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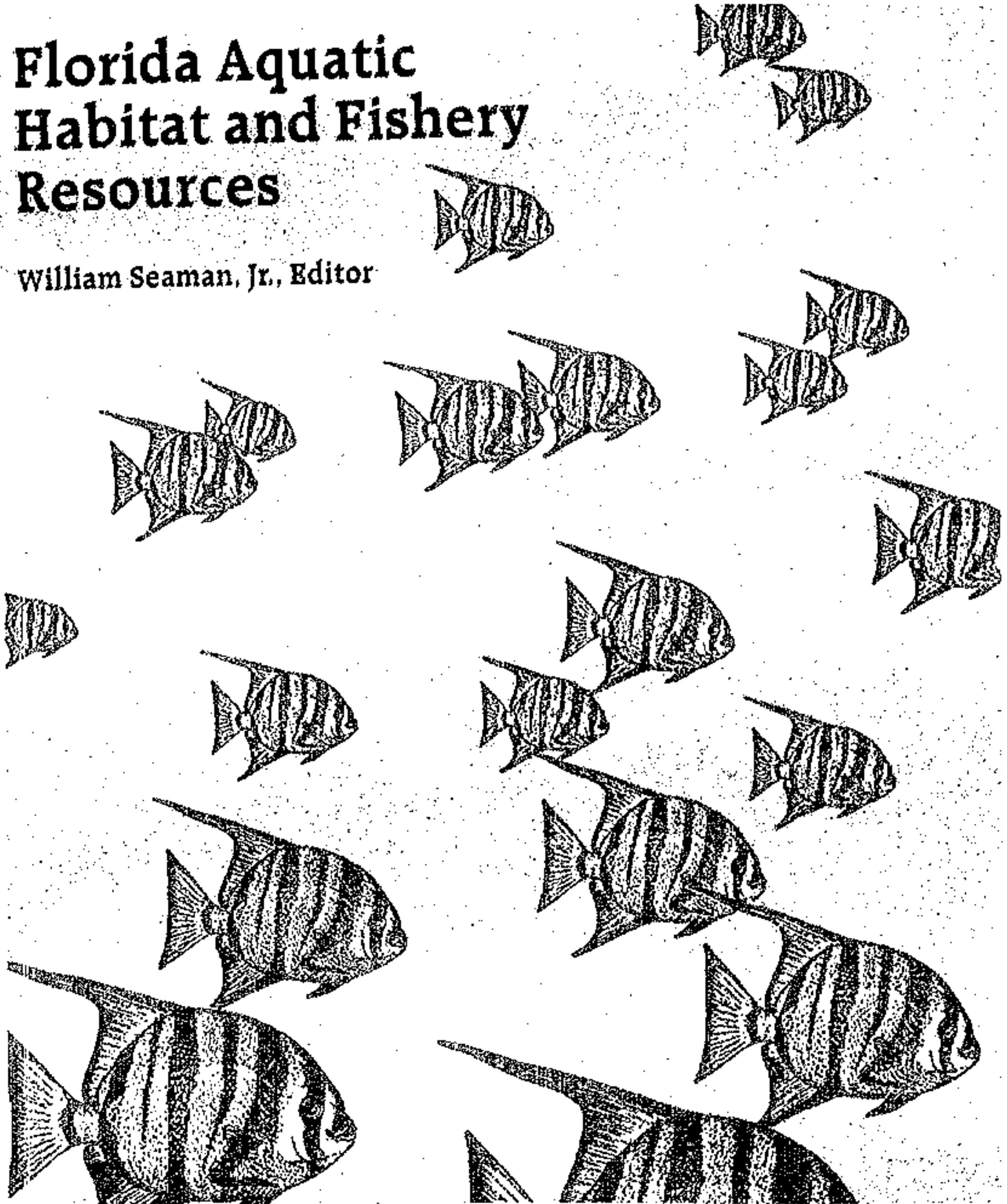
# Florida Aquatic Habitat and Fishery Resources

William Seaman, Jr., Editor



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# MANGROVE HABITAT AND FISHERY RESOURCES OF FLORIDA

R. R. Lewis, III, R. G. Gilmore, Jr., D. W. Crewz, and W. E. Odum

## INTRODUCTION

In the recent review of the ecology of mangroves in south Florida, mangrove forests are described as serving two distinct roles for fish populations (55). The first is as habitat for juvenile fish and the second as food, either directly as decaying leaf material (detritus), or more commonly as the source of energy for a detritus-based food web that supports numerous invertebrate species or small forage fish species that are food for other fish.

The role that mangroves play in supporting fishery resources varies with location. A total of 217 species of fish have been collected from mangrove areas in south Florida, many of which are important in commercial and recreation fisheries (55).

The purpose of this chapter is to discuss the fishery resources associated with mangroves not only in south Florida but also in other portions of Florida, and to discuss management alternatives important in restoring fisheries presently exhibiting declines due in part to lost or altered mangrove habitat (39, 41).

## HABITAT DESCRIPTION

In the classic paper on mangrove ecology (10) the word mangrove is referred to as " . . . more an ecological than a taxonomic concept." The appropriateness of this statement is particularly evident when the evolutionary diversity of families that include mangrove genera are considered on a worldwide basis. More than twelve families that contain species with mangrove are known to occur worldwide (9). Species commonly recognized in Florida are <u>Rhizophora mangle</u> L. (red mangrove), <u>Avicennia germinans</u> (L.) L. (black mangrove), and <u>Laguncularia racemosa</u> Gaertn. f. (white mangrove). A fourth species, <u>Conocarpus erecta</u> L. (buttonwood), is not frequently classed as a "true" mangrove because it lacks typical mangrove characteristics such as vivipary (germination of the seed while still attached to the parent plant) and aerating roots. Since buttonwood is closely associated with the "true" mangroves at the transition zone to upland areas, it frequently contributes to the mangrove ecosystem in the form of biomass and habitat, although usually not in quantities comparable to other species of mangroves.

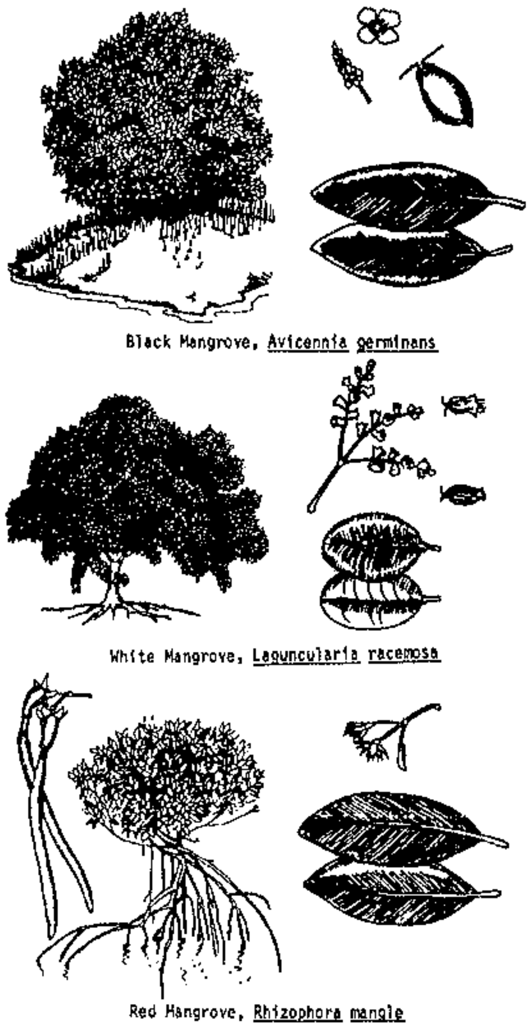



Figure 1. Tree form, leaf shape, and propagule shape of the three Florida species of mangrove (from 55).



The red mangrove (Figure 1), generally the most seaward of the three Florida species, has attracted the attention of many investigators. Arching "prop" roots, arising from the trunk and lower branches, serve to brace the tree in the substratum and to promote gas exchange in the roots under anoxic conditions. The pencil-shaped propagules, which may reach 18 inches (46 cm) in length, hang conspicuously from the branches during the late summer. Potentially the tallest of the three species, red mangroves have been reported to reach heights of 100 feet (31m) (68, 69, 76).

The black mangrove (Figure 1), which usually grows landward of the red mangrove, may reach 60 feet (18m) in height. Fruits of this species have been described as "lima bean-shaped" and are approximately 1 inch (2.5cm) long. Most characteristic of the black mangrove is its network of horizontal "cable" roots that give rise to vertical, aerating roots called pneumatophores, which emerge finger-like from the soil around the plant. Like the red mangrove, the black mangrove fruits predominantly during late summer and early fall.

The white mangrove (Figure 1) normally lacks both prop roots and pneumatophores, although it may occasionally have pneumatophore-like structures called pneumathodes (31) or adventitious roots similar to proproots when subjected to certain flooding stresses. It is a shrub or small tree reaching 50 feet (15m) in height. Leaves of white mangroves are yellow-green, oval, and have two salt glands on the petiole. The deltoid-shaped fruits are less than 3/4 inch (2 cm) long and are also produced in late summer and early fall.

## Environmental Controlling Factors

Since the mangrove concept is defined by habitat, an appreciation of the parameters that regulate mangrove distribution is important in understanding the multifaceted interactions that occur in a mangrove forest. Some of the major environmental factors that regulate mangrove distribution are: 1) climate, 2) salt water, 3) tidal fluctuation, 4) substrate, and 5) wave energy (55). The first of these parameters, climate, limits mangrove distribution in a geographical sense. Mangroves are primarily tropical/subtropical in distribution (ca. 25N-25S) because they do not tolerate freezing temperatures well. In Florida, black mangroves are the most cold tolerant and are found as far north as Cedar Key on the Gulf coast and to approximately St. Augustine on the Atlantic coast, although isolated small patches may occur farther north (Figure 2) (65, 7, 55). Black mangroves along the western Gulf of Mexico range from Mexico north to Texas and Louisiana where they become stunted in response to colder temperature. Increasing tolerance to cold among black mangroves appears to be heritable along a gradient from the tropics (Belize) to Texas (49). White mangroves, however, showed no such adaptive gradient. Red and white mangroves are less tolerant of cold and, although found in the Cedar Keys area, major forest development occurs only south of Tarpon Springs on the Gulf Coast and south of Cape Canaveral on the Atlantic coast (55, 7).

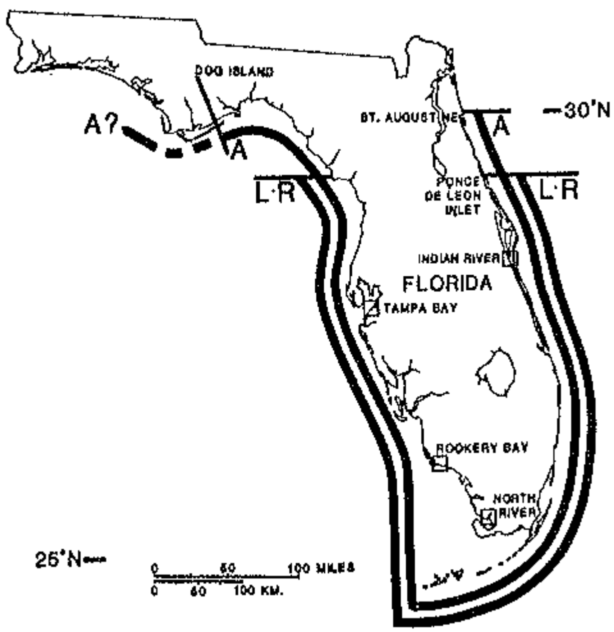



Figure 2. Distribution of Rhizophora (R), Laguncularia (L), and Avicennia (A) along Florida's coastline.

Reduced species richness and forest complexity occurs with lower temperatures in the mangrove forests of Mexico (42). Similarly temperature stress modifies structural complexity by decreasing tree



height, leaf size and number, and by increasing tree density (45). In addition, low temperatures limit growth as far south as Fort Myers on the Gulf coast and Jupiter on the Atlantic coast (10). Consequently, 90 percent of the estimated 500,000 acres (202,350 ha) of mangroves that occur in Florida are located in the four southernmost counties of Lee, Collier, Monroe and Dade (Table 1). This distribution can principally be attributed to two factors: 1) warmer climate which increases growth rates, and 2) suitability of substrate as related to slope. Gradual slopes provide longer expanses of habitat for colonization and, coupled with the freshwater sheet flow emanating from the Everglades region, mangroves attain their best development in Florida in these southern areas.

The relative effects of the remaining factors that modify mangrove distribution are not easily separable. Tidal effects, salinity, substrate quality, and wave energy interact in a complex manner to limit or encourage different aspects of mangrove growth and establishment.

Higher than normal tides and occasional storms decrease competition from upland, salt-intolerant plants. Although higher salinities may depress mangrove productivity, the flushing action of tides removes toxic substances from sediments (e.g. sulfides) that may inhibit growth.

Mangroves grow best where overlying water salinity is between 1 and 2 percent (10-20 ppt) (11). For this reason freshwater input from upland areas is important in ameliorating some of the effects of the higher salinity sea water and is a valuable source of nutrients for mangrove areas (28). Substrate type (mud, peat, sand, etc.) affects nutrient retention and can also determine the extent to which sediment salinity can affect plant growth. For example, a study of the physiology of certain salt marsh plants determined salinities for different types of marsh substrates (70). The highest salinity was found in silty clay sediments (32 ppt) and the lowest in higher elevation sandy soils (12 ppt). Intermediate values were obtained for clay (18 ppt) and lower elevation sands (24 ppt). Fluctuation of sediment salinity is often greater in sandy soils than in sediments with a higher proportion of silt (8). This fluctuation may cause increased stress and result in lower plant productivity (64).

Table 1. Estimates of emergent wetland acreages of coastal counties in Florida. (Sources: NWI: National Wetland Inventory, St. Petersburg, 1982. CCC: Coastal Coordinating Council, 1973).

| | Mangroves | | Mangroves | | Tidal Marshes | | Tidal Marshes | |
|---|---|---|---|---|---|---|---|---|
| County | ac (NWI) | ac (CCC) | ha (NWI) | ha (CCC) | ac (NWI) | ac (CCC) | ha (NWI) | ha (CCC) |
| Bay | - | - | - | - | 7,207 | 5,630 | 2,918 | 2,279 |
| Brevard | 6,623 | 1,020 | 2,681 | 413 | 17,435 | 1,470 | 7,059 | 595 |
| Broward | 1,704 | 704 | 690 | 285 | - | - | - | - |
| Charlotte | 22,431 | 13,060 | 9,081 | 5,287 | 3,831 | 4,420 | 1,551 | 1,789 |
| Citrus | 3,394 | 4,100 | 1,374 | 1,660 | 36,273 | 32,700 | 14,685 | 13,239 |
| Collier | 85,513 | 71,940 | 34,621 | 29,126 | 14,177 | 27,840 | 5,740 | 11,271 |
| Dade | 96,337 | 81,340 | 39,003 | 32,931 | 24,743 | - | 10,017 | - |
| De Soto | 204 | 510 | 83 | 206 | 204 | 190 | 83 | 77 |
| Dixie | 243 | - | 98 | - | 19,259 | 23,620 | 7,797 | 9,563 |
| Duval | - | - | - | - | 37,603 | 34,370 | 15,224 | 13,915 |
| Escambia | 78 | - | 32 | - | 2,075 | 1,920 | 840 | 777 |
| Flagler | 259 | 130 | 105 | 53 | 2,628 | 2,110 | 1,064 | 854 |
| Franklin | - | - | - | - | 16,538 | 21,180 | 6,696 | 8,575 |
| Gulf | - | - | - | - | 5,257 | 1,120 | 2,128 | 453 |
| Hernando | 136 | 60 | 55 | 24 | 11,792 | 10,500 | 4,774 | 4,251 |
| Hillsborough | 10,095 | 3,460 | 4,087 | 1,401 | 1,675 | 3,260 | 678 | 1,320 |
| Indian River | 4,133 | 2,690 | 1,673 | 1,089 | 910 | 380 | 368 | 154 |
| Jefferson | - | - | - | - | 4,865 | 4,160 | 1,970 | 1,684 |
| Lee | 40,164 | 32,260 | 16,261 | 14,275 | 2,832 | 4,160 | 1,147 | 1,684 |
| Leon | 441 | - | 179 | - | - | - | - | - |
| Levy | - | - | - | - | 35,703 | 36,350 | 14,455 | 14,716 |
| Manatee | 5,754 | 3,780 | 2,330 | 1,530 | 1,029 | - | 417 | - |
| Martin | 35 | 3,650 | 14 | 1,478 | - | - | - | - |
| Monroe | 361,036 | 234,180 | 146,179 | 94,810 | 11,834 | 177,090 | 4,791 | 71,696 |
| Nassau | 511 | - | 207 | - | 27,329 | 17,920 | 11,064 | 7,255 |
| Okaloosa | - | - | - | - | 257 | 700 | 104 | 283 |
| Palm Beach | 754 | 1,790 | 305 | 725 | - | - | - | - |
| Pasco | 10,588 | 260 | 4,287 | 105 | 12,228 | 3,780 | 4,951 | 1,530 |
| Pinellas | 7,216 | 2,820 | 2,921 | 1,142 | 423 | - | 171 | - |
| St. Johns | 306 | - | 124 | - | 19,573 | 12,670 | 7,924 | 5,130 |
| St. Lucie | 5,497 | 4,610 | 2,226 | 1,866 | 557 | - | 226 | - |
| Santa Rosa | 148 | - | 60 | - | 7,125 | 16,630 | 2,885 | 6,733 |
| Sarasota | 1,115 | 510 | 451 | 206 | 1,128 | 900 | 457 | 364 |
| Taylor | 154 | - | 62 | - | 23,740 | 21,950 | 9,611 | 8,887 |
| Volusia | 9,331 | 2,750 | 3,778 | 1,113 | 10,601 | 8,260 | 4,292 | 3,344 |
| Wakulla | - | - | - | - | 19,658 | 20,100 | 7,914 | 8,138 |
| Walton | 14 | - | 6 | - | 2,938 | 2,110 | 1,189 | 854 |
| TOTAL | 674,241 | 468,624 | 272,973 | 189,725 | 383,317 | 497,490 | 155,190 | 188,885 |

High wave energy and currents prevent establishment of mangrove propagules, undermine root systems, and prevent the accumulation of fine-grained sediments in which mangroves grow best. Therefore, mangrove establishment and growth is generally best in low energy estuarine areas where fine-grained sediments are common and where freshwater also lessens the deleterious effects of higher salinities.

## Zonation

The classical view of mangrove zonation (10) had become a point of dogma until recent years. This viewpoint held that pioneering red mangroves colonized suitable substrates and built land in the process of maturing. As the habitat became modified, black and white mangroves could become established in successive landward zones, following the red mangrove zone in its march toward the sea, thereby reclaiming submerged land. It was proposed that this succession of plant species eventually would give way to upland non-halophytic vegetation as the land elevation increased.

Although this "zonation-succession-landbuilding" hypothesis was only superficially tenable, the theory gained wide acceptance and remained untested for many years. Recently, this classicial interpretation of observed zonation patterns has been questioned. An alternative opinion proposes that geomorphological processes acting in concert govern the expression of zonation patterns (77). Change in sea level was invoked as a mechanism for determining mangrove migration -- mangroves moving seaward when sea level drops and landward when it rises (74, 55). Therefore, sea level changes, linked with the influence of other physical factors (e.g. salinity, tidal amplitude, etc.), tidal sorting of propagules (62, 63), and interspecific competition (1), may result in zonation of mangroves. It has been stated that because mangroves react passively to geomorphological forces, they "... should be regarded as 'land-stabilizers' rather 'land-builders.' (55).

In areas where relative sea level is static, mangrove forests may be regarded as a "steady-state cyclical system" (43). That is, once succession leads to the stable "climax" forest, species composition



remains fairly constant until a large scale perturbation such as a hurricane sets the system back to a less mature stage. Further research into the mechanisms governing mangrove succession and zonation patterns is required before an accurate description can emerge. In the interim, zonation patterns of mangroves should not be unequivocally accepted as being only the result of successional processes. In reference to mangrove zonation mechanisms, it has been noted that "... the species which can maximize its photosynthetic output with greatest metabolic efficiency dominates in competition with other species" (71).

## Structure

### Community Types

Based on the criteria of periodicity of tides, seasonal terrestrial runoff, species composition and gross structure, five mangrove community types are commonly distinguished (72). These community types are summarized as follows:

Basin forests are located along inland strand-like drainage patterns that channel terrestrial runoff toward the coast. Where basin forests are exposed to regular tidal flushing, red mangroves dominate; as tidal flushing decreases, black and white mangroves increase in frequency. A variant of the basin forest is the hammock type which, although floristically similar to the basin forest, occupies elevations that are slightly higher than surrounding areas. Inland, the basin forest type gradually grades into less saline associations (44).

Riverine forests occur along river floodplains in coastal regions. In these areas the predominant red mangroves have historically reached their greatest height in Florida (76). During wetter periods of the year, salinity drops but water current remain slow enough that little of the accumulated organic matter is removed from these areas (44).

Fringe forests are located along edges of the mainland and larger islands where high elevations prevent tidal overwashing. When extreme environmental perturbations (e.g. hurricanes, freezing temperatures, etc.) are minimal, these forests frequently reflect the zonation pattern for which mangroves are well known. Tidal velocities are reduced in these areas and allow entrapment and accumulation of large quantities of debris by extensively developed prop root and pneumatophore systems.

Overwash forests become established on small islands and narrow mainland projections that are of low elevation and therefore subject to regular tidal flushing. Relatively strong tidal velocities prevent the accumulation of organic matter and the islands remain structurally simple with red mangrove usually the dominant species (44).

Dwarf or scrub forests occur on low-lying, nutrient-poor substrates principally in southeast Florida. Because of the low-nutrient conditions, the dominant red mangroves, although mature (40-50 years old), are stunted and biomass production is relatively restricted (44).

Recently, the overwash forest community designation has been merged with the fringe forest designation due to structural similarity (46). Also, another variant of the basin community has been suggested -- the lagoonal type (37). The lagoonal type occurs in areas separated from the sea by a low-lying sand beach and usually has an entrance channel which is small compared to the length of the barrier beach. Finally, a shrub forest type has been proposed (16) which is similar to the "scrub marsh" (58). Both of these cover areas which are climatically marginal for mangrove growth such as the upper east and west coast of Florida. At this time, however, the five major community types will be used for the comparisons that follow.

## Plant Community Comparisons

Quantitative structural studies have revealed considerable variation in many aspects of mangrove ecosystems. To compound the problem, comparisons between sites and species have been hampered by different research objectives and techniques (57). To standardize comparisons between "natural" mangrove sites and to correlate easily measurable structural characteristics with major forcing functions (e.g. tidal dynamics, geomorphological processes, etc.), structural development based on species importance values and complexity indices has been measured in Central America, Puerto Rico, and Florida mangrove populations (57). The species importance value is a measure of within-stand importance of a species obtained by summing its relative



frequency, relative density, and relative basal area. The complexity index (CI) (29) is the product of number of species, number of individuals with DBH (diameter at breast height) greater than a specified diameter (usually 10 cm or 2.5 cm), basal area ($m^2$), and height (m) divided by 1000 (for a 0.1 ha plot). The complexity index, therefore, is a measure of the level of development of a particular forested area.

Complexity indices and importance values for south Florida mangrove populations are presented by community type in Table 2. The data illustrate the dominance of red mangrove in all community types except for the basin forest in which black mangrove is dominant. Riverine and basin forests have the highest complexity values especially when smaller diameter stems are counted. Scrub mangroves have the lowest complexity index (short canopy and low basal area), with overwash and fringe mangroves intermediate in development. Comparing the Florida complexity measures to those from Puerto Rico and Central America reveals that the degree of development is greatest in riverine forests of Central America. This is attributed to the lack of hurricanes, which

Table 2. Summary of complexity indices and importance values of mangrove forest types for southern Florida (after 56).

| Community | Complexity Index | | Importance Value[1] | | |
|---|---|---|---|---|---|
| Type | >2.5 cm | >10 cm | Red | Black | White |
| Fringe | 9.6 | 1.4 | 72.1 | -- | 27.9 |
| Riverine | 27.7 | 2.3 | 58.3 | 41.7 | -- |
| Basin | 23.4 | 1.9 | 37.8 | 47.0 | 9.9 |
| Overwash | 3.4 | 0.8 | 75.3 | -- | 24.7 |
| Dwarf (scrub) | 1.5 | 0.0 | 100.0 | -- | -- |

1 For trees >2.5 cm DBH

allows forests to reach full maturity in this region (57). In Puerto Rico, fringe mangroves have the highest complexity index if the smaller diameter stems are included but this value drops significantly if only the larger size class is used. Arid environments and hurricanes are proposed as the main controlling factors causing suppression of mangrove growth in Puerto Rico. The complexity index for mangroves in Puerto Rico was determined to range from 8.4 to 135.8 (37). Mean CI values for the lagoonal variant of the basin forest type and fringe forest were 29.3 and 81.1, respectively. These values are higher than those previously determined (57) and may result from inclusion of buttonwood and smaller diameter stems (minimum DBH was not specified) as well as recognition of the lagoonal variant.

The value of using a standardized quantitative approach such as the complexity index becomes apparent when making comparisons between different areas and environments. Effects of different environmental variables can be correlated with stand structure more easily, thereby clarifying directions for ecosystem management. Unfortunately, at this time, the majority of mangrove research in Florida has occurred in well developed southern stands (55) while relatively few studies have been conducted in less developed populations farther north (16). The production of mangrove biomass which might be cycled through northern marine ecosystems in the form of detritus may demonstrate significant variation from southern populations of mangroves. Therefore, measurements of production (litter, $CO_2$ exchange, etc.), coupled with measures of stand structure (CI), would help illuminate potential mangrove contributions to the marine systems of Florida (73).

The combination of different tidal influences, drainage patterns, and weather produces a gradient of mangrove forest structural types as shown in Figure 3. The classic diagrammatic representation of mangrove zonation (11) is shown in comparison to those patterns seen in a number of other locations in Florida. It is obvious that no single diagrammatic representation accurately describes mangrove forests in Florida. The North River estuary (Figure 2) was essentially a monoculture of red mangroves with white mangroves present as scattered individuals and mixed with reds. Black mangroves were absent and needlerush (*Juncus*



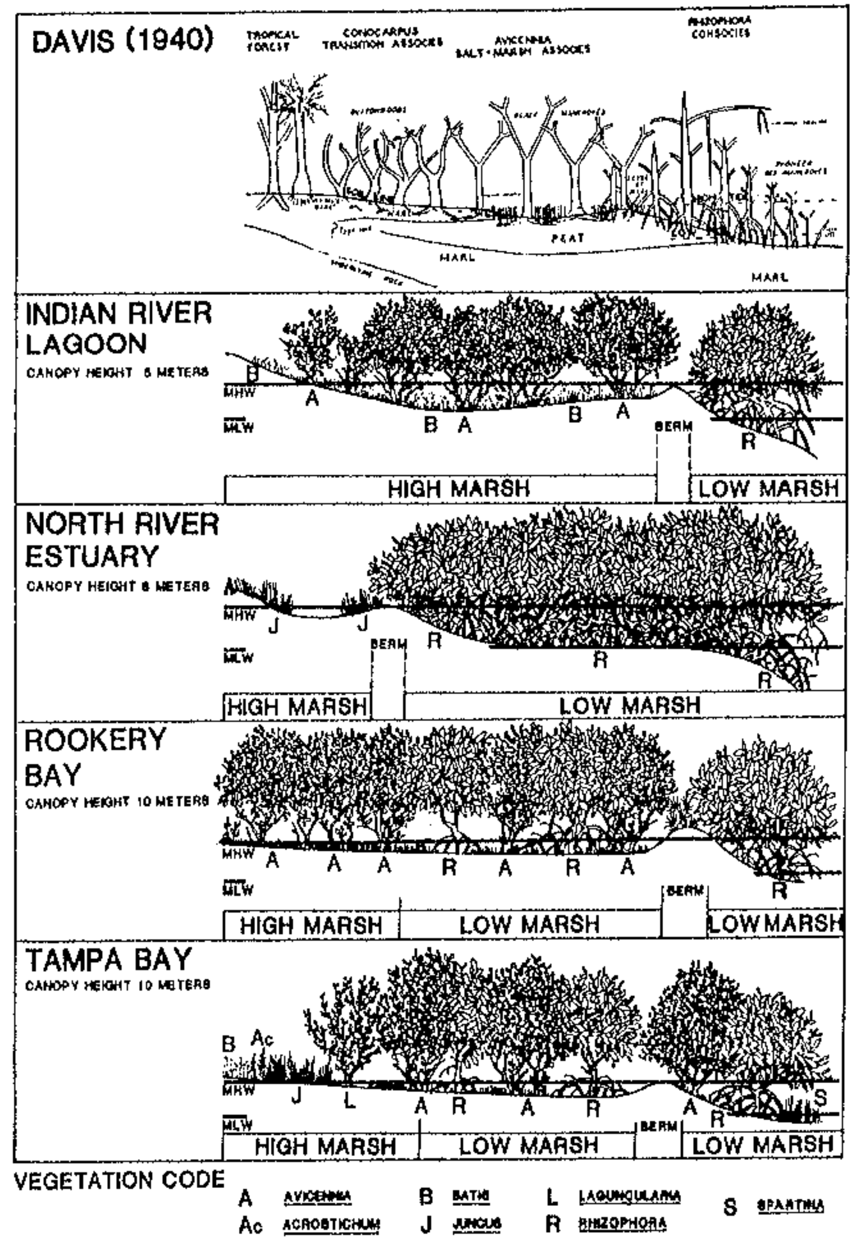



Figure 3. Comparison of mangrove zonation patterns at four locations with that illustrated by Davis, 1940 (10).

*roemerianus* Scheele) and sawgrass (*Cladium jamaicense* Crantz) were present in the upper reaches of the North River (25, 53).

Extensive mangrove growth in salt marsh habitat reaches its northernmost point along the central east coast of Florida in the vicinity of Cape Canaveral (7). These subtropical marshes are a portion of a transitional marsh ecosystem extending along the periphery of the Indian River, Banana and Mosquito lagoons from the vicinity of Ponce de Leon Inlet (29°05'N), south to the Jupiter Inlet (26°58'N), approximately 157 miles (253 km). The mangrove habitat in this region of Florida is typically dominated by black mangrove, glasswort (*Salicornia* spp.) and saltwort (*Batis maritima* L.) (59). These marshes are generally inundated only by tides approximately mean high water and mean spring high water (58, 59, 60, 61). Low mean tidal levels within estuaries along the coast of east-central Florida and regional topography have produced a greater percentage of high marsh habitat than low marsh (below mean high water) (Fig. 3).

In studying the role of black mangroves in estuarine food webs it was noted that in the forests studied at Rookery Bay (Figure 2 and 3), black mangroves were the dominant species based upon basal area measurements (46). It has been reported that the total area of black mangrove forests in Florida is 245,219 acres (99,279 ha) or 36 percent of the 674,243 acres (272,973 ha) of mangrove forests in Florida (46).

Secondary succession in a disturbed mangrove forest in Tampa Bay has been studied and it was noted that the undisturbed forest exhibited the classical zonation pattern with white mangroves dominant at higher elevations, mixed white and black mangroves at lower elevations behind a natural levee, and red mangroves dominant at lower elevations and along mosquito control ditches (13). For the entire forest the white mangrove had the highest importance value (107), followed by the black mangrove (53) and the red mangrove (40). Smooth cordgrass (*Spartina alterniflora* Loisel.) was noted as a minor component of the undisturbed forest but a major component of the disturbed forest where it apparently acts as a "nurse plant," catching floating mangrove seeds and assisting in their establishment (35). Needlerush and leather fern (*Acrostichum aureum* L.) are the dominant marine plant species in the highest marsh



areas and in saline streams or rivers upstream of the mangrove forests (16).

## Estimates of Total Mangrove Forest Area

Estimates of the total acreage occupied by mangrove communities in Florida vary widely between 430,000 acres to over 650,000 acres. Several reasons have been cited for the lack of agreement among estimates (55). These include: 1) inclusion or exclusion in surveys of small bays, ponds and creeks which occur within mangrove forests and 2) incorrect identification of mangrove areas from aerial photography as a result of inadequate "ground-truth" observations, poorly controlled photography, and simple errors of planimetry.

The Coastal Coordinating Council (CCC) estimated a total of 469,000 acres (190,000 ha) were covered by mangroves in Florida and suggests that an expected margin of error of 15 percent (i.e. their estimate lies between 400,000 and 540,000 acres, or 162,000 and 219,000 ha).

Draft figures released by the National Wetland Inventory (NWI), St. Petersburg, Florida, are shown in Table 2. The areal coverage of tidal marshes and mangroves are shown by county for all of Florida. These figures show a total of 674,241 acres (272,973 ha) of mangroves and 383,317 acres (155,190 ha) of tidal marshes in Florida. Since these data are not yet final, and we find some of the areal measurements to be higher than previously reported, we would suggest they be used with caution.

It is interesting to note that the totals for both CCC and NWI are very close (966,132 acres versus 1,057,558 acres), and this suggests the problem lies with separating marshes from mangroves.

## Energy Flow and Food Webs

Figure 4 illustrates the potential pathways of energy flow and fixed carbon to consumers in any marine ecosystem that includes mangroves (55). Depending on the areal extent of mangroves in relation to other

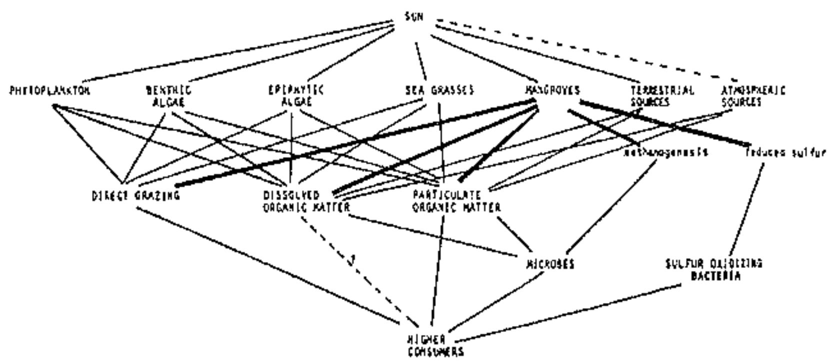



Figure 4. Potential pathways of energy flow in mangrove ecosystems (from 55).

sources of primary production, mangroves may play a major or minor role as sources of energy (55). Three examples of these differences are the North River Estuary in South Florida, the east Florida mangrove/marsh mixture in the Indian River, and the large west Florida estuaries such as Charlotte Harbor and Tampa Bay (Figure 2 and Figure 3).

The North River estuary has a drainage basin of 4,100 ac (2,170 ha) of which 2,644 ac (1,070 ha) are occupied primarily by red mangroves; 77.6 ac (31.4 ha) by sawgrass, and 75.6 ac (30.6 ha) by hardwoods (25). Open water occupies approximately one-third 1,784.9 ac (722.6 ha) of the watershed, and macroalgae and seagrasses are "found only in scattered patches" (53). In this system approximately 85 percent of all debris produced comes from red mangroves (25). It is this "debris" (leaves, stalks, twigs, roots, fruits and seeds) that is fragmented into detritus or decayed organic material with its associated bacteria and fungi. This detritus forms the basis of energy flow in mangrove dominated food webs (Figure 5). Detritus is fragmented, consumed, and excreted by a number of consumers beginning with small crustaceans (amphipods, caridean shrimp, xanthid crabs), leading through a relatively simple food web



(Figure 5) which includes small forage fish species (*Cyprinodon* spp., *Fundulus* spp.), and then to larger secondary consumers that include gray snapper (*Lutjanus griseus*), tarpon (*Megalops atlantica*), snook (*Centropomus undecimalis*), red drum (*Sciaenops ocellatus*) and spotted seatrout (*Cynoscion nebulosus*).

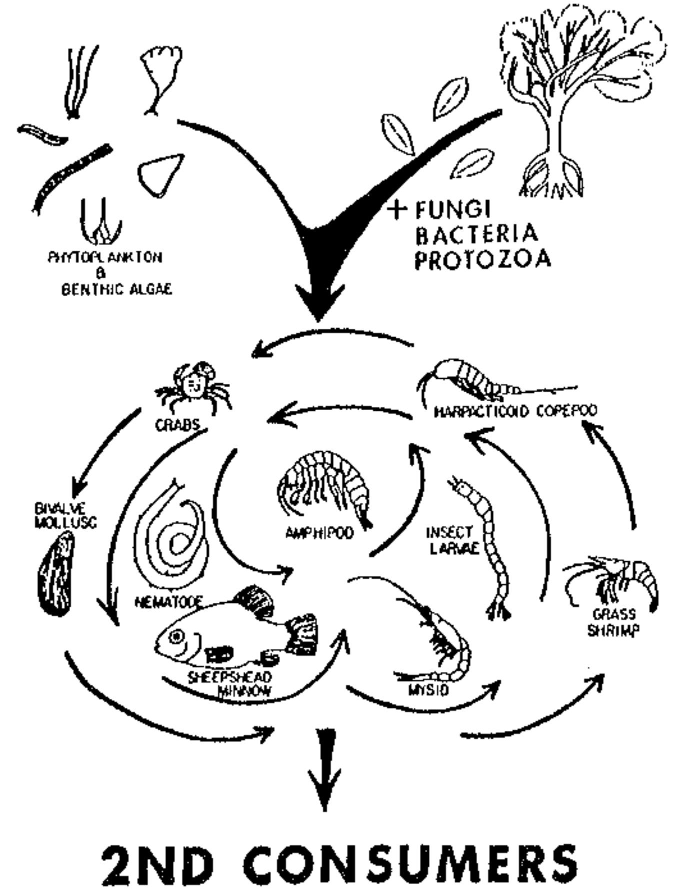



Figure 5. Detrital food chain based on red mangrove detritus (from 53).

The east Florida subtropical saltwort-mangrove/marsh habitat found in the Indian River differs signficiantly in hydrography, associated flora and fauna, and energetics from those dominated by cordgrass (Spartina alterniflora) and needlerush (Juncus roemerianus) north of Volusia County (29°20'N) to Cape Cod (42°00'N) or those dominated by red mangrove south of Martin County (27°00'N, including the North River estuary mentioned above). Cordgrass marshes and red mangrove forests are predominantly at lower elevations with most halophytic plant growth below the mean high water level and seaward of a higher elevation zone generally delineated by a change in vegetation (Figure 3, Table 3). The higher elevation zone of temperate North America is generally restricted and lies just below mean spring high water levels, and is only flooded by tides above mean high water. This temperate high marsh is characteristically vegetated with Spartina patens and Distichlis spicata (58, 14). The higher elevations of the extensive red mangrove forest of southwest Florida is characteristically vegetated with white mangrove and needlerush (53). In contrast, east-central Florida coastal wetlands are predominantly high marsh, heavily vegetated with marsh succulents (glasswort, Salicornia virginica, and saltwort, Batis maritima) and black mangrove (58). Temperate cordgrass marshes and tropical red mangroves receive more freshwater flow and tidal energy than higher areas, and form well-studied detrital ecosystems (53, 51). The east-central Florida subtropical high marsh, however, has been found to form a seasonally flooded halophytic macrophyte food chain (Figure 6) (23). The subtropical high marsh/mangrove mixture therefore receives less tidal and freshwater flow energy subsidies, and probably differs significantly in net primary productivity from tropical and temperate intertidal wetlands which are principally at lower elevations. Further study is necessary to delineate the net primary productivity and basic energetics of transitional subtropical marsh/mangrove ecosystems.

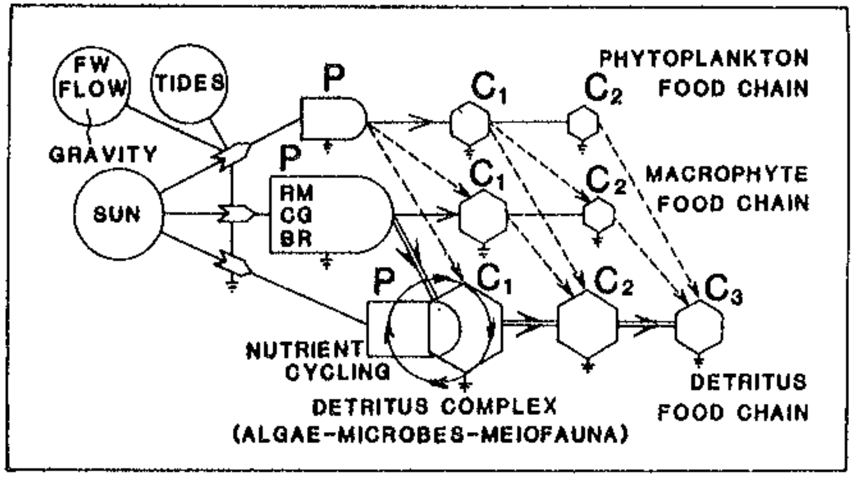
As an example of a third distinct area of mangrove forest habitat, one could look at a large west coast estuary such as Charlotte Harbor or Tampa Bay. Charlotte Harbor covers about 430,000 ac (174,021 ha) of which 58,495 ac (23,672 ha) are covered by submerged seagrass meadows, 1,435 ha (3,547 ac) by emergent tidal marshes, and 56,631 ac (22,918 ha) by mangroves (24). Obviously seagrass meadow primary production must play a major role in total estuarine production in contrast to that of the



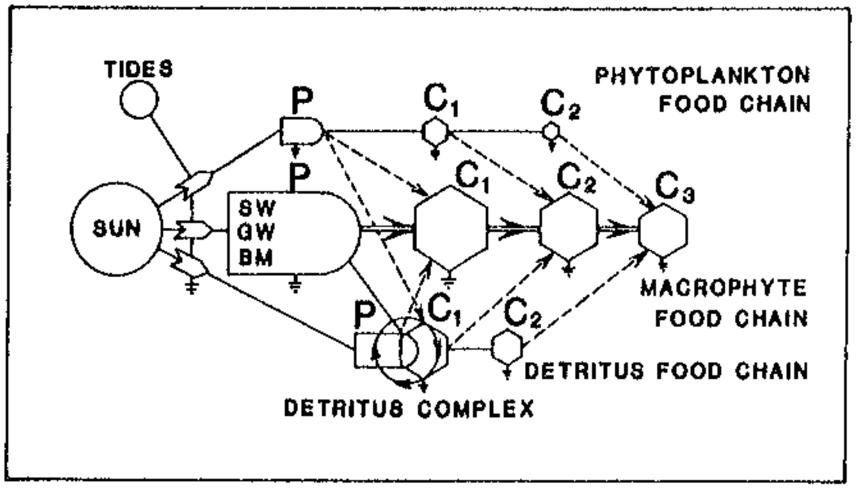
Table 3. Dominant vegetation in mangrove transitional subtropical and temperate marsh habitats.

| Tropical Florida: North River Basin, Everglades National Park (53) | Transitional Florida: Indian River Lagoon, Barrier Island Marshes (61) | Warm Temperate: North Florida to North Carolina, South Atlantic Bight Salt Marsh (14, 61) |
|---|---|---|
| Lower marsh[1]<br>Red mangrove[1]: abundant<br>White mangrove: scattered<br>Black mangrove: rate | Lower marsh<br>Red mangrove: scattered<br>Cordgrass: rare | Lower marsh[1]<br>Cordgrass[1]: abundant<br>Black rush[1]: abundant |
| Upper marsh<br>Sawgrass: scattered<br>Black rush: scattered | Upper marsh[1]<br>Glasswort[1]: abundant<br>Saltwort[1]: abundant<br>Black mangrove[1]: abundant<br>White mangrove: scattered | Upper marsh<br>Salt meadow hay: common<br>Spike grass: scattered |

1 Forms the majority of the marsh.




**TROPICAL MANGROVE / TEMPERATE CORDGRASS MARSH ENERGETICS**
**(A LOW MARSH SYSTEM)**




**SUBTROPICAL SALTWORT-MANGROVE MARSH ENERGETICS**
**(A HIGH MARSH SYSTEM)**

**RM RED MANGROVE CG CORD GRASS BR BLACK RUSH**
**SW SALTWORT GW GLASSWORT BM BLACK MANGROVE**

**BASED HARRINGTON AND HARRINGTON, 1961.**

Figure 6. A comparison of temperate cordgrass/tropical mangrove energetics with subtropical saltwort/mangrove energetics.



North River. For Tampa Bay, with a total area of 103,115 ha (254,700 ac) (38), of which only 13,906 ac (5,630 ha) is occupied by mangrove forests and tidal marshes and 14,200 ac (5,750 ha) by seagrass meadows (33) micro- and macroalgal production are probably of much greater importance as sources of primary production.

Because of these variations, a gradient of mangrove-associated fish communities has been hypothesized (Figure 7) and that emphasizes the different roles that mangroves might play depending on which of five types of fish communities were involved (55). These fishery habitat types are:

1. Black mangrove basin forest
2. Riverine
3. Estuarine bay
4. Oceanic bay
5. Overwash island, Keys

For category 1 there is a high importance of mangrove detritus as a food source for the associated fish community, while in category 5 there is a relatively low importance.

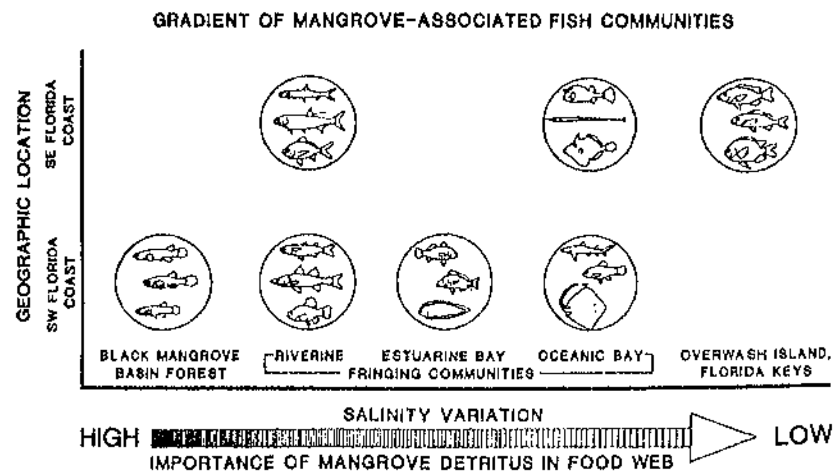



Figure 7. Gradient of mangrove associated fish communities (modified from 55).

Table 4. Upper and lower marsh fishes associated with the subtropical salt-wort-mangrove habitat, Indian River lagoon, Florida (18,22) (impoundment No. 12 collections March-October 1982). (Numerical distribution is derived from impoundment collections made from March to October, 1982. Upper marsh species were also collected in the lower marsh; however, lower marsh species were not collected in the upper marsh.)

| Upper Marsh | | | | Lower Marsh | | | |
|---|---|---|---|---|---|---|---|
| Species[1] | Number | Weight(g) | Classification[2] | Species[1] | Number | Weight(g) | Classification[2] |
| C. variegatus | 33,364 | 13,292.52 | r;p,d,o;l,j,a | A. mitchilli | 128 | 33.97 | t;p;l,j,a |
| P. latipinna | 21,899 | 13,667.40 | r;p,o;l,j,a | D. auratus* | 37 | 70.86 | t;p,c;j |
| G. affinis | 6,694 | 1,213.85 | r;p,o;l,j,a | S. scovelli | 34 | 6.40 | t;p;j,a |
| E. saurus* | 2,246 | 2,912.77 | t;p,c,sc;l,j | B. smithi* | 17 | 1.35 | t;p;l,j |
| F. confluentus | 798 | 789.99 | r;p,c,sc;l,j,a | M. gulosus | 12 | 2.68 | t;p,c;j,a |
| M. cephalus* | 577 | 8,440.97 | t;p,h,d;l,j | A. probatocephalus* | 6 | 312.70 | t;o;j |
| L. parva | 200 | 23.57 | r;p,c;l,j,a | E. argenteus | 6 | 2.46 | t;p,c;j,a |
| M. curema* | 147 | 132.53 | t;p,h,d;l,j | S. barracuda* | 6 | 1.51 | t;c,sc;j |
| F. grandis | 144 | 276.48 | t;p,c,sc;l,j,a | M. punctatus | 5 | 4.38 | t;c;j,a |
| M. peninsulae | 144 | 72.34 | r;p;l,j,a | A. lineatus | 4 | 0.96 | r;p,c;l,j,a |
| C. undecimalis* | 130 | 37.69 | t;p,c,sc;j | G. cinereus* | 3 | 3.36 | t;p,c;j |
| P. cromis* | 79 | 14.25 | t;c;j | G. robustum | 2 | 0.74 | t;p,c;j,a |
| M. atlantica* | 59 | 1,406.86 | t;p,c,sc,tc;l,j | L. griseus* | 1 | 185.53 | t;c,sc;j |
| L. xanthurus* | 54 | 55.11 | t;p,c,sc;j | L. rhomoboides* | 1 | 47.44 | t;o;j |
| D. maculatus | 23 | 69.73 | t;c;j,a | E. gula | 1 | 3.54 | t;p,c;j,a |
| M. beryllina | 5 | 4.15 | r;p;l,j,a | S. notata | | | t;sc;j,a |
| R. marmoratus | 2 | - | r;p,c;l,j,a | S. timucu | | | t;sc;j,a |
| F. similis | 1 | 0.65 | t;c;j,a | M. martinica | | | t;p;l,j,a |
| D. plumieri* | | | t;c;j | S. louisianae | | | t;p;j,a |
| E. lyricus | | | t;c;j,a | T. falcatus* | | | t;p,c;j |
| E. lyricus | | | t;c;j,a | B. chrysoura* | | | t;c,sc;j,a |
| | | | | M. undulatus* | | | t;c;j |
| | | | | S. ocellata* | | | t;c,sc,tc;j,a |
| | | | | G. hastatus | | | t;p,c;l,j,a |
| | | | | G. bosci | | | r;p,c;l,j,a |
| | | | | F. carpio | | | t;o;j,a |
| 20 Species | | | | 26 Species | | | |

1* = fishes of direct fishery value.

2Residency groups: t = transient, r = resident; Trophic groups: p = planktivore, h = herbivore, d = detritivore, o = omnivore, c = primary carnivore, sc = secondary carnivore, tc = top carnivore; Ontogenetic group: l = larba, j = juvenile, a = adult.



Table 5. Distribution of subtropical saltwort-mangrove high marsh fishes (Indian River Lagoon) among residency, trophic and ontogenetic groupings. (These data are derived from Table 4.) There is considerable overlap between groupings particularly in marsh resident categories, cyprinodontids and poeciliids.

| | Residency[1] | | Trophic Groups[2] | | | | | | | Ontogenetic groups[3] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R | T | P | H | D | O | C | SC | TC | L | J | A |
| No. of Species | 11 | 35 | 30 | 2 | 3 | 6 | 29 | 12 | 2 | 19 | 46 | 29 |
| No. of Indiv. | 63,110 | 3,719 | 66,707 | 724 | 34,088 | 61,964 | 3,813 | 3,438 | 59 | 66,284 | 66,829 | 63,466 |
| Weight (g) | 29,063 | 14,014 | 4,246 | 8,574 | 2,187 | 28,534 | 4,447 | 5,666 | 1,407 | 42,270 | 43,079 | 29,456 |

1Residency groups: R = resident, T - transient
2Trophic groups: P = planktivore, H = herbivore, D = detritivore, O = omnivore, C = primary carnivore, SC = secondary carnivore, TC = top carnivore
3Ontogenetic groups: L = larva, J = juvenile, A = adult

Table 6. Sport and commercial fishery composition of tropical mangrove, subtropical saltwort-mangrove and temperate cordgrass marsh communities.

| Location | Total No. Species | No. Species Fishery Value | Dominant Vegetation | Source |
|---|---|---|---|---|
| Terminos Lagoon, Mexico (Station PA, PE, CHB, CP) S. Gulf of Mexico | 53 | 25(47%) | Mangrove | 85 |
| Laguna de Hizache, Mexico Eastern Pacific | 31 | 15(48%) | Mangrove | 82 |
| North River Estuary, Florida | 55 | 23(42%) | Mangrove | 53 |
| Indian River Lagoon, Florida | 46 | 19(41%) | Saltwort-Mangrove | 18,22 |
| Marsh Island, Louisiana | 39 | 20(51%) | Cordgrass-Black Rush | 83 |
| North Inlet Estuary, South Carolina | 51 | 28(51%) | Cordgrass-Black Rush | 6 |
| Cape Fear River Estuary, North Carolina | 80 | 37(46%) | Cordgrass-Black Rush | 84 |



The fish faunas associated with the three major wetland regions of Florida -- temperate/cordgrass, tropical/mangrove, and subtropical/saltwort-mangrove -- also reveal species differences associated with tidal systems and vegetation. Warm temperate cordgrass marshes are numerically dominated by juvenile sciaenids (especially spot, *Leiostomus xanthurus*), cyprinodonts (killifishes, *Fundulus* spp.), atherinids (silversides, *Menidia* spp.), mugilids (mullet, *Mugil cephalus* and *M. curema*), and the planktivorous menhaden and anchovies (*Brevoortia tyrannus* and *Anchoa mitchilli*) (6, 12, 48, 67, 75, 83, 84). Published quantitative data for fish populations inhabiting tropical mangrove marsh habitats in Florida appear to be lacking. However, both temperate cordgrass marsh and tropical mangrove forest ichthyofaunas are members of a detrital ecosystem (55, 54). East-central Florida high marsh ichthyofaunas are dominated by the cyprinodontid, *Cyprinodon variegatus*; the poecilid livebearers, *Poecilia latipinna* and *Gambusia affinis*; larval and juvenile ladyfish, *Elops saurus*; marsh killifishes, *Fundulus confluentus*, *Lucania parva*; and larval and juvenile mullet, *Mugil cephalus* and *M. curema* (Table 4). In the unimpounded marsh habitat the majority of the latter species were either carnivorous, herbivorous, and/or omnivorous (Figure 6, Table 5) (21, 22). Total detrital consumption for all marsh species combined was 7 percent and algal consumption was 2 percent of the total diet (23). This low detrital consumption is a major transition from the tropical mangrove detrital ecosystem of southwest Florida.

Although the subtropical saltwort-mangrove high marsh is principally tidally inundated only during exceptionally high tides, seasonal migration of fishes across the upper marsh in extensive, as twenty fish species, eight of sport and commercial fishery value, have been recorded from the upper marsh (Table 4). Shallow marsh depressions connected to the adjacent open estuary increase the species diversity to 26 species of which 11 are of direct fishery value (Table 6). This species list is qualitatively similar to that for the red mangrove dominated estuary off the North River in southwest Florida (53). Fifty-five species were listed, including seven primary freshwater species, the remaining 48 being predominantly euryhaline marine species. Twenty-three, or 42 percent, of the North River species were of direct sport and commercial fishery value. Warm temperate cordgrass marshes have been found to produce comparable numbers of species although differing qualitatively (Table 6).

It can be concluded that geographically transitional subtropical coastal wetlands of east-central Florida form a productive ecosystem and habitat for a variety of fishes comparable to those of both tropical mangrove and temperate marsh habitats. The dominant flora, fauna and trophic relationships may differ significantly from tropical mangrove ecosystems but the production of fishery species is similar. Seasonal timing in the arrival of transient species is all important in subtropical saltwort-mangrove high marshes in order to take full advantage of high marsh inundation. Annual fall increases in sea level and peak rainfall combine to promote favorable nutrient, plankton and peripheral habitat availability for both reproduction in marsh residents and arrival of larval and juvenile marsh transients including fishery species that utilize the marsh. Of course, the present direct fishery value of the subtropical saltwort-mangrove high marsh is dependent on the reclamation of much of this habitat from the extensive mosquito control impoundment isolation and floristic damage that has taken place during the past twenty-five years.

## Habitat Values

Of much greater general value statewide is the role that mangroves play as fishery habitat. From the above discussion it is obvious that the value of mangroves as a source of food for fish and invertebrates varies widely with location.

In understanding the role of mangroves as fishery habitat it is important to first understand the life history of those species of concern. Figures 8-14 illustrate the life history of snook, tarpon, redfish, spotted seatrout, gray snapper, pink shrimp and spiny lobster in relation to which habitats are utilized. Several things are apparent from these figures. First, with the exception of the spotted seatrout, all of the species are near-shore oceanic spawners. Secondly, all use a multitude of habitats throughout their life cycle (i.e., none spend their entire lives in



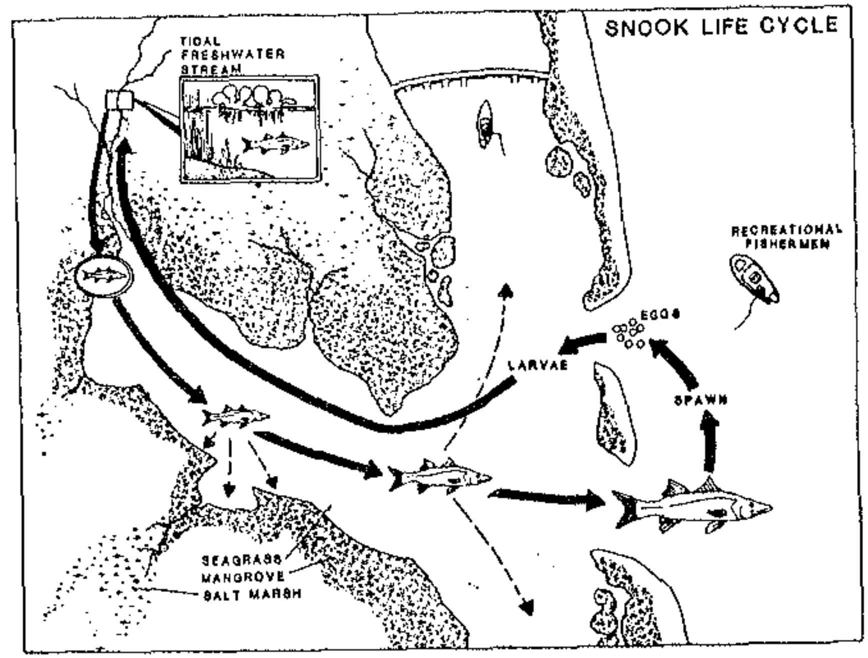



Figure 8. Life cycle of the snook, Centropomus undecimalis.

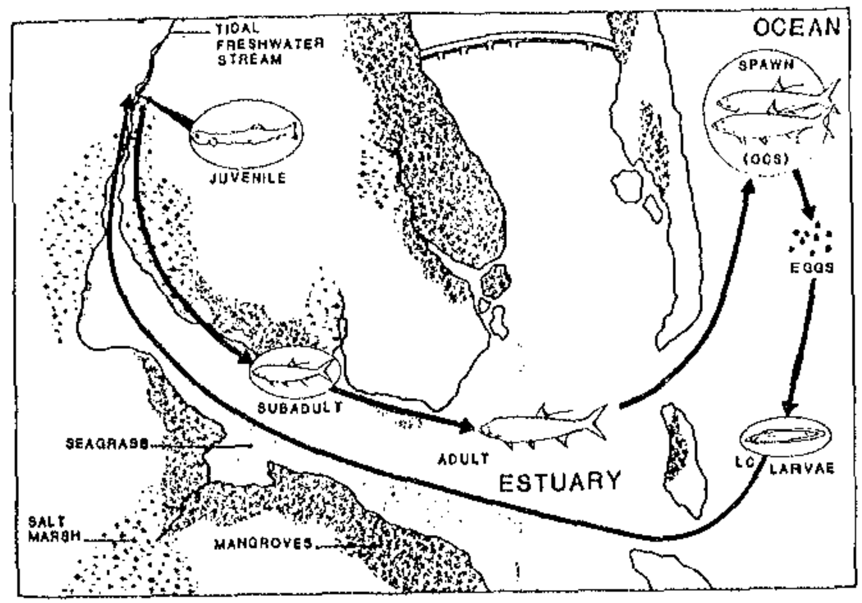



Figure 9. Life cycle of the tarpon, Megalops atlantica.

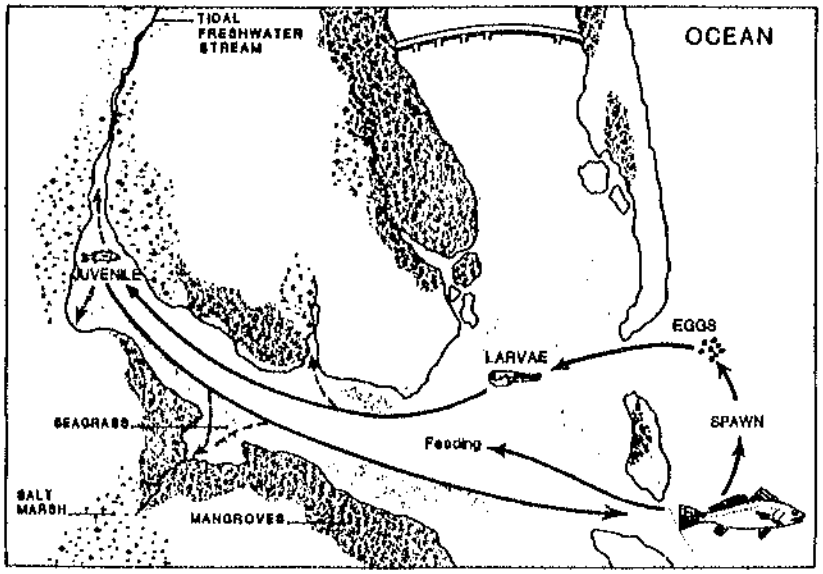



Figure 10. Life cycle of the redfish, Sciaenops ocellatus.

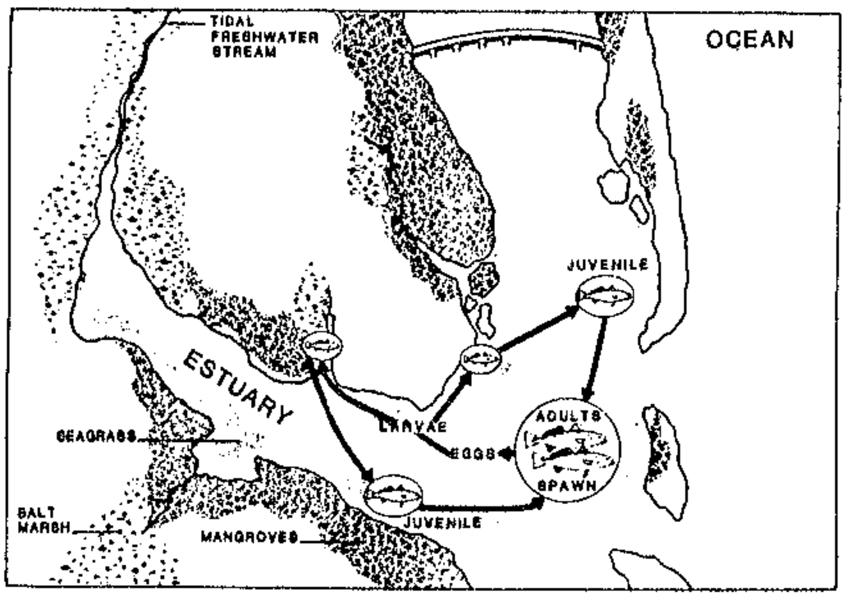



Figure 11. Life cycle of the spotted seatrout, Cynoscion nebulosus.



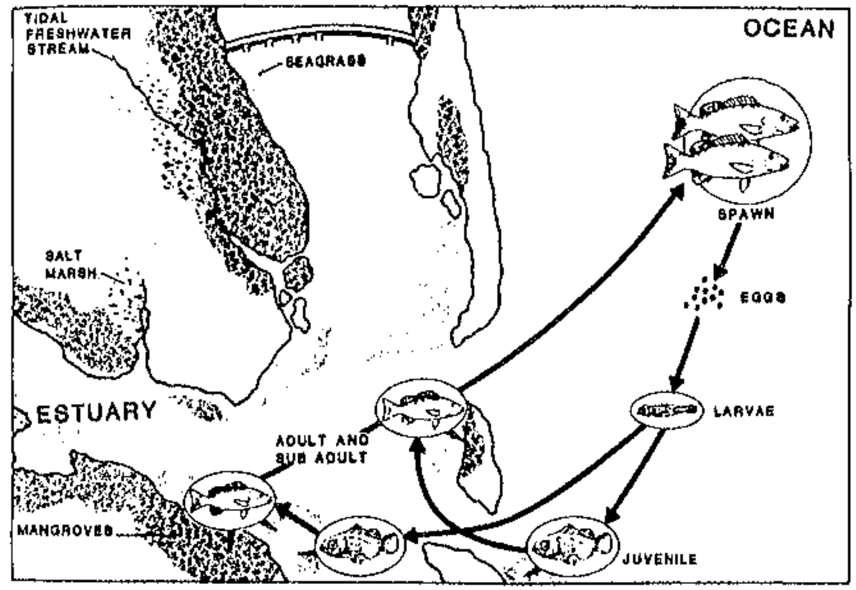



Figure 12. Life cycle of the gray snapper, Lutjanus griseus.

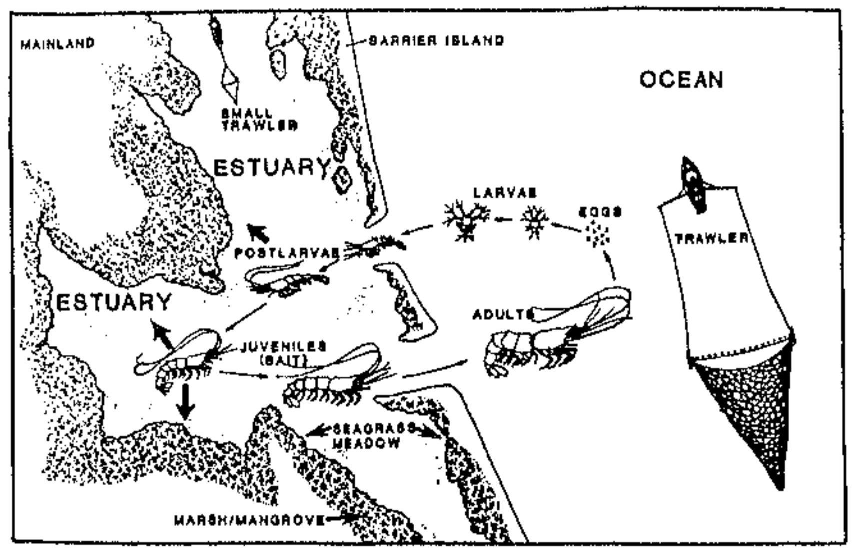



Figure 13. Life cycle of the pink shrimp, Penaeus duorarum.

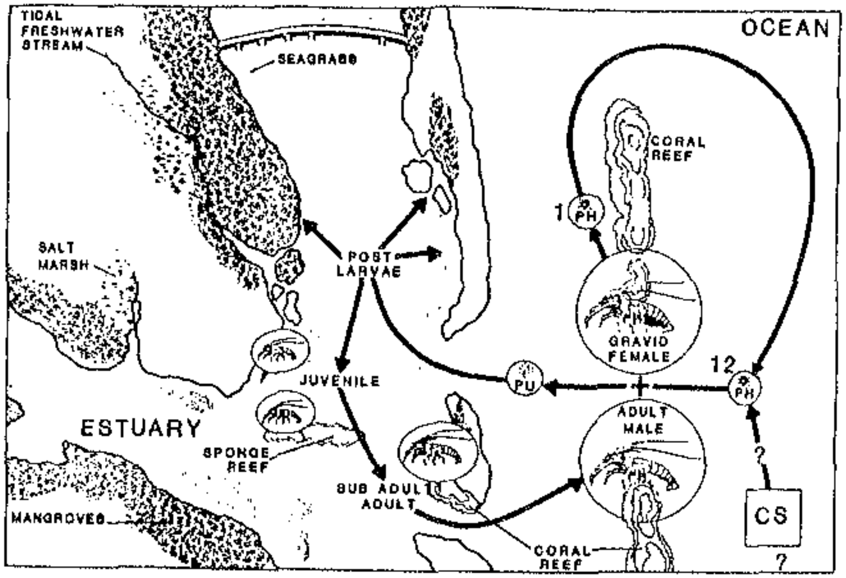



Figure 14. Life cycle of the spiny lobster, Panulirus argus.

mangroves). Thirdly, four of the species (snook, tarpon, redfish, pink shrimp) show a preference for a low salinity nursery habitat that often includes marshes or mangroves at the upper limit of tidal influence in tidal freshwater streams. A fifth species (spotted seatrout) is often found in this habitat though not necessarily as postlarvae. The other two species (spiny lobster and gray snapper) generally prefer higher salinities throughout their lives (55). Although grey snapper can be found in areas where salinities vary widely.

This complex use of several habitats during a life cycle we have termed a "habitat mosaic." Like a puzzle it is only functional when all the pieces are present. If only one of the key habitats is altered or removed, it can effectively stop the cycle and reduce or eliminate the recruitment of juveniles to the adult population, and thus reduce the available harvestable adult population. This fact and the general ignorance of the complexity of the life histories of these species has led



to an overemphasis on certain management practices (e.g. bag limits for snook) while others are largely ignored (e.g. protection of tidal freshwater stream habitat).

Recent studies on snook in Everglades National Park (78) suggest that the majority of harvested fish are much older than the age at which they reach legal size, suggesting recruitment failure of juveniles. The study notes the lack of research on the early life history of this species and thus the inability to determine any agents responsible for the possible recruitment failure.

## Trends in Habitat Quantity and Quality

Due to the fact that no comprehensive mapping of mangrove forests in Florida occurred prior to efforts by the U.S. Fish and Wildlife Service and National Marine Fisheries Service in the late 1960s and middle 1970s (50, 41, 81), accurate analyses of trends in the quantity and quality of mangrove habitat in Florida do not exist.

Localized analyses have been done for Tampa Bay (33), Biscayne Bay (20), Charlotte Harbor (24), and Lee County (15). Table 7 summarizes the results of the trend analysis. Losses range from 19

Table 7. Documented trends in areal cover of mangrove forests for selected areas of Florida.

| Location | Original Acreage | Existing Acreage | Percent Loss or Gain | Reference |
|---|---|---|---|---|
| Northern Biscayne Bay | 156,351 | 27,417 | -82 | 20 |
| Tampa Bay | 24,830 | 13,906 | -44 | 33 |
| Lee County | - | - | -19 | 15 |
| Charlotte Harbor | 51,524 | 56,631 | +10 | 24 |

percent in Lee County to 82 percent in Northern Biscayne Bay. Charlotte Harbor has shown a 10 percent increase in mangrove cover, apparently due to colonization of unvegetated tidal flats (15). Existing laws designed to protect mangroves have also prevented large scale losses since these laws were passed prior to the massive development pressure in this area.

Protection of the existing mangrove forests from dredging and filling is obviously of prime importance. But increasingly it is apparent that the full value of the forests to fisheries can only be realized if the quality of the remaining forests is maintained. Factors which degrade the quality of the habitat include impounding or ditching for mosquito control (18), reduction in fresh water input (5), and clear cutting. Each of these will be discussed in relation to management problems of mangroves in Florida.

## FISHERY RESOURCES

Figure 15 shows the relative economic contribution of each of the major commercial fisheries to the statewide commercial fisheries harvest for 1977. Shrimp and lobster, two of the species of interest in relation to mangroves, comprise over 50 percent of the total economic value of the fishery. As mentioned before, these species are not restricted to one habitat, but occupy and require a number of different habitats throughout their life history. Mangrove forests are important, as are tidal marshes, seagrass meadows, and other marine habitats. The trends for these species are shown in Figure 16 and 17. The trends in economic value and total weight of landings for all commercial marine landings are shown in Figure 18 and 19.



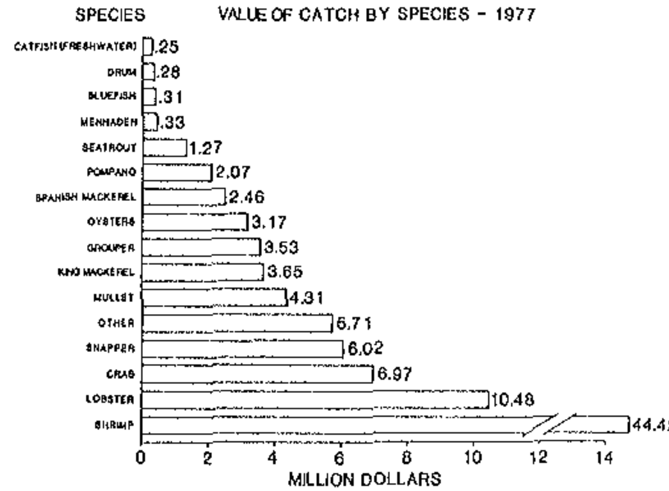



Figure 15. Value of commercial fisheries catch in Florida by species, 1977.

It is apparent that total commercial marine landings in Florida have shown a steady decline over the last three decades, while the direct value of the fishery has increased steadily as supply and demand dictate higher prices for fishery products. For certain species such as shrimp, (Figure 16) the commercial harvest has mimicked the overall decline, while for certain underharvested species such as spiny lobster (Figure 17) increases have occurred, apparently as effort increased. It is now believed however, that the spiny lobster fishery is rapidly approaching overexploitation (66).

Data on trends in recreational fisheries harvests are restricted to just a few studies and their interpretation is therefore difficult. Changes in the red drum and spotted seatrout fisheries in the Everglades National Park have been documented between 1958 and 1978 (11). Recreational fishermen caught 96 percent of the red drum and 55 percent of the spotted seatrout in the study area between 1972 and 1977. Three significant changes in the fishery were noted. These were: 1) a shift in age structure toward larger fish, 2) consistent trends in catch rates with increases for red drum and decreases for spotted seatrout, and 3) marked reductions in variability of year-to-year catch rates for both species. It was concluded that fishing-induced mortality did not significantly alter age structure or abundance of the two species, but

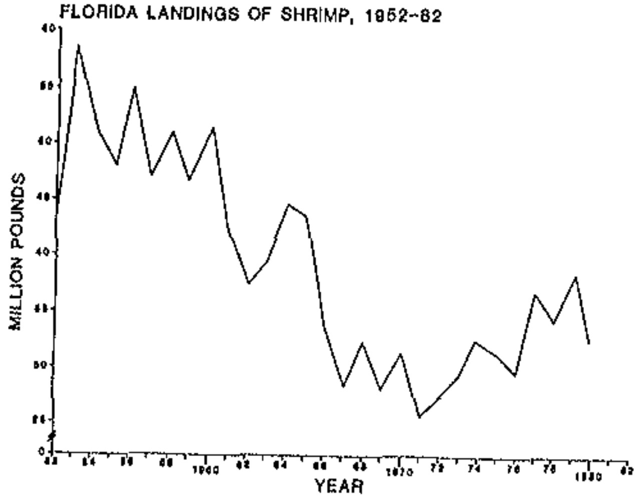



Figure 16. Commercial landings of shrimp for Florida, 1952-82.

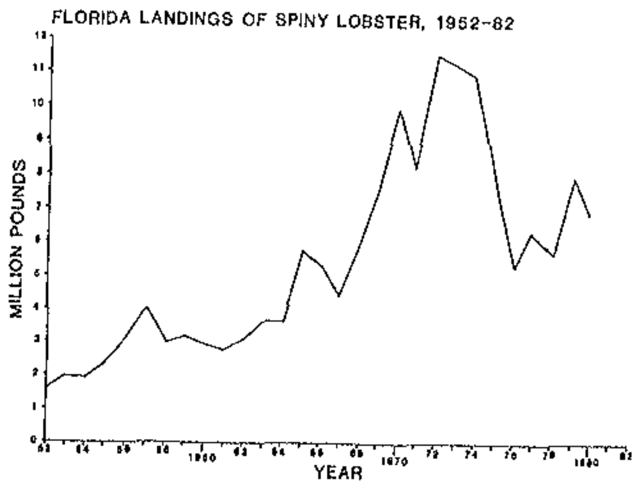



Figure 17. Commercial landings of lobster for Florida, 1952-82.



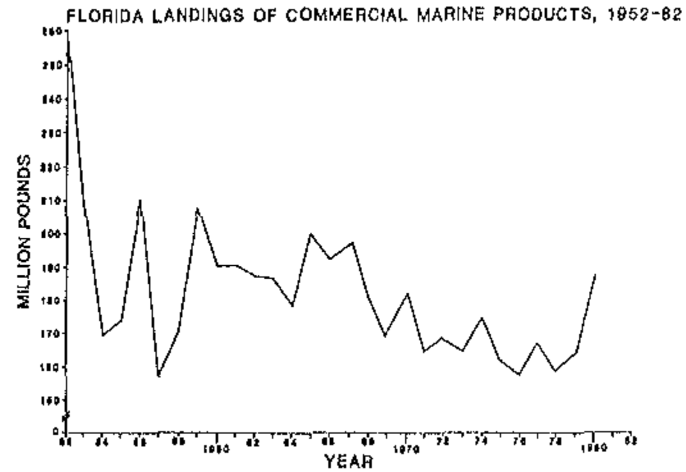



Figure 18. Florida landings of all commercial marine products, 1952-82.

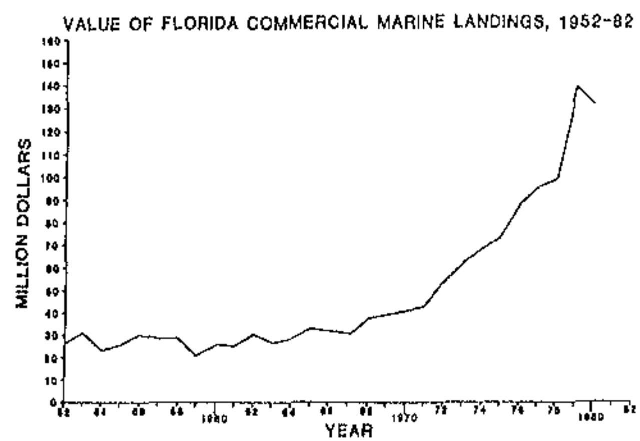



Figure 19. Value of Florida commercial marine landings, 1952-82.

that the observed changes were probably due to changes in environmental conditions, particularly increasing salinities in Whitewater Bay due in part to alterations in water flow through the Everglades. As noted in this study, "while still productive for direct fishery harvest, a shift from brackish nursery conditions to a coastal marine situation may well cause significant problems in the future with these same fisheries and others, such as the pink shrimp (Penaeus duorarum), that depended on these estuaries for recruitment" (11).

A more recent study utilizing average quarterly water levels in the Everglades as an index of freshwater runoff to the estuaries of Everglades National Park has found that landings of pink shrimp on the Tortugas grounds were positively related in three out of four quarters of the year and for the year as a whole (5). Fifteen years of monthly standardized effort data for pink shrimp were used (1965-1979).

In addition to the role of a salinity gradient in providing protection for euryhaline juvenile fish from more stenohaline predators, salinities reduced to about one-half that of seawater result in the highest mangrove litter fall rates (44) and increasing salinities could result in less available detritus as a food source for invertebrates and forage fish important in some estuarine food webs.

It has been noted that about 90 percent of the commercial fisheries harvest and 70 percent of the recreational fisheries harvest are made up of species that are dependent on estuarine habitats during all or part of their life cycle (39, 41). Early reports (41) indicated that 23,521 acres of wetlands and open water had been filled along the west coast of Florida (up to 1972) and 1,792 miles of navigation channels dredged. The figures reported here (Table 8) indicate a minimum of approximately 150,000 acres of mangroves have been lost. In relation to the approximately 500,000 acres of remaining mangrove forest wetlands in the same area, these figures indicate approximately a 23 percent loss of mangroves acreage in Florida. However, the significance of these figures cannot be determined simply by areal cover. Dredging has historically disturbed much more bay bottom than was actually filled due to siltation, and those areas filled are often the most productive or important nursery habitats in the estuary. Channelization can adversely impact very large



Table 8. Summary of mangrove forest community litter production in Southern Florida (from 73).

| Mangrove[1] Forest Type | Collection[2] Period (years) | Number[3] of Data Points | Location[4] and Site No. | Site[5] Character | Litter Production ($g/m^2$ - year) |
|---|---|---|---|---|---|
| Fringe Forest | 2.3 | 940 | S.E. Fla. (37) | A | 1,082 |
| | 3.1 | 1,240 | S.W. Fla. (5-11) | B | 981 |
| Riverine | 3.1 | 620 | S.W. Fla. (6-14) | B | 1,066 |
| | 3.1 | 620 | S.W. Fla. (6-15) | B | 1,173 |
| Overwash | 3.1 | 620 | S.W. Fla. (3-7) | B | 1,024 |
| Basin | 4.5 | 1,600 | S.W. Fla. | B | 741 |
| Hammock | 2.3 | 940 | S.E. Fla. (30) | A | 750 |
| Dwarf | 2.2 | 352 | S.E. Fla. (23) | C | 168 |
| | 2.2 | 352 | S.E. Fla. (30) | C | 271 |

1 Based on the classification reported by ref. 44.

2 Through March 1975; data collected to present data remain unanalyzed.

3 Number of collection dates x number of within-site replicates.

4 Southeastern and southwestern Florida.

5 A=high salinity, low nutrient, carbonate environment with subsurface peat deposits.
B=low salinity, hiwh nutrient, organic-rich environment with subsurface peat deposits.
C=high salinity, low nutrient, carbonate environment without subsurface peat deposits.

areas without directly destroying them due to alterations in tidal flows or historical freshwater discharges (11).

The importance of better documenting recreational fisheries harvest and their economic impact on Florida's economy is becoming more important (2). During 1980-81, 5,224,539 saltwater anglers spent 58,528,081 angler days fishing and generated $5.058 billion in direct and indirect income to Florida's economy (2). Recreational fisheries generated from 5.6 to 6.5 times the primary sales of commercial fishery products during the same period.

Unfortunately, trend data for recreational harvests similar to that for commercial harvests seen in Figures 16-19 do not exist. We can hypothesize that recreational harvests have suffered the same fate as commercial harvests with significant declines occurring, particularly in those portions of the state where significant habitat losses have occurred. Interviews of recreational fishermen reveal that 50 percent of the respondents felt snapper, seatrout and grouper stocks were on the decline. From 36 percent to 41 percent said these stocks were increasing or stable. Too many commercial fishermen and habitat destruction were opined as the two top reasons for these perceived declines (2).

## MANAGEMENT ISSUES

Mangroves are inherently vulnerable to certain natural and man-induced perturbations due primarily to their aerial root systems, which can be easily blocked by excess sediment, oil, or standing water (55). In examining the question of the role of water quality in mangrove ecosystem dynamics it has been noted that their field studies indicate that mangroves do not actively take up organic pollutants, but can have metal concentrations up to six times background relative to marine waters (13). The implications of this relative to transfer of metals into detrital food webs are cited as needing further study.

In examining several indices of mangrove forest "health," it has been concluded that the "rate of litter production proved to be the most useful single index" (73). Table 8 shows a range in litter fall from 217-



1082 $g/m^2/yr$. The maintenance of high rates of litter fall depends on the presence of organic soils and peat which act as nutrient reservoirs and appears less related to mean salinity of the interstitial water than previously reported (73).

Specifically in relation to fisheries production, five major mangrove forest management problems exist. The first is adequate mapping and characterization of forest areas. The second is maintenance of low and variable salinity nursery areas in mangrove and marsh areas. The third is continued protection of existing mangrove areas from physical alteration. The fourth is the balancing of the need for mosquito control with the requirements for proper tidal flushing to maintain mangrove forests and their fisheries. And finally, an active program of restoring damaged mangrove areas through dike removal, dechannelization, and restoration plantings, must be initiated. The latter two issues are closely interrelated on the east coast of Florida where tens of thousands of acres of mangroves have been impounded.

### Mapping and Trend Analyses

As is apparent from Table 2, there is still no agreement as to the total area of mangrove forest and tidal marsh remaining in Florida, nor any valid estimate of historical coverage. Without an accurate trend analysis, it is obvious that management efforts aimed at preserving the remaining mangroves and restoring damaged areas will lack proper direction.

Localized mapping efforts have shown significant declines in both mangroves and tidal marshes in certain portions of Florida (e.g. Tampa Bay - 44%, Northern Biscayne Bay - 82%) due to activities of man including dredging and filling and the impoundment of wetlands for mosquito control. It is hoped that once the U.S. Fish and Wildlife Service's National Wetland Inventory is finished in Florida and the maps are checked for accuracy by local experts, that a beginning data base will exist.

## Low Salinity Wetlands

In studying the life history of the common snook along the east-central Florida coast it was observed that although spawning took place in high salinity environments, juvenile recruitment to the estuary was concentrated in tidal freshwater tributaries to the estuary where they reside for approximately 10-70 days, arriving at lengths of about 0.43 inch (11 mm) and leaving at a length of about 2.0 inches (50 mm) (Figure 8) (19). The most common food item during this period are *Gambusia affinis* (mosquito fish), the common freshwater to brackish water minnows. As a late juvenile of size 3-6 inches (150-300 mm) snook are most often found in seagrass beds. These observations fit well with other research (47, 80), indicating young snook occur in "marginal" habitat, that is, ditches and tidal creeks that were commonly turbid and with widely varying salinities (47). It has been noted that "the largest areas of this type of habitat are found in the southwest portion of the state in Lee and Collier counties. These areas coincide with maximum snook production. Juvenile snook have been colleted from brackish water sloughs and ditches in mangrove areas. Since the snook apparently spawn in the saline water of the passes, the eggs and larval forms perhaps are carried by currents, or swim into these areas where they probably remain until they reach maturity. Most of the small snook that were caught and tagged by sport anglers were captured in this type of habitat. It has been shown that 50 percent of the snook are mature at two years of age and the rest at three years, therefore, this type of habitat is probably essential for a considerable period of the fish's life. Many adult fish were also found in these areas, and a few fish that were tagged in saline waters moved into these brackish waters. Therefore, alterations to the mangrove environment by filling, dredging, draining, bulkheading, etc., may affect the abundance of snook" (80). Another researcher concluded that: "The data obtained from these collections serve well to indicate the type of habitat in which young *C. undecimalis* can be found. In the Ten Thousand Islands, a relatively great acreage of such habitat occurs, in the form of sloughs, shallow drainage streams and ditches, and large shallow bays" (47). In spite of these earlier observations, the only major management programs for snook were the outlawing of sales of snook in 1957, thus stopping commercial fishing, and bag limits for recreational fishing. Large scale destruction of mangroves was not stopped until 13 years later, and maintenance of tidal freshwater streams in mangrove and marsh areas is still today not an organized management tool.



## Continued Protection

Under both Federal (P.L. 92-500 Section 404) and State (Chapter 17-4 F.S.) law, mangroves are a protected habitat that requires both state and federal permits for excavation or filling. Unfortunately, the federal role in wetlands protection is being reduced by the present administration and federal protection may be limited to only those areas below the mean high water line or eliminated altogether. If this should happen, the present state law would leave much of the transition zone wetlands adjacent to mangrove forests subject to intense pressure for development and with much less statutory protection than presently exists with both federal and state protection. For this reason the present state law should be strengthened to provide for mandatory permits for all wetlands alteration including transition zone and adjacent freshwater wetlands.

In addition, much of the present mangrove acreage is in private ownership due to the fact that the state sold much of its wetland acreage in the early part of this century. Every effort should be made to acquire conservation easements or other protective covenants on these areas in exchange for reduced taxes on the land. The tax structure in many parts of Florida still measures the taxable value of land by its "highest and best use," which for mangroves often means as a dredged out marina or industrial site. Repeated legal challenges have upheld the state's right to regulate privately owned wetlands, but just one successful challenge could wipe out the state's jurisdiction over mangroves it sold, and which are heavily taxed by local government in spite of the fact that permits for development are not likely to be issued.

## Mosquito Control

The control of mosquitos in Florida has revolved around two alternate approaches, temporary and permanent control. Temporary control involves the seasonal use of chemical pesticides to kill larvae (larvicides) or adults (adulticides). Diesel oil is also used to kill larvae in isolated water bodies by blocking respiration through the air-water interface (17). Permanent control involves water management by ditching or impounding mangrove forests with dikes. We will concentrate here on these permanent control practices, although some concern about the use of certain adulticides (e.g. Baytex) in mangrove areas and their possible toxicity to crustacean food organisms and larval and juvenile fish (e.g. snook) is currently being expressed by fishery scientists.

The subtropical marsh/mangrove communities of east-central Florida were ditched by hand during the 1930's and 1940's. These ditches were used not only to drain shallow water basins and depressions but to allow larvivorous fish access to principal mosquito breeding sites. These ditches were shallow and narrow and quickly filled with sediment, detritus and vegetation. In the natural marsh red mangroves, Rhizophora mangle, were limited to the perimeter of the high marsh, however, ditching permitted this species, in addition to the black mangrove, to grow prolifically through most of the shallow ditches. Therefore, after ditching many of the marshes that had been characteristically covered with extensive meadows of glasswort and saltwort with interspersed black mangroves began to show a successional growth of red mangroves (58, 61).

The mangrove forests and tidal marshes of south and west coast Florida were also ditched by hand and later ditched by draglines which deposited the excavated material ("spoil") as spoil piles in the forest. Ditching was more effective in these areas due to larger tidal ranges and more regular inundation. Thus large areas of forest were ditched and an unknown acreage of forest buried under spoil piles. The ecological malfunctions caused by this ditching have not been adequately studied (32, 79). Concern about possible adverse affects have lead to a virtual



halt of large scale ditching although small scale use of rotary ditchers which do not produce spoil piles is underway.

On the east coast, the failure of ditching to adequately control mosquitos lead to the introduction of diking and permanent flooding of marshes and mangroves to prevent oviposition (egg-laying) by female saltmarsh mosquitos which will not lay their eggs in standing water (58, 61).

From 1954 to the early 1970's dikes were built around the perimeter of 39,240 acres (15,800 ha) of marsh and marsh/mangrove from Volusia County south to Martin County to contain water pumped from the adjacent estuary. Maintenance of non-tidal waters over the marsh effectively reduced marsh mosquito populations. The depth to which many of the marshes were flooded also effectively killed all vegetation within the impoundment as mangrove pneumatophores and prop roots were covered as were the marsh succulents Salicornia and Batis. However, some impoundments have been constructed with careful control of water levels which in turn allowed all natural marsh vegetation to survive demonstrating that the marsh could be effectively impounded without eradication of resident vegetation (58). Also, restoration of tidal water fluctuations (principally during the mosquito non-breeding season) has promoted revegetation of impoundments previously denuded of vegetation by improper flooding practices (18). In fact, certain impoundments in which tidal flow has been reestablished through culverts to the Indian River lagoon have shown a marked growth of red and black mangroves over much of the marsh which had historically been dominated by large meadows of saltwort and glasswort. The succession of red and black mangrove forest over saltwort-glasswort high marsh vegetation has an undetermined effect on the high marsh fauna and associated fisheries.

Fishes associated with the subtropical transitional high marsh habitat were documented prior to impoundment (22). Their intensive study of food consumed by marsh fishes during the fall inundation of the marsh also documented the trophic interrelationships of the marsh flora and fauna. The same marsh site (Impoundment No. 12, Indian River Co., Fla; 126 acres, 51 ha) was studied again two years after it was impounded. Not only was the ichthyofauna considerably reduced from 16 to 5 species, but the feeding strategies of residual fishes changed (Figure 20). Fishes with carnivorous and vascular herbivorous diets prior to marsh impoundment were found to switch to a detritivorous and algal herbivorous diet in impounded waters. Five of the original sixteen species collected in the natural marsh prior to impoundment were sport or commercial fishery species that used the marsh as a juvenile nursery

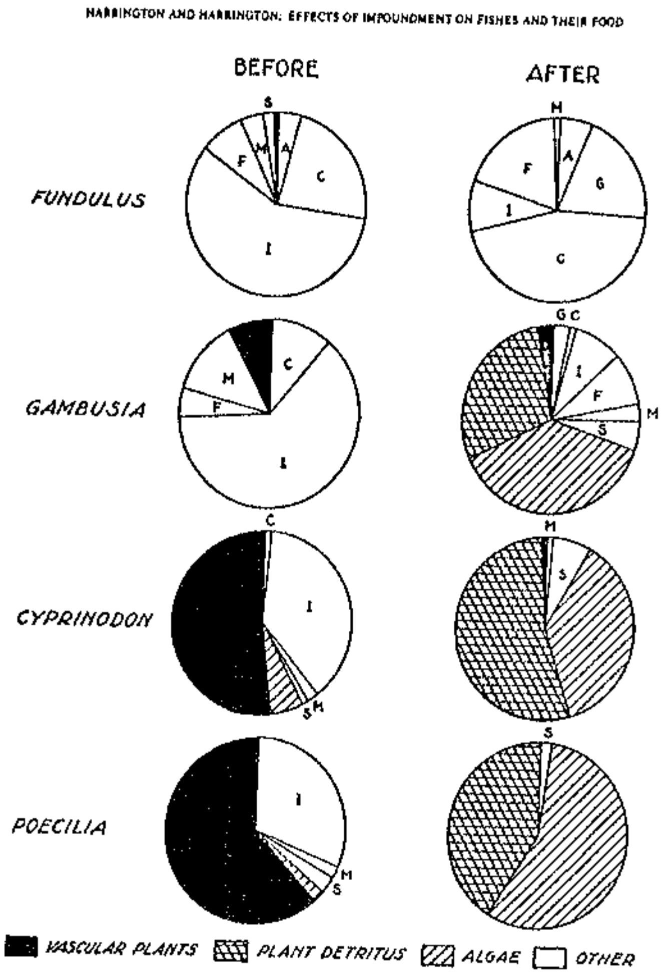



Figure 20. Percentage of stomach contents in pre- and post-impoundment fish species (from 23).



ground. None of the fishes collected after impoundment were of fishery value but were principally resident livebearers and killifishes capable of withstanding impounded environmental conditions.

This same marsh site was again studied in 1979 thirteen years after the last study (1966) (18). The 1979 study found twelve fish species inhabiting the marsh including marsh transients of fishery value, tarpon, and snook. These species have apparently been fortuitiously pumped into the impoundment during the routine water level maintenance or had entered during high fall tides and storm tides associated with the passage of a hurricane. In general, the impounded marsh was found to contain a depauperate fauna as it was a hostile aquatic environment with great evaporative water loss, salinities reaching 200 ppt, temperatures of 14 - 34°C and dissolved oxygen levels varying widely between 1.2 and 14.2 ppm.

A 398 acre (161 ha) impoundment which had been reopened to tidal influence through an 80 cm (32.0 in) diameter culvert has also been studied (18). Physical parameters were considerably more moderate than in the closed impoundment (i.e. salinity: 25 - 38 ppt, temperature: 13.4 - 30°C, dissolved oxygen: 2.2 - 7.5 ppm) and revegetation occurred rapidly. A total of forty-one fish species were captured in this impoundment, eighteen (44%) of these species occurring in local sport and commercial fisheries. The tarpon, lady fish, Elops saurus, snook, Irish pompano Diapterus auratus, yellowfin mojarra, Gerres cinereus, striped mullet and white mullet, were the most abundant fishery species utilizing the marsh/mangrove habitat. All of these species were most abundant as juveniles recruited during or just after principal adult spawning periods. Snook reached maximum densities of 1.0/10 $m^2$ in a perimeter ditch seine transect (18).

Impoundment No. 12 is currently under further investigation. It has been reopened to tidal influence with intensive study of biweekly fluctuations of fishes, macrocrustaceans, zooplankton and macrovegetation. Collections are quantitative and cover the entire marsh and adjacent estuarine water, sand bottom and seagrass habitats. Forty-one species of fishes and macrocrustaceans have been collected in the marsh during an eight month period. These organisms passed through a single

61.0 cm (24 in) diameter culvert. Seventeen of these species are of direct sport and commercial fishery value. Observations in this latter study and examination of historical field notes made by the late Dr. Robert Harrington (Florida Medical Entomology Laboratory) demonstrated that predaceous juveniles of ladyfish snook, tarpon, mullet and Irish pompano will migrate over the entire higher elevation marsh/mangrove habitat to the hammock line (mean spring high tide line) during the fall-spring tide inundation of the marsh in combination with maximum annual sea levels. During their temporary residency in the marsh, tarpon, ladyfish and snook prey heavily on killifishes, livebearers and crustaceans and may partially account for reductions in numbers of resident fishes captured during the fall marsh inundation. However, small resident species have also been observed to disperse widely over the marsh during this period reducing the numbers captured at standard collection locations. Post inundation collections show that marsh killifish and livebearer populations have increased indicating major reproductive success during inundation periods.

It is obvious from these observations that a relatively small aperture allowing tidal access to the impounded marsh will also allow migration of transient species into and out of the marsh in relatively large numbers (Figure 21).

When the sea level falls in late November and December large numbers of killifishes, livebearers, ladyfish, tarpon and snook aggregate in the lower marsh elevations, ponds, and creeks. It is at this time that large numbers of wading birds, larger juvenile ladyfish and snook prey upon these concentrated fishes (18).

It has now been demonstrated that impounded and denuded marsh habitats will undergo rapid endemic floral succession when tidal access is reinstated, even through single limited apertures such as culverts (3). Endemic faunal elements can also be reintroduced to the marsh through culverts. Culverts can be easily installed and maintained and many are presently in place in impounded marshes throughout much of the Florida east coast. Multiple culverts would allow increased access and export of marsh materials to the adjacent estuary. The number of culverts



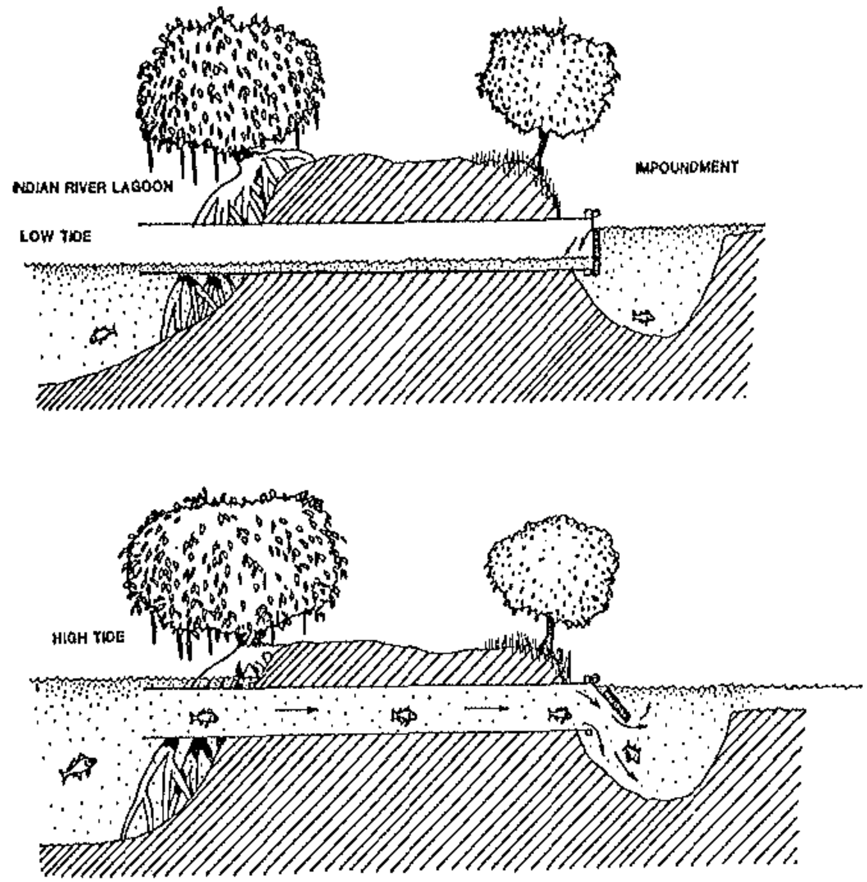



Figure 21. Movement of fishes into impounded marsh/mangrove habitat through flap gate rise systems designed to also prevent mosquito oviposition.

necessary to insure adequate access and material export will be dependent on the nature of the impounded marsh (i.e. elevation, tidal access, associate flora and fauna). However, to satisfy the mosquito control mandate, water levels must be maintained at high enough levels to preclude oviposition during the primary mosquito breeding periods. Several methods have been employed to maintain impoundment water levels yet allow tidal water and organisms to enter the impoundment. The most promising of these is a tide gate assembly fitted to the impoundment end of the culvert (Figure 21). Boards may be adjusted for variable water height requirements and the apparatus only needs to function from May to late August or early September which are the primary mosquito breeding months. Marsh transients still could enter during this period but would find limited opportunity to leave until the gate structure is removed during the late summer. The fall is the predominant period of fish and crustacean immigration and emigration between marsh and open estuaries (18). Therefore, proper timing for marsh access would benefit both estuarine resources and mosquito control. The tide gate assemblies and other techniques of water level management need to be studied and, except for weir structures (83, 26, 27), have received little research attention to date. Due to the relatively high elevations of intertidal communities and the low tidal range in the Indian River lagoonal system, weir structures would greatly limit the movement of organisms and organic materials between the marsh and the estuary.

The use of adulticides and larvicides to control mosquito populations would be the least advantageous method from the standpoint of the marsh biota. Abundant literature on chemical uptake by marsh organisms and the concentrations of these contaminants through the food chain, export to other ecosystems, highlights the deleterious effects of wholesale adulticiding and larviciding mosquito populations (79). The least expensive, most passive , most permanent, and least biologically deleterious method of eliminating mosquito populations is "source reduction" through hydrological means (60). Fishery resources produced in managed marsh habitats would be of little value if they are contaminated with larvicides that may decrease their survival rate or contaminate fishery predators (including man).

The principal problem with "source reduction" management of breeding mosquito populations is that a percentage of impounded marshes (e.g. 37% in Indian River County) are unmanaged due to private



land owners' objections to mosquito control manipulation of water on their marshland. In these cases mosquito control efforts are limited to aerial treatment with larvicides and adulticides. Marsh reclamation and promotion for fisheries resources in these cases is totally subject to the landowner's personal desires. Management incentives are vitally needed to encourage reopening of these systems (3).

## Active Restoration Efforts

Recent progress in handling and planting marsh grasses and mangroves (34, 35) has opened up the possibility of actively reversing the well documented trend of ever decreasing acreages of both mangrove forests and tidal marshes.

These planting techniques are routinely used now for mitigation planting (36) where small areas of wetlands that are needed for development or public facilities are permitted for destruction with the condition that at least equal if not more acreage of new wetlands is created by lowering the elevation and planting uplands into wetlands or restoring a damaged wetland. This results in a "no net loss"or "zero habitat loss" (40).

The techniques could equally be applied to the planting of dredged material deposits or stabilization of eroding shorelines to yield a net **increase** in habitat (30, 34, 35). Funds derived from fishing permits or public works funds could be used for this purpose. As yet there is no organized governmental source to fund **increase** in habitat, but it can be done, and in those areas such as Tampa Bay or Biscayne Bay where substantial areas of mangroves have been destroyed, the effort to restore some of this lost habitat should be made.

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