# Florida Keys Coral Reef Fish Communities, Then and Now

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Coral reef fish in the Florida Keys have been heavily exploited since at least the 19th century. Historical baselines are needed to understand the full magnitude of decline in fish populations and the degree to which loss of abundant fish populations has contributed to ecological degradation in the Keys. We collected historic and ecological data on the relative abundance of 23 coral reef fish from three points in time: the 1880s, early 20th century, and 2005. Comparison of these data indicates major reductions in abundant fish populations, particularly for large carnivorous fish. Use of historic and ecological data provides a description of the ecosystem in a less-fished state, which (1) gives insight into more realistic targets for rebuilding modern coral reef fish stocks and (2) allows for understanding ecosystem structure in a more natural condition.

KEY WORDS: Coral reef fish, historical and ecological data, abundances

## Ayer y hoy de los Arrecifes Coralinos de Florida Keys (Los Cayos de Florida).

En los cayos de la Florida (Florida Keys) los arrecifes de coral han sido pescados intensivamente al menos desde el siglo XIX. Puntos de referencia son necesarios para entender la magnitud total del decline de las poblaciones de peces, y también para entender el grado al cual la reducción de especies abundantes ha influenciado la degradación ecológica de esta área. Nosotros colectamos información ecológica e histórica acerca de la abundancia relativa de 23 especies de peces de arrecife de coral en tres periodos de tiempo: 1880, 1940 y 2005. Los resultados indican la ocurrencia de reducciones importantes en la abundancia de grandes peces carnívoros de todas las especies. La comparación de información histórica y ecológica a lo largo de 125 anos provee una descripción de los ecosistemas en un estado menos impactado por la pesca y por lo tanto nos permite establecer metas más realistas del punto al cual requerimos reconstruir las poblaciones de peces de arrecife de coral.

PALABRAS CLAVES: Peces de arrecife, datos históricos y ecológicos, abundancia

## INTRODUCTION

Historical marine ecology integrates historical data and analyses with traditional ecological approaches in order to understand the long-term trajectories of ecosystem change and the cumulative impacts that human activity has had on marine systems. The importance of understanding historical resource use is particularly clear in the Caribbean region, where marine communities were heavily exploited well before modern industrial fishing began (Jackson 1997, Jackson *et al*. 2001, Pandolfi *et al*. 2003, McClenachan *et al*. 2006) The reef ecosystems of the Florida Keys and Dry Tortugas are among the most degraded in the Caribbean (Pandolfi *et al*. 2005, Newman *et al*. 2006), with declines in large predatory fishes (Bohnsack 2003), coral overgrowth by macroalgae (Porter and Porter 2002, Jaap *et al*. 2003) and emergence of coral disease (Harvel *et al*. 2002). A major component of ecological degradation includes depletion of fish stocks, but the degree to which populations of coral reef fish have been depleted over long-time scales is largely unknown. This study quantified changes in the relative abundances of reef-associated fishes in the Florida Keys using historic data from the 1880s, early 20th century and modern data collected in 2005.

Commercial fishing in the Florida Keys was intensive as early as the 18th century, when Cuban fishermen were so numerous that contemporary observers described the coast of Florida as "covered with fishermen's huts" (Romans 1775). In the 1820s, American and Bahamian settlers established a near-shore fishing industry in Key West, which supplied both the local market and provided fish for export to Havana. By the 1840s, more than one hundred boatloads of fish were brought each year to Havana where the fishmarket was known for its variety and quantity of fresh fish (Turnbill 1840, US Customs Records).The Key West fleet grew as the local population expanded, so that by the time that the first federal fisheries assessments were conducted in the 1880s, the twenty-one vessels employed fishing for the Havana were accompanied by forty hook and line and three seine vessels fishing to supply the Key West market. These boats typically fished over coral reefs within ten miles from Key West (Goode 1887). In the 1880s, the United States Commisson on Fish and Fisheries published an analysis of the history, contemporary state, and potential for fisheries development, as well as the natural history and habits of commercial fishes. This series, "The Fisheries and Fisheries Industries of the United States," spans an impressive five volumes with over 3500 pages of information on the U.S. fishing industry at the end of the 19th century. This set of documents provides the first comprehensive historic information on Florida Keys coral reef fisheries from which ecological data can be extracted and used to create a historic baseline of coral reef fish communities before major industrial fishing began.

## METHODS

We used the 1880s as the historic baseline and determined changes in relative abundance of reef fish by com-

paring the baseline to later survey data. Historic data from the US Fish Commission Report indicate that 34 species were commonly caught in the Florida Keys in the 19th century (Goode 1887). Many scientific names have changed since the19th century, and we identified the species listed in the 1880s assessment using a database of historic names (calacademy.org/research/ichthyology). Species were included in our analysis if they (a) were listed as commonly caught in the 1880s, (b) were reef residents or reef-associated and (c) abundance data existed for later time periods. We discarded data on 11 fish for which later data did not exist and/or the species was not associated with coral reefs, and included 23 species in the analysis (Table 1).

Historic ecological data for the early 20th century were taken from two sources. The majority of the data were contained in the monograph "Systematic Catalogue of the Fishes of the Tortugas, Florida," which is a compilation of observations by the marine biologist William H. Longley over the 25 year period he was stationed at the Dry Tortugas Lab as well as observations by the US Fish and Wildlife Service Ichthyologist, Samuel Hildebrand, based on his work in Key West (Longely 1941). The second source was the 1963 book "Caribbean Reef Fishes" which is based on several decades of observation by the ichthyologist and marine biologist John Randall (Randall 1968). Observations of mid-20th century fish abundances in the Florida Keys were extracted from these two historic ecological sources (Table 2).

Modern ecological data were collected in 2005 at ten sites in the lower Florida Keys and Dry Tortugas at 5 and 15 meters using visual censuses in 50m long by 5m wide transects. The abundances of all fish species observed were recorded. For each of the 23 fish species, we determined the number of sites at which it occurred, the number of transects, and the abundance as a percentage of the total number fish observed in the Florida Keys and Dry Torgugas (Table 3).

The goal of this process was to determine the number of species that were considered rare in each time period. To compare among time periods, we standardized all data according to the following assumptions:

i. We assumed that the most commonly caught fish in the 1880s were also those most commonly found on the reefs. Given the highly unselective type of fishing gear in use and the wide variety of fishes caught and sold in the Key West fish markets, it is valid to assume that the catch reflected the natural abundances of the species. Therefore, no species that was described as commonly caught in 1880 was rare on the reef.
ii. Early 20th century observation of a species as rare is based on qualitative descriptions. For example if a fish was described as "rare" or "infrequent" it was coded as rare (See Table 2).
iii. A species was considered to be rare in 2005 if all of the following conditions were met: it was absent at more than half of the sites, absent at more than 80% of transects, and represented less than 10% of the total abundance of fish recorded in all observations.

## RESULTS

Of the fish that were commonly caught in the 1880s, 22% were rare by the middle of the 20th century and 52% are rare today (Figure 2, Table 4). Of these fish, long-lived species and top predators have suffered the most population change in the last half-century. Long-lived species are defined as those whose population doubling time is >4.5 years (fishbase.org). Only 11% of long-lived fishes were rare by the middle of the 20th century, but that number increased to 56% in 2005. Seventeen percent of top predators (fish with a trophic level of 4.5 or higher, fishbase.org) were rare by the mid 20th century and 67% of these fish are rare today.

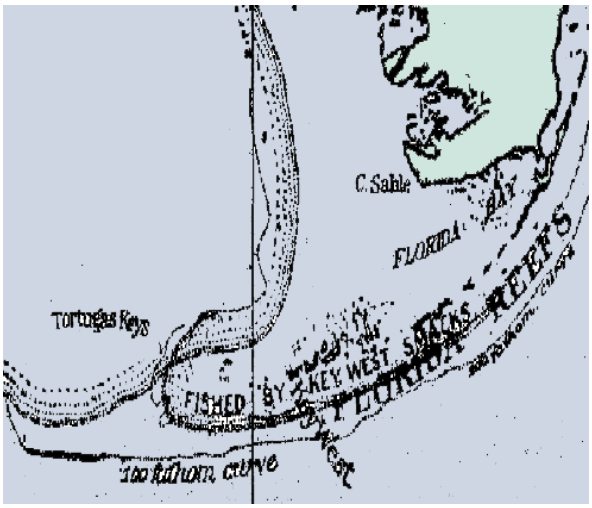


**Figure 1.** Area "Fished by Key West Smacks" 1880. Modified from Goode 1887.

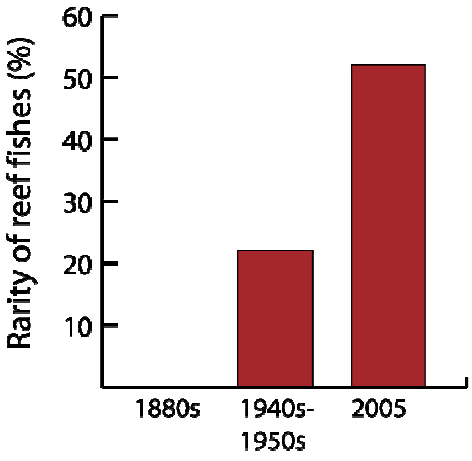


**Figure 2.** Rarity of Florida Keys reef fishes, 1880-2005

**Table 1.** Fish species included in analysis. *Not included in analysis, but population status is Critically Endangered.

| Modern scientific name | Common name | Alternative historic names | Included |
|---|---|---|---|
| *Caranx crysos* (Carangidae) | Blue runner | *Paratractus pisquetus* (Goode)<br>*Caranx fusus* (Randall) | Yes |
| *Caranx hippos* (Carangidae) | Crevalle jack | *Carangus hippos* (Goode) | Yes |
| *Cephalopholis fulva* (Serranidae) | Coney | *Enneacentrus punctatus* (Goode)<br>*Cephalopholis fulvus* (Longley) | Yes |
| *Chaetodon ocellatus* (Chaetodontidae) | Spotfin butterflyfish | *Sarothrodus bimaculatus* (Goode) | Yes |
| *Decapterus punctatus* (Carangidae) | Round scad | | Yes |
| *Epinephelus morio* (Serranidae) | Red grouper | | Yes |
| *Epinephelus striatus* (Serranidae) | Nassau grouper | | Yes |
| *Haemulon flavolineatum* (Haemulidae) | French grunt | *Haemulon punctatus* (Goode) | Yes |
| *Holacanthus ciliaris* (Pomacanthidae) | Queen angelfish | | Yes |
| *Holacanthus tricolor* (Pomacanthidae) | Rock beauty | | Yes |
| *Kyphosus sectator* (Kyphosidae) | Bermuda sea chub | *Cyphosus boscii* (Goode)<br>*Kyphosus sectatrix* (Longley) | Yes |
| *Lutjanus apodus* (Lutjanidae) | Schoolmaster snapper | *Lutjanus caxis* (Goode)<br>*Lutianus apodus* (Longley) | Yes |
| *Lutjanus campechanus* (Lutjanidae) | Northern red snapper | *Lutjanus blackfordii* (Goode) | Yes |
| *Lutjanus griseus* (Lutjanidae) | Grey snapper | *Lutjanus stearnsii* (Goode)<br>*Lutianus griseus* (Longley) | Yes |
| *Lutjanus synagris* (Lutjanidae) | Lane snapper | *Mesaprion uninotatus* (Goode)<br>*Lutianus synagris* (Longley) | Yes |
| *Mycteroperca bonaci* (Serranidae) | Black grouper | *Trisotropis brunneus* (Goode) | Yes |
| *Mycteroperca interstitialis* (Serranidae) | Yellowmouth grouper | *Trisotropis falcatus* (Goode) | Yes |
| *Ocyurus chrysurus* (Lutjanidae) | Yellowtail snapper | | Yes |
| *Pagrus pagrus* (Sparidae) | Common seabream | *Sparus pagrus* (Goode) | Yes |
| *Scomberomorus caballa* (Scombridae) | King mackerel | *Scomberomorus caballa* (Goode) | Yes |
| *Scomberomorus maculatus* (Scombridae) | Spanish mackerel | | Yes |
| *Scomberomorus regalis* (Scombridae) | Cero | | Yes |
| *Sphyraena barracuda* (Sphyraenidae) | Great barracuda | *Sphyraena picuda* (Goode) | Yes |
| *Epinephelus drummondhayi* (Serranidae) | Speckled hind | *Epinephelus Drummond-Hayi* (Goode) | No* |
| *Epinephelus nigritus* (Serranidae) | Warsaw grouper | | No* |
| *Balistes capriscus* (Balistidae) | Grey triggerfish | | No |
| *Centropristis striata* (Serranidae) | Black seabass | *Centropristis atrarius* (Goode) | No |
| *Lagodon rhomboides* (Sparidae) | Pinfish | | No |
| *Menticirrhus americanus* (Sciaenidae) | Southern kingcroaker | *Menticirrus alburnus* (Goode) | No |
| *Mycteroperca acutirostris* (Serranidae) | Comb grouper | *Trisotropis undulosus* (Goode) | No |
| *Pomatomus saltatrix* (Pomatomidae) | Bluefish | | No |
| *Sciaenops ocellatus* (Sciaenidae) | Red drum | | No |
| *Seriola lalandi* (Carrangidae) | Yellow tail amberjack | *Seriola punctatus* (Goode) | No |
| *Trachinotus falcatus* (Carrangidae) | Permit | *Lachnolaimus falcatus* (Goode) | No |

## DISCUSSION

This analysis demonstrated that overfishing over the last century has reduced populations of once abundant reef fishes in the Florida Keys. More importantly, the use of historical data revealed that changes in fish communities occurred before the 1950s, so that without historic data, these losses would remain undetected. Analyses using qualitative data can never provide precise quantitative results, but because traditional fisheries data are not available for more than a few decades, qualitative descriptions of relative abundance give a more accurate picture of long term change than would be achieved by relying only on recent data.

The results of this analysis are sensitive to how com-

**Table 2.** Early 20th century observations of fish abundance

| Species | Early 20th century observation |
|---|---|
| *Caranx crysos* | "The young are apparently common" (Longely p79) |
| *Caranx hippos* | "It may be assumed that the species is rare at Tortugas as it is at Key West" (Longely p79) |
| *Cephalopholis fulva* | "This fish is rare" (Longely p92) |
| *Chaetodon ocellatus* | "The commonest species of the genus at Tortugas" (Longley p149) |
| *Decapterus punctatus* | "15-20 specimens…were picked up among the refuse of the Bird Key rookery" (Longely p75) |
| *Epinephelus morio* | "By far the commonest of its genus, and the commonest representative of its family…in shallow water at Tortugas" (Longely p96)<br>"Abundant in Florida" (Randall p60) |
| *Epinephelus striatus* | "Common in the coral-gorgonian belt" (Longely p75) |
| *Haemulon flavolineatum* | "most commonly about patches of massive or branching coral" (Longely p127) |
| *Holacanthus ciliaris* | "Only 1 fully grown specimen and 2 young were seen in the course of much work on the reefs" (Longley p153) |
| *Holacanthus tricolor* | "I have seen one single adult and no young" (Longely p153) |
| *Kyphosus sectator* | "found along ledges of beach rock of Loggerhead Key, about the Laboratory wharf, in and about the large coral stacks off Bird Key, and around the Palythoa-covered ledges off Bush Key." (Longely p134) |
| *Lutjanus apodus* | "next to *L. griseus*, it is the most abundant snapper in the vicinity" (Longely p118) |
| *Lutjanus campechanus* | No data |
| *Lutjanus griseus* | "the commonest of the Tortugas snappers and in many respects the dominant fish in the local fauna" (Longely p115) |
| *Lutjanus synagris* | "it may be concluded that it is less numerous than the gray snapper and schoolmaster, about as common as the muttonfish and the dog snapper" (Longely p120) |
| *Mycteroperca bonaci* | "Common in… the Florida Keys" (Randall p65) |
| *Mycteroperca interstitialis* | "A single individual…was observed" (Longley p100) |
| *Ocyurus chrysurus* | "Few Tortugas fishes are more numerous than this species which is found by the hundreds among gorgonian thickets and *Orbicella* heads." (Longley p121) |
| *Pagrus pagrus* | No data |
| *Scomberomorus maculatus* | "abundant in the vicinity of Key West only from about November to April, when large quantities are marketed" (Longely p71) |
| *Scomberomorus regalis* | "abundant enough [in Key West] during the winter to be a food fish of imporance" (Longely p71) |
| *Scomberomorus caballa* | "abundant in Key West only during the winter" (Longely p72) |
| *Sphyraena barracuda* | "occurs wherever other fishes gather, whether at the shore or about the reefs, banks or bars" (Longely p69) |

monality and rarity are defined. However, while the percent of rare species might change if different criteria were used, strong signals of the extent of decline are incontrovertble. First, 40% of fish that were commonly caught in 1880 were not seen in any transects conducted in 2005. For example, *Epinephelus striatus* and *Lutjanus synagris*, both common in the early 20th century, did not appear in any of the 2005 surveys. Second, four of the species commonly caught in the 1880s (*Epinephelus nigritus, E. drummondhayi, E.striatus,* and *Pagrus pagrus)* are listed by the IUCN as Critically Endangered or Endangered (IUCN 2006).

Our analyses are conservative in their estimates for several reasons. Only commercially caught fishes were considered and we did not attempt to measure declines in nontarget and cryptic species due to habitat loss. Reduction in the cover of coral cover in the last half century has been extensive (Gardner *et al*. 2003), so that change for entire coral reef fish assemblages due to habitat loss are highly likely, but not recorded by our analysis. Further, our analysis is based on relative abundance descriptions within a particular time period, and therefore results are not completely free of a "shifted baseline." It is likely that in absolute terms, even the most common commericially exploited species today has smaller populations than it did before intensive fishing. Likewise, fish populations that were common in the 1880s had already undergone at least a half a century of exploitation and were therefore altered to some unknown extent.

Historic declines in reef fish are universal and reversing these declines is not always possible. However, understanding the degree of change in fish populations is essential to setting goals for restoration. Further, the timing of loss can help ecologists determine the factors that may have led to ecological change and aid futher understanding of the dynamics of change in modern coral reef communities.

**Table 3.** Modern data on fish abundance

| Species | Percent of sites present | Percent of transects present | Percent of total fish |
|---|---|---|---|
| *Caranx hippos* (Carangidae) | 0 | 0 | 0 |
| *Cephalopholis fulva* (Serranidae) | 0 | 0 | 0 |
| *Epinephelus striatus* (Serranidae) | 0 | 0 | 0 |
| *Lutjanus campechanus* (Lutjanidae) | 0 | 0 | 0 |
| *Lutjanus synagris* (Lutjanidae) | 0 | 0 | 0 |
| *Mycteroperca interstitialis* (Serranidae) | 0 | 0 | 0 |
| *Pagrus pagrus* (Sparidae) | 0 | 0 | 0 |
| *Scomberomorus maculatus* (Scombridae) | 0 | 0 | 0 |
| *Scomberomorus regalis* (Scombridae) | 0 | 0 | 0 |
| *Epinephelus morio* (Serranidae) | 40 | 31 | 0.98 |
| *Holacanthus tricolor* (Pomacanthidae) | 40 | 14 | 2.3 |
| *Lutjanus apodus* (Lutjanidae) | 40 | 12 | 11 |
| *Kyphosus sectator* (Kyphosidae) | 50 | 12 | 2.4 |
| *Mycteroperca bonaci* (Serranidae) | 50 | 8 | 0.42 |
| *Lutjanus griseus* (Lutjanidae) | 70 | 21 | 6.3 |
| *Holacanthus ciliaris* (Pomacanthidae) | 80 | 22 | 1.7 |
| *Chaetodon ocellatus* (Chaetodontidae) | 90 | 33 | 3.4 |
| *Haemulon flavolineatum* (Haemulidae) | 90 | 32 | 39 |
| *Sphyraena barracuda* (Sphyraenidae) | 90 | 17 | 1.2 |
| *Ocyurus chrysurus* (Lutjanidae) | 100 | 59 | 22 |

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**Table 4.** Relative abundante, (v) reef associated, visitor, * listed as Critically Endangered, Endangered, or Vulnerable by the IUCN

| Species | Rare 1880s | Rare 1940s-1950s | Rare 2005 | Lifespan | Trophic level |
|---|---|---|---|---|---|
| *Caranx crysos* (v) | No | No | No data | Short | 4.4 |
| *Caranx hippos* (v) | No | Yes | Yes | Medium | 3.9 |
| *Cephalopholis fulva* | No | Yes | Yes | Medium | 4 |
| *Chaetodon ocellatus* | No | No | No | Short | 3.2 |
| *Decapterus punctatus* (v) | No | No | No data | Short | 4.3 |
| *Epinephelus morio* | No | No | No | Long | 3.6 |
| *Epinephelus striatus* | No | No | Yes* | Long | 4 |
| *Haemulon flavolineatum* | No | No | No | Medium | 3.2 |
| *Holacanthus ciliaris* | No | Yes | No | Medium | 3 |
| *Holacanthus tricolor* | No | Yes | Yes | Medium | 3 |
| *Kyphosus sectator* | No | No | Yes | Long | 2.3 |
| *Lutjanus apodus* | No | No | No | Medium | 4.2 |
| *Lutjanus campechanus* (v) | No | No data | Yes* | Long | 4 |
| *Lutjanus griseus* | No | No | No | Medium | 4.2 |
| *Lutjanus synagris* | No | No | Yes | Medium | 3.8 |
| *Mycteroperca bonaci* | No | No | Yes | Long | 4.5 |
| *Mycteroperca interstitialis* (v) | No | Yes | Yes | Long | 4.5 |
| *Ocyurus chrysurus* | No | No | No | Long | 4 |
| *Pagrus pagrus* (v) | No | No data | Yes* | Medium | 3.6 |
| *Scomberomorus maculatus* (v) | No | No | Yes | Medium | 4.5 |
| *Scomberomorus regalis* (v) | No | No | Yes | Medium | 4.5 |
| *Scomberomorus caballa* (v) | No | No | No data | Long | 4.5 |
| *Sphyraena barracuda* | No | No | No | Long | 4.5 |

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