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The biology of yellowtail snapper, *Ocyurus chrysurus*, with emphasis on populations in the Caribbean

by

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Introduction

Yellowtail snapper, Ocyurus c*hrysurus* (Bloch, 1791), is a common reef fish species found extensively throughout the tropical and subtropical western Atlantic shelf and coastal waters (Figures 1 and 2). Because of the excellent taste and common occurrence, this species is highly sought after by recreational and commercial fishers off the southeastern U.S. (Florida), Cuba, and in the Caribbean (Piedra 1969, Johnson 1983, Manooch and Drennon 1987). In the western Caribbean, especially off Puerto Rico yellowtail snapper comprises a major component of the commercial fishery landings along with lane, mutton, and silk snapper (Matos-Caraballo 2000). The rarity of parasites, common in many marine food fishes, has also influenced the species popularity among consumers (Collins 1984). Biological information and the status of populations inhabiting the coastal areas of the southeastern U.S. were presented in Muller et al. 2003. The popularity of this species throughout the Caribbean is also further evident as national stamps featuring the yellowtail snapper have been created by several Caribbean countries (Figure 3).

Recent concern over the status of yellowtail snapper populations off Puerto Rico and the U.S. Virgin Islands prompted the need to review and assemble the available biological information for yellowtail snapper in this region. Of major importance in the construction of population models is accurate information on the life history and ecology. This report reviews and synthesizes biological information from published and un-published sources with emphasis on yellowtail snapper populations in the Caribbean.

Summarized Biological Information

The majority of studies of the life history of yellowtail snapper have been based on fishery dependent samples of adults and/or juveniles taken from Florida headboat fisheries (Johnson 1983, Garcia 2003) and commercial hook and line and trap samples in the U.S. Virgin Islands, Jamaica, and in Cuba (Manooch and Drennon 1987, Munro et al. 1973, Thompson and Munro 1974, Piedra 1969). More recently, researchers have focused on larval growth and development (Riley et al. 1995), age, growth and reproduction, from independent fishery sampling off south Florida (Barbieri and Colvocoresses 2003, Vose and Shank 2003), and habitat utilization of juveniles studies off the British Virgin Islands and the Netherlands Antilles (Nagelkerken et al. 2000, Watson et al. 2002).

Taxonomy

Snapper larvae are pelagic and widely dispersed consequently larval samples are rare in taxonomic collections (Munro 1987). Efforts to separate the early developmental stages of snappers using meristic and morphological studies were difficult (Everman and Marsh 1900, Vergara 1980, Starck and Schroeder 1971). Sarver et al. (1996) reviewed the main taxonomic problems associated with identification of and separation of lutjanids mainly caused by meristic and morphological similarities within the group and the apparent ability of several species to hybridize. This ability to hybridize was previously addressed by Rodriquez-Pino (1961), Anderson (1967), Richards (1988), and Domeier and Clarke (1992). At very small sizes, <5mm, the species has very similar morphological characters, especially with relation to pigmentation and size, to red snapper (*Lutjanius campechanus)*, gray snapper (*L. groseis)*, and vermillion snapper (*L. aurorubens*). Schultz et al. (1996) developed prototypic immunological procedures to separate western Atlantic lutjanid species. Recent information from rearing, anatomical, meristic, and morphometric studies of yellowtail (see Domeier and Clark 1992, Loftus 1992, Riley et al. 1995, and Clarke et al. 1997) and, genetic and biochemical analyses (Chow and Walsh 1992 and Sarver et al. 1996), suggests however that this species may belong with the genus Lutjanus and not to the Genus Ocyurus. Domeier and Clark (1992), pointed out that the Ocyurus genus, containing only one type, is separated from other Lutjanids by a very few morphological characteristics, all of which appear to be ecologically adaptive to their pelagic lifestyle. These included 1) presence of forked tail and fusiform body that optimizes swimming and feeding in the water column, 2) reduced canine teeth and 3) increase in number and length of gill rakers that allow more efficient feeding on zooplankton. In addition, 4) the bones in the head and jaw are much reduced since they are not needed in supporting strong grinding muscles. The characters that align the yellowtail snapper with the Lutjanid genus include: 1) dorsal fin spines, 2) dorsal fin rays, 3) anal fin spines and rays, 4) pectoral fin rays and 5) lateral line scales (Anderson 1967 cited in Domeier and Clark 1992). As recently as 2004, confusion remains as to the validity of the Ocyurus genus (Lindeman et al. 2004).

Morpholgy and morphometrics

Adult yellowtail snapper are small in size in comparison to most other snappers. Other distinct features that set the species apart include a very small head and mouth and a protruding lower jaw. The body is slender with a depth about 30-35% of the standard length (SL). The upper jaw teeth are tightly grouped, fine, hair like, “villiform” and several canine teeth are present, common in all the snapper species. The lower jaw has larger villiform teeth. The species is further characterized by long pectoral fins that begin at the mouth and reach the anus and also a deeply forked caudal fin. A pronounced mid-lateral yellow band or stripe runs from the snout to the caudal fin base. Body coloration is olive to bluish/violet with scattered yellow spots along the sides. The lower sides and belly are whitish with narrow pink (to reddish) and yellow longitudinal stripes, and the anal and pelvic fins, whitish (Bester 2004, Bortone and Williams 1986, Fishbase 2004, Allen 1985). A summary of available conversions for converting between standard, fork and total length measures is provided in Table 1 for yellowtail snapper populations.

Distribution

The yellowtail snapper ranges mainly from the Carolinas southward to southeastern Brazil (Druzhinin 1970, Figure 2). Occasional reports in Bermuda and off Massachusetts and in the Cape Verde Islands off the Atlantic coast of Africa exist, however these occurrences are not common (Druzhinin 1970). This species is most commonly observed in the Bahamas, off south Florida, the Netherlands Antilles, Campeche Bank and throughout the Caribbean (Randall 1967, Hoese and Moore 1977, Fischer 1978, Allen 1985). Yellowtail snapper are also occasionally found in the eastern Atlantic along with the gray, queen, and lane snappers.

Habitat

Throughout their geographical range, adult yellowtail snapper are commonly found near shore reefs, associated with hard or live bottom, and also near the edge of shoals and banks, wrecks, and other artificial reefs. This species is known to aggregate in large numbers, nearly always off the bottom. Adults tend to be more abundant at depths of 20-40 m near the edges of shelves and banks (Thompson and Munro 1974- Jamaica). Off the central east coast of Brazil, yellowtail snapper are predominately caught by commercial handliners between 20 and 60 m depth, although catches of yellowtail up to 80 m occur but do not comprise a major portion of the catch (Costa et al 2003). Paiva and Fonteles-Filho (1995) reported that, off the rocky coast of Brazil in the Abrolhos region, yellowtail snapper are mostly taken in the fishery that operates between 30 and 60 m depth. Paiva et al.(1996) analyzed the spatial distribution including the depth of catches of commercial bottom-liner from logbooks off the southeast coast of Brazil fishing between 38^o W 18^o N and 47^o W 24^o N between 1975 and 1985. Only catches from continental shelf area were considered. Paiva et al. (1996) reported that the fishery was concentrated mainly in areas off shore and near the edge of the continental shelf. CPUE (kg/boat-day) were generally highest in 40-50 m zone.

Interestingly, several researchers noted the lack of a relationship between individual fish size and depth distribution (see Thompson and Munro 1974). Yellowtail and vermillion snapper are reported to have a similar niche requirement in that they both are usually observed over the bottom, often swimming in larger schools (Grimes 1976).

Yellowtail snapper utilize a variety of habitat types during their life, making ontogenetic migrations between settlement, sub adult, and adult developmental stages. Larvae undergo a relatively short pelagic existence, settling out in the sea grass after about 35-40 days of age (Lindeman 1997, Jones et al. unpublished). Juveniles off St. Croix, U.S.V.I. were reported in the seagrass up to about 10 cm TL, and adults mainly inhabit hard rocky bottom, including patch reef, rubble, and also algal sand flats (Mateo and Tobias 2001). Juveniles have been reported in mangrove habitats off the southwest coast of Puerto Rico and Tortola British Virgin Islands (Kimmel 1985, Boulon 1988, Rooker and Dennis 1992 and also off the Netherlands Antilles (Nagelkerken et al. 2000).

The extent to which yellowtail snapper depend on mangrove prop root habitat as a larval and juvenile nursery area is not clear (see Dennis 1988). For juveniles the mangrove habitat may be important on a seasonal basis as yellowtail snapper were reported there only occasionally (see Rooker and Dennis 1992, Boulon 1988). Seagrasses may be more favorable as a larval nursery habitat, as post settlement larvae and small sub adults are able to hide among the individual grass blades from predators (Dennis 1988). It was suggested by Dennis (1988) that the mangrove prop root habitat may serve as an intermediary habitat refuge when the juveniles outgrow their seagrass habitat before emigration onto the coral reef area. Nagelkerken (2000) suggested that yellowtail only use the seagrass habitat up to about 2.5 cm TL and thereafter moved into mangrove and other habitats (e.g., hard rubble, coral reefs) off of Curaco, Netherlands Antilles. Watson et al. (2002) found that sizes up to 7.5 cm always were in the seagrass and never observed on the reef. The lack of comparative studies across multiple habitats, using multiple sampling gears over a long time period especially in the

Caribbean, has been a problem in interpreting the importance of each of these habitat types, (coral reef, mangrove, sea grasses) as a nursery area (see Dennis 1988, Nagelkerken et al. 2000).

Stock structure

Yellowtail snapper populations in the western Atlantic mainly range from the Carolinas to southeastern Brazil, the Gulf of Mexico and the Caribbean archipelago. The species is very abundant off south Florida, the Bahamas and the Caribbean Sea. Difficulties involving separation of the lutjanid species based on meristic studies and morphology differences were reviewed earlier in this report. Separation at the individual stock (population) level is also uncertain. Hoffman et al. (2003) using mtDNA D-loop analysis (n=310), reported that the level of genetic variability in yellowtail populations from the Florida Keys, southeast Florida, and Puerto Rico was very high. This finding is considered common in fishes with large population sizes and open water pelagic life history stages (Hoffman et al. 2003). The authors noted that genetic variability was higher within collections than between collections. The only genetic structuring observed in the analyses of mtDNA D-loop samples was between southern Florida and Puerto Rico and Biscayne Bay (FL) and Puerto Rico, suggesting a single stock exists in southern Florida. Hoffman et al (2003) reported that their results suggest that subtle isolation by distance may exist between widely separated yellowtail populations (e.g., Florida and the Caribbean) or between widely separated Caribbean locations. These results suggest that yellowtail populations off the Puerto Rico geological platform (Puerto Rico, U.S. Virgin Islands (St. Thomas, St. John) and the British Virgin Islands) are probably not providing recruitment to the populations in south Florida (and on the North American plate).

Information on stock structure based on tagging studies is very limited. Acoustic tagged fish off Conch Key in the Florida Keys during 2001 (Lindholm 2004) suggested the movements of yellowtail were very restricted as most fish stayed very close to the tagging area. Lindholm reported that 60% of all tagged yellowtail showed site fidelity. Randall (1962, 1963) tagged some 343 yellowtail snapper off Lamshur Bay on the south shore of St. John, U.S.V. I. Of the 15 fish recaptured one fish was reported caught 7 miles from the tagging location, one fish 1 mile away and the remainder were reported caught within one half mile of the release site.

Watson et al. (2002) observed young newly settled yellowtail snapper off the British Virgin Islands using visual census surveys. They reported that newly settled recruits, size 2-3 cm TL, rarely moved more than about 20 cm from their initial position. At sizes from 3-3.5 cm apparently the range begins to increase. Watson et al. (2002) reported that up to about 3.5 cm TL the home range was about 6.3 square meters, and at these sizes yellowtail snapper feeding habits changed also from a benthic to more piscivovry, and individuals began moving away from the seagrass habitat, and also began showing aggression towards individuals in their territory. These researchers also tagged pre-settled yellowtail caught in light traps with fluorescent orange elastomer (n=96). At about 2-2.5 cm the elastomeric tagged individuals were released and observations made to evaluate site fidelity, 48 tagged fish were retained initially for 24 hours to estimate tag loss rate (=13%). Of the releases, 32 re-sightings were made and only one fish moved more than 2-3 m from where it was first censused after release, providing some support for site fidelity after settlement. The tagging experiments indicate that very little if any movement occurs immediately after settlement, during the early sub adult and juvenile phases of this species and long distance transfer rates between regions is not likely to be high for adults.

Although the possibility of larval exchange between regions exists, it is thought by most researchers that recruits are mainly from resident yellowtail populations in these regions. Recent examination of surface current patterns suggests there is little likelihood that yellowtail larvae are passively transported to Puerto Rico or the nearby islands off Puerto Rico (e.g., St. Thomas, St. John in the U.S. VI and also the British Virgin Islands) from outside this region (see Roberts 1977, Watson and Munro 2004). For species like yellowtail snapper that undergo a pelagic larval duration of about one month time the likelihood of upstream recruitment from other locales in the Caribbean does not seem high. Watson and Munro (2004) point out for marine species requiring about two months transport time that the area off Puerto BVI, and U.S V.I. could possibly receive settlers from islands and banks to the east (e.g., Saba Bank, Anguilla, St. Marten and the Netherlands Antilles) however, this length of the planktonic phase is significantly longer than the consensus for yellowtail snapper of about 30-40 days maximum.

Trophic Structure

Yellowtail snapper are carnivorous, with adults and juveniles feeding above bottom. Detailed information on feeding habits is limited to just a few studies off Cuba, Virgin Islands, south Florida, and the Netherlands Antilles. Longley and Hildebrand (1941, reported in Thompson and Munro 1974) indicated that yellowtail did not restrict feeding to nocturnal periods as commonly seen in other Lutjanids, but ranged freely throughout the reef and fed both by day and night. The species is considered to have diverse feeding habits (eurphagous). The dominant food items reported for juveniles were crustaceans (shrimp, crabs) and post larval fishes and juveniles (Randall 1967-Virgin Islands, Piedra 1969-Cuba, Carrillo de Albornoz- Cuba 1988, Sierra 1997-Cuba). Other food items include cephalopods and worms (Barbieri and Colvocoresses 2003-south Florida). Small juveniles <10cm, while inhabiting mainly seagrass tend to feed on zooplankton (Cocheret de la Moriniere et al. 2003- Netherlands Antilles) and later as they grow in size, benthic crustaceans (shrimp and crabs) (Piedra 1969, Sierra 1997- Cuba). Sierra found that by about one year of age, juvenile diets were similar to adults. Watson et al. (2001) documented feeding preferences in newly settled yellowtail snapper (both caged and wild) in the British Virgin Islands. Newly settled yellowtail snapper (about 3 - 4 cm in size) remained nearly stationary in the sea grass, near bottom and picked off plankton (Watson et al. 2001). Older recruits fed primarily on fishes including juvenile Atherinidae, Clupeids and also on Malacostraca. Other foods included annelids.

The diversity of their diet as well as the size of the foraging area increases with the size of the juveniles, possibly reflecting ontogenetic changes in diet with growth. Yellowtail also feed on the spawn of other fishes. Rose (1972) observed this behavior in yellowtail snapper off Freeport, Grand Bahamas Island, in an area of spawning stoplight parrot fishes, where yellowtail feeding was observed on the freshly released eggs and cloud of milt.

Several researchers reported seasonal variability in feeding. Carrillo de Albornoz (1988) found the majority of yellowtail stomachs sampled off Cuba to be full from January to April, and, a reduction in stomach content from May on, correlating with the observed season of spawning in that region (Mar-August, peaking in June). Collins and Finucane (1989) reported similar observations for fish sampled off south Florida.

Few studies exist regarding predators of yellowtail snapper. Likely predators include sharks, groupers and barracuda (see Thompson and Munro 1974). Randall (1967) reported that yellowtail snapper were preyed on by groupers, barracuda, jacks, and also king mackerel. Yellowtail snapper are reported to be cleaned on the reef by the scarlet striped cleaner shrimp, gobies, juvenile Spanish hogfish, and angelfishes (Sazima et al. 1999, Anonymous 1995)

Maturation and Reproduction

Sex Ratio, Maturation Timing and Fecundity

Figuerola et al. (1998) sampled yellowtail snapper from commercial catches and also research surveys between June 1996 and July 1997 (n=322). These researchers observed spawning activity from February through October with peak activity from April through July. Sexual dimorphism in size of maturation between sexes was reported by Figuerola et al. (1998), who found males maturing as small as 11 cm (FL) and females by about 19 cm (FL). Figuerola et al. calculated 50% sexual maturity for yellowtail snapper off Puerto Rico to be 22.4 mm (FL) males and 24.8 cm (FL) females. Erdman (1976) reported spawning from March to September for an area near Puerto Rico.

Piedra (1969) noted that sex identifications can be made very early, by 10-11 cm (FL) for the yellowtail snapper off Cuba. Piedra also reported that sex can usually be determined visually, even though the sex glands are not always fully formed. Off Cuba, the sex ratio of yellowtail snapper was equal during most months (0.49 (females): 0.51 (males) 1962, 0.55 (females): 0.45 (males)-1963) but the proportion of males in the catch during May and June was higher (Piedra 1969). Piedra also reported that males were smaller than females. Piedra's study reported mature individuals as small as 13-14 cm (FL) commonly observed in the catch. Piedra (1969) reported the gonads begin maturing from March – September in that study which, was conducted from 1962-1963, with maximum ripe gonads observed during May.

Carrillo de Albornoz (1988) reported an equal male: female sex ratio during most of the year off the southwest and northwest coasts of Cuba, but also reported that at around 17-18 cm (FL) the sex ratio was unequal. Length at first maturity was 20-21 cm (FL) for females and 19-20 cm for males. During the maximum spawning frequency period (i.e., around April) the authors was noted that individuals did not usually have full stomachs. Mature fish were commonly observed between March and August. Carillo de Albornoz (1988) reported the maximum spawning activity off Cuba to occur in April.

Bustamante et al. (2001) reported that yellowtail snapper first reach reproductive maturity at 24 cm (FL) or about age 2 off Cuba. Bustamante et al. (2001) noted that the mesenteric body cavity fat index (MFI) increased from winter until early summer, or about the peak in spawning season off Cuba, in yellowtail snapper. These authors also noted that liver weight increased during egg development in yellowtail snapper and also in gonad development, particularly of ovaries. In addition, Bustamante documented that during the first few months of development yellowtail snapper body fat is nearly absent and suggested that energy during this early developmental period is directed towards growth.

Munro et al. (1973) reported sexually mature yellowtail snapper were observed on shallow reefs off Port Royal on the south coast of Jamacia (between 2 and 15 m depth) March to May 1969-1971 and that year round spawning activity was observed on unexploited oceanic banks (from 5 to 250 m) off that region from 1968-1971. These authors noted that the maximum frequency of spawning occurred during the coolest months and particularly around September. Thompson and Munro (1974) again reported on spawning of yellowtail snapper off Jamaica from extended sampling conducted between 1971 and 1973, and suggested that although ripe fish were found year round on offshore oceanic banks that two main spawning periods exist, February-April and September-October. This suggestion of two intense spawning periods differs from most researchers observations of yellowtail from more northern regions (i.e. off Cuba) who reported one main period of spawning, during late spring (April-May). Interestingly mature fish were found on shallow reefs during spring however, no observations of spawning fish were reported for the shallow reefs during the spring months by either Munro et al. (1973) or Thompson and Munro (1974). The data of Thompson and Munro (1974) suggest that the mean maturation size on offshore banks off Jamaica during 1968-1971 was 26 and 29 cm (FL) for males and females respectively.

Pinkard and Shenker (2001) reported low gonadosomatic indices (GSI's) for yellowtail snapper sampled in the Florida Keys between January and March, increasing beginning in April with a peak around August, and remaining high through December. Collins and Finucane (1989) reported increasing GSI's from April through July and maximum in June, for yellowtail sampled off the Florida Keys in 1980-1981 however noted that some ripe fish were observed year round. These researchers suggested that the size of 50% maturation for yellowtail off the Florida Keys was about 20 cm. They also addressed the seasonal variability in spawing with size, noting that most fish >28 cm were mature by April while smaller sized individuals did not mature, until later in the summer. As suggested by other studies, Collins and Finuance (1989) reported serial spawning in the yellowtail snapper off the Florida Keys. Barbieri and Colvocoresses (2003) reported increasing GSI's from February through June thereafter decreasing for yellowtail sampled off Tequesta, Florida.

Summary information on the size and seasonality of maturation for yellowtail snapper populations is provided in Table 2 and Figure 4 for the geographical regions discussed above.

Limited information is available to document fecundity of the yellowtail snapper. Fecundity for fish sampled off Cuba was calculated from 4 individuals by Piedrea (1969) and also by Carrillo de Albornoz (n=60 individuals per a graphic) (1989, 1993) (Table 3a). Fecundity information is presented for another study off Cuba and also for south Florida in Tables 3b-3c.

Aspects of Growth

Growth estimates from Hardpart Structures

Several studies evaluated growth in yellowtail snapper using otoliths. Manooch and Drennon (1987) described growth for yellowtail populations using sectioned otoliths collected off St. Thomas and St. Croix, U.S. Virgin Islands (720) and Puerto Rico (n=77) from commercial hook and line catches between 1983 and 1984. Von Bertalanffy parameters were estimated from back calculated sizes at length and formulae for estimating weight from length were given (Tables 5 and 6). Manooch and Drennon reported that sectioned otoliths were much clearer than were whole otoliths. Johnson (1983) also reported that sectioned otolths were much more legible than were whole otoliths in his study of yellowtail snappers from the Florida Keys. Interestingly, even with sectioned otoliths, Manooch and Drennon reported that rings were identified on 82% (468 of 797) of all otoliths examined and that from these samples, only 59% (468 of 797) were distinct enough for measurements to be made for purposes of back – calculations. Additionally, Manooch and Drennon reported that by age 5, the rings had considerable overlap introducing an addition source of error in age determinations.

Johnson (1983) estimated von Bertalanffy parameters from mean back-calculated length (BCL) at ages readings derived, from sectioned otoliths collected from commercial and recreational hook and line catches off the Florida Keys, Miami and the Dry Tortugas (FL) between 1979 and 1980 in addition to deriving formulae for estimating individual weight from individual length (Tables 5 and 6). Both studies indicated through marginal increment (MI) readings that annular marks were deposited once per year during late spring to early summer with the minimum MI deposition occurring by March in the Manooch and Drennon study and by June in the Johnson study. Although Johnson (1983) provided combined sex BCL's for ages up to 14, for ages 5 and older the sample sizes were small ($n<6$ for ages >5). In addition, the low sample sizes for ages above 3 disallowed any meaningful analyses of growth differences between sexes for this study. Neither Johnson (1983) nor Manooch and Drennon (1987) evaluated sex differences in the relationship used to describe the otolith radius (OR) : body length (BL) relation which was later used to estimate BCL's at age. Johnson (1983) and also Piedra (1969) suggested that females were larger than males at older ages but this was not evaluated in any of the hardpart ageing studies.

Carrillo de Albornoz and Ramiro (1988) and Claro and Garcia-Arteaga (2001) described growth of yellowtail snapper off southwestern Cuba from the urohyal (vertebrae). They suggested two growth rings were formed annually, one in March and another in November, however, no study confirmed nor disproved this hypothesis. These authors further reported that one growth equation could be used for both sexes however statistical evaluations of sexual dimorphic growth were not made. Piedra (1965, 1969) discussed the difficulties of attempting to age this species (off Cuba) using scales and otoliths. She reported that the rings on neither scales nor otoliths were sufficiently clear for separation of marks. Piedra reported that annualar rings from the vertebrae were clearly. Piedra indicated that at older ages females were larger but this was not evaluated statistically. Claro and Garcia-Arteaga (2001) also reported the presence of two annual rings in the uroyhal and otolith of yellowtail snapper off Cuba, one during early winter and another in the late fall. These authors noted that this was frequently observed in yellowtail in their first year of life (age 0+ individuals) and suggested that the second mark may coincide with other physiological changes including dietary changes. Apparently several other researches also attempted to age yellowtail snapper sampled off the Yucatan using scales (see Mexicano-Cintora and Arreguin-Sanchez, 1989 and Cantarell 1982). Information on growth parameters derived from the studies conducted off Mexico (Yucatan) and in Cuba was not thoroughly reviewed for this report as the original manuscript papers were not available however the summary results are presented in Table 6.

More recently Garcia et al. (2003) re-evaluated growth in yellowtail snapper populations off the southeastern U.S. using more geographically comprehensive and more recent hardpart collections. Commercial and headboat hook and line catches were sampled between 1994 and 1999 from Daytona Beach (Fl) through Key West (FL). Garcia et al.'s (2003) study reported MI growth minimum during late spring and annual mark deposition complete between March and May as did Manooch and Drennon (1987) and Johnson (1983) for fish from Puerto Rico and south Florida respectively. Von Bertalanffy derived estimates from Garcia et al. (2003) and the previously described hardpart studies are provided in Table 6 for comparison purposes. Garcia's data set contained observations for age groups through age 13 however, as in the Johnson (1983) and Manooch and Drennon (1987) study few fish greater than age 6 were examined. Observed sample sizes for ages 7-13 were 8, 3, 1,3,0,1, and 2 fishes respectively. Garcia used a single combined sex OR:BL relation as did these two authors to estimate mean BCL at age for use in estimating the von Bertalanffy growth parameters. Garcia employed the Francis (1990) body proportional hypothesis in estimating BCL at age. Johnson assumed the a power relation in estimating the OR:BL formula and Manooch and Drennon (1987) assumed a linear relationship. None of the three studies using otoliths to determine age (Johnson, Manooch and Drennon, Garcia) presented statistical support as to the choice of the OR:BL relationship (i.e., linear, proportional, power) later used in the calculation of BCL's at age. Differences in meristic relations (FL:TL, SL:TL) between sexes have not been reported were not reported in any of these studies however Piedra noted off Cuba that males were often larger than females, perhaps suggesting differential mortality with increasing size for the species, which has also been reported for other tropical fast growing species (e.g., dolphinfish, *Coryphanaea hippurus* and the king mackerel, *Scombermorous cavalla.)*

Barbieri and Colvocoresses (2003) provided von Bertalanffy growth estimates derived from yellowtail sampled through fishery independent trap surveys off south Florida (Table 6). These researchers reported that no differences in growth rate between sexes and presented results for sexes combined. Barbieri and Colvocoresses (2003) derived growth parameter estimates by fitting the Marquardt non-linear least squares parameter estimation method to the observed length at age data (Marquardt 1963). Growth differences between sexes were evaluated using Kimura's (1980) method so the authors pooled the data for final parameter estimation. The amount of variability in observed length at reader assigned age in this species is very high. The plotted data of Barbieri and Colvocoresses (2003) is presented here to demonstrate the variability in length at age for the yellowtail snapper (Figure 6).

Growth estimates from length frequency analyses

Growth parameters have also been derived for yellowtail snapper from length frequency analyses by several researchers. Carrillo de Albornoz (1999) evaluated populations off Cuba from 1985-1999, and used the Fournier and Breen (1983) method to estimate growth parameters. Dennis (1991) evaluated populations off Puerto Rico from 1984-1985 and Acosta and Beaver (1999) off south Florida between 1985 and 1996 using the ELEFAN method (Pauly and David 1981). Acosta and Beaver (1999) used a slightly modified form of ELEFAN I which incorporates seasonality aspects of growth in the model (see Gayanilo et al. 1995, Weatherall et al. 1987 and Pauly and Gaschutz 1979) as referenced in Acosta and Beaver 1999). Thompson and Munro (1983) studied yellowtail populations off Jamaica and noted that otoliths did not reveal clear patterns useful for age determinations; in-fact the authors reported that scales were probably better ageing structures for young fish for this species. Table 7 provides growth parameter estimate results from these length frequency studies and also from Perez and Rubio (1986) who evaluated growth off southeast Cuba. Parrack and Cummings (2003) evaluated the use of length frequency analysis methods for ageing a fish like the yellowtail snapper which exhibits rapid growth during the early years and relatively high variability in length within an age group. Simulation results from that study suggested that length frequency analyses methods were accurate in separation of modal groups for about the first quarter of the distribution of ages commonly observed in the catch if the variation in length at age was reasonably low (CV~0.05), or about 4 ages including the first age of recruitment (about age 2). Johnson (1983) noted that the variation in length at age for yellowtail snapper was very high, and especially at young ages and suggested that length was a poor indicator of age for this species. Barbieri and Colvocoresses's et al. (2003) data indicate that the variation of length at age is on the order of 30%.

Tagging Studies

Information on growth of yellowtail snapper from tagging data is very limited. Randall (1962, 1963) tagged 343 yellowtail snapper off Lamshur Bay on the south shore of St. Thomas, U.S. V.I. in the early 1960's using dart and spaghetti tags. Of the 15 recaptures eight fish were at larger more than one month and of these three fish showed positive growth. More extensive tagging experiments are needed in order to further evaluate the use of tagging data to determine growth of this species.

Overview of growth

Growth in yellowtail snapper is very rapid, near linear in form during the first two to three years, slowing down thereafter, and by age seven or eight reaching an asymptotic length. The hardpart and length frequency analysis growth studies available for this species indicated large uncertainty in the characterization of growth. Whether yellowtail snapper deposit multiple rings each year is unclear as otolith and vertebral studies suggested that fish off Cuba and Mexico could deposit two annual rings. Indirect annulus validation results from MI analyses suggested, the time of mark (annulus) formation was contracted over quite a length period lasting from early spring to late summer varying somewhat with geographical location and aligning in general temporally with the spawning period. Several studies suggested that males grew more slowly than did female yellowtail snapper although no conclusive support of this was given. Growth parameter estimates are not directly comparable across studies due to differences in sampling gears (hook and line vs traps vs trawls), locales (Puerto Rico, USVI, Cuba, Yucatan, south Florida), differences in age determination method, and procedures used in calculating BCL's used in parameter estimation, and also growth model fitting methods varied. Nearly all of the hardpart ageing studies reported different maximum age observed. Johnson (1983) reported only five fish >age 10 off south Florida between 1979 and 1980. Manooch and Drennon (1987) reported fish up to age 17 (and 12 fish > age 10) off the U.S. VI and Puerto Rico between 1983 and 1984. Garcia et al. (2003) reported fish up to age 14 (excluding age 11) off south Florida from 1994-1999. Piedra (1969) and Clarao (1983) for fish sampled from 1957-1963 and from 1972-1973 respectively off Cuba, reported fish only up to age eight (with n>5). At least some of the differences between studies are no doubt simply due to different sampling gears as Johnson's fish were caught by commercial and recreational hook and line, Manooch and Drennon's samples were from the commercial trap fisheries and Garcia samples from commercial hook and line samples. The Cuban hardpart collections were from hand lines, trawls, and seines.

A summary of observed maximum size information is presented in Table 4. Estimates of predicted size at age for the studies discussed above are presented in Table 5 and Figure 5. Weight to length conversions are provided in Table 6.

Natural Mortality (M)

Muller et al. (2003) applied a rate of 0.15 per year for the instantanteous rate of M calculated using Hoenig's method and assuming F=0.1 for populations off south Florida. Using Pauly's (1980) method, Carrillo de Albornoz (1999) estimated M to be 0.4 for yellowtail snapper off Cuba. Dennis (1992) derived M for yellowtail snapper off Puerto Rico applying the Pauly method to age and length frequency derived growth estimates to be 0.32 and 0.44 respectively. Dennis's age derived growth estimates were calculated by re-fitting the von Bertalanffy curve to the mean BCL's of Manooch and Drennon (1987) excluding the age 17 observation. Dennis's two estimates of M were calculated assuming two different treatments of Mannoch and Drennon's data. Thompson and Munro (1974) calculated an M value of 0.6 for yellowtail snapper off Jamaica. The range of M values from these analyses were 0.15 - 0.6.

Population Enhancement Considerations

Studies have evaluated the feasibility of carrying out stock enhancement of yellowtail snapper. Benetti et al. (2004) discussed the feasibility of aquaculture for yellowtail snapper and noted that survival rates during larval rearing was very low in this species and that laboratory reared fingerlings demonstrated slow growth and high food utilization rates. Watson et al. (2001) evaluated survival of cage reared yellowtail snapper captured via light traps off the British Virgin Islands. The authors reported that survival of cage reared yellowtail snapper was about 30-40 % higher than survival of wild individuals. Estimates of mortality of post settlement yellowtail snapper from the literature range from 80% to 40% during the first month after settlement. Watson et al.'s study (2001) reported that initial mortality could be reduced by 20-40 % with very careful, near optimal rearing practices. The optimal size (age) of yellowtail for the cage rearing experiments were thought to be about 3-3.5 cm (3-4 weeks) as the size of the foraging area becomes larger soon after. Watson et al. (2001) suggested that fairly low tech rearing methods could provide a viable method of improving stock recovery in heavily (e.g., off the north Jamaican shelf) to moderately (off Tortola in the British Virgin Islands) exploited regions. This enhancement strategy might benefit geographical regions with yellowtail snapper populations thought to be self replenishing and not intensively exploited, however no information is available to quantify survival rates of released fish after rearing and long term population benefits.

References

American Society of Ichthyologists and Herpetologists, 1995. Associations of fishes and their cleaners on coral reefs of Bonaire, Netherlands Antilles. Copeia 1995(2):477-481.

Allen, G.R. 1985. Snappers of the world. An annotated and illustrated catalogue of lutjand species known to date. FAO species catalogue 6. FAO Fish. Synop. 125. 208 pp.

Anderson, W.D., Jr. 1967. Field guide to the snappers (Lutjanidae) of the western Atlantic. U.S. Fish Wild. Serv. Circ. 252. 14 p.

Acosta, A. and R. Beaver. 1999. Fisheries, growth, and mortality of yellowtail snaper, *Ocyurus chrysurus,* in the Florida Keys, Florida, U.S. A. Proceedings of 51st Gulf and Caribbean Fisheries Research Institute..

Barbieri, L.R. and J. A. Colvocoresss. 2003. Southeast Florida reef fish abundance and biology. Five-year performance report to the U.S..

Bertenshaw, V.J. 2001. Settlement behaviour and survirorship of Ocyurus chrysurus and other juvenile reef fish species of the British Virgin Islands. MSc thesis, Univ. of Plymouth.

Bester, Cathleen. Biological Profiles. Ichhyology. Florida Museum of Natural History. 9 p.

Bortone, S.A. and J. L. Williams. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (south Florida) – gray, lane, and yellowtail snappers. U.S. Fish Wildl. Serv. Biol. Rep. 82(11),U.S. Army Corps of Engineers, TR EL-82-4, 18 p.

Bottini, Paolo. 1999. Brussels Belgium. pbott@compuserve.com

Boulon, Ralf. H. 1988. Use of mangrove prop root habitats by fish in the northern U.S. Virgin Islands. Proceedings of the 41st Gulf and Caribbean Fisheries Research Institute 41:189-204.

Breen, P.A. & Fournier, D.A., 1984. A user´s guide to estimating mortality rates from length frequency data with the method of Fournier and Breen. Can. Tech. Rep. Fish. Aquat. Sci. 1239, 63p

Bustamante, G., R. Claro, and M.I. Shatunovsky. 2001. Ecophysiology of Cuban Fishes. [In: Ecology of the marine fishes of Cuba. Edited by R. Claro, K.C. Lindeman, and L.R. Parenti. Smithsonian Institution Press, Washington, 253 p]

Cantarell, E., 1982. Determinación de la edad y el ritmo de crecimiento del pargo canané (*Ocyurus chrysurus*), Bloch 1871), en el estado de Yucatán .. Tesis de Licenciatura E.N.E.P.I., UNAM, México.

Carrillo de Albornoz and y Eduardo Grillo. 1993. Fecundidad de la rabirrubia (*Ocyrurus chrysurus*) en el oeste de la plataforma suroriental de Cuba. Centro de Investigaciones Pesqueras. Ministerio de la Industria Pesquera. Ciudad de La Habana, 62-68

Carrillo de Albornoz, 1999. Crecimiento y evaluacion de la rabirruboa (*Lutjanus chrysurus*) en el oeste de la plataforma suroriental de Cuba. Rev. Invest. Mar. 20(1-3):45-52.

Claro, R. and J.P. Garcia-Arteaga. Growth patterns of fishes of the Cuban shelf. [In: Ecology of the marine fishes of Cuba. Edited by R. Claro, K. C. Lindeman, and L.R. Parenti. Smithsonian Institution Press, Washington, 253 p.

Clarke, M. E., M. L. Domeier, and W. A. Laroche. 1997. Development of larvae and juveniles of the mutton snapper (*Lutjanus analis),* lane snapper *(Lutjanus synagris)* and yellowtail snapper (*Lutjanus chrysurus). Bull. Mar. Sci.* 61(3):511-537.

Chow, S. and P. J. Walsh. 1992. Biochemical and morphometric analyses for phylogenetic relationships between seven snapper species (Subfamily Lutjanidae) of the western Atlantic. *Bull. Mar. Sci*. **50**:508-519.

Collins, L.Alan and J.H. Finucane. 1989. Reproductive biology of yellowtail snapper, *Ocyurus chrysurus*, from the Florida Keys. U.S. Department of Commerce, NOAA, NMFS, SEFSC, Panama City Laboratory, PCL Contrib. No. 89-11, 23 p.

Collins, M. R. 1984. Hatshekia oblonga (Copepoda, Caligoida) from yellowtail snapper (*Ocyurus chrysurus*) in the Florida Keys. Journal of Wildlife Diseases, 20(1):63-64.

Dosta, P.A.S., A. da Costa Braga, L.O. Frota da Rocha. 2003. Reef fisheries in Port Seguro, eastern Brazilian coast. Fish. Res. 60:577-583.

Dennis, G.D. 1988. Island mangrove habitats as spawning and nursery areas for commercially important fishes in the Caribbean. Proceedings of the 41st Gulf and Caribbean Fisheries Research Institute 41:205-225.

Dennis, G.D. 1991. The validity of length-frequency derived parameters from commercial catch data and their application to stock assessment of the yellowtail snapper (*Ocyurus chrysurus*). Proceedings of the Gulf and Caribbean Fisheries Institute 40:126-138.

Domeier, M. L. and M. E. Clarke. 1992. A laboratory produced hybrid between *Lutjanus synagris* and *Ocyurus chrysurus* and a probable hybrid between *L. griseus* and *O. chrysurus* (Perciformes: Lutjanidae). *Bull. Mar. Sci*. **50**:501-507.

Druzhinin, A.D. 1970. The range and biology of snappers (Fam. Lutjanidae), Jour. Icthyology, 10(6):717-736.

Evermann, B.W. and M.C. Marsh. 1900. The fishes of Porto Rico. Bull. U.S. Fish Comm.: 51-350, 49 col. Pls., 112 text-figs.

Evermann, B.W. and M.C. Marsh 1902. The fishes of Puerto Rico. Investigations of the aquatic resoures and fisheries of Porto rico by the United States Fish Commission steameer fish Hawk in 1899. Part 1. G.P.O., Washington, D.C. v-xv, 1-350 + 49 pl.

Fournier and Breen 1984. Fournier, D.A: & Breen, P.A., 1983. Estimates of abalone mortality rates with growth analysis. Trans. Am. Fish. Soc. 112: 403-411.

Francis, R.I.C.C. 1990. Back-calculation of fish length: a critical review. J. Fish. Biol. 36:883-902.

Froese, R. and D. Pauly. Editors. 2004. FishBase. World Wide Web electronic publication. www.fishbase.org, version (09/2004).

Figuerola, M., D. Matos-Caraballo y, and W. Torres. 1998. Maturation and reproductive seasonality of four reef fish species in Puerto Rico. Proceedings of the Gulf and Caribbean Fisheries Institute 50:938-968.

Fischer, W. editor. 1979. FAO species identification sheets for fishery purposes, western central Atlantic, volume III. Food and Agriculture Organization of the United Nations, Rome, Italy.

Frota, L.O. P.a.S. Costa, and A.C. Braga. 2004. Length-weight relationships of amrine fishes from the central Brazilian coast. NAGA, 27(1&2):20-26.

Garcia, E.R., J.C. Potts, R.A. Rulifson and C.S. Manooch, III. 2002. Age and growth of yellowtail snapper, *Ocyurus chrysurus*, from the southeastern United States. Bull. Mar. Sci.. 72(3):909-921

Gayanillo, F.C., Jr., P. Sparre and D. Pauly. !995. The FAO-ICLARM Stock Assessment Tools. (FISAT) User's Guide. FAO Computerized Information series Fisheries, 8. Rome, Italy, FAO. 126 p.

Grimes, C. B. 1987. Reproductive biology of the lutjanidae: a review. Pages 239-294. *in* J. J. Polovina and S. Ralston (eds.) *Tropical Snappers and Groupers - Biology and Fisheries Management*. Westview Press, Inc.

Grimes, C.B. 1976. Certain aspects of the life history of the vermillion snapper, *Rhomboplites aurorubens* (Cuvier) from North and South Carolina waters. Ph.D. Dissertation, Univ. North Carolina, Chapel Hill, North Carolina. 240 p. [as referenced in Muller et al. 2003].

GMFMC, SAFMC et al. 2003. A stock assessment of yellowtail snapper, *Ocyrurus chrysurus*, in the Southeast United States. 217 p.

Hoffman, E.M. T.M. Bert, and M.M. Wilson. 2003. Genetic stock structure assessment of yellowtail snapper (*Ocyrurus chrysurus*). 14 p.

Johnson, A.G. 1983. Age and growth of yellowtail snapper from South Florida. Trans. Amer. Fish. Soc. 112:173-177.

Kimura, D.K. 1980. Likelihood methods for the von Bertalanffy growth curve. Fish. Bull. 77:765-766.

Jones, D.L., M. R. Lara, C.Yeung, M.M. Criales, T. L. Jackson, and W.J. Richards. Coastal Processes affecting larval supply into the Florida Bay: Snappers (Pisces: Lutjanidae). Poster Presentation.

Lindeman, K.C., R. Pugliese, G.T. Waugh, and J.S. Ault. 2000. Developmental patterns within a multipspecies reeffish fishery: Management applications for essential fish habitats and protected areas. Bull. Mar. Sci. 66(3): 929-956.

Lindeman, K.C. 1997. Development of grunts and snappers of southeast Florida: Cross-shelf distributions and effects of beach management alternatives. Ph.D. Dissertation, Univ. Miami, Coral Gables, FL. 419 p. [cited in Lindeman et al. 2000).

Longley, W.H. and S.F. Hildebrand. 1941. Systematic catalogue of the fishes of Tortugas, Florida with observations on color, habits, and local distribution. Pap. Tortugas Lab., 34 (Carnegie Inst. Wash. Pub. 5335): xiii + 331, 34 pls. [as referenced in Thompson and Munro 1974].

Lindholm, J. 2004. Research: Florida Keys Tagging, Movement patterns of coral reef fishes in the northern Florida Keys. Pfleger Inst. Env. Res. 2 p.

Loftus, W. F. 1992. *Lutjanus ambiguus* (Poey), a natural intergeneric hybrid of *Ocyurus chrysurus* (Bloch) and *Lutjanus synagris* (Linnaeus). Bull. Mar. Sci. **50**:489-500.

Manooch, C.S. III and C.L. Drennon. 1987. Age and growth of the yellowtail snapper and queen triggerfish collected from the U.S. Virgin Islands and Puerto Rico. Fish. Res. 6:53-68.

Marquardt, D.W. 1963. An algorithm for least squares estimation of non-linear parameters. J.Soc. Ind. Appl. Math. 11(2):431-441.

Mateo, I. and W. J. Tobias. 2001. Distribution of shallow water coral reef fishes on the northeast coast of St. Croix, USVI. Caribbean Jour. Science, 37(3-4):210-226.

Mexicano-Cíntora, G. and F. Arreguín-Sánchez, 1989. Estimación de edad y crecimiento del pargo canané (*Ocyurus chrysurus*) del litoral de Yucatán, México.. Centro de Investigación y Estudios Avanzados del Instituto Politécnico Nacional, Unida Mérida, México. (manuscript). 12 p., 3 tabs, 1 fig.

Muller, R.G., M.D. Murphy, J. de Silva, and L.R. Barbieri 2003. A stock assessment of yellowtail snapper, *Ocyrurus, chrysurus*, in the Southeast United states. (DRAFT). SEDAR 3 (Southeast Data, Assessment, Review) Workshop. IHR 2003-10. 182 p. Fl. Fish Wild. Comm., Fl. Mar. Res. Inst., St. Petersburg, FL.

Munro, J.L. V.C. Gaut, Rhompson, and P.H. Reeson. 1973. The spawning seasons of Caribbean reef fishes. J. fish Biol. 5:69-84.

Munro, J.L. 1987. Workshop synthesis and directions for future research. In J. Polovina and S. Ralston (eds.). Tropical snappers and groupers: biology and fisheries management, p. 639-659. Westview Press, Boulder, Colorado.

Nagelkerken, G. van der Velde, M.W. Gorissen, G.J. Meijer, T. van't Hof, and C. den Hartog. 2000. Importance of mangroves, seagrass beds and the shallow coral reef as a nursery for important coral reef fishes, using a visual census technique. Estuaries, Coastal and Shelf Science, 51:31-44.

Nakamura,E. L. 1976. Recreational fishing for snappers and groupers in the Gulf of Mexico. Pages 77-85 *in* H. R. Bullis, Jr and A. C. Jones (eds.). Proceedings: Colloquium on snapper-grouper fishery resources of the western Atlantic Ocean. Vol. Rept. #17, Mississippi.- Alabama Sea Grant.

Paiva, M. Pinto and A.A. Fonteles-Filho. 1995. Distribuicao e. abundancia de alguns pixes bentonicos na area de Abrolhos (Brazil). Arq. Cien. Mar. Fontaleza, 29(1-2):36-41.

Parrack, M.L. and N.J. Cummings. 2003. Errors in transforming length samples to age frequencies without age samples. Fish. Res. 63:235-243.

Pauly, D. 1980 On the interrelationships between natural mortality, growth parameters and the mean environmental temperature in 175 fish stocks. J. Cons. CIEM 39(3):175-192.

Pauly, D. & David, N., 1981. ELEFAN I, a BASIC program for the objective extraction of growth parameters from length-frequency data. Meeresforsch. 28: 205-211.

Pauly, D. & Gaschütz, G., 1979. A simple method for fitting oscillating length growth data, with a program for pocket calculator. Int. Council. Explor. Sea, Council Meeting 1979/G:24, Demersal Fish Cttee., 26

Pauly, Ilya . 1995. ICLARM - FishBase Project. www.fishbase.cigar.org

Piedra, G. 1969. Materials on the biology of the yellowtail snapper (*Ocyurus chrysurus* Black*)*. Pages 251-269 *in* A. S. Bogdanov (ed.). *Soviet-Cuban fishery research*. Translated from Russian: Israel Program for Scientific Translations, Jerusalem, Israel.

Pinkard, D.R. and J.M. Shenker. 2001. Seasonal variation in density, size, and habitat distribution of juvenile yellowtail snapper (*Ocyrurus chrysurus*) in relation to spawning patterns in the Florida Keys. Am. Zool. 41(6):1556-1557.

Randall, J. E. 1968. *Caribbean Reef Fishes*. TFH Publications, Inc., 350pp. 1st edition.

Randall, J.E. 1967. Feeding habits of West Indies reef fishes. Studies in tropical Oceanography 5, 847 p.

Randall, J.E. 1963. Additional recoveries of tagged reef fishes from the Virgin Islands. Proceedings of the Gulf and Caribbean Fisheries Institute 15:155-157.

Randall, J.E. Tagging reef fishes in the Virgin Islands. 1962. Proceedings of the Gulf and Caribbean Fisheries Institute 14:1201-241.

Rodriquez-Pino, Z. 1961. *Lutjanus ambiguous*. Cent. Invest. Pesq. Cuba 14:1-20.

Richards, W.J., K.C. Lindeman, J.L-Shultz, J.M. Leis, A. Ropke, M.E. Clarke, and B.H. Comyns. 1994. Preliminary guide to the identification of the early life history stages of lutjanids fishes of the western central Atlantic. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-345, 49 p.

Richards, W.J. 1988. Review of "Tropical snappers and groupers" by J.J. Polovina and S. Ralston (eds.). Bull. Mar. Sci. 42:342-343.

Riley, C. M., G. J. Holt, and C. R. Arnold. 1995. Growth and morphology of larval and juvenile captive bred yellowtail snapper, *Ocyurus chrysurus. Fish. Bull.* (93):179-185.

Roberts, Callum M. Connectivity and management of Caribbean coral reefs. Science 278: 1454-1457.

Rose, Ben. 1972. Balance of nature in Sparisoma uiride. Underwater Naturalist 7: pg 33.

Sarver, S. K., D. W. Freshwater, and P. J. Walsh. 1996. Phylogenetic relationships of western Atlantic snappers (family Lutjanidae) based on mitochondrial DNA sequences. *Copeia* 1996(3):715-721.

Sazima, I., R. L. Moura and C. Sazima, 1999. Cleaning activity of juvenile angelfish, *Pomacanthus paru*, on the reefs of the Abrolhos Archipelago, western South Atlantic.. Environ. Biol. Fish. 56(4):399-407.

Schultz, D.R., P.I. Arnold, T.R, Capo, C.B. Paris-Limouzy, J. E. Serafy, and W.J. Richards. 1996. Immunologic methods for species identification of early life stages of lutjanids fishes from the western central Atlantic. Part I: Characterization of an interspecies protein. Fish. Bull. 94:734-742.

Starck, W.A. 1971. Biology of the gray snapper, *Litjanus griseus*, (Linnaeus) in the Florida Keys. Stud. Trop. Oceanogr. Univ. Miami 10:12-150.

Starck, W.A. 1971. Biology of the gray snapper, *Lutjanus griseus* (Linnaeus) in the Florida Keys. Stud. Trop. Oceanogr. Univ. Miami 10: 12-150.

Thompson, R. and J.L. Munro. 1974. The biology, ecology, and bionomics of the snappers, Lutjanidae. In: Caribbean Coral Reef Fishery Resources, ed. By J.L. Munro. ICLARM Studies and Reviews 7: 94-109.

Thompson, R. and J. L. Munro. 1983. The biology, ecology, and bionomics of Caribbean reef fishes: Lutjanidae (snappers). Pages 94-109 *in* J. L. Munro (ed.). *Caribbean coral reef fishery resources.* ICLARM Studies Rev. 7. Manila, Philippines.

U.S.F.D.A. 2004. Seafood Products Research Center, Center for Food Safety and Applied Nutrition, Regulatory Fish Encyclopedia (RFE). RFE Page1 2 p.

Vose, F.E. and B. Shank. 2003. Feeding ecology of four species of snappers (Lutjanidae) from southeast Florida waters. Fl. Mar. Res. Inst. Unpublished report. St. Petersburg, Fl. [in Barbieri and Colvocoresses 20034] [as referenced in Muller et al. 2003].

Vergara, R.R. 1980. Consideraciones filogeneticas sobre las especies Cubanas Genero *Lutjanus* (Lutjanidae, Perciformes, Teleostei). Informe Cientifico-Technico 113:1-39. *[cited in Sarver et al. 1996].*

Wallace, E.M. et al. 2003. Genetic stock structure assessment of yellowtail snapper (*Ocyurus chrysurus*) in southern Florida, estimated by mtDNA D-loop sequencing. Special Report to the Fish and Wildlife Conservation Commission (preliminary draft, not for distribution or citation).

Watson, M. and J.L. Munro. 2004. Settlement and recruitment of coral reef fishes in moderately exploited and overexploited Caribbean ecosytems: implications for marine protected areas. Fish. Res. 69:415-425.

Watson, M., J.L. Munro, and F.R. Gell. 2002. Settlement, movement and early juvenile mortality of the yellowtail snapper, *Ocyurus chrysurus*. Mar. Ecol. Prog. Ser., 237:247-256.

Wetherall, J.A., J.J. Polovina and S. Ralston. 1987. Estimating growth and mortality in stead-state fish stocks from length-frequency data. Pages 53-74 in D.Pauly and G. Morgan (eds). Length-based methods in fisheries research. ICLARM, Manila.

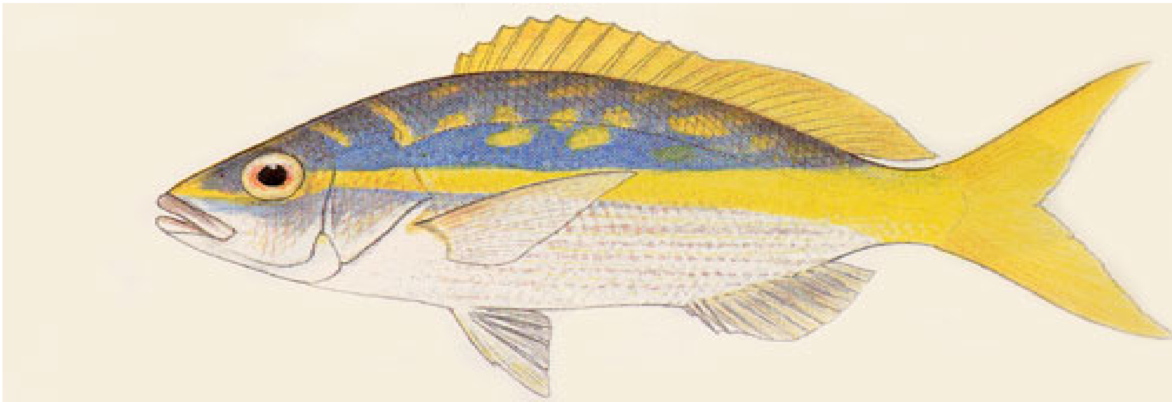

Figure 1. Yellowtail snapper, *Ocyurus chrysurus,* from Fishbase 2004 (FAO species Catalogue).

Figure 2. Worldwide distribution of yellowtail snapper from Fishbase 2004 Fishmapper.

Figure 3a. Yellowtail snapper stamp from Fishbase 2004, submitted by F. Lehmann.

Figure 3b. Yellowtail snapper stamp from Antigua and Barbuda from Fishbase 2004, submitted by Paolo Bottini.

Figure 3c. Yellowtail snapper stamp from Belize from Fishbase 2004, submitted by Ilya Pauly.

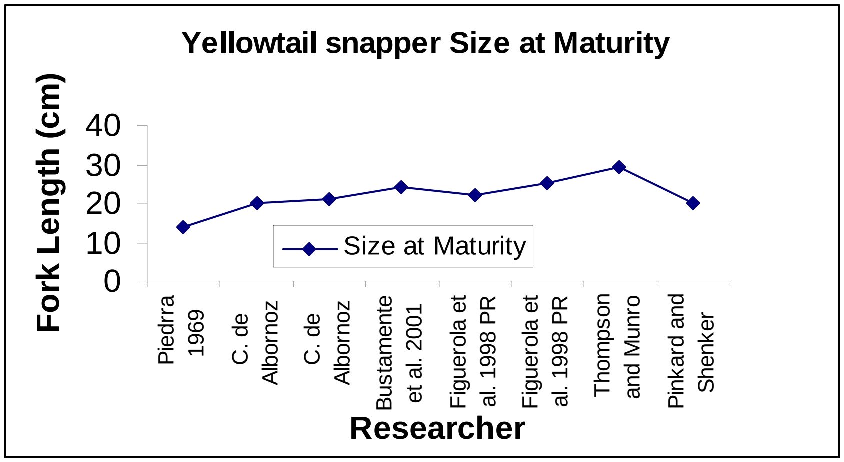

Figure 4. Observed size at at maturation for yellowtail snapper from eight researchers throughout the Caribbean and south Florida.

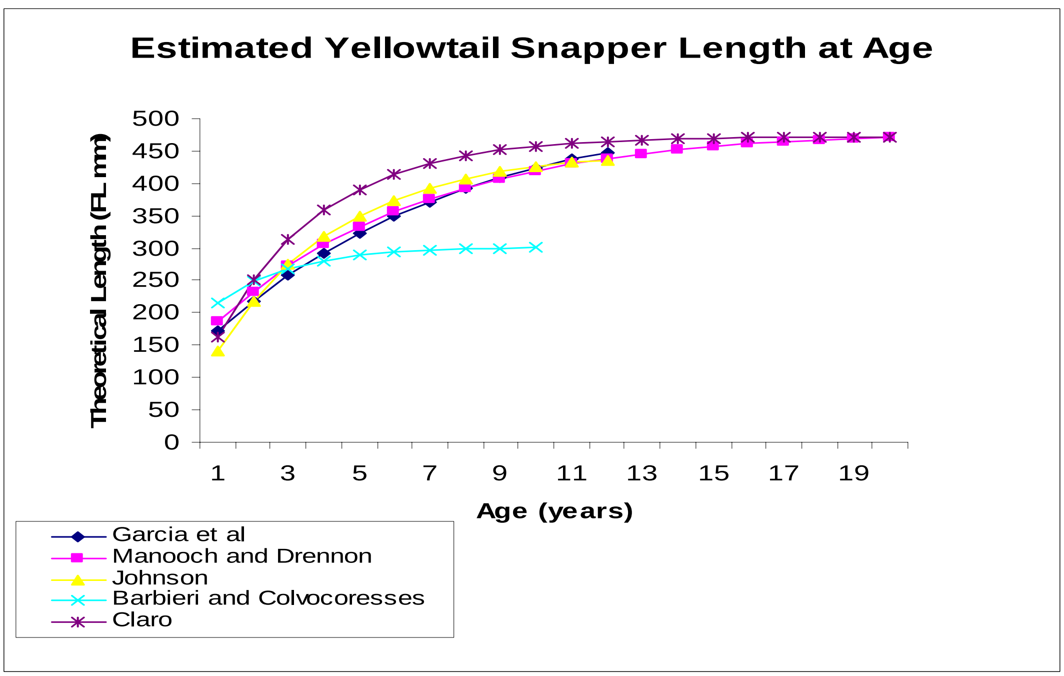

Figure 5. Theoretical length at age for yellowtail snapper from hardpart studies.

Table 1. Length to length conversions for yellowtail snapper, *Ocyrurus chrysurus*, sexes combined.

FL(cm) = 0.17 + 1.09 x SL (cm), n=548, Length range(cm)=14.0-38.0 Cuba (Claro 1983)
FL(mm) = 17.7 + 0.78 x TL(mm), n=?? , r=0.97, south FL (Johnson 1983)
SL(cm) = 0.3 + 0.828 x FL(cm), n=23, Length range(cm)=8.0-52.0, Jamaica (Thompson and Munro 1983)
TL(cm) = -0.8 + 1.266 x FL(cm), n=23, Length range(cm)=8.0-52.0, Jamaica (Thompson and Munro 1983)

TL(mm)= 1.3126 x FL(mm) - 23.1166, N=409, Florida (Muller et al. 2003)
TL(mm)= 1.3341 x SL(mm) + 19.8671, N=1,547, Florida (Muller et al. 2003)

FL(mm)= 0.7473 x TL(mm) + 23.4645, N=409, Florida (Muller et al. 2003)
FL(mm)= 1.1080 x SL(mm) + 10.3715, N=409, Florida (Muller et al. 2003)

SL(mm)= 0.8883 x FL(mm) - 4.7384, N=409, Florida (Muller et al. 2003)
SL(mm)= 0.66867 x TL(mm) + 7.9526),N=1,547, Florida (Muller et al. 2003)

SL(mm)=4.52 + 0.69 x TL(mm), N=1,610,r=0.97 (Barbieri and Colvocoresses 2003)

TL(mm)= 9.96 + 1.20 x FL(mm), N=1,254, r=0.94 (Garcia et al. 2003)
FL(mm)= 7.56 + 0.79 x TL(mm), N=1,254, r=0.97 (Garcia et al. 2003)

FL(mm)=18.304 + 0.7587 x TL(mm), N=243,r=.981(Bendezu unpublished), south Florida

Table 2a. Observed sizes at maturation for yellowtail snapper, *Ocyrurus chrysurus*

Area	Males	Females	Reference
Cuba	13-14 cm (mature fish, unsexed)		Piedra 1969, western Cuba
Jamaica	26 cm FL	29-31 cm FL	Thompson and Munro 1973
Puerto Rico	22.4 cm FL	24.8 cm FL	Figuerola et al. 1998
south Fl	21 cm TL (mature, unsexed)		Muller et al. 2003
south FL	19 cm FL	20 cm FL	Collins and Finucane (1989)

Table 2b. Observed seasons of spawning for yellowtail snapper, *Ocyrurus chrysurus*

Area	Peak spawning period	Range of months	Comments
Cuba	April - May	March - September	Piedra 1969, western Cuba
Jamaica	February - April	Year round, ripe fish observed, oceanic banks only	Thompson and Munro 1973
Puerto Rico	April - July	February - October	Figuerola et al. 1998
south FL	April - August		Allen 1985
south FL	April - August	January - December	Collins and Finucane 1989
	Collins and Finucane noted that individuals >280mm tended to mature earlier in the year than smaller sized individuals.		
south FL		spring-early fall	Barbieri and Colvocoresses 2003)

Table3a. Fecundity of four yellowtail snapper off western Cuba (from Piedra 1969).

Length (mm)	Individual fish Weight (grams)	Ovary Weight	Total # eggs[1]
292	402	9.74	176,660
382	920	35.00	618,742
302	460	7.27	99,666
305	460	8.69	1,472,594[2]

[1]Total number eggs determined from 3 samples.

[2]Piedra's estimate for the 305 mm fish was edited to 145,000 eggs by Collins and Finucane (1989)

Table 3b. Fecundity of yellowtail snapper off the southwest coast of Cuba (from Carrillo de Albornoz and E. Grillo 1993).

Fecundity = 1,097 x FL (cm) ** 2.8831, r=0.9081, length range of fish in the estimation was from 19 cm to 38 cm (FL), n=60 individuals

Table 3c. Fecundity information for yellowtail snapper from south Florida (from Muller et al. 2003)

Proportion mature (Length) = exp(0.0114 * TL(mm) - 2.383) / (1 + exp(0.0114 * TL(mm) - 2.383))

The above equation estimates that approximately the size of 50 % maturation occurrs at about 209 TL (mm)

Proportion mature (Age) = exp(2.349 * Age - 4.004) / (1 + exp(2.349 * Age - 4.004))

Table 3d. Fecundity estimates from Collins and Finucane (1989) for the Florida Keys

Egg Number = $4.575 * 10^{-2}$ (FL mm) ** 2.627 (r=0.658, n=60 fish from 200-480 mm)

Egg Number = $2.661 * 10^{2}$ (TW grams) ** 1.043 (r=0.721, n=60 fish from 168 to 1,784 grams TW) and

TW (grams) = $2.92978 * 10^{-5}$ * FL (mm) ** 2.91762 (r=0.837 n=109)

Table 4a. Observed maximum sizes for yellowtail snapper, *Ocyrurus chrysurus*

Area	males	females	unsexed	Reference	Years
Cuba				Piedra 1969, western Cuba	
Jamaica	55 cm	56 cm		Thompson and Munro 1973, Virgin populations	
Puerto Rico			71 cm,5 l bs	Randall (1968)	
US Virgin Is	55	56		Reference??	
South FL	42 cm FL	40.1 cm FL	56.7 cm FL	Johnson 1983	
Florida			54 cm FL	Bendezu unpublished 2002	

Table 4b. Relationship between flork lengths (FL) and body depths (D) of the yellowtail snapper, *Ocyurus chrysurus*.

Relationship	Sample Size	Length Range observed
FL= -1.2 + 3.686 D	18	8-23 cm FL

From Bohlke and Chaplin 1968 as cited in Thompson and Munro 1974.

Table 5. Estimated theoretical length at age (TL mm) for yellowtail snapper from growth equations derived from hardparts

Age(years)	*Garcia (n BCL's)*	*Manooch and Drennon 1987 (n BCL's)*	*Johnson 1983 (n BCL's))*	*Barbieri and Colovoroscess 2003*	*Claro 1983*	*Piedra 1965*
1	*171.91 (11)*	*186.79 (44)*	*142.00 (77)*	*215.68*	*162.73*	*213.59*
2	*217.91 (492)*	*233.22 (36)*	*217.21 (243)*	*247.94*	*250.38*	*277.33*
3	*257.89 (549)*	*272.40 (23)*	*274.10 (190)*	*268.10*	*313.27*	*326.48*
4	*292.66 (232)*	*305.45 (89)*	*317.15 (133)*	*280.70*	*358.40*	*364.38*
5	*322.88 (77)*	*333.33 (128)*	*349.71 (92)*	*288.57*	*390.78*	*393.60*
6	*349.16 (25)*	*356.85 (80)*	*374.35 (30)*	*293.50*	*414.00*	*416.13*
7	*372.00 (7)*	*376.70 (34)*	*392.98 (10)*	*296.57*	*430.67*	*433.50*
8	*391.86 (3)*	*393.44 (15)*	*407.08 (12)*	*298.50*	*442.63*	*446.89*
9	*409.12 (1)*	*407.57 (5)*	*417.75 (10)*	*299.70*	*451.21*	*457.22*
10	*424.13 (3)*	*419.49 (2)*	*425.82 (5)*	*300.45*	*457.37*	*465.18*
11	*437.18 (0)*	*429.54 (2)*	*431.93 (2)*	*300.92*	*461.78*	*471.32*
12	*448.52 (1)*	*438.02 (0)*	*436.55 (2)*		*464.95*	*476.06*
13	*458.38 (2)*	*445.18 (0)*	*440.04 (1)*		*467.23*	*479.71*
14		*451.22 (0)*			*468.86*	*482.52*
15		*456.31 (1)*			*470.03*	*484.69*
16		*460.61 (6)*			*470.87*	*486.36*
17		*464.23 (3)*			*471.47*	*487.65*
n	*Sum up*			*NA*	*NA*	*NA*
Linfinity	*524*	*483.8*	*450.9*	*301.7*	*473*	*492*
K	*0.14*	*0.17*	*0.279*	*0.47*	*0.332*	*0.26*
tzero	*-1.84*	*-1.87*	*-0.3557*	*-1.67*	*-0.27*	*-1.19*
Gear	*Hook and Line:Commercial and headboat*	*Hook and Line and Traps: Commercial*	*Hook and Line: commercial, recreational*	*Fishery Independent sampling, traps and hook and line*	*Trawls, traps*	*Hand line,traps, Seines*
Structure	*Sectioned Otoliths*	*Sectioned Otoliths*	*Sectioned Otoliths*	*Sectioned Otoliths*		*Vertebrae (urohial)*
Estimation Method	*Mean BcL's at age*	*Individual BCL's at age*	*Mean BCL's at age*	*Non-Linear LSsquares fit to observed lengths at age*	`	*Unclear,Estimates Not corroborated*

Table 6. Weight – length conversion formulae for yellowtail snapper populations.

Study	Location	Years in Study	Relation	n	Size range	R
Johnson (1983)	South Florida	1979-1980	$W(g)=6.13 \times 10^{-5}$ $FL(mm)^{2.76}$	517	100-500 mm	0.97
Manooch and Drennon (1987)	U.S. VI Puerto Rico	1983-1984	$W(g)=1.17*10^{-4}FL(mm)^{2.6504}$	171	140-590 mm	NA
Garcia et al. (2003)	South Florida	1994-1999	$W(g)=4.14 \times 10^{-5}FL(mm)^{2.83}$	1,254	NA	0.94
Garcia et al. (2003)	South Florida	1994-1999	$W(g)=3.64 \times 10^{-5}TL(mm)^{2.76}$	1,254	NA	0.93
Piedra (1969)	Cuba	1957-1963	$W(g)=7.327 \times 10^{-4}TL(mm)^{2.73927}$	5,823	NA	NA
Barbieri and Colvocoresses (2003)	South Florida	1997-2003	$TW(g)=2.95 \times 10^{-5}TL(mm)^{2.80}$ sexes combined $TW(g)=3.26 \times 10^{-5}TL(mm)^{2.78}$ females $W(g)=3.01 \times 10^{-5}TL(mm)^{2.80}$ males	1,415 690 622	NA NA NA	0.99 0.98 0.98
Frota et al. (2004)	Central Brazil	1993-2000	$TW(g)=3.28 \times 10^{-2}FL(mm)^{2.812}$ $TW(g)=2.35 \times 10^{-2}\cdot TL(mm)^{2.74}$	986 661	230-535 mm 280-638 mm	0.99 0.99

NA= not available.