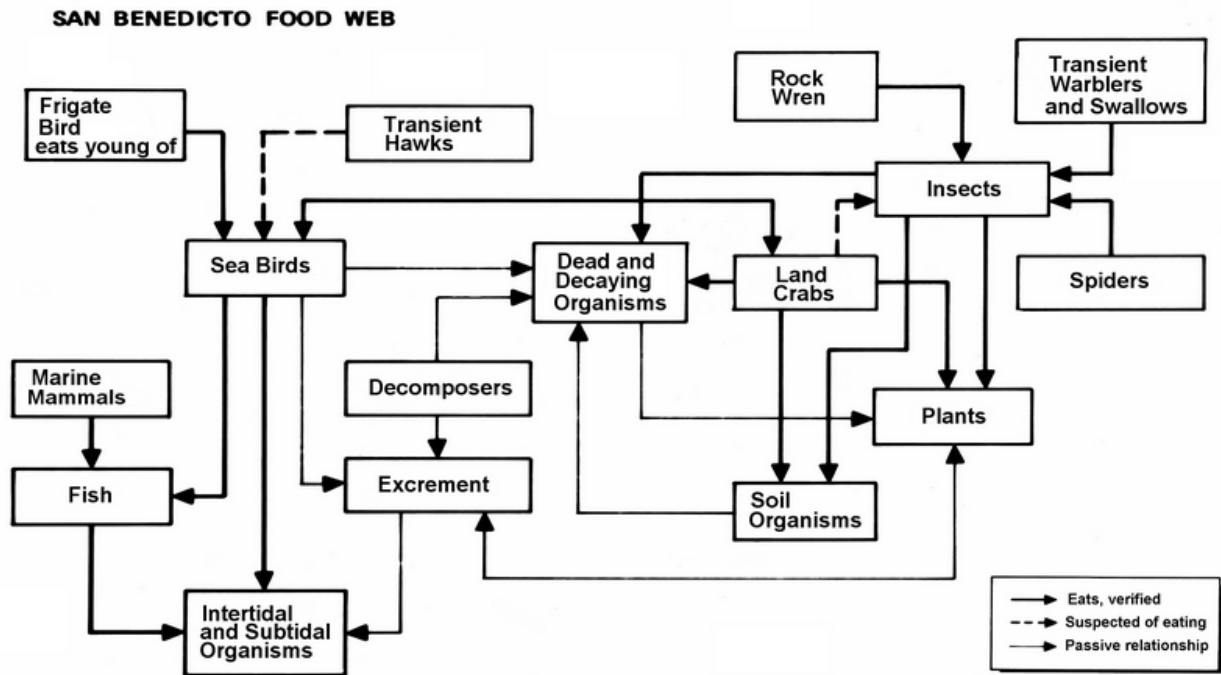


Fig. 7. Diagram of food web for San Benedicto Island.

Fig. 8. Diagram of food web for Clarion Island.

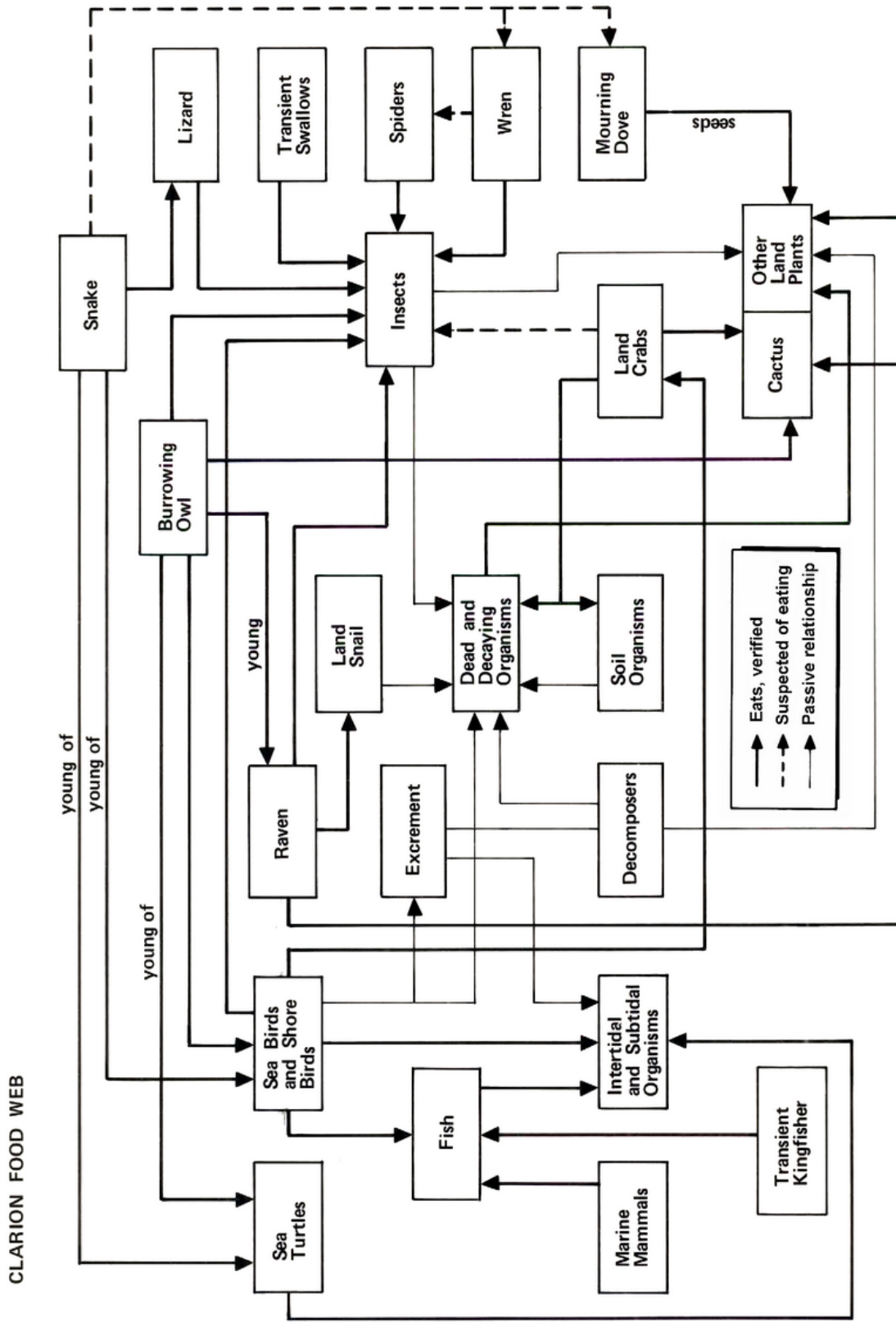
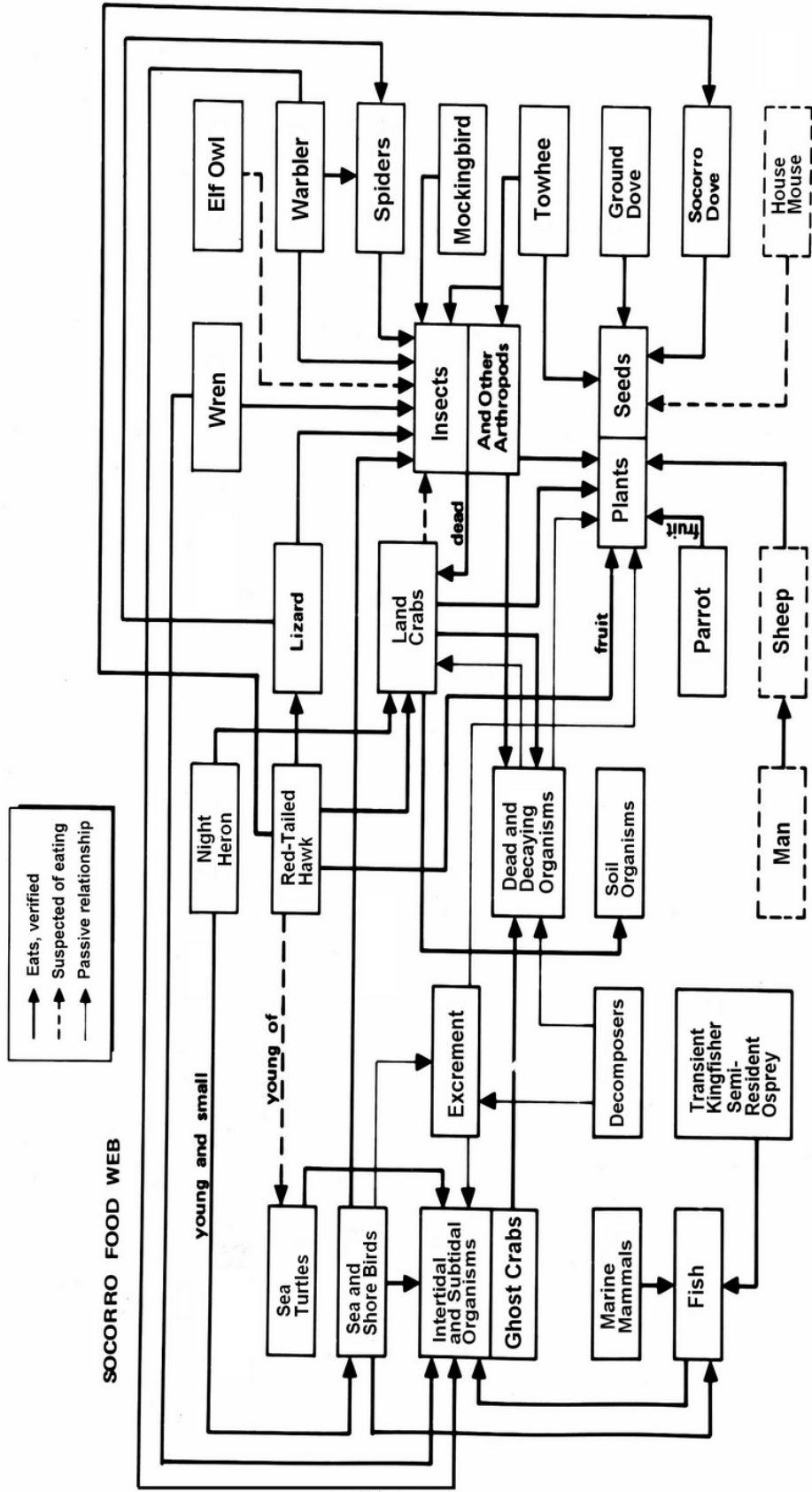


Fig. 9. Diagram of food web for Socorro Island. The domestic animals at the military base are not included.



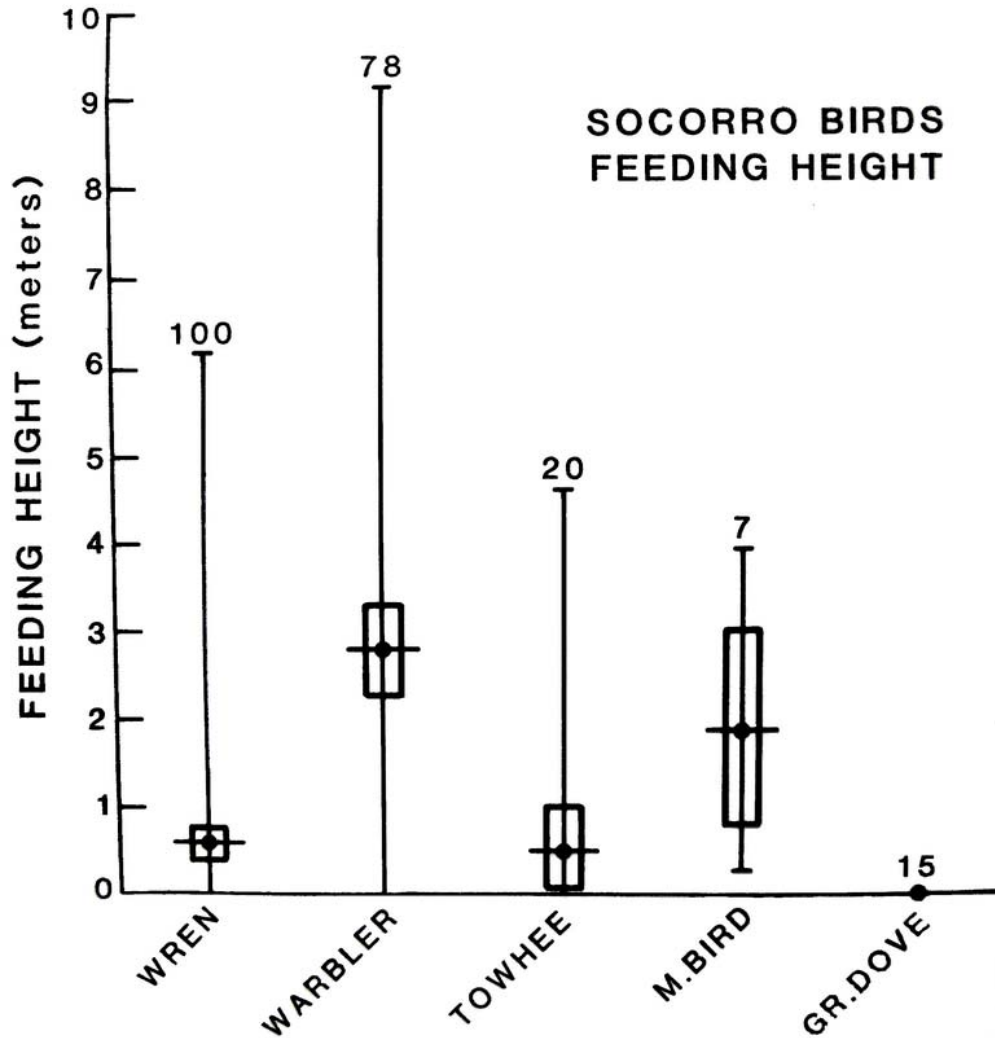


Fig. 10. Foraging heights utilized by some Socorro Island birds, (Lines = range; dots = means; boxes = 2 S.E.).

Wren = Socorro Wren, *Troglodytes sissonii*

Warbler = Tropical Parula, *Parula pitiayumi graysoni*

Towhee = Rufus-sided Towhee, *Pipilo erythrophthalmus socorroensis*

M. Bird = Socorro Mockingbird, *Mimodes graysoni*

G. Dove = Ground Dove, *Columbiana passerina socorroensis*

SOCORRO BIRDS FEEDING LOCATIONS

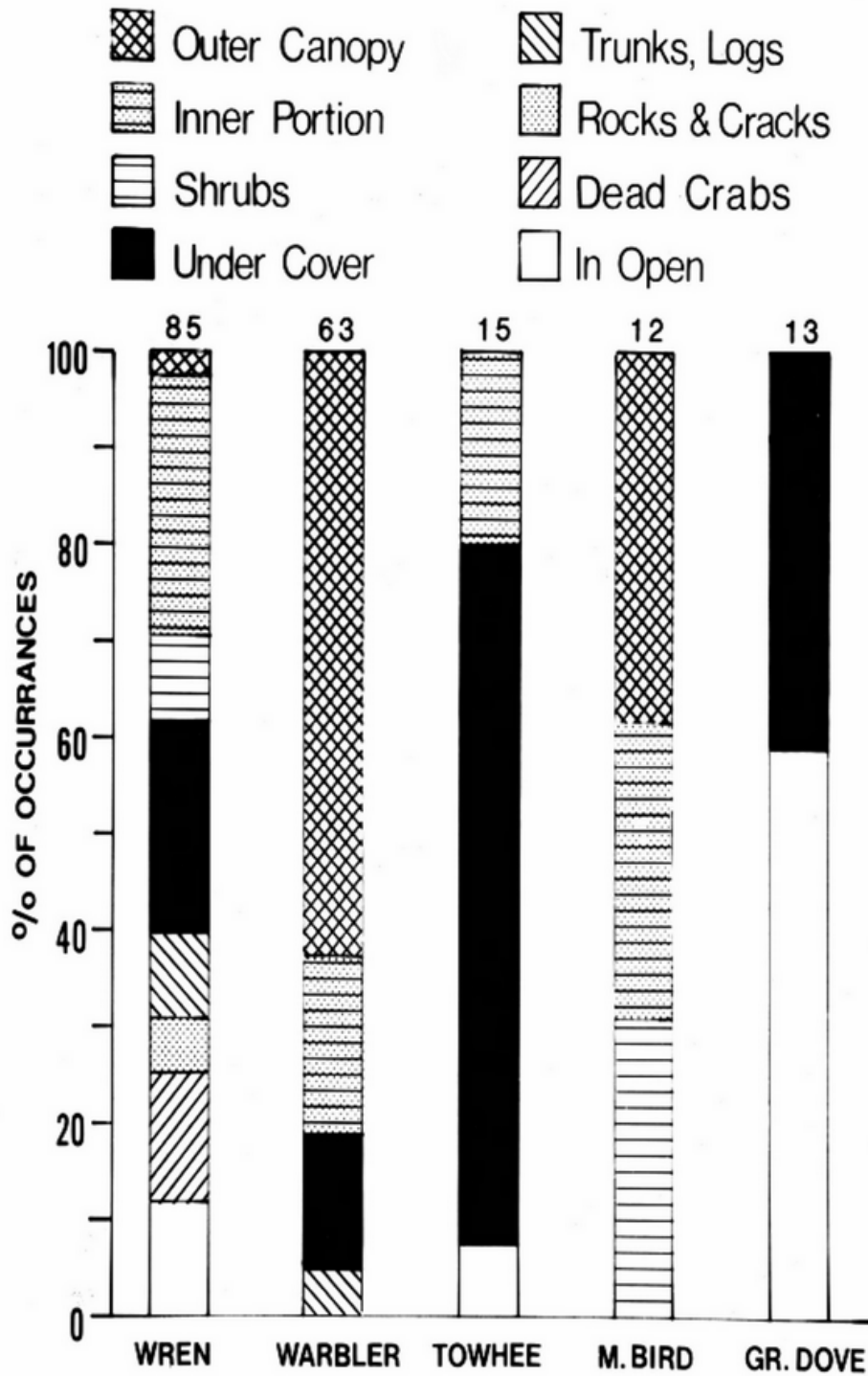


Fig. 11. Feeding locations utilized by some Socorro Island birds.

Legend as in Fig. 10.

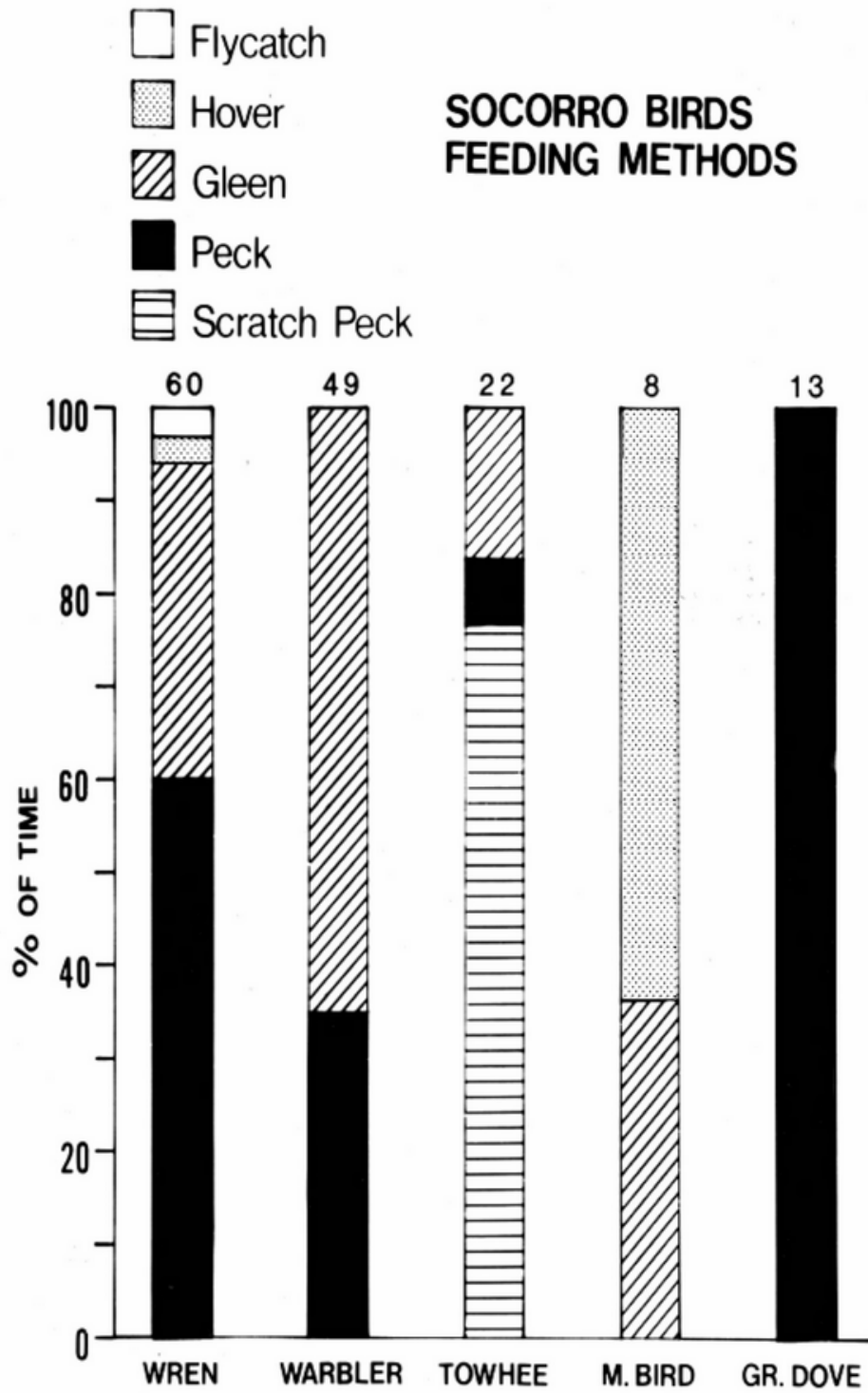


Fig. 12. Feeding methods utilized by some Socorro Island birds.

Legend as in Fig. 10.

LITERATURE CITED

- Águirre-Muñoz, A., R. Mendoza Alfaro. 2009. Especies exóticas invasoras: impactos sobre las poblaciones de flora y fauna, los procesos ecológicos y la economía, en *Capital natural de Mexico*, vol. II: *Estado de conservación y tendencias de cambio*. Conabio, México, D. F. pp 277-318.
- _____, A.; Samanigo-Herrera, A.; Luna-Mendoza, L; Ortiz-Alcaraz, A.; Rodriques-Malagón, M.; Méndez-Sánchez, F; Félix-Lizárraga, M.; Hernández-Montoya, J. C.; González-Gómez, R.; Torres-García, F.; Barredo-Barberena, J. M.; and Latofski-Robles, M. 2011. Island restoration in Mexico: Ecological outcomes after systematic eradications of invasive mammals. In: Veitch, C. R.; Clout, M. N. and Towns, D. R. (eds). *Island Invasives: Eradication and management*, pp. 250-258. IUCN, Gland, Switzerland.
- Álvarez-Cárdenas S., A. Castellanos, P. Galina, A. Ortega-Rubio y G. Arnaud. 1994. Aspectos de la población y el hábitat del Borrego doméstico (*Ovis aries*). En: Ortega, R. A., Castellanos, A. V. Eds. *La Isla Socorro, Reserva de la Biosfera Archipiélago de Revillagigedo, México*. Centro de Investigaciones Biológicas del Noroeste S. C. pp 301-317.
- Aldrete, A.N.G. 1994. New Psocids (Insecta: Psocoptera) from Socorro Island, Socorro Island, Revillagigedo Archipelago, Mexico. *Bull. Southwestern Nat.* 39: 83-88.
- _____, A. C. Carrión, and L. C. Peredo. 1992. Psocoptera (Insecta) of Socorro and Clarion Islands, Revillagigedo Archipelago, Mexico. *Acta Zool. Mexicana (n.s.)* 50: 1-20.

- Anthony, A. W. 1898. Avifauna of the Revillagigedo Islands. *Auk* 15:311-318.
- Aubrey, F.T., S. Leatherwood, E. D. Mitchell, and W. Rogers. 1985. Nesting Green Sea Turtles (*Chelonia mydas*) on Isla Clarion, Islas Revillagigedo, Mexico. *Bull. Southern Calif. Acad. Sci.* 83(2): 69-75.
- Baptista, L.F. 1987. Andrew Jackson Grayson and the "Solitary Dove". *Pacific Discovery*, April-June: 28-37.
- _____, W.I. Boarman, and P. Kandianidis. Behavior and taxonomic status of Grayson's Dove. *Auk.*, 100(4):907-919.
- Brattstrom, B.H. 1953. The cactus of the Revillagigedo Islands, Mexico. *Cactus and Succulent J.* 25: 181-182.
- _____, 1955. Notes on the herpetology of the Revillagigedo Islands, Mexico. *Am. Midl. Nat.* 54: 219-229.
- _____, 1963. Bárcena Volcano, 1952: Its effect on the fauna and flora of San Benedicto Island, Mexico. In: Grisset J.L. Ed. *Pacific Basin Biography*. Bishop Museum Press, pp. 499-524.
- _____. 1982a. The comparative social behavior of *Urosaurus auriculatus* and *U. clarionensis* on the Islas Revillagigedo, Mexico *Herpetological Rev.* 13(1): 11-12.
- _____. 1982b. Breeding of the Green Sea Turtle, *Chelonia mydas*, on the Islas Revillagigedo, Mexico 13(3): 71.
- _____. 1998. Strategies of predator attacks on the schooling fish, *Selar crumenophthalmus* in Academy Bay, Socorro Island, Islas Revillagigedo, Mexico. *Bull. Southern Calif. Acad. Sci.* 97(2): 76-81.
- _____. 1990. Biogeography of the Islas Revillagigedo, Mexico *J. Biogeography*

- 17: 177-183.
- _____. and T. R. Howell. 1956. The birds of Revillagigedo, Islands, Mexico. *Condor* 59: 107-120.
- Castellanos, A. and R. Rodriguez-Estrella, 1993. Current status of the Socorro Mockingbird. *Wilson Bull.* 105(1): 167-172.
- Clayton, D.H. 1985. Nocturnal foraging of the Yellow-crowned Night Heron in the Bahamas. *Florida Field Natr.* 13: 34-35.
- Cohen, J.E., R.A. Beaver, S.H. Cousins, D.L. DeAngelis, L. Goldwasser, H.L. Hoeng, R.D. Holt, A.J. Kohn, J.H. Lawton, N. Martinez, R. O'Malley, L.M. Page, B.C. Patten, S.L. Pimm, G.A. Polis, M. Rejmanek, T.W. Schoener, K. Schoenly, W.G. Sprules, J.M. Teal, R.E. Ulanowicz, P.H. Warren, H.M. Wilbur, and P. Yodis 1993. Improving food webs. *Ecology* 74(1): 252-258.
- Everett, W. T. 1988. Notes from Clarion Island. *Condor* 90: 512.
- Frazier, J. 1985. Misidentifications of sea turtles in the East Pacific: *Caretta caretta* and *Lepidochelys olivacea*. *J. Herpetology* 19(1): 1-11.
- Goldwasser, L. and J. Roughgarden. 1993. Construction and analysis of a large Caribbean food web. *Ecology* 74(1): 1216-1234.
- Gómez, and R. L. Curry. 1995. First description of the nest and eggs of the Socorro Mockingbird. *Wilson Bull.* 107: 551-555.
- Hogue, C.L. 1978. Summary report of entomological investigations. Steele Expedition to the Revillagigedo, 1977 (mimeo), 8 pp.

- Howell, S. and S. Webb. 1989. Additional notes from Isla Clarion, Mexico.
Condor 91: 1007-1008.
- _____ and _____. 1990. The seabirds of the Islas Revillagigedo, Mexico.
Wilson Bull. 102: 140-146.
- Jaksic, F.M. and C.D. Marti. 1981. Trophic ecology of *Athene* owls in
Mediterranean-type ecosystems: A comparative analysis. Canadian
J. Zool. 59: 2331-2340.
- Jehl, J.R., Jr. and K.C. Parkes. 1982. The status of the avifauna of the
Revillagigedo Islands, Mexico. Wilson Bull. 94(1): 1-19.
- _____ and _____. 1983. "Replacements" of land bird species on Socorro
Island, Mexico. Auk 100(3): 551-559.
- Jiménez, M. 1991. Araneofauna de las Islas Revillagigedo, Mexico. Anales
Inst. Biol. Univ. Nac. Auton, Mexico, Ser. Zool. 62(3): 417-429.
- Johnston, I.M. 1931. The flora of the Revillagigedo Islands. Proc. Calif. Acad.
Sci. Ser. 4, 20: 9-104.
- Johnson, K. P. and D. H. Clayton. 2000. A molecular phylogeny of the dove
genus *Zenaida*: Mitochondrial and nuclear DNA sequences.
Condor 102(4): 864-870.
- Keast, A. 1970. Adaptive evolution and shifts in niche occupation in island
birds. Biotropica 2: 61-75.
- Kondoh, M. 2003. Foraging adaptation and the relationship between food
web complexity and stability. Science 299: 1388-1391.
- LeCorre, M. 2008. Cats, rats and seabirds. Nature 451: 134-135.
- _____ and P. Jouventin. 1997. Kleptoparasitism in tropical seabirds:

- Vulnerability and avoidance responses of a host species, the Red-footed Booby. *Condor* 99: 162-168.
- Levin, G.A. 1989. Systematics and conservation. Field notes, San Diego Nat. Hist. Mus. 11(1): 7.
- _____ and R. Moran. 1989. The vascular flora of Isla Socorro, Mexico. *Mem. San Diego Soc. Nat. Hist.* 16: 1-71.
- Martinez-Gómez J. E., J. K. Jacobsen (2004) The conservation status of Townsend's shearwater *Puffinus auricularis auricularis*. *Biological Conservation* 116:35-47.
- McLellan, M. E. 1926. Expedition to the Revillagigedo Islands, Mexico, in 1925, VI. The birds and mammals. *Proc. Calif. Acad. Sci.*, 4th ser. 15:297-322.
- Mrosovsky, N. 1971. Black vultures attack live turtle hatchlings. *Auk* 88: 672-674.
- Murdoch, W.W. 1969. Switching in general predators: Experiments on predator specificity and stability and prey situations. *Ecol. Mono.* 39: 335-354.
- Ortenburger, A.I. 1928. the whip snakes and racers, genera *Masticophis* and *Coluber*. *Mem. Univ. Mich.* 1: 1-247.
- Palacios-Vargas, J. G., J.Llampallas and C. L. Hogue. 1982. Preliminary list of the insects and related terrestrial arthropods of Socorro Island, Islas Revillagigedo, Mexico. *Bull. Southern Calif. Acad. Sci.* 81(3): 138-147.
- Pimm, S.L., J.H. Lawton and J.E. Cohen. 1991. Food web patterns and their consequences. *Nature* 150: 669-674.
- Pitman, R. and L. Balance. 1990. Daytime feeding by Leach's Storm-petrel on

- a mid-water fish in the Eastern Tropical Pacific. *Condor* 92: 524-527.
- _____ and _____. 1992. Parkinson's Petrel distribution and foraging ecology in the Easter Pacific: aspects of an ecclusive feeding relationship with dolphins. *Condor* 94: 825-836.
- Richards, 1959. Geology of the Islas Revillagigedo, Mexico: I. Birth and development of Volcan Bárcena, Isla San Benedicto. *Bull. Volcanologique, Ser.* 22: 73-123.
- _____. 1964. Geology of the Islas Revillagigedo, Mexico, 4. Geology and Petrography of Isla Roca Partida. *Bull. Geol. Soc. Amer.* 75: 1157-1164.
- _____. 1965. Geology of the Islas Revillagigedo, 3. Effects of erosion on Isla San Benedicto 1952-61, following the birth of Volcan Bárcena. *Bull. Volcanologique* 28: 1-23.
- _____. 1966. Geology of the Islas Revillagigedo, Mexico, 2. Geology and petrography of Isla San Benedicto. *Proc. Calif. Acad. Sci.* 33: 361-414.
- _____. and B.H. Brattstrom. 1959. Bibliography, cartography, discovery, and exploration of the Isla Revillagigedo. *Pro. Calif. Acad. Sci. Ser. 4* 29: 315-360.
- Rodríguez-Estrella, R., G. Arnaud, S.C. Alvarez, and A. Rodriquez. 1991. Predation by feral cats on birds at Isla Socorro, Mexico. *Western Birds* 22: 141-143.
- _____, E. Mata, and L. Rivera. 1992. Ecological notes on the Green Parakeet of Isla Socorro, Mexico. *Condor* 94: 523-525.

- Santaella, L. and A.M. Sada. 1991. The avifauna of the Revillagigedo Islands, Mexico: additional data and observations. *Wilson Bull.* 103(4): 668-675.
- SEMARNAT, 2004. Programa de Conservación y Manejo Reserva de la Biósfera Archipiélago de Revillagigedo. Primera Edición. México.
- Townsend, C. H. 1890. Birds from the coasts of western North America and adjacent islands, collected in 1888-89, with description of new species. *Proc. U.S. Natl. Mus.* 13:131-142.
- Vazquez, L. 1958. Notas sobre Lepidopteros de las Islas Revillagigedo. II. *Annal. Inst. Biol. Mex.* 29: 349-353.
- Vickery, J.A. and M. de L. Brooke. 1994. The kleptoparasitic interactions between Great Frigatebirds and Masked Boobies on Henderson Island, South Pacific. *Condor* 96: 331-340.
- Walter, H.S. 1990. Small viable population: The Red-tailed Hawk of Socorro Island. *Cons. Biol.* 4: 441-443.
- Wanless, R.M. and A. Angel. 2007. *Masticophis anthonyi* (Clarion Racer). *Diet. Herpetological Rev.* 39(4): 468.
- _____, A. Aguirre-Muñoz, and J.D. Jacobsen. 2009. Birds of Clarion Island, Revillagigedo Archipelago, Mexico. *Wilson J. Ornith.* 121(4): 745-751.
- Watts, B.D. 1988. Foraging implications of food usage patterns in Yellow-crowned Night Herons. *Condor* 90: 860-865.
- Wolda, H. 1975. The ecosystem on Malpelo Island. *Smithsonian Contr. Zool.* 2: 203-216.
- Yanga, S., J.E. Martínez-Gómez, R.M.N. Sehgal, P. Escalante, F.C. Camacho,

and D.A. Bell. 2011. A preliminary survey for pathogens in
Columbiform birds on Socorro Island, Mexico. *Pacific Cons. Biol.*
17: 11-21.

Zarn, M. 1974. Habitat management series for unique or endangered species:
report Nol 11, Burrowing Owl, *Speotyto cunicularia hypugaea*.
Bur. Land Management Tech. Note 250: 1025.