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The Impact of United States Recreational Fisheries on Marine Fish Populations

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The Impact of United States Recreational Fisheries on Marine Fish Populations

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We evaluated the commercial and recreational fishery landings over the past 22 years, first at the national level, then for populations of concern (those that are overfished or experiencing overfishing), and finally by region. Recreational landings in 2002 account for 4% of total marine fish landed in the United States. With large industrial fisheries excluded (e.g., menhaden and pollock), the recreational component rises to 10%. Among populations of concern, recreational landings in 2002 account for 23% of the total nationwide, rising to 38% in the South Atlantic and 64% in the Gulf of Mexico. Moreover, it affects many of the most-valued overfished species—including red drum, bocaccio, and red snapper—all of which are taken primarily in the recreational fishery.

Many of the ecological and political problems associated with fishing in U.S. waters historically have been attributed to foreign fishers (*1*, *2*). This perspective led to the passage of the Magnuson Act nearly 30 years ago to eliminate foreign competition, which set in motion a wave of expansion for U.S. commercial fishing fleets. By 1996, it was clear that removing the foreign fleets had not resulted in sufficient conservation (*3*), and amendments to the Magnuson Act more strongly emphasized reducing the fishing pressure of domestic fleets.

In the years following the amendment, the public focused on stock depletion, bycatch, and habitat damage caused by commercial fisheries (*4*, *5*) but paid little attention to the recreational sector. The perception that recreational fishing had little influence on stock declines derived from estimates that it contributed only 2% to U.S. landings (*6*). However, marine recreational fishing effort has increased by over 20% in the past 20 years (*7*), rivaling commercial fisheries for many major fish stocks, including summer flounder (*Paralichthys dentatus*), scup (*Stenotomus chrysops*), and red snapper (*Lutjanus campechanus*) (*8*).

We examined data from the National Marine Fisheries Service (NMFS) online databases (*9*), because we assumed that these readily accessible data sets were used to produce the existing estimates of recreational landings. Using these data, we produced a similar estimate. However, substantial inconsistencies in the online databases cloud the relevance of the number, such as the inclusion of commercially caught freshwater species and the exclusion of recreational data sets, such as data from the southeastern headboat sector (table S1).

We developed a comprehensive landings database (*10*) with data provided by the Marine Recreational Fisheries Statistics Survey (MRFSS), NMFS science centers and fishery management councils (FMCs), multistate marine fisheries commissions, and state natural resource agencies (table S2). We included landings data only and did not include fish discarded at sea either as regulatory discards (for commercial and recreational fisheries) or as a result of catch-and-release (exclusively a recreational fishing practice). After standardizing the data to allow for reasonable comparisons of these diverse data sets (tables S1 to S3), we assimilated a 22-year (1981 to 2002) time series of commercial and recreational landings.

We conducted analyses for the continental United States at national and regional levels, the latter based on the management jurisdictions of the following FMCs: Northeast (combining Northeast and Mid-Atlantic FMCs, Maine through Virginia), South Atlantic (*11*) (North Carolina through the east coast of Florida), Gulf of Mexico (the west coast of Florida through Texas), and Pacific (Washington through California, including Alaska only in the nationwide comparisons).

The nationwide analyses included three successively smaller groups of species: all federally managed marine fish; all marine fish, excluding walleye pollock (*Theragra chalcogramma*, used to produce frozen fish products) and menhaden (*Brevoortia tyrannus* and *Brevoortia patronus*, used almost exclusively to produce fish meal); and all "populations of concern" [i.e., those populations listed by NMFS (*12*) as either overfished or experiencing overfishing]. Menhaden and pollock were excluded because they have little or no recreational value and they are not considered overfished (*12*), although they comprise more than half of all U.S. fisheries landings: pollock landings approximate 1.8 million metric tons

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(4 billion pounds) annually, and menhaden landings approximate 0.454 million metric tons (1 billion pounds). The regional analyses focused only on the populations of concern.

Our database indicates that the percentage of all U.S. landings of marine finfish attributable to recreational fishing in 2002 is actually about 4%, averaging 5% over 22 years (Fig. 1A). Excluding pollock and menhaden raises the recreational contribution to 10% of the total landings in 2002 (Fig. 1A), and focusing on the most relevant populations—the populations of concern—raises it to 23% (Fig. 1B). The regional differences in landings of populations of concern are pronounced (Fig. 1, C to F). In the Gulf of Mexico, 64% are taken recreationally (Fig. 1C); in the South Atlantic, 38% (Fig. 1D); along the Pacific Coast, 59% (averaging 14% over 22 years) (Fig. 1E); and in the Northeast, 12% (Fig. 1F) (*13*).

Current management of recreational fisheries focuses on controlling the landings of individual fishermen without restricting the number of individuals allowed to fish. In this open access scenario, control is limited to bag limits and size limits, which increases regulatory discards, thereby increasing fishing mortality (*14–20*) and sublethal effects on growth and reproduction (*21–24*). Increased fishing mortality also occurs with nonregulatory discards caused by high grading (wherein fishermen limited by quotas or bag limits discard small, less-valued fish to replace them with larger, more-valued fish) and catch-and-release in recreational fisheries. Discards are not included in this analysis, so these results underestimate likely impacts. Current regulatory methods have done little to constrain recreational fisheries, and for some major fish populations, recreational landings in the United States outstrip commercial landings, notably for red drum (*Sciaenops ocellatus*) in the South Atlantic (93% recreational), bocaccio (*Sebastes paucispinus*) on the Pacific Coast (87%), and red snapper (*Lutjanus campechanus*) in the Gulf of Mexico (59%).

Commercial and recreational fishing have similar demographic and ecological effects on fished populations. They truncate size and age structures, reduce biomass, and alter community composition (*25–31*). Whereas commercial fisheries fish intensely on both lower levels (e.g., menhaden and anchovies) and upper levels (top-level predators) of the food web, the recreational sector concentrates on the latter. All these fishery removals can cause cascading trophic effects that alter the structure, function, and productivity of marine ecosystems (*1*, *32–37*). Where recreational fishery landings rival those of commercial fisheries for major stocks of concern, sometimes even replacing them, they can have equally serious ecological and economic consequences on fished populations. If the goal of fishery management is to sustain viable populations and ecosystems, then recreational as well as commercial fishing requires effective regulations.

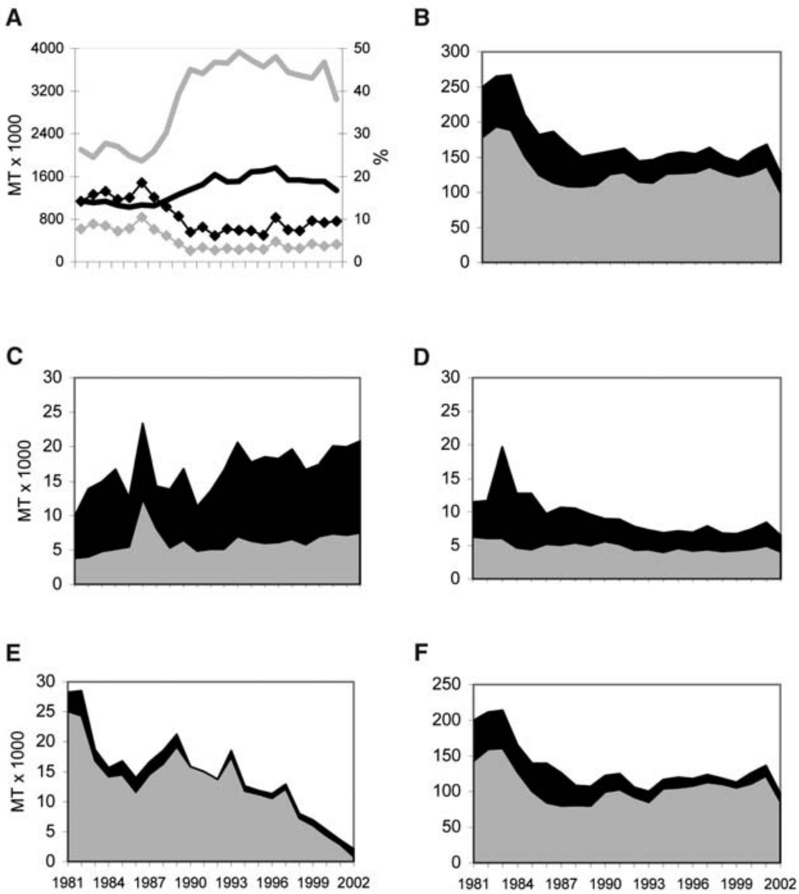

Fig. 1. Time series of marine fisheries landings from the continental United States in metric tons (MT) × 1000. (**A**) Total combined commercial and recreational landings (left *y* axis, solid lines) with recreational percentage of the total (right *y* axis, diamonds). The total, including all species, is shown in gray and the total, excluding menhaden and pollock, is in black. (**B** to **F**) Total (cumulative) landings of populations of concern separated into commercial (gray) and recreational (black) components for (B) all regions combined, (C) Gulf of Mexico, (D) South Atlantic, (E) Pacific Coast (excluding Alaska), and (F) Northeast. On the Pacific Coast, no complete sets of recreational data were collected for the years 1990 to 1992 from any of the federal or state organizations that maintain these databases.

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Amazonian Ecology: Tributaries Enhance the Diversity of Electric Fishes

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Neotropical rivers support a diverse array of endemic taxa, including electric fishes of the order Gymnotiformes. A comprehensive survey of the main channels of the Amazon River and its major tributaries (>2000-kilometer transect) yielded 43 electric fish species. Biogeographical analyses suggest that local mainstem electric fish diversity is enhanced by tributaries. Mainstem species richness tends to increase downstream of tributary confluences, and species composition is most similar between tributaries and adjacent downstream mainstem locations. These findings support a "nodal" or heterogeneous model of riverine community organization across a particularly extensive and diverse geographical region.

Biogeographers since Alfred Russel Wallace (*1*) have observed that the distribution of many terrestrial plant and animal species concords with the geography of major river systems. In the Amazon basin, for example, river and tributary channels appear to limit the ranges of taxa such as primates and lowland-forest birds [(*2*, *3*) but see (*4*)]. Similarly, divides between river basins can circumscribe the distribution of aquatic taxa such as freshwater fishes (*5*). Less clear, especially for large river systems such as the lowland Amazon, is the relationship between the structure of rivers [including channel geometry, network configuration, and geomorphology (*6*, *7*)] and the distribution of aquatic species.

Previous studies of fishes in temperate regions have suggested that local species diversity along main river channels is relatively high at tributary confluences (*8*, *9*). Tributaries might enrich mainstem fish diversity by providing access to the mainstem for migrating fishes, offering refugia for early life stages of mainstem species, or enhancing local ecological heterogeneity and thus augmenting local niche diversity (*6*, *10*). The potential impact of tributaries on fish distribution and diversity, however, has never been tested on as broad a spatial scale as that of the Amazon River basin.

Here, we report on the diversity and distribution of electric fishes (Teleostei, Gymnotiformes) along the Amazon mainstem and its major tributaries. Electric fishes are a distinctive and moderately diverse clade endemic to the freshwaters of South and Central America (*11–13*). These fishes are best known for their electroreceptive sense and production of electric fields for near-field orientation and electrocommunication (*14*). Recent taxonomic studies of these fishes have revealed an impressive degree of diversity, with 46 new species described within the past quarter century (*15*). In 1992, two of us (C.C.F. and J.G.L.) initiated the "Calhamazon Project," designed to document the fish fauna of the principal river channels of the Brazilian Amazon. Our field operations produced large samples of fishes trawl-netted in the deep main channels along >2,000 km of the Brazilian Solimões-Amazon mainstem, and in the lower reaches of major tributaries from the Içá River downstream to the Tocantins River (Fig. 1) (*16*). From these collections, we have recently described two new species of a new genus (*17*), identified 11 additional undescribed species, and resolved taxonomic errors caused by pronounced sexual dimorphism (*18*, *19*). These efforts set the stage for the present analysis of species diversity and distribution.

We focus here on three questions: (i) How many species of electric fishes are there in the mainstem channels of the Brazilian Amazon River and its major tributaries? (ii) What is the contribution, if any, of major tributaries to electric fish species diversity in the Amazon mainstem channels? (iii) How do patterns of electric fish diversity vary along the extent of the Amazon River?

Based on morphological criteria, we identify in our collections 43 electric fish species: 29 *Apteronotidae*, 8 *Sternopygidae*, 5 *Rhamphichthyidae*, and 1 *Hypopomidae* (table S1). The cumulative number of species collected, plotted as a function of the number of individuals sampled [in which sample order was randomized with the use of EstimateS (*20*)], yields a curve that is asymptotic (Fig. 2). Thus, our survey of channel species was arguably complete within the limits of our sampling method, and an accurate estimate of species richness was reached after about 16,000 individuals were captured. We do not imply that there are no additional electric fish species in the Amazon; other species are certainly present in microhabitats that were not sampled with our deep-water gear and possibly present in substrate depressions, among the branches of submerged trees, or in shallows near islands or the riverbank.

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