Summary

Dennis M. Power
Santa Barbara Museum of Natural History,
Santa Barbara, California 93105

It is interesting to compare the works in this symposium with the research of the past. Progress can be measured by the fact that there are new means of gathering and analyzing data and that, with these tools, new information continues to be obtained on the geology, biology, and anthropology of the islands. New ideas and theories also are being tested, such as the dynamic equilibrium model and related concepts in the theory of island biogeography. In this section, I want to examine some of the new facts that are being gathered, some of the established theories being analyzed, and some of the more recent models being tested. I will also deal in a very general way with multidisciplinary comparisons of marine faunas, species diversity, evolution, and with the direct and indirect impact of man on the islands.

Multivariate Statistics

Among the new research tools that have become widely available in the last ten years are computers and multivariate data analysis. "Cluster analysis" is used by Littler in assessing the biogeography of macrophytes and macroinvertebrates of the rocky intertidal zone, by Seapy and Littler in examining the biogeography of macroinvertebrates, by Murray, Littler, and Abbott for the biogeography of marine algae, by Kanter for the biogeography of invertebrate communities in mussel beds, and by Ebeling, Larson, and Alevizon to describe kelp-bed fish assemblages. "Canonical variates analysis" (also called "multiple discriminant functions analysis") is used by Kanter to examine the importance of certain abiotic ecological factors for island and mainland mussel communities, by Haldorson to examine morphological similarities among populations of surfperches, by Bezy, Gorman, Adest, and Kim to analyze scalation patterns and divergence in the Island Night Lizard, by Power to describe phenetic variation in island and mainland populations of House Finches and Rock Wrens, and by Gill to analyze skull variation in island and mainland Deer Mice (*Peromyscus*). "Factor analysis" is used by Ebeling, Larson, and Alevizon to examine habitat variables for kelp-bed fishes and by Gill to assess morphological variation in Deer Mice. "Principal components analysis" is also employed by Haldorson in his study of gene flow to and from Santa Cruz Island populations of surfperches.

Multivariate data analysis is often used to seek patterns that might not otherwise be discerned and to *generate*, rather than *test*, hypotheses. A causal pathway may be inferred in a descriptive multivariate analysis, but is often not tested. This situation should not detract from the utility of these methods, just as models that are often so simplified as to not reflect a specific ecosystem still have a place in pointing the way toward greater understanding.

Biochemical Systematics

Electrophoretic analysis of tissue proteins has also become an important analytical method in recent years. Starch gel electrophoresis is used by Busath to investigate genetic variation between island and mainland populations and between beach and non beach "races" of an amphipod on Santa Cruz Island. Haldorson uses starch gel electrophoresis to determine that Channel Island populations of surfperches were genetically isolated from mainland populations of the same species. In Yanev's electrophoretic survey of salamanders of the genus *Batrachoseps*, genetic distances are used to derive divergence times of sibling species. Bezy *et al.*

also use electrophoretic analysis to derive genetic distances and to hypothesize divergence times among populations of the Island Night Lizard and their mainland relatives. Finally, Gill analyzes 30 protein systems to examine genic heterozygosity and distance among populations of the Deer Mouse.

The Distribution and Biology of Species

Continuing research on a number of fronts has brought new information on the distribution and biology of species. Lindberg, Roth, Kellogg, and Hubbs, for example, give descriptions of fossil invertebrate species from Guadalupe Island and find that faunal components in the late Pleistocene indicate that ocean temperatures averaged 2 to 3°C warmer than present. Recent species from the Californian Province dominate the assemblage now, a change characterized by the extinction of Panamanian elements. In an appendix to the foregoing paper, Durham describes a new fossil species from Guadalupe Island.

Considering extant forms, Wicksten provides new knowledge on the distribution of crab species in the Southern California Bight, especially in relation to substrate characteristics. T. Brown confirms the existence of a Garter Snake population on Santa Catalina Island, and P. Brown reports on the distribution of bats on the Channel Islands, including new records of several species.

Hunt, Pitman, and Jones compare past and present distributions of sea birds on the Channel Islands. They find, for example, that Common Murres and Tufted Puffins once nested on the islands but no longer do so. The numbers of Brown Pelicans, cormorant species, and Cassin's Auklets have decreased, while numbers of Xantus' Murrelets have increased. Many of these changes may be linked with the activities of man. Studies of the breeding biology of certain sea birds have also revealed some new twists. Wingfield, Martin, Hunt, Hunt, and Farner find that homosexual (female-female) pairs of Western Gulls occur on Santa Barbara Island with a frequency of seven to thirteen per cent of clutches. This may be related to a skewed sex ratio in favor of females, or may be a result of abnormal hormonal cycles. Hand reports that in a colony of Western Gulls on Bird Rock, Santa Catalina Island, the population is not shrinking but the number of young birds fledged is significantly lower than that of a decade ago; increased nesting density may be causing higher rates of chick mortality. Le Boeuf and Bonnell examine changes in pinniped populations since the time of Bartholomew's review at the 1965 symposium (Philbrick 1967). The Northern Fur Seal, Northern Elephant Seal, California Sea Lion, Harbor Seal, and Guadalupe Fur Seal are all increasing their numbers.

Records of bird and mammal faunas from the recent past have been uncovered in Indian middens. Guthrie determines that three species of sea birds not currently known to nest on San Miguel Island probably bred there within the last 2,000 years—the extinct, eider-like genus *Chendytes*, Manx Shearwater, and Leach's Storm Petrel. Over 50 species of marine and land birds have been identified from one midden site alone. An extinct species of vampire bat was also recorded. Walker examines mammal remains from middens on San Miguel Island. There is a substantial number of bones of a large form of Deer Mouse which went extinct roughly 2,000 years ago, possibly due to large-scale habitat destruction caused by wind erosion, water erosion, and overgrazing by elephants. There is also evidence for the presence of a shrew and a spotted skunk, species which do not now occur on San Miguel.

Land Bridges

As more information comes to light, old concepts often give way to new. One case for the California Islands concerns inter-island and island-mainland connections. Vedder and Howell summarize geological and paleontological information on the period covered by the late Miocene (five to six million years ago) to the Recent to describe, in general terms, the key events that created the present seafloor topography of the southern California borderland.

Because of intervening deep water, it is unlikely that San Clemente or Santa Cruz-Santa Catalina Ridges formed pathways over which terrestrial biota could move. There appears to be no evidence for the widely-held idea of a Pleistocene land bridge from the Santa Monica Mountains to the Northern Channel Islands platform (see papers in Philbrick 1967). Junger and Johnson provide geological evidence for the absence of a Pleistocene land bridge between Anacapa Island and the mainland. They report that sub-bottom seismic reflection profiles across the narrow eastern end of the Santa Barbara Channel force them to conclude that at no time during the Quaternary was the water depth between the island and the mainland less than 100 m. Wenner and Johnson call attention to the lack of geologic evidence for a Pleistocene land bridge and explain vertebrate distribution on the Northern Channel Islands in this new light. They note that the land vertebrate fauna is depauperate and not at all representative of the mainland, or of what would be expected if a direct land connection had existed. As an alternate theory, they interpret biological and anthropological evidence to suggest a combination of "sweepstakes" dispersal by rafting and both conscious and unintentional transport by Indians in plank canoes. One interesting case is the Dwarf Mammoth, which, based on information about modern elephants, is now believed to have been a capable swimmer. At a time of lowered sea levels in the Pleistocene, ancestors of the Dwarf Mammoth would have had to cross only a relatively short, 6-km stretch of water between the mainland and the eastern end of Anacapa Island.

Dynamic Equilibrium Theory

MacArthur and Wilson (1963, 1967) were the first to develop the idea that the diversity or richness (numbers) of species on islands results from a dynamic balance between the rate of addition of new species through immigration and the rate of loss through extinction. These rates are affected by the physical characteristics of an island, such as size and distance from a source of colonizing species. Wilcox explains why some reptile faunas on the California Islands are above or below the predicted equilibrium number of species. The higher latitude Channel Islands are subsaturated, presumably due to climatic instability associated with Pleistocene glacial advances and retreats. Islands with recent land bridges to the mainland are regarded as supersaturated. The reptile fauna on the San Benito Islands appears to be in balanced equilibrium.

Diamond and Jones also address the issue that species composition on an island will vary through time, even though the number of species may remain roughly constant. On the Channel Islands, average annual turnover of breeding land birds is one to six per cent of the avifauna per year. It is also pointed out that turnover studies are not accurate unless based on data gathered in several consecutive years; there is a decline in "apparent turnover" with increasing census interval.

Density Compensation

Theoretically, if a fauna on an island is depauperate, the species that do exist there can use part of the resources that might otherwise have gone to the missing species. The existing species may therefore occur in greater numbers than on the mainland. The phenomenon of species in an impoverished community compensating in abundance for absent species was termed "density compensation" by MacArthur, Diamond, and Karr (1972). In this regard, Laughrin finds that densities of the Island Fox on Santa Cruz Island are greater than densities of Gray and Red Foxes on the mainland. An analysis of age structure also indicates a higher proportion of older animals in Island Fox populations. Diamond and Jones note that species of land birds that reach the islands and successfully establish breeding populations may increase their abundance or broaden their ecological niches by using resources that, on the mainland, would have been pre-empted by competitors. Philbrick also reports that some island plant species seem superabundant in comparison with mainland relatives.

Vicariance

With the widespread acceptance of plate tectonics and continental drift, it became apparent that the explanation of biotic distribution and subsequent evolution now fell into two classes—dispersal and vicariance (*e.g.*, see Platnick and Nelson 1978). Dispersal models explain disjunction in distribution by dispersal across pre-existing barriers, such as Wenner and Johnson discuss for the recent distribution of land vertebrates on the Northern Channel Islands. Vicariance models explain disjunction by the appearance of barriers fragmenting the ranges of ancestral species. Yanev relies on the vicariance approach to hypothesize possible divergences of lineages of *Batrachoseps* salamanders. The lineages are superimposed on maps showing a time-series of reconstructions of the geologic, botanic, and climatic history of California.

Faunal Components

Cool waters in the California Current System run south along the coast of California. Veering from the east-west trending coastline at about Point Conception, the current eventually begins a counterclockwise loop, called the Southern California Eddy, which runs in a northerly and northwesterly direction and brings warmer water along the coast. The currents become more complex as they strike the submarine ridges and platforms on which the Channel Islands are situated. There is also considerable variation in direction and intensity of the currents, brought on by changes in the seasons and weather. Seapy and Littler give a general description of the current system, and maps are provided in Kanter's paper. These currents affect the dispersal of marine organisms from one island to the next. Temperature differences lead to the survival of more northern species in the cool waters of the northern and outermost islands and favor the survival of more southerly species in the warmer waters of the islands to the south and nearer to shore.

To begin the section dealing with the marine realm, Owen reviews the existence of eddies, transport, and the ecological effects of the California Current System. The Southern California Eddy owes its character, and perhaps its existence, to the islands and banks off southern California. It is seasonal, occurring only from July through January. The presence and absence of eddies and countercurrents have an important impact on enrichment of the ecosystem—nutrient concentrations, phytoplankton production, zooplankton, nekton stocks, and most marine communities.

Littler finds some relationship to the predicted faunal-components patterns in his data on macrophyte and macroinvertebrate cover in the rocky intertidal zone. His analysis of similarity between various island and mainland sites shows a clustering of (1) warm-water sites of Santa Catalina and San Clemente Islands; (2) cold-water sites of San Miguel and San Nicolas Islands; and (3) mixtures of cold- and warm-water sites, such as Santa Barbara and Santa Cruz Islands. It is also shown, however, that these relations are affected by other factors, such as the degree of site disturbance.

Seapy and Littler record macroinvertebrates in the rocky intertidal zone and observe that the percentages represented by northern and southern species are essentially in agreement with the hypothesis of inter-island affinities based on hydrographic conditions. Santa Catalina and San Clemente Islands—two of the Southern Channel Islands—had the highest percentage of southern species, followed by Anacapa and Santa Barbara Islands. Northern species exceeded southern ones on the more northerly islands of San Miguel, Santa Rosa, and Santa Cruz and on outlying San Nicolas Island. Similarity analysis supports this by linking San Miguel Island, San Nicolas Island, and Cayucos Point on the mainland—all sites subject to the cold California Current. Rocky intertidal faunas are also similar on Santa Catalina and San Clemente Islands—sites which are in the path of the warm Southern California Eddy.

Murray, Littler, and Abbott look at range end-points of marine algae and show that Point

Conception is an important biogeographical boundary, especially for species with a more southerly distribution. Similarity analysis linkage groups are: (1) Anacapa, San Clemente, and Santa Catalina Islands; (2) Santa Barbara and Santa Cruz Islands; and (3) San Miguel, San Nicolas, and Santa Rosa Islands. They conclude that these clusters exist because of sea temperatures and the current system in the Southern California Bight.

Kanter examines marine invertebrates associated with mussel beds. His similarity analysis shows the following clusters: (1) Corona del Mar and San Diego on the southern mainland; (2) San Miguel, Santa Rosa, Santa Cruz, and San Nicolas Islands (most of the Northern Channel Islands); (3) Government Point near Point Conception on the northern mainland; and (4) Goleta Point, a northern mainland site with southern exposure. For these special intertidal communities, Kanter suggests it is not so much temperature regimes that are accounting for salient similarities, but the sea currents that carry planktonic larvae. There are also site-specific patterns—most notably due to quantities of tar, amount and size of sediment, and amount of detritus—the latter two factors relating to the number of microhabitats within the mussel community.

On the other hand, interlocality differences in kelp-bed fish density, diversity, and composition in the Santa Barbara Channel reflect differences in habitat structure, rather than variations in the oceanographic regime. Ebeling, Larson, and Alevizon examine fish at a site on the north side of Santa Cruz Island which receives relatively warm water from the Southern California Eddy system. Island reefs in the Santa Barbara Channel are in clearer water and are steeper, deeper, and physically much more diverse than nearby mainland reefs. The composition of kelp-bed fish faunas is primarily dependent on these physical conditions.

Sea birds, because of their vagility, might not be expected to demonstrate the overlap of northern and southern faunas that is evident in some other classes of organisms. However, Hunt, Pitman, and Jones report that, of the thirteen species of sea birds known to breed or to have bred on the California Channel Islands, five reach their southern breeding limits and three reach their northern limits within the Channel Islands. All of the northern species have their greatest numbers on San Miguel Island, while southern species occur almost entirely on Santa Barbara and Anacapa Islands.

Gill, in her study of genic similarities of populations of Deer Mice, suggests that there may be gene flow from populations on San Miguel and Santa Rosa Islands to that on San Nicolas Island. Transport of mice could have been by rafting (carried along by the southward-flowing California Current) or by Indian canoes.

Species Diversity and Richness

The diversity of species on the California Islands, relative to that on the mainland, is low for terrestrial plants and animals but high for elements of the marine biota. Littler finds greater average biomass, numbers of taxa, richness, evenness, and diversity for the island rocky intertidal biota than for the mainland sites. Island sites also have greater cover and density of macroinvertebrates, but no island-mainland differences in these two attributes are found for macrophytes. Kanter finds that island invertebrate communities in mussel beds contain more species than do most of those on the mainland, which appears related, in part, to human disturbance of mainland sites and to other site-specific factors. For example, richness increases with physical heterogeneity as measured by the quantity of coarse fraction material and sediment size, but decreases with an increase in amounts of detritus and tar from natural seeps. Straughan and Hadley observe that the island sandy beach macrofaunas follow trends of increasing abundance of species with increasing stability of the habitat (*e.g.*, finer sediments and more sheltered conditions). Ebeling, Larson, and Alevizon find that island kelp beds favor higher fish density and diversity than do similar mainland habitats.

On the other hand, Wilcox reports that reptile faunas of the California Islands have fewer species than those on the mainland, and Diamond and Jones note that there are fewer land bird species on the islands. Wenner and Johnson discuss why the land vertebrate faunas of the island should be depauperate—colonization was by sweepstakes dispersal and Indian transport, not land bridges.

Evolution

The California Islands have always been a natural laboratory for the study of evolution. The first naturalists on the islands were concerned with taxonomy and the description of variation in populations. Evolutionary biologists today continue to describe new variation but they also are interested in its adaptive significance. For plants, Philbrick discusses the range of endemic taxa on the islands, Guadalupe and San Clemente emerging as islands that have a high proportion of endemic plants. Power finds high edemicity for land birds on these two islands, as well. Philbrick also describes some general trends he has found in the evolution of island plants: a tendency for pinkish flowers; a tendency for grayish foliage; a relatively large habit of growth, leaves, or fruits (Carlquist's [1974] "gigantisms"); a genetically determined prostrate form; and hybridization.

Hochberg describes the characteristic of larger leaves in a number of island chaparral species; the adaptive significance of this trait is not yet known. Young documents hybridization between two species of *Rhus* in an ecotone between chaparral and coastal sage scrub on Cedros Island. Davis describes hybridization in *Malacothrix* and suggests such interbreeding may have played a role in the evolution of species of this plant genus. Vivrette examines the association between certain coastal plant species and salt gradients in the soil and provides evidence that, instead of the plants having adjusted to natural degrees of salinity in the soil, the salt gradients are due to species-specific rates of salt recycling.

Busath examines genic differences in island and mainland populations of an amphipod and identifies beach and non-beach "races" on Santa Cruz Island. Haldorson finds genetic variation in two species of surfperches, a result that shows even species regarded as highly vagile may be genetically differentiated in island waters. This parallels the situation in birds—discussed by Power and by Diamond and Jones—in that even potentially mobile species may come to differ from mainland populations through natural selection or genetic drift if actual dispersal rates are low.

Divergence times of species can be inferred from genetic distance data. Yanev examines *Batrachoseps* salamanders and hypothesizes that the island form of *B. pacificus* diverged from the mainland form about four million years ago, that certain semispecies within *pacificus* diverged from one another about eight to ten million years ago, and that the sibling species *pacificus*, *attenuatus*, and *nigriventris* diverged between twenty and thirty-five million years ago. Bezy places divergence times for populations of the Island Night Lizard at about one million years ago, while divergence between the island species and the nearest mainland relative is put at about ten to fifteen million years ago. Bezy also reports that data on genetic distance, scalation, color pattern, and body size all suggest a consistent order to the relationship among populations of this lizard: Santa Barbara—San Clemente—San Nicolas, a pattern which correlates with distance from the mainland but not with island area, elevation, latitude, plant species number, or lizard species number.

Power examines morphological variation in certain species of land birds on the California Islands. Seventy per cent of the total resident avifauna on distant Guadalupe Island are endemic races; on many of the Channel Islands, endemicity ranges from 40 to 45 per cent of the breeding land bird fauna. Some species, such as the House Finch, show rather gradual morphological variation along the islands, culminating with the most extreme island phenotype on Guadalupe. Others, such as the Rock Wren, may also show extreme differentiation on Guadalupe but vary hardly at all, or in a less regular pattern, on other California Islands. Several island bird populations show larger body size and, in some cases, proportionately larger bills and shorter flight feathers, presumably as an adaptation to island conditions.

A more specialized case of evolution concerns one of the most clearly marked races of birds on the Channel Islands—the Santa Cruz Island Scrub Jay. Atwood examines the breeding biology of this form. In most respects, it is like its mainland counterpart; however, mean clutch size is lower in the island jay than in the adjacent coastal mainland subspecies. This suggests that the island population is at or near carrying capacity on Santa Cruz and that natural selection is tending to favor greater efficiency in raising a few young that are likely to survive, rather than a high reproductive output, as is common in an expanding population or in one subject to less climatic stability.

Gill examines genic and morphological variation among island and mainland populations of Deer Mice (*Peromyscus*). Morphologic divergence has been much greater than genic divergence. The island mice are all larger than mainland mice. San Clemente Island mice are the most distinct in all traits—genic and morphological—a situation which matches Power's data for certain land birds and Philbrick's records of high endemicity in plants. Populations of mice from the Northern Channel Islands are the most similar to one another; however, there is also a somewhat surprising relatively high similarity between mice on San Nicolas Island and those on Santa Rosa and San Miguel Islands. Among the Southern Channel Islands, San Clemente and Santa Catalina populations are similar. In general, there seems to be little gene flow between populations. Observations in the laboratory suggest that behavioral mechanisms may enhance reproductive isolation among island populations. There is also a high level of genetic variability in island populations, suggesting that they have not undergone serious diminution or a genetic bottleneck. High levels of variability are taken by Gill to indicate large populations, not gene flow between the islands.

Aboriginal Man

Interactions between humans and the biota of the islands have gone on for thousands of years. Indian villages are known from most of the islands, the most notable exception being Guadalupe. The plank canoe was a unique mode of transportation among Indians of southwestern California, making possible colonization and trade between islands.

How long ago were people on the islands? To answer this question, charcoal from a fire area believed to be a hearth was subjected by Berger to a radiocarbon assay. He found no measurable radiocarbon activity, which indicates an age of greater than 40,000 years. If this date is correct, it represents a new record for early man on the islands—earlier than many have suspected man was even in the New World. The site appears to be in conjunction with a Dwarf Mammoth kill and may be one of the oldest early man sites in the Americas.

Working with evidence of more recent human occupation, Glassow notes that, because of isolation, the number of intact Indian sites on the islands is especially high, in stark contrast to the coastal mainland strip. In a survey of recent archaeological sites, Glassow finds that individual sites may contain episodes of midden occupation distributed intermittently through the course of 3,000 years. Depth or size of a site turns out to be an unreliable indicator of the length of occupation of a site. Some sites on Santa Cruz show no change of constituents through 2,000 to 3,000 years, while others, such as those on the south coast, do show change. Guthrie's analysis of bird remains in a midden site on San Miguel Island has turned up evidence that Snow Geese and other granivorous ducks and geese were eaten by the Indians. Most marine species represented in middens (*e.g.*, cormorants) appear to have been killed for their feathers rather than for food. Whistles and tools, such as awls, tubes, and scrapers, are made from sea bird limb bones. Guthrie's sites vary in age from 2800 B.C. to A.D. 1500.

Recent Landscape Changes

Early voyagers from Europe visited the islands, and whaling and trade in seal oil and furs were booming in the 1800s. Purposely-introduced exotic species, or domestic stock that returned to a wild state, have had a severe impact on the landscape of many of the islands. The history of people on the islands indicates both harmony and flagrant abuse, with the most recent trend being a greater appreciation of the unique character of the islands and the fragility of their plant and animal communities.

Johnson examines the history and geography of San Miguel Island. He shows that, since the mid-1800s, drought, overgrazing by domestic stock, and cultivation have led to vegetation stripping, sand dune encroachment, and wind erosion. Dramatic landscape changes may pre-date man, however, for it is suspected by Johnson that prehistoric fires and overgrazing by elephants led to episodes of erosion on San Miguel Island during the Pleistocene.

Minnich maps vegetation of Santa Cruz and Santa Catalina Islands. Some of the most interesting aspects of the island vegetation are the arborescent appearance of chaparral shrubs, open configuration of stands, relative unimportance of woody vegetation, and widespread extent of grassland. Rather than being due to a cool, equable climate, Minnich believes these characteristics are attributable to long-term overgrazing by feral sheep and goats. Grazing also reduces the natural fire regime by removing flammable brushland fuels. It is surmised that without feral animals (and given occasional fires) prehistoric island vegetation would have resembled that on coastal southern California mountains today. Brumbaugh reports that on Santa Cruz Island coastal sage is especially reduced, while pines and chaparral woodland suffered slow attrition due to the introduction of sheep in the mid-19th century. Upland erosion and adjacent valley bottom deposits correlate with changes in vegetation. Also on Santa Cruz, Hobbs notes that the northern populations of pines and shrubs have been reduced and are not regenerating because of grazing by feral sheep. Coblentz examines a similar problem—goats on Santa Catalina Island. In addition to overbrowsing, goats adversely affect vegetation by preventing a buildup of a mulch layer, which normally retains soil moisture, slows erosion, keeps soil temperature low, and provides nutrients.

Conservation

The case of feral animals having a severe impact on island vegetation bears an obvious message concerning conservation of the unique ecosystems on the California Islands. It is reassuring to have Brumbaugh note that there is evidence for a reversal of vegetation loss and erosion with the removal of sheep from parts of Santa Cruz Island. Coblentz also notes that there has been a resurgence of plant growth where goats have been removed from areas of Santa Catalina Island.

In the rocky intertidal zone, Littler's data suggest that human disturbance of certain mainland sites has caused declines of species; only species which were already rare have disappeared completely. Kanter observes that, near natural oil seeps, there are increased tar deposits which lead to a decrease in invertebrate species diversity in mussel communities. This observation suggests the kinds of problems that may occur due to oil pollution.

The populations of a number of sea birds nesting in the Southern California Bight have changed in recent decades. Hunt, Pitman, and Jones note that the major declines in the Brown Pelican and two cormorant species seem to have been caused by human disturbance of nesting grounds and the ingestion of chlorinated hydrocarbons. Increases in numbers of Xantus' Murrelets and Cassin's Auklets on Santa Barbara Island seem influenced by the removal of feral cats in recent years and the extinction of a natural predator, the Peregrine Falcon. These authors note that the impact of man on island sea birds includes harvesting by Indians, predation due to feral cats and rats, vegetation destruction and erosion caused by feral goats and sheep, disturbance by egg and specimen collectors, use of the islands as military practice targets, chemical pollution of the sea, and greater recreational use of the channel.

Kiff gives a historical account of certain birds of prey on the Channel Islands. The Bald Eagle once nested on all the Southern California Islands, including Los Coronados. Their populations declined because of shooting, nest disturbance, and poisoning. The Bald Eagle and the Peregrine Falcon finally became extinct locally in the mid-1900s, owing to effects of the pesticide derivative DDE in the food chain. This is suggested by the fact that extirpation is correlated with the introduction and widespread use of DDT, the simultaneous extinction of these species on all the islands, DDE-caused breeding failures of both species elsewhere in their ranges, unusually high DDE levels in the channel, and DDE-caused breeding failures of certain resident sea birds. The Osprey vanished about 1930 from unknown causes. Protection of the fauna and the natural "cleansing" of the marine ecosystem may permit re-establishment of these species.

Several pinniped species were near extinction in the late 1800s and early 1900s. They are now under federal protection. Le Boeuf and Bonnell describe the recent increase in abundance and distribution of seals and sea lions on the California Islands. Since 1965, Northern Fur Seals have established a strong population on San Miguel Island. The Northern Elephant Seal is showing a very good recovery from the brink of extinction—60,000 individuals were recorded in 1977. There are nearly twice as many California Sea Lions (80,000 to 125,000) and three times as many Harbor Seals (2,000) as estimated in 1965. The Guadalupe Fur Seal is continuing a much slower recovery—the entire world's population numbers less than 2,000.

A new form seems destined for the endangered species list. T. Brown suggests the endemic race of garter snake on Santa Catalina Island be accorded special status because of its restricted distribution and the transient and fragile nature of its habitat.

Support of Research

There has been significant private support of research on the California Islands over the years, and institutions have also made important financial and in-kind contributions. It should be noted that the federal government has been directly responsible for assisting a vast array of research projects on the California Islands. Eight of the 43 studies in this volume were substantially financed by the Bureau of Land Management in its effort to gather baseline data on the Southern California Bight: Littler on the ecology of the rocky intertidal biota; Seapy and Littler on the biogeography of rocky intertidal macroinvertebrates; Murray, Littler, and Abbott on the biogeography of marine algae; Wicksten on the biogeography of benthic decapods; Kanter on the biogeography of mussel communities; Straughan and Hadley on the ecology of sandy beaches; Hunt, Pitman, and Jones on the distribution of sea birds; and Le Boeuf and Bonnell on the abundance and distribution of seals and sea lions.

Two projects were directly administered by government agencies: Vedder and Howell, who wrote on the geology of the southern California borderland, are with the U.S. Geological Survey, and Owen, who wrote on ocean currents, is with the National Marine Fisheries Service. In addition, the data for Junger and Johnson's paper on land bridges were from U.S. Geological Survey cruises.

The National Science Foundation directly supported the research of Berger on early man, of Glassow on archaeology, of Ebeling, Larson, and Alevizon on fish ecology, of Wingfield on gull ecology, of Le Boeuf and Bonnell on pinnipeds, and of Power on evolution in birds. The National Institutes of Health provided research grants for the work by Wilcox on biogeography of reptiles and by Gill on the evolution of *Peromyscus*. Berger's study was also aided by the U.S. Navy, and additional funding for the work of Ebeling, Larson, and Alevizon was furnished by the National Oceanic and Atmospheric Administration.

REFERENCES

CARLQUIST, S. 1974. Island biology. Columbia University Press, New York, N.Y.

MACARTHUR, R. H., and E. O. WILSON. 1963. An equilibrium theory of insular zoogeography. Evolution 17:373-387.

———. 1967. Island biogeography. Princeton University Press, Princeton, N.J.

MACARTHUR, R. H., J. M. DIAMOND, and J. R. KARR. 1972. Density compensation in island faunas. Ecology 53:330-342.

PLATNICK, N. I., and G. NELSON. 1978. A method of analysis for historical biogeography. Syst. Zool. 17:1-16.