PN-AAW-850

# THE MANGROVE FORESTS OF CHAME AND AGUADULCE, REPUBLIC OF PANAMA: RESOURCE DEVELOPMENT POTENTIAL AND MANAGEMENT ALTERNATIVES

Prepared by:

**Samuel C. Snedaker**
Division of Marine Affairs
School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149 USA

Prepared for:

**The U.S. Agency For International Development**
Through USDA/OICD/TAD/LAC Programs
Purchase Order No. 40-319R-5-00296

March 1985

000142
S

## INTRODUCTORY COMMENT

This report is one of a series representing a sequence of tasks which collectively will lead to a demonstration management plan for a mangrove forest area in Panama. Two studies preceded this report: a larval shrimp and fish survey and a remote sensing study of the forest environments in Chame and Aguadulce. Although each study had obvious limitations, they provide a basis for the first phase of a planning process leading to an operational management plan.

This report in its present form requires the review and collaboration of Gilberto Cintron. If certain data and information are provided to the authors, sections which are "missing" in this draft may either appear in the final version or be assimilated into the final project document being prepared by Cintron. Whereas a jointly authored report is preferable to this arrangement, time and budget limitations did not allow for the alternative.

## MANGROVE FOREST RESOURCES IN PANAMA

Panama is reported to have some 505,000 ha in coastal land that is dominated by mangroves and mangrove forests (Falla 1978). These are distributed in eight major areas consisting of some 13 formations of which 11 formations lie on the Pacific Coast (Letourneau and Dixon 1982). The dominant genera of mangroves is the Rhizophora, individuals of which grow in excess of 30 m in height. In general, however, the Rhizophora, as well as species in the genera, Avicennia and Laguncularia, occur as forests of variable height and stocking. The taller, more structurally-complex forests grow in the more fertile areas where restrictive growth factors are minimal. Their tall height in part reflects the fact that Panama lies outside of the hurricane belt. Elsewhere within the Caribbean where hurricanes are a common event, windthrow, breakage and mortality prevent mangrove forests from attaining their maximum potential height. In the American tropics, Panama's mangrove forests area is the third largest (Snedaker and Brown, in prep.) following Brazil with 2.5 million hectares and Venezuela with 674,000 ha.

Although mangrove forest resources represent a major untapped resource base in the Americas, they have been subjected to a variety of traditional and domestic uses. More recently, large areas have been cleared and converted to shrimp growout ponds in response to the high worldwide demand (and price) for marine shrimp. Although many of the Latin American countries have laws and statutes for the protection of coastal resources (largely uninforced), few have developed management plans that encourage and guide the utilization of the forest resources; Venezuela is one example although its Orinoco utilization plan has been questioned in terms of sustainability (Federico Pannier, pers. comm.). Panama, through RENARE, has taken significant steps to develop its mangrove forest resources although progress has been slow and problematic in terms of implementation. This may be due in part to the unwarranted belief that mangrove wood and wood products are inferior to other commercial tree species, and that the mangrove environment makes harvesting and extraction an impractical endeavor (cf , Letourneau and Dixon 1982).

As best as can be determined, the direct uses of mangroves in Panama are limited to the production of charcoal, small poles and large dimension timber for mine props, railway sleepers, etc. These are small scale forms of utilization that do not require a large capital investment in a supporting infrastructure. For example, the tall straight-form Rhizophora are suitable for utility poles or conversion into sawn dimension wood, but such uses require heavy logging equipment and specialized means of bulk transport to the user or converter. Also, the absence of a traditional market for mangrove wood and wood products of these types poses another limitation on economic development of this natural resource.

## THE RELATIONSHIP BETWEEN MANGROVE FORESTS AND SHRIMP

Numerous kinds of marine-estuarine vertebrates (e.g., fishes, marine mammals, etc.) and invertebrates (e.g., shrimp, lobsters, crabs, oysters, etc.) are resident species in mangrove areas or spend some portion of their life cycles in such areas. Among the various forms of marine life, the high cash-value commercial shrimp species have received, and are receiving, worldwide attention. In one of the first studies of the interrelationship and interdependency among mangrove forests and commercial shrimp, Macnae (1974) summarized his finding in the quote, "No mangroves, no prawns." For many species of shrimp, mangrove areas provide the necessary shelter, detrital food sources, protection from predators, and moderate salinities which are unavailable in an open marine environment.

In the late 1970s, Turner (1977) and Martosubroto and Naamin (1977) independently published research results that empirically confirmed a correlational relationship between the regional area dominated by mangrove forests and the annual commercial harvest of penaeid shrimp. In general, these two studies indicate, rather conclusively, that regional losses in mangrove forest area necessarily result in reduced yields and harvests of those shrimp species that are dependent on mangroves and other forms of intertidal vegetation. For those species of shrimp that are not dependent on mangrove habitats, the relationship, of course, does not apply.

Based on the regression equation provided Martosubroto and Naamin (1977), and the mangrove area data from Hughes et al., the theoretical shrimp production attributable to the two study areas has been calculated (Appendix A) to be approximately 550 kg/yr. On a per hectare basis, this works out to between 115 to 130 kg of shrimp per hectare of intertidal mangrove forest. These estimates are reasonable for Pacific Latin America (cf., Turner 1977) but are high when compared to data and information assembled and interpreted by D'Croz and associates.

The basic relationship (between shrimp and mangrove forest area) can be used to calculate estimated effects on wild shrimp yields resulting from various combinations of land use in each of the two study areas. However, that requires a definitive management plan and is beyond the scope of this initial study project.

As part of the overall USAID Study, D'Croz and del Rosario (1985) undertook a preliminary fish and shrimp larval assessment survey in the Chame and Aguadulce study areas. These assessment surveys took place respectively, in November and December 1984, and used standard sampling and data-reporting techniques. Although the results of the study are informative and support the earlier conclusion of the principal author (D'Croz and Kwiecinski 1980), the data cannot be used to draw any significant conclusions concerning the two study areas. In general, the very large temporal and spatial variability in natural larval abundance would require that conclusions be based on very large data sets from several years of continuous monthly sampling in both areas. The similarities and differences reported by D'Croz and del Rosario in the present study are only valid for the specific sampling dates and cannot be extrapolated beyond that limitation. One of the reasons for caution in interpreting small data sets on shrimp larval abundance is that the factors that control the population variability have not been quantitatively documented.

**Comment of Shrimp Mariculture with Emphasis on Latin America**

The commercial production of shrimp in artificial growout ponds in

the tropical coastal zone is believed to have been first established on an economic basis in Ecuador in the late 1960s and early 1970s. Since that time, and still continuing, large commercial pond systems are being constructed at an accelerating pace throughout the world, a process that is driven by the relatively high world market price for shrimp. This has led to two problems: first, large areas of inter-tidal coastal habitat are converted to a single use activity that carries a relatively high opportunity cost. Secondly, the habitat conversions destroy the nursery habitat for the seed shrimp that are used to stock the growout ponds. As a result, the continued development of coastal mariculture in some areas has become self-limiting (lack of post-larvae seed shrimp) and, with the recent drop in the world market price for shrimp, uneconomical for marginal operators.

Two lessons have been learned from this short history. One is that commercial pond operations based on wild seed stock have a limited operational size and that new ponds should not be constructed if the demand for seed stock exceeds the natural source (wild population) base. Second, investors, both public and private should be encouraged to shift from extensive operations (i.e., building more and larger ponds) to the intensive management of the existing ponds based on maturation and hatchery facilities for seed stock production. Intensive management, for example, can double and triple current pond production levels through water quality maintenance and supplemental feeding. Maturation and hatchery facilities can likewise guarantee seed stock for multiple annual cropping cycles and minimize the overall economic risk.

## SELECTION OF A PILOT PROJECT STUDY SITE

As part of the original terms of reference, two regional mangrove forest areas, Chame and Aguadulce, were identified as potential study areas for the development of a demonstration management plan and an analysis of resource use options. The Aguadulce study area was ultimately chosen because it most closely represents the kind or type of mangrove forest habitat found along much of the Pacific Coast of Panama and adjoining Pacific coast countries (i.e., Colombia and Costa Rica). Also, it is experiencing many of the different kinds of problems that

are common in the region (e.g., watershed development, encroaching agriculture, conversion to shrimp growout ponds, and uncontrolled cutting, primarily for charcoal production and small construction timber). Although smaller in area than the Chame site, it was considered to be a more representative area in which management principles could be implemented and tested. Also, in contrast to the Chame study site, Aguadulce exists within a relatively arid environment with salinity and aridity gradients that permit exploration of a wider variety of management alternatives and options. With respect to the aerial survey and assessment, the Rio Grande forest area was selected by the Defense Mapping Agency for a detailed workup (Hughes, et al. 1985).

Chame was considered to be the less desirable of the two sites for several reasons. First, it resides in a geomorphologically unique situation defined by the proximity of mountains as opposed to a flat coastal plain. Whereas Chame sensu lato is thought to be more productive in biomass than Aguadulce, this was not a consideration in the selection. Also, Chame appears to be experiencing fewer different kinds of pressures and is therefore less representative of the regional situation.

Although Aguadulce is the site selected for intensive work, this report also includes Chame as a comparison area that may be used as a "control" site in any future work, particularly with respect to the effectiveness of management. Also, in the event that 1985 (or later) aerial photo coverage becomes available, Chame could be re-evaluated as a preferred management study area. The lack of recent photography must be recognized as a severe limitation to the development of management options for either of the two potential study areas.

## MANGROVE FOREST AREA MANAGEMENT

The management of coastal mangrove forests for economic use has its origin in the Nineteenth Century primarily in former British Colonies in Asia (e.g., Malaysia, Bangladesh, Pakistan) and also in Thailand at a later date. In certain production forests, for example, the Sundarbans in Bangladesh, and the Matang Forest in Malaysia, commercial logging is

now in its third and fourth rotation. Also, in these areas, mangrove silvicultural research is considered to be an ongoing activity that is necessary to maintain maximum sustained yields. In these areas, the mangrove trees are used for commercial sawn timber, pulpwood for paper making, poles for light construction and scaffolding, parquet, and cabinet wood for boat building and furniture.

The importance of the Asian forest management experience is that it has demonstrated that mangrove forests can be economically utilized on a sustained yield basis and in a manner that maintains the forest values for fisheries, coastal protection, water quality maintenance, etc. One objective in the management planning process for the Aguadulce forest area is the development of a sustained yield cutting/harvesting protocol that has economic merit and which promotes the conservation of the resource base.

## MANGROVE REHABILITATION IN DEGRADED AREAS

Within the Aguadulce (Rio Grande) study area, there are areas of degraded mangroves, including areas of mortality, that appear due to the singular result of artificial barriers prohibiting tidal incursion and drainage; in essence, they are impounded. Whereas mangroves can and do thrive in anaerobic sediments, such sediments require regular flushing and exchange of the interstitial water. Tidal inundation, for example, delivers dissolved oxygen for root respiration, removes metabolic waste products, and renews the sulfate and nitrate that are required for anaerobic metabolism and nutrient regeneration through the decomposition of sediment organic matter. When mangrove areas are impounded, these processes cease which results in severe stress and/or mortality. The resulting sediments become anoxic and incapable of supporting normal biological activity. Furthermore, impounded, anoxic areas remain unproductive as long as they remain impounded.

The first step that is required in the rehabilitation of impounded mangrove areas is to re-establish regular and complete tidal flushing. Within a relatively short period of time, the anoxic sediments become anaerobic and capable of sustaining mangrove growth and development as

long as the tidal flushing continues. The restoration of adequate tidal flushing, however, requires more than just providing a means for tidal inundation and drainage which under most topographic conditions does not allow total inundation and complete drainage on normal tide cycles. Ideally, it is best to have a system of multiple tidal access routes that is capable of handling the necessary flow volumes. Alternatively, the barrier to flow across a broad front could be removed to provide the necessary flow cross-section. In any event, the preferred engineering design must be developed on a site-specific basis and include a suitable topographic survey of the affected area and the potential routes for tidal flow.

The second step in the rehabilitation of an impounded area is the reseeding of mangrove propagules (Rhizophora and Avicennia) and seeds (e.g., Laguncularia). Under natural conditions of free and open tidal movement, reseeding occurs naturally through the tidal dispersion and distribution of propagules and seeds. However, in a fully impounded area that has only been minimally reopened to tidal flow, the process of natural reseeding may take several to many years thus poorly justifying the corrective engineering. In such cases, artificial reseeding or even replanting may be required. Various techniques have been described in Hamilton and Snedaker (1984).

Elsewhere in the Aguadulce study area, there are other barren areas defined as saltflats which occur beyond the reach of normal high tides. In such areas (in arid environments), salt accumulates within and on the sediment at concentrations beyond the salinity tolerance of the mangroves. Whereas saltflats can be rehabilitated through engineered flushing, such areas are also commonly preferred places for the construction of shrimp growout ponds. In this report, saltflats could be set aside as potential areas for future shrimp pond siting albeit with the caveat that the construction of new ponds does not create new barriers to surface water flow to the detriment of the existing mangroves.

## MANGROVE ECOSYSTEM DIVERSITY AS A PLANNING TOOL

In contrast to most tropical forest ecosystems, mangrove forest ecosystems (in the Western Hemisphere) have a remarkably low species diversity and are dominated by representatives of the mangrove genera Rhizophora, Avicennia and Laguncularia. Whereas the species diversity is low, the diversity of forest types (defined on the bases of forest height, tree density and basal area) within a regional mangrove ecosystem is usually relatively high. For example, based on the air-photo evaluations (Hughes et al. 1985) and an interpretation system developed by Cintron (pers. comm.), contrasting forest types have been identified in the Punta Chame and Aguadulce regional ecosystems. In general, the different forest types correspond to major differences in the physical environment, such as the frequency and duration of tidal inundation, the annual exposure to freshwater runoff, the average interstitial soil salinity, and the physical-chemical and oxidation reduction status of the underlying sediment or substrate.

Following the pioneering research of Odum (1971) and Heald (1971) on the role of Rhizophora in nearshore and coastal fisheries production, the shoreline fringing Rhizophora forests were considered to be the most important, and therefore most valuable, species and forest type. In fact, within the United States, specifically Florida, the majority of the environmental laws are oriented toward the protection of this one species and forest type. However, later research by others has demonstrated that all of the other species and forest types have equally important, albeit, functionally different roles. For example, in contrast to the particulate detrital production associated with fringing Rhizophora forests, landward forests dominated by the Avicennia, produce large quantities of dissolved organic matter that is exported to coastal waters on a regular seasonal basis (Twilley, ). The dissolved organic matter, upon flocculation and settling, creates a rich feeding substrate for benthic feeders such as shrimp, crabs and mullet. It has subsequently been argued (Snedaker and Brown 1981a) that the importance and value of mangroves is neither attributable to a single species nor a single forest type, but instead is related to the combined functioning and interdependence of all species and all forest types within a regional unit. Thus, efforts to conserve mangroves for ecol ical and economic benefits (e.g., fisheries production, coastal

protection, etc.) should focus on the protection of all representative forest types (and species) as a functional unit, as opposed to the identification of single types and single species as foci of protective efforts. (Note: Under certain condition such as severe erosion potential, a site-specific type may be identified for special protective consideration).

Thus, the concept of the mangrove ecosystem as an integrated and functional assemblage of different species and different forest types, is invoked as a planning tool in this study. However, because no one has yet determined what percentage of a regional ecosystem must be protected to perpetuate the ecological values of the ecosystem, an arbitrary percentage has been used as the basis for the recommendations in this report.

## MAINTENANCE OF WATERWAYS AND BUFFER ZONES

As stated above, representative percentages of all mangrove forest types and functional areas should be protected against abusive exploitation or conversion to noncompatible uses. When other priorities are not evident, the protected area can be assigned to a 50 to 100 m band bordering all of the permanent waterways and tidal channels. This designation does not preclude economic utilization but identifies these buffer areas as being excluded from clearfelling or destructive conversion to other uses.

The purpose of this planning requirement is to ensure that all waterways remain open and free to tidal access (and surface water runoff) and that sufficient area is retained under forest for the production of detritus benefiting fisheries. The waterway buffer zone also serves to minimize bank erosion and sedimentation in the flow channels.

With respect to surface water flow, it must also be recognized that freshwater runoff from the upstream watershed must be maintained in order to prevent salinization of the mangrove and estuarine areas. Contrary to popular wisdom (Snedaker and Brown 1981a), mangroves grow

best in areas where there is abundant freshwater runoff and, as a result, lowered salinity regimes.

## Agricultural Pollution

A common problem all along the Pacific coast of Latin America is the frequent excessive use of pesticides and herbicides in agricultural areas, particularly for such crops as cotton, sugarcane and bananas. The chemical amendments eventually leach and drain into coastal waters via runoff. Although mangroves appear to be highly resistent to most water-transported herbicides and pesticides (Snedaker and Brown 1981b), these materials, even in relatively low concentrations may be lethal to many kinds of marine/estuarine animals such as shrimp and offshore corals (Peter Glynn pers. comm.). Although there is no direct evidence that agricultural chemicals present a problem within the Aguadulce study area, that likelihood exists due to the presence of agricultural activities in the upstream watershed and in areas contiguous to the mangrove ecosystem.

In at least two areas along the Pacific Coast, El Salvador and Ecuador, agricultural chemicals have been implicated in the decline in local shrimp populations and harvests. It might also be conjectured that waters containing these chemicals and which are used as input water into shrimp growout ponds, may be related to reduced pond production in certain instances. In any subsequent continuation or extension of this project, the potential problem of agricultural pollution should be examined and taken into account in revising the area management plan.

## Estimates of Merchantable Wood Volume

As part of this study, an attempt was made to estimate the merchantable wood volumes for the Rhizophora and Avicennia forest types and to project the annual yields on a sustained basis of differing forms of utilization and rotations (Appendix and Tables ). The results are imprecise estimates that are useful only in a preliminary feasibility planning study. The calculation steps are described as

follows.

For each mangrove vegetation type (Cintron 1985), a wood volume per hectare estimate was multiplied by the type area in hectares which gives a total wood volume in cubic meters. It is assumed that each forest type as it presently exists, represents the steady-state maximum volume. The harvestable area was obtained by dividing the area in each type by the rotation; the result is the number of hectares that could be harvested each year in perpetuity. Accordingly, the volume of wood that is annually available was obtained by likewise dividing the total volume by the rotation. The results are tabulated in Table

For the purpose of this particular study area, it is assumed that any harvested wood would go into charcoal or be used as small poles for light construction, for example, as in the construction of bohios. Thus, the probable sustained-yield rotation would be around 10 yrs in the more productive sites and as long as 30 yrs in the less productive site classes.

In practice, harvesting would take place as a clearing felling of discrete blocks of several hectares each in which the tallest best-form trees would be left as seed or mother trees at the rate of 20/hectare. This provision prevents forest high-grading and guarantees a faster regeneration of the cut over site. Within the 50 to 100 m waterway buffer zones, the harvesting would be done on a selection felling basis that emphasized the harvesting of selected poor-form or cull trees. In all cases, it is recommended that the slash be left in place unless subsequent observations indicate that it is a hindrance to propagule dispersal and regeneration.

**Note:** This section was not completed due to discrepencies in the data base resulting from the aerial assessment and mapping, and the absence of site/type maps. It is believed that this information will be eventually provided at which time Gilberto Cintron and this author can discuss the data synthesis and interpretation.

**SUMMARY CONCLUSIONS AND RECOMMENDATIONS**

Work completed to date on this project indicates that a management scheme which emphasizes small-scale industrial development and conservation is practical (and desirable) for either the Aguadulce or Chame areas. However, prior to developing a management plan, it will be necessary to complete a survey and inventory using up-to-date aerial photography with ground truthing that includes mensurational parameters. The management plan must also take into upstream watershed activities that have the potential to impact the downstream mangrove forest and estuarine habitats. The development of the management plan should also include economic considerations that heretofore have not been incorporated in mangrove forest planning in the western Hemisphere.

The expansion of shrimp mariculture, based on the construction of growout ponds in the coastal zone, should be based on a limited entry protocol that guarantees a minimum production performance through intensive pond management, and the establishment of a maturation facility for the production of all required post larvae. In addition to the economic benefits (potentially higher profits for the investor), coastal resources are conserved for other economic benefits, including nearshore/offshore fisheries production.

The current techniques being used for charcoal production are inefficient and therefore wasteful of the wood resource. Consideration should be given to initiating the use of low-cost prefabricated retorts through some form of incentive (e.g., direct subsidy, tax preference) or the creation of a production cooperative. Together with recommendations on cutting limits, this will result in a better economic return and a sustained utilization of the mangrove forest crop designated for charcoal production.

When the current USAID-sponsored study is completed (with the inclusion of the missing data and information), it should be extended into a next phase with two major terms of reference: (a) convert the present mangrove-species/mangrove-structure maps into "potential product" maps; the former are suited for scientists/managers, whereas the latter may be more acceptable to public and private promotors of economic utilization; (b) each of the major "products" should be

subjected to an economic analysis to determine cost-profit potentials based on sustained utilization.

## LITERATURE CITED


Cintron, G. 1984. Unpubl. notes on mangrove forest assessment project (Chame and Aguadulce) for the U.S. Agency for International Development.

D'Croz L. and B. Kwiecinski. 1980. Contribucion de los manglares a las pesquerias de la bahia de Panama. Rev. Biol. Trop. 28(1):13-29.

D'Croz L. and J. del Rosario. 1985. Assessment of the population of fish and shrimp larvae in the mangrove swamps of Chame and Aguadulce, The Republic of Panama. Final Rept. Prepared for the U.S. Agency for International Development.

Donaldson P.O., K.M. MacDonald, J.W. Rankin and T.A. McKenzie. 1963. Forests of the Republic of Panama: resource development, industrial development, and product potential. Greenacres, Inc. Seattle, Washington.

FAO. 1976. Aquaculture planning in Latin America. ADCP/REP/76/3. Rome.

FAO/PNUMA. 1972. Inventariacion y demonstraciones forestales. Panama: Reconocimiento general de los bosques y inventario detallado de azuero. III. Resultados y Comentarios. FO:SF/PAN 6. Informe Tecnnico 12. Centre Technique Forestier Tropical. FAO, Rome.

Hamilton, L.S. and S.C. Snedaker. 1984. Handbook for Mangrove Area Management. Commission on Ecology, IUCN. Gland, Switzerland. 123 p.

Hughes, R.H., L. D'Croz, L. Manfull and J.B. del Rosario. 1985. Mangrove forest assessment and mapping with aerial photographs and LANDSAT digital MSS data in Aguadulce and Chame, Panama. Final Rept. Prepared for the U.S. Agency for International Development, Washington, D.C.

Letourneau, L.R. and R.G. Dixon. 1982. Mangrove management and harvesting: Panama. Rept. prepared for the Govt. of Panama. FAO/PNUD-RLA/77/019.

Macnae, W. 1974. Mangrove forests and fisheries. FAO/UNDP Indian Ocean Fishery Programme. Indian Ocean Fishery Commission. IOFC/Dev/74/34. 35 p.

Martosubroto, P. and N. Naamin. 1977. Relationship between tidal forests (mangroves) and commercial shrimp production in Indonesia. Mar. Res. in Indonesia No. 18:81-86.

Saenger, P., E.J. Hegerl and J.D.S. Davie (eds.). 1983. Global Status of Mangrove Ecosystems. Commission on Ecology Papers Number 3. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland. The Environmentalist 3(1983) Supplement No. 3. 88 p.

Snedaker, S.C. 1981. Mangrove forest management and utilization in Panama. Report prepared for the Govt. of Panama. FAO/PNUD-RLA/77/019.

Snedaker S.C. and M.S. Brown. 1981a. Mangrove misconceptions and regulatory guidelines, p. 61-70 In R.C. Carey, P.S. Markovits and J.B. Kirkwood (eds.) Proc. U.S. Fish and Wildlife Workshop on Coastal Ecosystems of the Southeastern United States. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-80/59. 257 p.

Snedaker S.C. and M.S. Brown. 1981b. Water Quality and Mangrove Ecosystem Dynamics. USEPA, Office of Pesticides and Toxic Substances. EPA-600/4-81-002. 79 p.

Sugden, E.A.N. 1978. Industrial uses of mangrove (Rhizophora racemosa). Proc. Eighth World Forestry Congress, Jakarta, Indonesia. FID/0-9.

Turner, R. E. 1977. Intertidal vegetation and commercial yields of penaeid shrimp. Trans. Amer. Fisheries Soc. 106(5):411-416.

Twilley,

Table 1.- Area (hectares) of mangrove habitat types in the Chame and Aguadulce study areas, Panama.[a]

| Habitat Type | Aguadulce | | Chame | |
|---|---|---|---|---|
| | Hectares | Percent | Hectares | Percent |
| Rhizophora Forest | 2791 | 49.9 | 4756 | 64.8 |
| Avicennia Forest | 2213 | 39.6 | 1507 | 20.5 |
| Salt Flats | 588 | 10.5 | 1075 | 14.7 |
| Sandy Areas | 3 | - | 0 | - |
| Grass Flats | 0 | - | 0 | - |
| Totals | 5595 | 100. | 7338 | 100. |

(a) Data modified from Hughes et al. (1985).
(b) Based on dominant form of vegetation or dominant physical/environment characteristic.
(c) Rio Grande study area, included within this mapping unit are undefined high ground (2374 ha) and contiguous water area (2685 ha).

Table 2.- Comparison of area (hectares) of mangrove forest vegetation types in the Chame and Aguadulce study areas, Panama.[a]

| Vegetation Type | Aguadulce | | Chame | |
|---|---|---|---|---|
| | Hectares | Percent | Hectares | Percent |

(a) Data modified from Hughes *et al*. (1985).
(b) Descriptors based on Cintron (1984).

Table 3.- Change in land use and habitat type between 1965 and 1982 within the Chame study area, Panama.[a]

| Habitat Type/ Land Use | 1965 | | 1982 | | Change | |
|---|---|---|---|---|---|---|
| | Hectares | Percent | Hectares | Percent | Hectares | Percent |
| Rhizophora Forest | 4751.6 | 70.6 | 3910.5 | 69.1 | | |
| Avicennia Forest | 1437.2 | 21.3 | 892.8 | 15.8 | | |
| Salt Flats | 368.0 | 5.5 | 389.7 | 6.9 | | |
| Sandy Areas | 6.4 | 0.1 | 26.1 | 0.5 | | |
| Grass Flats | 169.2 | 2.5 | 81.9 | 1.4 | | |
| Water | | | | | | |
| Upland Forest | | | | | | |
| Shrimp Ponds | 0.0 | 0.0 | 303.3 | 5.4 | | |
| Mud Flats | - | - | 52.2 | 0.9 | | |
| Totals | 6732.4 | 100. | 5656.5 | 100. | | |

(a) Data modified from Hughes et al. (1985).

Table 4.- Change in mangrove forest vegetation types between 1965 and 1982 within the Chame study area, Panama.[a]

| Vegetation Type | 1965 | | 1982 | | Change | |
|---|---|---|---|---|---|---|
| | Hectares | Percent | Hectares | Percent | Hectares | Percent |
| R2a | 1164.4 | | 2312.1 | | | |
| R2b | 2189.6 | | 1201.5 | | | |
| R2c | 25.6 | | 63.0 | | | |
| R3a | 220.4 | | 66.6 | | | |
| R3b | 310.0 | | 97.2 | | | |
| R3c | 591.2 | | 77.4 | | | |
| R3d | 21.2 | | 0.0 | | | |
| R4b | 23.2 | | 25.2 | | | |
| R4c | 122.0 | | 46.8 | | | |
| R4d | 57.6 | | 0.0 | | | |
| R5c | 26.4 | | 20.7 | | | |
| A1a | 142.0 | | 14.4 | | | |
| A1b | 16.8 | | 0.0 | | | |
| A2a | 464.0 | | 218.7 | | | |
| A2b | 46.4 | | 5.4 | | | |
| A3a | 398.0 | | 368.1 | | | |
| A3b | 176.8 | | 140.4 | | | |
| A3c | 32.0 | | 0.0 | | | |
| A4a | 20.4 | | 19.8 | | | |
| A4b | 11.2 | | 11.7 | | | |
| A4c | 70.0 | | 95.4 | | | |
| A4d | 59.6 | | 18.9 | | | |
| Sf1 | 337.6 | | 345.7 | | | |
| Sf2 | 30.4 | | 44.1 | | | |
| Sb | 6.4 | | 26.1 | | | |
| Gs | 169.2 | | 81.9 | | | |
| Sp | 0.0 | | 303.3 | | | |
| Mf | 0.0 | | 52.2 | | | |
| TOTAL | 6732.4 | | 5656.5 | | | |

(a) Datafrom Hughes et al. (1985).

Table 5.- Change in land use and habitat type between 1965 and 1980 within the Aguadulce study area, Panama.[a]

| Habitat Type/ Land Use | 1965 | | 1980 | | Change | |
|---|---|---|---|---|---|---|
| | Hectares | Percent | Hectares | Percent | Hectares | Percent |
| Rhizophora Forest | 2195.0 | 42.4 | 2622.6 | 58.8 | | |
| Avicennia Forest | 2550.4 | 49.3 | 1584.5 | 35.5 | | |
| Salt Flats | 265.8 | 5.1 | 189.7 | 4.3 | | |
| Sandy Areas | 48.0 | 0.9 | 48.9 | 1.1 | | |
| Grass Flats | 70.7 | 1.4 | 0.0 | - | | |
| Water | | | | | | |
| Shrimp Ponds | | | | | | |
| Upland Forest | No Data | | | | | |
| Pasture | | | | | | |
| Sugarcane | | | | | | |
| Rice | | | | | | |
| Laguncularia | 46.0 | 0.9 | 12.3 | 0.3 | | |
| Totals | 5176.7 | 100. | 4458.0 | 100. | | |

(a) Data modified from Hughes *et al*. (1985).

Table 6.- Change in mangrove forest vegetation types between 1965 and 1980 within the Aguadulce study area, Panama.[a]

| Vegetation Type | 1965 | | 1980 | | Change | |
|---|---|---|---|---|---|---|
| | Hectares | Percent | Hectares | Percent | Hectares | Percent |
| R1a | 1941.0 | | 2552.1 | | | |
| R1b | 9.2 | | 12.4 | | | |
| R1c | 9.2 | | 0.0 | | | |
| R2a | 154.8 | | 19.7 | | | |
| R2b | 48.7 | | 38.4 | | | |
| R2c | 30.3 | | 0.0 | | | |
| R3a | 1.8 | | 0.0 | | | |
| A1a | 416.5 | | 147.9 | | | |
| A1b | 4.6 | | 0.0 | | | |
| A2a | 782.7 | | 496.4 | | | |
| A2b | 124.8 | | 182.3 | | | |
| A2c | 64.9 | | 127.7 | | | |
| A3a | 349.1 | | 171.0 | | | |
| A3b | 234.7 | | 184.3 | | | |
| A3c | 109.2 | | 118.2 | | | |
| A3d | 11.3 | | 0.0 | | | |
| A4a | 173.8 | | 0.0 | | | |
| A4b | 105.9 | | 16.0 | | | |
| A4c | 78.0 | | 56.4 | | | |
| A4d | 94.9 | | 84.3 | | | |
| L2a | 2.4 | | 0.0 | | | |
| L3a | 44.4 | | 12.3 | | | |
| Sf1 | 72.8 | | 93.9 | | | |
| Sf2 | 193.0 | | 95.8 | | | |
| Sb | 48.0 | | 48.9 | | | |
| Gs | 70.7 | | 0.0 | | | |
| TOTAL | 5176.7 | | 4458.0 | | | |

(a) Data from Hughes et al. (1985).

Table 7.- Estimates of merchantable wood volume for *Rhizophora* site classes and *Avicennia* site classes based on rotations of 10, 20, and 30 years. Site classes adapted from Cintron (1985); area estimates modified from Hughes (1985); wood volume estimates derived from ( ) discussed in Appendix .

Aguadulce

| Site Class Descriptor | Area (Ha) | Volume m3/ha | Volume m3 | Allowable Harvest 10 yrs ha | 10 yrs m3 | 20 yrs ha | 20 yrs m3 | 30 yrs ha | 30 yrs m3 |
|---|---|---|---|---|---|---|---|---|---|

Table 8.- Wood volumes for the genera Rhizophora and Avicennia at the Aguadulce study area and a listing of potential natural products and/or forms of utilization. Compiled and modified from Saenger et al. (1983), Walsh (1972), and Hamilton and Snedaker (1984). Known forms of use or utilization in Panama are (a) for Aguadulce, (c) for Chame, and (o) for other areas in Panama. No listing is made for volumes less than cubic meters or for vegetation type areas of less than hectares. Listing is non-inclusive.

Rhizophora

Avicennia

## APPENDIX A

There have been two attempts to derive empirical and predictable relationships between mangrove forest area and the abundance of commercial shrimp on a regional basis (Turner 1977; Martosubroto and Naamin 1977). Both attempts resulted in regression equations with good correlation coefficients; Turner's for latitudes of the world, and Martosubroto and Naamin's for islands and island groups in Indonesia. The regression equation generated by Martosubroto and Naamin is given in equation 1:

$$Y = 5.473 + 0.1128\ X \qquad \text{Eq. 1}$$

Where X = area in mangrove forest ($10^4$ ha) and Y = annual shrimp production ($10^3$ ton). The correlation coefficient for this regression relationship is r = 0.089. The high Y-intercept (5.473) is reported to be due to the inclusion of non-mangrove dependent shrimp species in the catch statistics.

The equation has been recalculated using the total mangrove forest area for the Republic of Panama (505,600 ha), the Chame study area (4,803 ha) and the Aguadulce (i.e., Rio Grande) study area (4,219 ha). The shrimp "abundance" (or, potential yield in metric tons) that is theoretically attributable to each of these areas is tabulated below:

| | Panama | Chame | Aguadulce |
|---|---|---|---|
| Tons/year | 11,180 | 553 | 552 |

Note: For comparison, D'Croz and Rosaria (1985) cite other shrimp production estimates for Panama which show that over the period 1981-84 production ranged between 7,052 and 7,745 tons. Although the calculated figures are relatively high, they do not appear to be unrealistic for the Pacific coast of Latin America (cf., Turner 1977).