# Economic Fishery Valuation of Five Vegetation Communities in Lake Okeechobee, Florida

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*Abstract:* Vegetated areas of the littoral zone of Lake Okeechobee were sampled with 0.8-ha block nets during fall 1989, 1990, and 1991 to estimate fish assemblages and standing crops in 5 vegetation communities common in Florida. Data were used in conjunction with economic impact data of known-cause fish kill events, Rule 17-11.01 (animal damage valuation), Chapter 403, Florida Statutes, to estimate monetary values of the fisheries of important Lake Okeechobee vegetation communities. Mean total impact values per hectare of vegetated area ranged from $44,626 for Illinois pondweed (*Potamogeton illinoensis*) to $59,738 for hydrilla (*Hydrilla verticillata*). Replacement economic values made up at least 88.9% of the total impact value in the valuation of all vegetation types. Recreational values per hectare of vegetated area ranged from $447 for eel-grass (*Vallisneria americana*) to $5,378 for bulrush (*Scirpus californicus* and *S. validus*). Commercial values contributed nominally to the total impact values, constituting no more than 0.06% in the valuation of each vegetation type. Fish species that provided the greatest economic value were bluefin killifish (*Lucania goodei*), eastern mosquitofish (*Gambusia holbrooki*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropertus salmoides*), and redear sunfish (*L. microlophus*). Economic valuation of fisheries habitat may be used as a method of managing aquatic habitat in multiple resource water systems.

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Macrophytes form important habitat components of aquatic ecosystems by playing an integral role in nutrient and energy cycling, supporting intricate food webs and providing important habitat for macroinvertebrates, fish, and wildlife. Aquatic macrophytes influence fish species diversity and recruitment by providing spawning substrate and cover (Loftus and Kushlan 1987), foraging areas (Janacek 1988) and protective habitat for larval (Conrow et al. 1990) and subadult fishes (Barnett and Schneider 1974). The role of aquatic vegetation in aquatic ecology is especially important in Florida where fresh water habitat totaling more than 1 million surface hectares is characterized by shallow depth and extensive vegetated littoral habitat (Tarver et al. 1986).

Increases in the demand for water and its uses have led to a number of problems associated with aquatic system management in Lake Okeechobee and other water bodies throughout Florida. Eutrophication, which is accelerated by excess nitrogen and phosphorus loading, and the stabilization of water levels has resulted in changes in water quality (Phlips et al. 1995), aquatic macrophyte assemblages (Richardson et al. 1995), and fish community dynamics (Gelwick and Matthews 1990, Fox et al. 1992). Native aquatic macrophytes are especially sensitive to these changes and are often displaced by undesirable exotic and invasive native plant species. Water managers often place a monetary value on an acre-foot of water within a system in terms of the water's agricultural and urban uses outside the system and then employ these values to justify the need for regulation of water level regimes and other changes to the water system (South Fla. Water Manage. Dist. [SFWMD] 1993). For example, the Everglades Agricultural Area (EAA) along the lower east coast of Florida (Broward, Palm Beach, and Hendry counties) consumes about 1.8 million acre-feet of water each year from Lake Okeechobee and has a sales volume from agriculture production and manufacturing of $880 million. An economic value of about $500 is placed on an acre-ft of water in Lake Okeechobee as that water is used in the EAA (C. Woelhlcke, SFWMD, pers. commun.). Wegener and Holcomb (1972) recognized the need for assigning monetary values to natural resources within the system, such as its fishery, that are dependent on water resource demands of that system. These demands include the need for a vegetated littoral zone characterized by native aquatic macrophytes, improved water quality, and a more natural hydrologic regime, all of which are interdependent.

Disagreement regarding the management of aquatic vegetation continues among government agencies that have varying regulatory authority over aquatic plant management, water quality and supply, flood control, and fish and wildlife management. These regulatory questions are especially evident when discussing the management of exotic versus native vegetation. The importance of native aquatic vegetation as habitat for adult and juvenile centrarchids has long been recognized by fisheries biologists. Bulrush and eel-grass are frequently planted during lake restoration and habitat enhancements projects (Denson and Langford 1982, Marshall 1986, Rosegger 1993). The problems associated with exotic aquatic macrophytes, such as hydrilla, water hyacinth *Eichhornia crassipes,* and water-lettuce *Pistia stratiotes,* in lakes and rivers throughout Florida and the southeastern United States are well documented (Schardt and Schmitz 1989, Langeland 1990, Schardt and Schmitz 1990). Although hydrilla has been shown to be beneficial to fish populations at intermediate densities (Moxley and Langford 1982, Killgore et al. 1989), high densities cause declines in growth and fish condition (Colle and Shireman 1980, Maceina and Shireman 1982). Hydrilla can adapt to rapid changes in water levels and water quality, which permits it to out-compete native vegetation (Langeland 1990, Schardt and Schmitz 1990).

Resource managers must balance the advantages and disadvantages of both native and exotic vegetation communities and determine management strategies that may affect the health of native vegetation communities. To this end, determination of economic impact of the vegetation communities from recreational, commercial, and ecological standpoints would allow biologists to express fisheries data in terms of economic worth when considering water-use policies (Wegener and Holcomb 1972).

In this study, we determined fish species composition and abundance and used the data to estimate the monetary value of 5 types of aquatic macrophyte communities commonly found in Lake Okeechobee. The primary objective of the paper is to demonstrate a method of economic fisheries valuation and define those values for aquatic vegetation communities abundant in Florida. Use of this type of economic valuation as a tool in water and fisheries management is also discussed. This work was funded by Federal Aid in Sportfish Restoration. We appreciate the work of L. A. Bull, L. J. Davis, D. W. Brown, T. D. McCall, S. J. Miller, and J. G. Wullschleger of the Florida Game and Fresh Water Fish Commission in analysis of data and collection of fish and vegetation samples.

## Methods

Lake Okeechobee, located in south-central Florida, is Florida's largest lake and the second largest body of fresh water in the continental United States. Vast surface area (182,000 ha), shallowness (mean depth = 2.7 m) and extensive habitat diversity make the ecosystem unique on the North American continent. Lake Okeechobee serves as a multiple use resource that supports valuable commercial and sport fisheries, provides flood control, and acts as a reservoir for both potable and irrigation waters for much of south Florida. Lake Okeechobee's commercial fisheries, which generate $6.3 million annually, consist of a trotline fishery for catfish (*Ameriurus* sp. and *Ictalurus* sp.) and a haul seine fishery for catfish and bream (bluegill and redear sunfish) (Bell 1987). The recreational fishery targets largemouth bass, black crappie (*Pomoxis nigromaculatus*), and bream. The fishery generates $22.1 million per year and has an estimated asset value of $100 million (Bell 1987).

An expansive vegetated littoral zone (52,000 ha) is located in the northwest and west regions of the lake. Vegetation communities in Lake Okeechobee benefit from shallow littoral areas, natural and cultural eutrophication, and subtropical climatic conditions in south Florida. The dominant emergent macrophyte communities in Lake Okeechobee are bulrush, cattail *Typha spp.*, panic grasses *Panicum spp.*, and spikerush *Eleocharis spp.* (Ager and Kerce 1970, Pesnell and Brown 1977, Milleson 1987, Richardson 1990). Dominant submerged plant communities include eel-grass, hydrilla, and pondweed (Schardt and Nall 1988). Emergent and submerged aquatic macrophytes cover approximately 39,000 ha and 13,000 ha, respectively, of Lake Okeechobee (Schardt and Nall 1988).

Fish assemblages were sampled with 0.08-ha block nets and Wegener rings (4.0 $m^2$; Wegener et al. 1973) using rotenone in 5 vegetation communities in the northern, southern, and western regions of Lake Okeechobee. Block nets were used to sample fish ≥6 cm TL, and Wegener rings were deployed in each block net to estimate abundance of fish <6 cm total length (Miller et al. 1990). Sampling occurred during fall 1989, 1990, and 1991. Bulrush, eel-grass, and Illinois pondweed were sampled in all areas. Hydrilla and yellow water-lily (*Nymphaea mexicana*) were sampled only in the north and west areas. Attempts were made to sample monotypic populations of each vegetation community; however, a mixture of targeted and non-targeted plant species was frequently encountered. At each sample site, the targeted vegetation type had to be dominant (>85% coverage) and evenly distributed throughout the sample area.

Abundance (*N*/ha) and biomass (kg/ha) estimates for each fish species were generated for each sample (Fox et al. 1992). These data were used in conjunction with economic impact data of known-cause fish kill events, Rule 17-11.01 (animal damage valuation), Chapter 403, Florida Statutes, to estimate the monetary fishery value for each fish species (Table 1). These values provide market prices for all species of fresh water fishes, assuming a live fish has equal value of a fish killed in a pollution event. This method of fishery valuation has been utilized in economic fishery assessments of littoral and limnetic areas (Wegener and Holcomb 1972), aquatic vegetation loss (Haller et al. 1980), and recreational fisheries loss due to commercial fisheries (Ryan and Janssen 1993). Economic value, expressed as total impact in US dollars per hectare, was calculated by adding the replacement value, recreational value, and commercial value for each fish species (Am. Fish. Soc. Pollution Comm. 1993).

Replacement economic values, which may be equated to the ecological values of the fishery, were defined as the costs to restore a fishery to its previous condition prior to the fish kill or removal event. These values are non-traditional forms of economic value and are not based on direct monetary benefits to recreational or commercial users. Values were based on production costs for each fish species as determined by the Florida Game and Fresh Water Fish Commission (FGFWFC) upon surveying federal, state, and private fish hatcheries in the southeastern United States (T. Champeau, FGFWFC, pers. commun.). Recreational values, defined as costs of fishes lost that may be utilized by recreational fishermen, were derived from the product of the amount of recreational use lost and the U.S. dollar value of that use. Commercial values, defined as costs of fishes lost that may be utilized by the commercial market, were derived from the product of the biomass of fishes lost expressed in kilograms and the US dollar value per kilogram. Economic values calculated for each species was dependent on abundance and size (length and weight) (Table 1). Length and weight measurements in Rule 17-11.01 are reported in English units (inches ["] and pounds [lb.]), but were converted to metric units (centimeters and kilograms) for analysis. All economic values were expressed in US dollars per hectare.

Data were analyzed using the SYSTAT® statistical package (Wilkinson

**Table 1.** Replacement value, recreational value, and commercial value of fish collected in 0.08-ha block nets, fall 1989–1991, Lake Okeechobee, Florida. Values were derived from economic impact data for known-cause fish kill events, Rule 17-11.01, Chapter 403, Florida Statutes (animal damage valuation).

| Family | Common name | Size group | Replacement value (US $) | Recreational value (US $) | Commercial value (US $) |
|---|---|---|---|---|---|
| Lepisosteidae | gars | ≤6″ | .10/fish | | |
| | | >6–13″ | .34/fish | 4.69/fish | |
| | | >13″ | .84/lb. | 4.69/fish | |
| Amiidae | bowfin | ≤6″ | .10/fish | 4.69/fish | |
| | | >6–13″ | .34/fish | 4.69/fish | |
| | | >13″ | .84/lb | | |
| Clupeidae | herrings/shads | all sizes | .17/each | | .15/lb |
| Cyprinidae | carps and minnows | all sizes | .10/fish | | |
| | carps and minnows (golden shiner) | all sizes | .10/fish | | 1.00/lb |
| Catostomidae | suckers | ≤6″ | .67/fish | | |
| | | >6″ | 1.34/fish | | |
| Ictaluridae | bullhead catfishes | ≤7″ | .34/fish | | |
| | | >7–14″ | 1.68/fish | 6.09/fish | .51/lb |
| | | >14″ | 3.40/lb | 6.09/fish | .51/lb |
| | madtoms | all sizes | .10/fish | | |
| Esocidae | pikes | ≤7″ | .84/fish | | |
| | | >7–14″ | 3.36/fish | 4.69/fish | |
| | | >14″–4 lb. | 11.80/lb | 4.69/fish | |
| | | >4 lb. | 16.80/lb | 4.69/fish | |
| Belonidae | needlefishes | all sizes | .10/fish | | |
| Cyprinodontidae | killifishes | all sizes | .10/fish | | |
| Poecilidae | livebearers | all sizes | .10/fish | | |
| Atherinidae | silversides | all sizes | .10/fish | | |
| Syngnathidae | pipefishes | all sizes | .10/fish | | |
| Centropomidae | snooks | all sizes | 100.00/fish | | |
| Centrarchidae | sunfishes | ≤6″ | .84/fish | | |
| | (bream) | >6–10″ | 4.20/fish | 2.62/fish | |
| | | >10″–1.5 lb | 10.00/lb | 13.10/fish | |
| | | >1.5 lb. | 17.00/lb | 8.50/lb. | |
| | sunfishes | <6″ | 1.68/fish | | |
| | (largemouth bass) | ≥6–10″ | 5.88/fish | | |
| | | >10″–<8 lb. | 8.40/lb. | 13.79/fish | |
| | | ≥8–<10 lb. | 33.60/lb. | 23.64/lb. | |
| | | ≥10 lb. | 42.00/lb. | 189.09/lb. | |
| | sunfishes | ≤6″ | 1.01/fish | | |
| | (black crappie) | >6–9″ | 3.50/fish | 2.62/fish | |
| | | >9″ | 8.40/lb. | 3.81/fish | |
| | | >2 lb. | 16.80/lb. | 8.60/lb. | |
| Percidae | swamp darters | all sizes | .10/fish | | |
| Cichlidae | tilapias | ≤6″ | .84/fish | | |
| | | >6″ | 1.68/fish | .33/fish | .25/lb |
| Mugilidae | mullets | all sizes | 6.70/fish | | |
| Gobidae | gobies | all sizes | .10/fish | | |

1990). Mean values of replacement impact, recreational impact, commercial impact, and total fishery impact for combined species were compared with 1-way analysis of variance (ANOVA) and Tukey's post hoc multiple-range test between vegetation types. Data were normalized before analysis by the $\log_e$ $(x + 1)$ transformation. Values are reported as both arithmetic and geometric means. Significance of all statistical tests was determined at $P \leq 0.05$.

## Results

A total of 39 species representative of 18 families were collected in 117 block nets and 318 Wegener rings (Table 2). Replacement values in each vegetation community were dominated by 3 fish families: Cyprinodontidae (killifishes), Poeciliidae (livebearers), and Centrarchidae (sunfishes). Bluefin killifishes and bluegills made up the highest values in bulrush, eel-grass, and Illinois pondweed. Replacement values assigned to the eastern mosquitofish, a poecilid, represented the highest proportion of the total impact value for yellow water-lily. Values assigned to bluegill, redear sunfish, bluefin killifish, and sailfin molly (*Poecilia latipinnia*) contributed greatly to the replacement value calculated for hydrilla. The relatively high contributions by *Lepomis* sunfishes <2 cm in eel-grass and Illinois pondweed were indicative of the importance of these vegetation types as nursery areas for sunfishes and other fish species. Replacement values ranged from $44,418 for bulrush to $58,483 for hydrilla; however, no significant differences were observed between the economic values for each vegetation community (Table 2).

Recreational impact values were highly influenced by values assigned to centrarchid game fishes (Table 3). Largemouth bass, bluegill, and redear sunfish, all of which are primary game fishes sought in Lake Okeechobee's littoral zone, contributed greatest to the recreational values of all vegetation types. Environmentally tolerant non-game fishes, such as Florida gar (*Lepisosteus platyrhincus*) and bowfin (*Amia calva*) made notable contributions to the recreational value for yellow water-lily. Black crappie (*Pomoxis nigromaculatus*) and bullhead catfishes (*Ictalurus* spp. and *Ameiurus* spp.), which make the primary limnetic fishery in Lake Okeechobee, made nominal contributions to the recreational impact values in all vegetation communities. Recreational impact value calculated for bulrush was significantly higher than values determined for eel-grass, yellow water-lily, Illinois pondweed, and hydrilla (Table 3). Recreational values in Illinois pondweed and hydrilla were also significantly higher than those estimated in eel-grass.

Significant differences in commercial impact value were detected between the hydrilla and bulrush group and the eel-grass and Illinois pondweed group (Table 4). Differences were also observed between yellow water-lily and Illinois pondweed. Commercial impact within each vegetation, however, was virtually nonexistent with no more than 0.06% contribution to the total impact value for each vegetation type. Golden shiners (*Notemigonus crysoleucas*) made up the

**Table 2.** Replacement values of fish species collected in 117 0.08-ha block nets, fall 1989–1991, Lake Okeechobee, Florida. Total replacement value for each vegetation type is expressed as an arithmetic mean ± SD. Geometric means are in parentheses. Means with the same letter are not significantly different (Tukey's, $P \leq 0.05$).

| Species | | US$/ha | | | | |
|---|---|---|---|---|---|---|
| Scientific name | Common name | Bulrush ($N = 27$) | Eel-grass ($N = 27$) | Hydrilla ($N = 18$) | Yellow water-lily ($N = 18$) | Illinois pondweed ($N = 27$) |
| *Lepomis macrochirus* | Bluegill | 12,697.04 | 10,455.36 | 11,801.17 | 928.95 | 10,181.24 |
| *Lucania goodei* | Bluefin killifish | 7,871.60 | 14,406.48 | 8,213.53 | 6,264.25 | 10,454.48 |
| *Lepomis microlophus* | Redear sunfish | 6,890.70 | 8,644.20 | 9,905.42 | 1,176.89 | 6,769.89 |
| *Lepomis marginatus* | Dollar sunfish | 3,303.78 | 6,043.49 | 3,892.33 | 5,998.07 | 2,947.06 |
| *Micropterus salmoides* | Largemouth bass | 3,072.95 | 832.25 | 1,021.42 | 382.30 | 1,067.58 |
| *Gambusia holbrooki* | Eastern mosquitofish | 2,480.42 | 3,195.56 | 4,601.07 | 19,008.16 | 1,900.52 |
| *Lepomis spp.* | Sunfish < 2 cm | 1,416.80 | 5,060.32 | 2,075.64 | 1,537.71 | 5,663.78 |
| *Jordanella floridae* | Flagfish | 1,122.61 | 161.57 | 265.43 | 883.25 | 155.63 |
| *Lepomis punctatus* | Spotted sunfish | 894.48 | 737.46 | 224.70 | 270.11 | 305.81 |
| *Poecilia latipinna* | Sailfin molly | 597.12 | 4,495.48 | 8,030.68 | 3,688.03 | 73.17 |
| *Heterandria formosa* | Least killifish | 558.50 | 1,395.71 | 2,580.68 | 6,969.33 | 604.07 |
| *Mugil cephalus* | Striped mullet | 504.24 | 8.93 | 4.47 | 0 | 17.87 |
| *Microgobius gulosus* | Clown goby | 311.78 | 217.98 | 15.64 | 0 | 809.32 |
| *Fundulus chrysotus* | Golden topminnow | 210.55 | 58.02 | 92.18 | 898.06 | 91.75 |
| *Lepomis gulosus* | Warmouth | 205.74 | 340.79 | 490.28 | 341.93 | 224.31 |
| *Fundulus seminolis* | Seminole killifish | 151.17 | 486.86 | 109.82 | 92.37 | 240.10 |
| *Erimyzon sucetta* | Lake chubsucker | 124.84 | 153.33 | 59.89 | 80.66 | 81.74 |
| *Noturus gyrinus* | Tadpole madtom | 117.46 | 126.01 | 0.45 | 0 | 52.41 |
| *Pomoxis nigromaculatus* | Black crappie | 108.04 | 81.15 | 325.30 | 12.76 | 337.09 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Tilapia aurea* | Blue tilapia | 105.49 | 10.64 | 13.11 | 48.72 | 5.69 |
| *Enneacanthus gloriosus* | Bluespotted sunfish | 101.08 | 794.89 | 3,999.05 | 2,075.03 | 588.44 |
| *Menidia beryllina* | Inland silversides | 92.27 | 46.68 | 0 | 0 | 0.77 |
| *Ameiurus nebulosus* | Brown bullhead | 91.36 | 198.46 | 297.76 | 11.32 | 23.20 |
| *Esox niger* | Chain pickerel | 68.26 | 83.31 | 286.40 | 25.17 | 218.63 |
| *Lepisosteus platyrhincus* | Florida gar | 67.06 | 9.49 | 4.85 | 14.88 | 44.25 |
| *Notemigonus crysoleucas* | Golden shiner | 61.03 | 36.63 | 44.74 | 19.15 | 120.05 |
| *Labidesthes sicculus* | Brook silverside | 58.64 | 14.47 | 0 | 0 | 33.91 |
| *Dorosoma petenense* | Threadfin shad | 58.02 | 38.58 | 0.35 | 0 | 15.01 |
| *Notropis maculatus* | Taillight shiner | 39.22 | 123.50 | 25.19 | 160.28 | 308.00 |
| *Amia calva* | Bowfin | 14.27 | 5.74 | 25.77 | 33.17 | 16.32 |
| *Etheostoma fusiforme* | Swamp darter | 12.61 | 103.61 | 69.78 | 31.04 | 114.20 |
| *Dorosoma depedianum* | Gizzard shad | 3.15 | 1.46 | 3.97 | 0.11 | 0.92 |
| *Ameiurus catus* | White catfish | 2.58 | 0 | 0 | 0 | 0.45 |
| *Ameiurus natalis* | Yellow bullhead | 1.75 | 15.99 | 0.79 | 0.789 | 1.18 |
| *Strongylura marina* | Atlantic needlefish | 0.91 | 1.21 | 0 | 0 | 0.45 |
| *Microphis brachyurus* | Opossum pipefish | 0.62 | 0.15 | 0.45 | 0 | 0.15 |
| *Opsopoeodus emiliae* | Pugnose minnow | 0 | 6.04 | 0 | 0 | 0 |
| *Ictalurus punctatus* | Channel catfish | 0 | 10.57 | 0 | 0 | 0 |
| *Cyprinodon variegatus* | Sheepshead minnow | 0 | 0 | 0 | 105.22 | 0 |
| *Centropomus undecimalis* | Common snook | 0 | 0 | 0 | 0 | 44.44 |
| Replacement value (US$)/hectare | | 43,418.33 A<br>±16,388.14<br>(40,653.92) | 58,402.35 A<br>±29,833.26<br>(50,794.49) | 58,482.89 A<br>±22,082.38<br>(54,830.19) | 51,057.68 A<br>±14,233.64<br>(49,187.19) | 43,515.29 A<br>±16,471.23<br>(40,258.33) |
| Replacement value (US$)<br>(lake areal coverage in hectares) | | 155,277,009.30<br>(3,576.3) | 32,734,528.39<br>(560.5) | 195,800,068.20<br>(3,348.0) | 14,464,649.24<br>(283.3) | 59,454,954.39<br>(1,366.3) |

**Table 3.** Recreational values of fish species collected in 117 0.08-ha block nets, fall 1989–1991, Lake Okeechobee, Florida. Total recreational value for each vegetation type is expressed as an arithmetic mean ± SD. Geometric means are in parentheses. Means with the same letter are not significantly different (Tukey's, $P \leq 0.05$).

| Species | | US$/ha | | | | |
|---|---|---|---|---|---|---|
| Scientific name | Common name | Bulrush ($N$ = 27) | Eel-grass ($N$ = 27) | Hydrilla ($N$ = 18) | Yellow water-lily ($N$ = 18) | Illinois pondweed ( = 27) |
| *Micropterus salmoides* | Largemouth bass | 2,270.97 | 91.93 | 411.40 | 232.90 | 315.64 |
| *Lepomis macrochirus* | Bluegill | 1,975.67 | 52.50 | 157.64 | 28.53 | 149.53 |
| *Lepomis microlophus* | Redear sunfish | 531.57 | 52.20 | 133.91 | 37.26 | 114.99 |
| *Lepisosteus platyrhincus* | Florida gar | 223.56 | 33.35 | 34.65 | 82.59 | 150.95 |
| Lepomis punctatus | Spotted sunfish | 128.38 | 4.66 | 1.75 | 3.49 | 2.43 |
| *Lepomis gulosus* | Warmouth | 100.03 | 88.50 | 89.11 | 19.51 | 39.30 |
| *Pomoxis nigromaculatus* | Black crappie | 55.31 | 43.18 | 169.12 | 7.83 | 130.59 |
| *Ameiurus nebulosus* | Brown bullhead | 29.77 | 19.17 | 45.00 | 40.94 | 52.33 |
| *Amia calva* | Bowfin | 25.01 | 12.68 | 43.77 | 82.08 | 31.79 |
| *Esox niger* | Chain pickerel | 20.84 | 37.52 | 127.15 | 9.38 | 98.83 |
| *Tilapia aurea* | Blue tilapia | 11.26 | 0.44 | 1.12 | 9.46 | 0.15 |
| *Ameiurus catus* | White catfish | 2.71 | 0 | 0 | 0 | 2.71 |
| *Ameiurus natalis* | Yellow bullhead | 2.71 | 8.12 | 4.06 | 4.06 | 5.41 |
| *Ictalurus punctatus* | Channel catfish | 0 | 2.17 | 0 | 0 | 0 |
| Recreational value (US$)/hectare | | 5,478.10 A<br>±4,994.27<br>(3,630.04) | 446.95 C<br>±183.05<br>(400.61) | 1,219.38 B<br>±704.79<br>(1,004.25) | 558.03 BC<br>±87.19<br>(552.25) | 1,094.45 B<br>±772.17<br>(860.06) |
| Recreational value (US$)<br>(lake areal coverage in hectares) | | 19,233,663.27<br>(3,576.3) | 250,521.08<br>(560.5) | 4,082,484.24<br>(3,348.0) | 158,089.90<br>(283.3) | 1,495,347.04<br>(1,366.3) |

**Table 4.** Commercial value of fish species collected in 117 0.08-ha block nets, fall 1989–1991, Lake Okeechobee, Florida. Total commercial value for each vegetation type is expressed as an arithmetic mean ± SD. Geometric means are in parentheses. Means with the same letter are not significantly different (Tukey's, $P \leq 0.05$).

| Species | | US$/ha | | | | |
|---|---|---|---|---|---|---|
| Scientific name | Common name | Bulrush ($N$ = 27) | Eel-grass ($N$ = 27) | Hydrilla ($N$ = 18) | Yellow water-lily ($N$ = 18) | Illinois pondweed ( = 27) |
| *Notemigonus crysoleucas* | Golden shiner | 20.03 | 12.80 | 21.12 | 6.70 | 8.15 |
| *Tilapia aurea* | Blue tilappia | 6.46 | 0.18 | 2.15 | 20.17 | 0.03 |
| *Ameiurus nebulosus* | Brown bullhead | 3.29 | 2.03 | 7.46 | 8.10 | 6.87 |
| *Dorosoma cepedianum* | Gizzard shad | 1.00 | 0.59 | 4.74 | 0.15 | 0.30 |
| *Ameiurus catus* | White catfish | 0.34 | 0 | 0 | 0 | 0.32 |
| *Dorosoma petenense* | Threadfin shad | 0.27 | 0.25 | 0.01 | 0 | 0.08 |
| *Ameiurus natalis* | Yellow bullhead | 0.26 | 0.65 | 0.16 | 0.44 | 0.36 |
| *Ictalurus punctatus* | Channel catfish | 0 | 1.58 | 0 | 0 | 0 |
| Commercial value (US$)/hectare | | 31.66 A ±12.44 (29.93) | 18.07 BC ±3.02 (18.86) | 35.64 A ±18.97 (32.66) | 35.57 AB ±20.34 (28.70) | 16.12 C ±14.01 (12.55) |
| Commercial value (US$) (lake areal coverage in hectares) | | 113,189.90 (3,576.3) | 10,133.84 (560.5) | 119,322.72 (3,348.0) | 10,074.15 (283.3) | 22,011.09 (1,366.3) |

**Table 5.** Total impact monetary value of fish species collected in 117 0.08-ha block nets, fall 1989–1991, Lake Okeechobee, Florida. Total impact value for each vegetation type is expressed as an arithmetic mean ± SD. Geometric means are in parentheses. Means with the same letter are not significantly different (Tukey's, $P \leq 0.05$).

| Species | | US$/ha | | | | |
|---|---|---|---|---|---|---|
| Scientific name | Common name | Bulrush ($N = 27$) | Eel-grass ($N = 27$) | Hydrilla ($N = 18$) | Yellow water-lily ($N = 18$) | Illinois pondweed ($N = 27$) |
| *Lepomis macrochirus* | Bluegill | 14,672.71 | 10,507.85 | 11,959.17 | 957.47 | 10,330.77 |
| *Lucania goodei* | Bluefin killifish | 7,871.60 | 14,406.48 | 8,213.74 | 6,264.25 | 10,454.48 |
| *Lepomis microlophus* | Redear sunfish | 7,422.27 | 8,696.40 | 10,039.33 | 1,214.15 | 6,884.87 |
| *Micropterus salmoides* | Largemouth bass | 5,343.92 | 924.19 | 1,432.83 | 615.20 | 1,383.22 |
| *Lepomis marginatus* | Dollar sunfish | 3,303.78 | 6,043.49 | 3,892.33 | 5,998.07 | 2,947.06 |
| *Gambusia holbrooki* | Eastern mosquitofish | 2,480.42 | 3,195.56 | 4,601.07 | 19,008.16 | 1,900.52 |
| *Lepomis spp.* | Sunfish < 2 cm | 1,416.80 | 5,060.32 | 2,075.64 | 1,537.71 | 5,663.78 |
| *Jordanella floridae* | Flagfish | 1,122.61 | 161.57 | 265.43 | 883.25 | 155.63 |
| *Lepomis punctatus* | Spotted sunfish | 1,022.86 | 742.12 | 226.45 | 273.60 | 307.81 |
| *Poecilia latipinna* | Sailfin molly | 597.12 | 4,495.48 | 8,030.68 | 3,688.03 | 73.17 |
| *Heterandria formosa* | Least killifish | 558.50 | 1,395.71 | 2,580.68 | 6,969.33 | 604.07 |
| *Mugil cephalus* | Striped mullet | 504.24 | 8.93 | 4.47 | 0 | 17.87 |
| *Microgobius gulosus* | Clown goby | 311.78 | 217.98 | 15.64 | 0 | 809.32 |
| *Lepomis gulosus* | Warmouth | 306.08 | 429.29 | 580.09 | 361.43 | 263.61 |
| *Lepisosteus platyrhincus* | Florida gar | 290.61 | 42.84 | 39.51 | 97.47 | 195.20 |
| *Fundulus chrysotus* | Golden topminnow | 210.55 | 58.02 | 92.18 | 898.06 | 91.75 |
| *Pomoxis nigromaculatus* | Black crappie | 163.36 | 124.33 | 494.42 | 20.59 | 467.48 |
| *Fundulus seminolis* | Seminole killifish | 151.17 | 486.86 | 109.82 | 92.37 | 240.10 |
| *Erimyzon sucetta* | Lake chubsucker | 124.84 | 153.33 | 59.89 | 80.66 | 81.74 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Ameiurus nebulosus* | Brown bullhead | 124.43 | 219.66 | 346.49 | 56.31 | 82.40 |
| *Tilapia aurea* | Blue tilapia | 123.40 | 11.26 | 15.31 | 68.26 | 5.87 |
| *Noturus gyrinus* | Tadpole madtom | 117.46 | 126.01 | 0.45 | 0 | 52.41 |
| *Enneacanthus gloriosus* | Bluespotted sunfish | 101.08 | 794.89 | 3,999.05 | 2,075.03 | 588.44 |
| *Menidia beryllina* | Inland silversides | 92.27 | 46.68 | 0 | 0 | 0.77 |
| *Esox niger* | Chain pickerel | 89.10 | 120.83 | 413.55 | 34.55 | 317.47 |
| *Notemigonus crysoleucas* | Golden shiner | 81.06 | 49.43 | 55.30 | 22.50 | 128.20 |
| *Labidesthes sicculus* | Brook silverside | 58.64 | 14.47 | 0 | 0 | 33.91 |
| *Dorosoma petenense* | Threadfin shad | 58.29 | 38.82 | 0.35 | 0 | 15.09 |
| *Amia calva* | Bowfin | 39.29 | 18.42 | 69.54 | 115.24 | 48.11 |
| *Notropis maculatus* | Taillight shiner | 39.22 | 123.50 | 25.19 | 160.28 | 308.00 |
| *Etheostoma fusiforme* | Swamp darter | 12.61 | 103.61 | 69.78 | 31.04 | 114.20 |
| *Ameiurus catus* | White catfish | 5.63 | 0 | 0 | 0 | 5.32 |
| *Ameiurus natalis* | Yellow bullhead | 4.72 | 24.77 | 4.93 | 5.07 | 6.95 |
| *Dorosoma cepedianum* | Gizzard shad | 4.16 | 2.04 | 6.34 | 0.19 | 1.22 |
| *Strongylura marina* | Atlantic needlefish | 0.91 | 1.21 | 0 | 0 | 0.45 |
| *Microphis brachyurus* | Opossum pipefish | 0.62 | 0.15 | 0.45 | 0 | 0.15 |
| *opsopoeodus emiliae* | Pugnose minnow | 0 | 6.04 | 0 | 0 | 0 |
| *Ictalurus punctatus* | Channel catfish | 0 | 14.86 | 0 | 0 | 0 |
| *Cyprinodon variegatus* | Sheepshead minnow | 0 | 0 | 0 | 105.22 | 0 |
| *Centropomus undecimalis* | Common snook | 0 | 0 | 0 | 0 | 44.44 |
| Total impact value (US$)/hectare | | 48,828.09 A<br>±17,298.82<br>(45,752.42) | 58,867.40 A<br>±29,966.41<br>(51,225.87) | 59,737.91 A<br>±21,412.61<br>(56,443.76) | 51,651.28 A<br>±14,159.31<br>(49,811.44) | 44,625.86 A<br>±16,633.59<br>(41,315.79) |
| Total impact value (US$)<br>(lake areal coverage in hectares) | | 174,623,969.80<br>(3,576.3) | 32,995,177.70<br>(560.5) | 200,002,522.70<br>(3,348.0) | 14,632,807.62<br>(283.3) | 60,972,298.85<br>(1,366.3) |

highest values in hydrilla, bulrush, eel-grass, and Illinois pondweed. Blue tilapia (*Tilapia aurea*), an established exotic species, made the greatest contribution to the commercial value observed in yellow water-lily.

Total impact values in each vegetation community were comprised primarily of the replacement value, which ranged from 88.9% (bulrush) to 99.2% (eel-grass) of the total impact value calculated for each vegetation type. Total impact values ranged from $44,626 for Illinois pondweed to $59,720 for hydrilla; however, no significant differences were observed between vegetation communities (Table 5).

To estimate total economic worth of each vegetation community, the areal coverage of individual plant species was derived from Florida Department of Natural Resources reports (Schardt and Nall 1988, Schardt and Schmitz 1989, Schardt and Schmitz 1990). Arithmetic mean monetary values per hectare for all species combined were multiplied by the most current areal coverage data. Replacement values were highest in hydrilla ($195,800,068) and bulrush ($155,277,009) and lowest in yellow water-lily ($14,464,649) (Table 2). Bulrush also had the highest total recreational impact value at $19,233,663 (Table 3). Total commercial impact values, although highest in bulrush and hydrilla, were negligible in all vegetation types (Table 4). Total impact values ranged from $200,002,523 in hydrilla and $174,623,969 in bulrush to $14,632,808 in yellow water-lily (Table 5).

## Discussion

Exhaustive discussion and debate over the merits of various methods of fisheries resource assessment and valuation have occurred in recent years (Talhelm et al. 1987). Advantages and disadvantages of the valuation method utilized in this paper could also be debated at length. However, this valuation method's ease in understanding and calculation as well as its use by Florida's Department of Environmental Protection to penalize offenders of known-cause fish kill events as specified by the American Fisheries Society (Pollution Comm. 1993) justify its use in determining the economic fisheries worth of vegetation communities and other aquatic habitat. Also, management implications of this economic fishery valuation technique include, but are not limited to: expression of fisheries data in more public-friendly monetary terms, counterbalance against claims of water's economic value outside the system when changes in water and habitat management within the system are being considered, mitigation of habitat loss due to development or destructive water management practices, and justification of economic benefits due to aquatic vegetation restoration.

Economic values derived from this type of analysis will exhibit seasonal and annual variations as relative abundance and standing crop of fish species changes. An associated study on Lake Okeechobee by Fox et al. (1992) found distribution patterns of fishes, especially centrarchids and cyprinodontids, were influenced by vegetation type (structural complexity), vegetation biomass, lake level, and water quality (dissolved oxygen concentration). These observed variations in fish population structure are indicative of changes occurring in response to biological and physical changes throughout the ecosystem. Development of economic fishery values quantifies the role of vegetation communities as fish habitat and enables scientists to express fisheries dynamics in terms the general public can more easily comprehend.

Each vegetation community examined as a whole unit had similar ecological worth as measured by replacement value; however, monetary values of individual fish species demonstrated differences in the ecological and recreational values of each vegetation community. The high replacement values of non-game forage species, such as the cyprinodontids and poecilids, in all vegetation communities reflect their importance to the ecology of the vegetated littoral zone. Eel-grass and Illinois pondweed provided valuable habitat for juvenile game and forage fishes. Yellow water-lily, which grows in stagnant, poor quality water, served as important habitat for poecilids and other environmentally tolerant fishes that serve as forage for fish and wildlife species. Bulrush, hydrilla, and Illinois pondweed account for the majority of the recreational fishery value. Bulrush recreational impact value per hectare was over 4 times greater than any other vegetation community. Recreational impact values per hectare for largemouth bass and bluegill in bulrush were also higher than other vegetation types and further indicates its importance as game fish habitat. Hydrilla and Illinois pondweed were very similar in recreational impact value for game fishes; however, hydrilla provided a larger contribution of non-game forage fishes.

Individual vegetation communities occupy important ecological roles in Lake Okeechobee and other water bodies throughout Florida. Their roles in a water body's fishery can now be quantified in both ecological (Fox et al. 1992) and economic terms. The 4 native vegetation communities, with 5,786 ha of areal coverage on Lake Okeechobee, totalled over $283 million in total economic value and $21 million in recreational economic value. Hydrilla, the primary submerged exotic vegetation species in Lake Okeechobee with an areal coverage of 3,348 ha, accounted for $200 million in total economic value and $4 million in recreational economic value. These dollar values, which do not consider the significant black crappie recreational fishery (peak season mean = 547,497 angler-hours; Fox et al. 1992) and catfish/bream commercial fishery (annual mean = 1.6 million kg; Fox et al. 1992) concentrated in Lake Okeechobee's limnetic areas, dwarf the recreational fishery asset value of $100 million reported by Bell (1987). This study further validates the importance of vegetated littoral areas to this lake and other lakes' fisheries and ecological existence.

The issues concerning water management decisions and the subsequent impact on native and exotic aquatic macrophytes continue as a subject of scientific and sociological debate. Native aquatic vegetation is highly desirable for its value as fishery habitat and associated aesthetic qualities. Hydrilla is least desirable of the sampled macrophytes due to its exotic origin, its ability to outcompete native plant species, and its nuisance to navigation. Native aquatic vegetation has required little management throughout the 1980s with less than $5 million spent for control in Florida (Schardt and Schmitz 1990). Hydrilla control, through chemical, physical, and biological measures, cost Florida approximately $50 million during the 1980s (Schmitz 1990). The high monetary value of the fish populations supported by hydrilla indicates a benefit that may justify its management at intermediate levels. Hydrilla, like bulrush and Illinois pondweed, is utilized extensively by largemouth bass and black crappie fishermen in Lake Okeechobee and other lakes through Florida (Colle et al. 1987; T. D. McCall, FGFWFC, pers. commun.; W. Porak, FGFWFC, pers. commun.). The impending question facing water system managers becomes: Do we continue to manage for a fishery supported by native aquatic vegetation communities, which require improved water quality and ecologically supportive water level regimes, or should we redirect our fisheries management focus to exotic aquatic plant species, such as hydrilla, which benefit from a shift in water management schemes that diverge from the natural state of a water body?

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