

period of intensive dam construction and one in which the costs of mitigation entailed in fish passage facilities at dams and supplemental production facilities and research were correspondingly high.

The third and last period which might be considered is the period 1968 to 2000 for which gross benefits and, consequently, net benefits have been projected for a sport fishery which is assumed to continue its growth at the same linear rate recorded for the 12 years, 1956 to 1968. With fixed supply, the increase in sport catch is accommodated by a corresponding reduction in the commercial catch.

Two distinct periods are discernible in this span of some 30 years into the future.

For the first 20 years—1968 to 1987 inclusive—costs outweigh benefits; however, from 1988 onward, the situation is reversed. Benefits exceed costs and the gap grows increasingly wider so that by the year 2000, net benefits exceed costs by \$6,000,000 annually. The accumulated excess benefits for the 13 years—1988 to 2000—totaling \$40,534,000, greatly exceed the accumulated losses (the excess of costs over benefits) for the earlier period—1968 to 1987—which amounted to \$32,426,000. And benefits continue to increase, outpacing costs as time elapses.

As a renewable resource of appreciating value, the program of maintaining the salmon-steelhead fishery in the Columbia River has resulted in a net contribution to social welfare, and on the basis of the assumptions and projections included in this analysis, will continue to increasingly add to net social welfare after about 1990.

The disposition of benefit and costs over the total period under review illustrates a fundamental principle that irreversibilities should be avoided where economically and technically feasible. The excess of costs over benefits in the period 1968 to 1987 might be considered insurance premiums paid by society to avoid maximum social losses—the loss of the fishery. Indeed, to retain a renewable appreciating resource for perpetuity by such payments for a relatively short period of time is only a sensible investment by society.

DISCUSSION

DISCUSSION LEADER RICHARD STROUD: What is the net value in dollars assigned to sport fishing?

DR. BOLLMAN: We'll furnish a written resume on this question.

MR. GERALD Z. WOLLAM (Medford, Oregon): Is it not true that no chinook salmon go up the river above St. Joseph's Dam? The fish hatchery has not been used because no salmon reach it. There is no production in the Columbia River above Pasco. What is the future of the Columbia River? I understand there are nine nuclear power houses considered for this river. Will not the proposed nuclear power plants effectively eliminate this river as a salmon-producing stream? The water temperature is approaching the lethal limit for fingerlings. There is supersaturation of nitrogen, and the effect on chinook is that they do not spawn suc-

cessfully. There is no movement of water on the Snake River, which is badly polluted. The fish cannot find their way. It is very likely that the upper river runs will be lost. Will the supersaturation of nitrogen be modified?

DR. BOLLMAN: I do not know the current conditions in the river with respect to nitrogen supersaturation (See footnote 4). I understand that there have been some alterations in the original plans to locate nuclear power stations on the river. You can expect to receive a written answer to your question when the current status and conditions have been ascertained. Answers to some of these questions in the unpublished Ph.D. dissertation cited in Footnote 1 of my paper.

DISTRIBUTION AND MANAGEMENT OF CARIBBEAN SEA TURTLES¹

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People, especially turtle hunters, have recognized for a long time that sea turtle populations were declining in the Caribbean region. Descriptions of the abundance of turtles, especially the green turtle, *Chelonia mydas*, during the settlement of the West Indies seem almost unbelievable today. Unfortunately, a complex of related factors associated with population growth and economic development in the Caribbean and the burgeoning market for exported turtle products are accelerating the decline year by year. Coordinated action is needed soon if these valuable resources are not to be destroyed. Available distributional data with salient aspects of conservation work in important areas are compiled to give an overview in hopes of stimulating more active regional interest. Five species of sea turtles are known to live in the Caribbean, *Lepidochelys olivacea*, the olive ridley; *Dermochelys coriacea*, the leatherback; *Caretta caretta*, the loggerhead; *Eretmochelys imbricata*, the hawksbill; and *Chelonia mydas*, the green turtle, and these are treated in approximate order of increasing economic importance.

Sea turtles of the genus *Lepidochelys* are not common or widespread in the Caribbean, Kemp's ridley, *L. kemp*, is primarily an inhabitant of the Gulf of Mexico (there is a record from Isla Mujeres [Smith & Taylor, 1950]) and consequently it is not treated here. Isolated records of individual adult olive ridleys, *L. olivacea*, are known from Gibara, Oriente Province, Cuba (Aguayo, 1953) and off San Juan, Puerto Rico (Caldwell & Erdman, 1969). Small numbers

¹ Contribution No. 105, Virgin Islands Ecological Research Station, Caribbean Research Institute, College of the Virgin Islands, St. Thomas.

of olive ridleys are caught regularly in the extreme southeastern corner of the Caribbean Sea. In eastern Venezuela this species is known from Isla la Tortuga, Islas Píritu, and the region of Cumaná (Flores, 1969). A few nest each year on Trinidad (Bacon, 1971). The animals from Venezuela and Trinidad are the eastern fringe of the olive ridley population which feeds on the fertile continental shelf of northeastern South America and nests at various sites in the Guianas, but primarily in a major aggregation at Eilanti, Surinam (Pritchard, in press). Based on the ratio of tagged to untagged turtles, Pritchard (1969b) concluded that 1,500 females nest at Eilanti. This and other ridley nesting beaches are included in a nature reserve established in 1969. The turtles are totally protected and egg collection is restricted in order to establish a sustained yield of protein (Schulz, 1971).

The leatherback, *Dermochelys coriacea*, is known to nest occasionally on island and continental beaches throughout the Caribbean, but significant numbers consistently nest in only a few localities. Pritchard (1971) summarizes all available data on the biology and distribution of the leatherback. He estimates that roughly 15,000 leatherbacks (out of an estimated world total of 24,000 to 49,000 breeding females) nest in the largest known aggregation near the mouth of the Organabo River in eastern French Guiana. Some turtles (200 to 400) from this aggregation nest across the border in Surinam. Aggregations occur in the Caribbean at Matina Beach, Costa Rica (at least one thousand nesting turtles), Trinidad (estimated 500 turtles from Bacon, 1971), and on Venezuela/Guyana border (Pritchard, 1971), with small numbers nesting regularly in Colombia east of Santa Marta (Kaufmann, 1971) and near Acandí on the Gulf of Urabá (Medem, 1962).

Away from the area of the nesting beaches leatherbacks are rarely seen at sea in the tropics, so there is no developed fishery for them in the Caribbean region. Where leatherbacks (and other sea turtles) nest frequently the meat typically is not highly regarded, and the main threat at the species worldwide is excessive egg collecting. Thorough-going illegal collecting is a serious long-term drain on the Matina Beach aggregation (Carr, 1969). In the Lesser Antilles the odd leatherback caught in a turtle net or while nesting encounters less discrimination and is usually killed for food and oil. In the Virgin Islands "trunk oil" rendered from the cartilaginous body armor of the leatherback is considered a potent medicine for respiratory infections and other ailments and consequently sells for phenomenal prices. Bacon (1970) estimates that 20 to 30 percent of the leatherbacks nesting each year at Matura Bay, the main nesting beach in Trinidad, are illegally killed by local villagers.

Green turtle hunters on Shell Beach, Guyana, kill nesting leatherbacks because they consider them to be "useless" but numbers there are small compared to Surinam and French Guiana. In Surinam the leatherback is fully protected and enforcement is effective. In French Guiana, though restrictive legislation exists, the large aggregation is protected primarily by its isolation (Pritchard, 1971). In Mexico Caribbean nesting is limited, but the leatherback is totally protected.

The meat of the loggerhead is considered less desirable than that of other species but its importance for both local food and export has increased as the abundance of greens and hawksbills has declined. The primary nesting areas of the loggerhead are in the southeastern United States. However, significant nesting occurs in the Caribbean in Quintana Roo, Mexico, the cays south of Cuba, and Columbia east of Santa Marta. Individuals and small groups of loggerheads nest throughout the Caribbean but the distribution is not uniform. Only one nesting loggerhead had been observed in fifteen years of surveillance at Tortuguero (Carr, 1969). Very few are caught offshore from the Guianas and only one is known to have nested there despite considerable nesting there by all other species (Pritchard, 1969a; Schulz, 1971).

Loggerheads occur commonly off northern Trinidad and may rarely nest there (Bacon, 1971). Very few are caught in the central and southern Lesser Antilles, but they are reported to be more common from some of the northern Leeward Islands to Puerto Rico. In Puerto Rico about two hundred a year are caught, but they are not known to nest (Rebel, in press). Loggerheads nest on the mainland and offshore islands of Venezuela (Flores, 1969) but are not common in Venezuelan waters (Medem, MS, 1965). Kaufmann (1971) estimates that four to six hundred loggerheads per year nest on 60 kilometers of beach east of Santa Marta. Because of overhunting the green and hawksbill rarely nest here. Beginning in 1970 an important 7.5 kilometer section of this beach was protected by government guards, but elsewhere all nesting females and eggs encountered are taken for local use. Except for the few Caribbean localities where protective legislation is enforced, loggerhead or any other sea turtle eggs are collected at every opportunity for food and sale.

Mexico and Cuba appear to commercially exploit the loggerhead on a large scale than other Caribbean nations. Both countries seek to protect turtle eggs and have provisions for the incubation of shelled eggs removed from slaughtered females. Some component of the catch is obviously breeding turtles (despite protection of nesting females and a closed season for nesting in Mexico). In Cuba the fishing season for loggerhead and other species corresponds to their nesting season

so it appears that primarily breeding adults are exploited (Cardona & de la Rúa, 1971). They describe collection centers where turtles are held before slaughter and give methods for collecting and incubating eggs in enclosures. They recommend that hatchlings be held and fed for two months prior to release.

The loggerhead is the most abundant turtle in the Caribbean waters of Mexico, but it is less desirable than the green (Fuentes, 1967). Seasonal camps for the protection of nesting female loggerheads and greens and incubating eggs are established on Isla Mujeres. Some small-scale captive culture and release of juveniles is done. Turtles taken around Mexico's Caribbean islands are processed in plants in Yucatán and 50 percent of the loggerhead meat is exported frozen to the United States (Rebel, in press). Very little scientific work has been done on Caribbean loggerhead populations, and more tagging is needed to outline the range of populations from various breeding sites.

Though once abundant in the Caribbean, and still widespread, hawksbill stocks are declining severely under intensive hunting, primarily for its decorative shell. Hawksbills are usually coral reef dwellers and diffuse nesting on beaches near their feeding grounds appears to be a common pattern for this species in the Caribbean. Partly because of this we know very little about this species despite its economic importance worldwide. Carr *et al.* (1966) discuss seasonal changes in abundance and some tag returns from Tortuguero hawksbills and concludes there is evidence for long-distance migration and nesting aggregation at some localities. A beach on Chiriquí Point, Panama, was once considered the major western Caribbean nesting site for hawksbills (Carr, 1955), but exploitation has been intensive for many years and its current status is unknown. The San Blas Islands, Panama, which once supported large numbers of hawksbills, are badly depleted. Columbian hawksbill hunters are moving to Panamanian waters because of decreased catches (Medem, ms. 1962). Similar word-of-mouth tales of decline come from throughout the Caribbean, and in the Lesser Antilles and offshore islands of Venezuela hawksbills are usually captured incidental to other fisheries; small quantities of shell are used in local industries or exported (Roze, 1956; Rebel, in press).

In two western Caribbean areas some concentrations persist. Hawksbills are seasonally abundant on Columbia's offshore atolls and banks and up to one hundred per day are taken with large dipnets over the reefs (Ben-Tuvia & Ríos, 1971). Nesting turtles are also turned and eggs collected by turtle hunters who stay on the cays during the season. This fishery, based primarily on the high export

price for shell, is completely unregulated (Ríos, pers. comm.). Turtles from San Andres, Providencia, Jamaica, and the Cayman Islands have been visiting these atolls, especially Roncador, for hawksbill for well over one hundred years (Parsons, 1956).

A survey of the important hawksbill populations in cays off the east coast of Nicaragua in July, 1971, showed that approximately 5 percent of the eggs laid went uncollected and 50 to 60 percent of the nesting females were killed (Nietschmann, MS, 1971). Because of the high price for shell augmented by the eggs, meat, and calipee, they are subjected to phenomenal fishing pressure in this uncontrolled fishery. Nietschmann recommended a complete ban on hawksbill fishing and sale of hawksbill products from these waters for three years to avoid the imminent demise of the resource. Unfortunately, the Nicaraguan government is not likely to respond to this suggestion.

The natural distribution of green turtles partly controlled early pattern of settlement in the Caribbean, and the species is still an important food resource and item of commerce. Parsons (1962) describes the long history of overexploitation and consequent local extirpation in this region and elsewhere. Like the other common species of sea turtles, isolated nesting and probably small aggregations occur at numerous localities throughout the Caribbean. Only two major nesting aggregations remain, one at Tortuguero, Costa Rica, and the other at Aves Island west of the Lesser Antilles arc. Returns from turtles tagged at Tortuguero since 1955 show that they come in numbers from feeding grounds all over the western Caribbean, notably the Miskito Cays, the coast of Panama, and the Guajira Peninsula of Columbia. A few have come from surprisingly distant points such as Florida; Campeche and Isla Mujeres, Mexico; and Isla Coche in eastern Venezuela (Carr, 1967). The work of Carr and his students has generated awareness of the critical importance of Tortuguero to the continued availability of green turtles in the western Caribbean, and Costa Rica has taken increasing steps to protect the aggregation. An important section of the beach is included in the plans for Tortuguero National Park.

Recognizing the continuing decline in the resource because of overhunting, fisheries personnel from Costa Rica, Nicaragua, and Panama met late in 1969 and agreed to prohibit the commercial exploitation of the green turtle and its eggs for three years and to gather information that would lead to a rational exploitation policy. They invited other countries to join them in the ban. The agreement was promptly ratified by the governments of Costa Rica and Panama, but not by Nicaragua, and exploitation of green turtles in the Miskito Cays has continued (Carr, 1971).

Early in 1969 a turtle freezing plant with an exclusive license for the east coast of Nicaragua was under construction in Puerto Cabezas supported by a loan from INFONAC under the A.I.D. program. The operator planned to butcher 30 turtles per day weighing over 150 pounds each, supplied by Nicaraguan fishermen. The meat, calipee, and hawksbill shell were to be exported. This ill-conceived project seems likely to have contributed to the collapse of the Tripartite agreement. To favor its own developing fishery, Nicaragua officially banned Cayman turtlers from the shelf waters where they have hunted, but boat-loads of turtles from the area are still arriving in Grand Cayman.

At Tortuguero harpooning of turtles during the nesting season is currently legal at distances greater than 5 kilometers offshore and the product of this fishery goes primarily to two turtle export freezing plants. During the 1970 season increased land and sea patrols considerably reduced the incursions of the harpoon boats close to shore and the activities of poachers on the 24-mile long beach (Carr, 1971). Unless cooperative efforts to manage the population both on the nesting grounds and the feeding grounds are renewed, the long-term survival prospects are dim.

Long ago turtlers recognized Aves Island as the major remaining site of green turtle aggregation in the eastern Caribbean, and they have hunted there consistently for at least a hundred years (Parsons, 1962). The island is an extremely isolated, waterless, sandy cay 220 kilometers west of Dominica in the Lesser Antilles. Venezuela was the victor in an arbitrated international dispute over the island and its guano accumulations in the late nineteenth century. Aves is uninhabited and 500 kilometers from the Venezuelan mainland, so that turtle poachers and bird egg collectors from many of the Lesser Antillean islands occupy it freely. The extremely small size (4 hectares) of the island makes it convenient to collect every nesting turtle that comes ashore until the capacity of the hunters' vessel is reached. The number of turtles each night during the peak of the season has declined considerably over the last ten years under this intense exploitation, but the high price (\$75 U.S.) for a turtle makes the rough trip worthwhile for even a small boat.

There are no long distance recoveries from the tagging program which was begun last year at Aves (Rainey, MS, 1971), but the aggregation is presumably drawn from Lesser Antillean feeding grounds. Except in a few outlying areas, green turtles are no longer common in the islands and they are taken only occasionally, generally in the nesting season. Survival prospects of the Aves aggregation are

improved as a result of recent field work and a brief meeting there last year on the problems of protecting the island. Returning Venezuelans petitioned their government to declare Aves and surrounding waters a faunal preserve. Protection and study of the population from a small, periodically resupplied station on the island seems feasible. The opportunity to tag and examine the entire nesting population could provide data which is difficult to obtain elsewhere.

Significant numbers of green turtles nest in the Guianas, notably Surinam. Tag returns from Surinam turtles show that they are being caught in numbers along the northeast coast of Brazil, principally in the State of Ceará (Pritchard, in press). Tag returns from green turtles nesting on Ascension Island overlap with the Surinam returns off Brazil leading to the suggestion that separate breeding populations may reside in the same area (Carr, 1971). Multiple tag returns have led to concern about the heavy exploitation of the Surinam population on the Brazilian coast. In Surinam the killing of sea turtles is effectively prohibited and the taking of eggs is carefully restricted, but it is difficult to justify these conservation measures without accompanying controls in Brazil (Schultz, 1971).

There is also an important green turtle breeding ground and fishery in the coral islands and along the mainland coast of Quintana Roo, Mexico. Until the development of the Pacific ridley fishery, the green turtle in the Caribbean was the primary Mexican sea turtle fishery (Márquez, Ms, 1968). The earlier discussion on the loggerhead fishery in the area is all equally applicable to the green except that most of the processed catch is exported to the United States. Carr suggested that this nesting ground is the source of west Florida's population of immature green turtles (Parsons, 1962). Some tagging of nesting females was done in this region in the past (Solís, 1966), but it would appear from a recent summary of Mexican sea turtle conservation work (Andreu, 1971) that the program has stopped.

A few of the Caribbean countries harboring significant sea turtle concentrations have a reasonable idea of the magnitude of the resource and have control of the exploitation, e.g., Surinam, Costa Rica, and Mexico. But even these countries have no control and little information on exploitation at the other end of the turtles' migratory pathways. The more typical Caribbean pattern seems to be a decentralized fishery with little regulation which is generally not enforced, and very limited data on stocks or exploitation. Fisheries personnel are generally already overcommitted and important fishing areas may be nearly inaccessible. Especially in the coastal areas where sea turtle stocks are already reduced to economically inconsequential levels, the prospects for effective management with diffuse marketing are poor.

Restoration of depleted stocks would require reduction or temporary cessation of turtle hunting and is not likely to be a popular program. Hungry people and those in remote areas will continue to take turtles and eggs as they have for generations.

These coastal populations are growing rapidly and require more protein to sustain them. Improved transportation accompanying development in Caribbean nations has provided greater access to inland markets, especially for perishable turtle products. Modern fishing equipment, especially the outboard motor, has markedly increased the range and effectiveness of turtle hunters. (Before the availability of outboards the wasteful, wholesale slaughter of several species nesting on Shell Beach, Guyana, did not occur.) Tourism has created large new markets paying disproportionately high prices for the novelty of eating sea turtle or taking home a lacquered juvenile hawksbill. Tourist facilities, scenic coastal highways, and burgeoning coastal villages displace turtles from nesting beaches. People and governments regard these growth trends and their correlates (e.g. an active money economy) as largely beneficial, so they are likely to continue.

In addition to the growth of internal markets, the export market for sea turtle products has grown and immense markets for new products have been developed through mass marketing campaigns in wealthy nations. The consumption of additional turtle products (e.g. meat and soup) has grown considerably, especially in Europe, through the efforts of German turtle processors.

Two other mass markets for luxury turtle products have recently been developed on a large scale in the United States, one for turtle oil in cosmetics and the other for sea turtle leather. As most crocodilians were driven to the brink of extinction by hide-hunting and the trade in them was increasingly restricted, an alternative source of reptile leather for luxury shoes, handbags, etc. was developed from the small area of soft skin on the underside of the neck and axilla of sea turtles. The export trade in hides was a primary reason for the phenomenally rapid growth of the olive ridley fishery on Mexico's Pacific coast. Large quantities of hides were shipped to the United States and Japan. In recognition of the radical decline in the catch, Mexico recently closed the fishery completely for one year. This was undoubtedly a difficult step, but warranted under the circumstances. The drain from illegal exploitation is still heavy. Like calipee, the dried plastral cartilage used in making soup, and hawksbill shell, properly cured hides are a low-bulk, high-value product amenable to illegal exploitation.

The most feasible if seemingly drastic approach to reducing over-harvesting of sea turtles is to modify the international market. This is especially relevant in the case of the hawksbill, which is vanishing around the world because of hunting for shell. By placing the hawksbill on the Endangered Species List, any bulk trade in shell into the United States has been eliminated, although it is likely that tourists still bring in fabricated articles illegally. It is necessary to apply whatever leverage is available through international organizations to spread the ban to other countries importing shell, e.g., England, Holland, and Japan. The demise of the shell trade would not assure the survival of reduced populations because hunting for food for local markets would persist, but the respite might provide time for the development of regional controls.

In general, a continuing export of sea turtle products from the Caribbean means trading the piecemeal destruction of a potential protein resource for hungry coastal populations for a small gain in foreign exchange. The fecundity of sea turtles is low compared to other marine organisms and they will require careful management (all out of proportion to their contribution to the balance of payments) in the areas where they are accessible, to restore depleted stocks to optimum levels.

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DISCUSSION

DR. CRAIG KOENSLER (UN—Mexico): There is now an organization, CICAR, composed of countries from the north as far as the U.S. to the south as far as Brazil, trying to disseminate knowledge about sea turtles, their exploitation and protection.

DR. CLARENCE COTTAM (Texas): Is there any program for the artificial propagation of turtles?

MR. RAINEY: There are a number of efforts. The one on the largest scale is on Grand Cayman Island on green turtles. They now have 40,000 and are considering slaughter. In three years, the turtles weigh 100 lbs.

RESOURCE MANAGEMENT PROGRAMS FOR OCEANIC ISLANDS

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The remote and varied oceanic islands of the world are currently experiencing an insidious metamorphosis into densely populated, urbanized, homogeneous tourism-oriented communities with seriously degraded environments. While the stresses and pressures of unrestrained development and modern technology are partly at fault, a serious methodological crisis is increasingly apparent in the matter of resource planning, allocation, and management for island systems.

This paper considers three problem areas that have a bearing on programs of resource management in oceanic islands. The first, relates to the peculiar characteristics of islands that argue for special management approaches. The second, deals with implications of long-term growth within a finite island system; while the third, is addressed to the more immediate problems of market failure. Taken together, these problems present management with a formidable challenge.

A simple construct with six constituents that are judged to be of key importance in a program for oceanic islands is developed. It is suggested that a favorable long-term solution to island resource problems will depend, in part, on how successfully the key constituents are incorporated into management programs for island systems.¹

¹ A model, based on the Virgin Islands case, will be the subject of a subsequent paper.