CHAPTER 2.1.10.4: KING MACKEREL	AUTHORS: F. LUCENA-FRÉDOU, R. SIQUEIRA LIMA and T. FRÉDOU (UFRPE); B. MOURATO (UNIFESP)	LAST UPDATE: June 2021 Original: English

2.1.10.4 Description of king mackerel (KGM)

1. Names

1.a. Classification and taxonomy

Species name: *Scomberomorus cavalla* (Cuvier, 1829)
ICCAT species code: KGM
ICCAT names: King mackerel (English), Thazard (French), Carite lucio (Spanish).

According to Collette and Nauen (1983), the king mackerel is classified as follows:

- Phylum: Chordata
- Subphylum: Vertebrata
- Superclass: Gnathostomata
- Class: Osteichthyes
- Subclass: Actinopterygii
- Order: Perciformes
- Suborder: Scombroidei
- Family: Scombridae
- Genus: Scomberomorus
- Species: *Scomberomorus cavalla*

1.b. Common names

List of vernacular names used by different countries according to ICCAT, FAO and Fishbase (www.fishbase.org).

The list of countries is not exhaustive and some local names might not be included.

Brazil: Cavala, Cavala-aipim, Cavala-branca, Cavala-perna-de-moça, Cavala-preta, Cavala-sardinheira, Cavala-verdadeira, Perna-de-moça.
China Main: 大耳馬鮫.
Colombia: Carite, Carito.
Cuba: Serrucho, Sierra.
Denmark: Atlantisk kongemakrel.
Dominican Republic: Carite, Sierra.
France: Thazard barré.
Finland: Kuningasmakrilli.
Former USSR: Korolevskaya makrel.
French Guiana: Maquereau.
Germany: Königsmakrele.
Italy: Sgombro reale.
Japan: Oo-sawara, Sawara.
Martinique: Taza blan, Thazard barré.
Mexico: Carito, Carito lucio, Peto.
Nicaragua: Carite lucio.
Norway: Kongemakrell.

Poland: Makrela kawala.
Portugal: Cavala, Cavala inpigem, Cavala verdadeira, Serra real.
Puerto Rico: Carite.
Russian Federation: Korolevskaya makrel, кавалла.
Spain: Carite lucio, Sierra.
Sweden: Kungsmakrill.
Trinidad Tobago: Kingfish, Log, Taza.
UK: King mackerel, Kingfish.
USA: King mackerel, Kingfish.
Venezuela: Carite lucio, Carite sierra, Rey, Sierra.

2. Identification

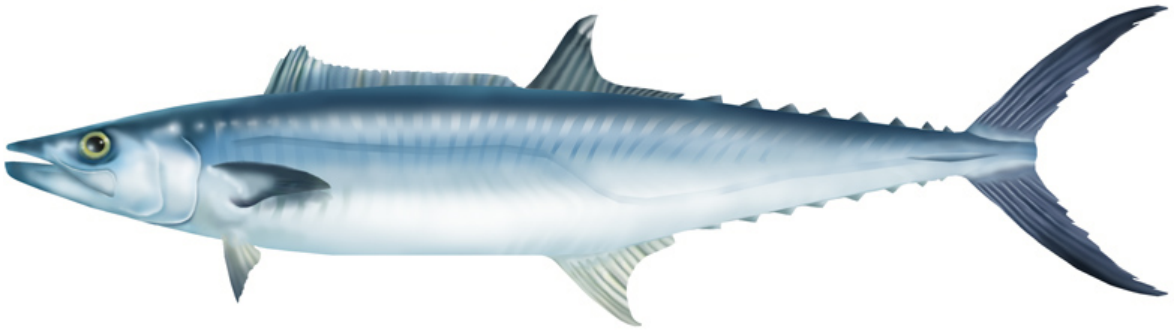

Figure 1. Drawing of an adult king mackerel (by A. López, 'Tokio').

Characteristics of *Scomberomorus cavalla* (see Figure 1 and Figure 2)

King mackerel is a small tuna species with a reported maximum size of 182.2 cm fork length (FL) in Northwest Atlantic (Manooch *et al.*, 1987) and 136 cm FL in the Southwest region (Nóbrega and Lessa, 2009). Maximum weight is 45 kg weight (Collette and Nauen, 1983).

Colour:

- Colour plain silver on sides without bars or spots.
- Juveniles with bronze spots smaller than the pupil of the eye in 5-6 irregular rows.
- No black area on the anterior part of the first dorsal fin.

External:

- Body elongated and strongly compressed.
- Body entirely covered with small scales.
- Snout much shorter than rest of the head.
- Posterior part of maxilla exposed.
- Gill rakers on first arch: 1-3 on upper limb; 6-10 on lower limb; usually 9-10 total.
- Two scarcely separated dorsal fins. First dorsal with 12-18 spines (usually 15). Second dorsal with 15-18, followed by 7-10 finlets (usually 9).
- Anal fin with 16-20 rays (usually 18-19) followed by 7-10 finlets (usually 8).
- Pectoral fin with 21-23 rays.
- Lateral line abruptly curving downward below second dorsal fin.
- Inter-pelvic process small and bifid.

Internal:

- Swim bladder absent.
- Vertebrae: 41-43.
- Intestine with two folds and 3 limbs.

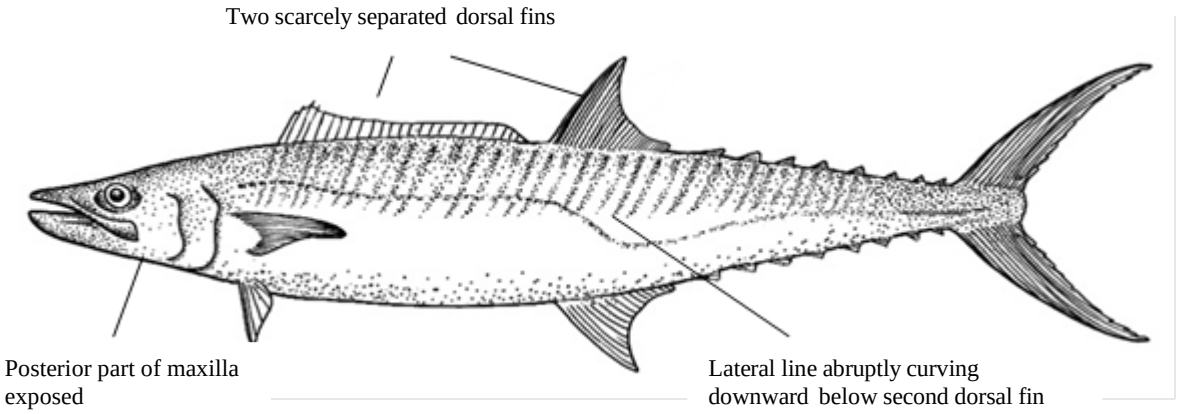

Figure 2. Synthesis of the most outstanding characteristics of king mackerel (by A. López, 'Tokio').

3. Distribution and population ecology

3.a. Geographical distribution

This species is distributed at western Atlantic from Massachusetts (USA) to São Paulo, Brazil, with a higher probability of occurrence in Northeast Brazil, Gulf of Mexico and Caribbean (**Figure 3**). It also inhabits Saint Paul's Rocks in eastern central Atlantic (Collette and Nauen, 1983; Lubbock and Edwards, 1981).

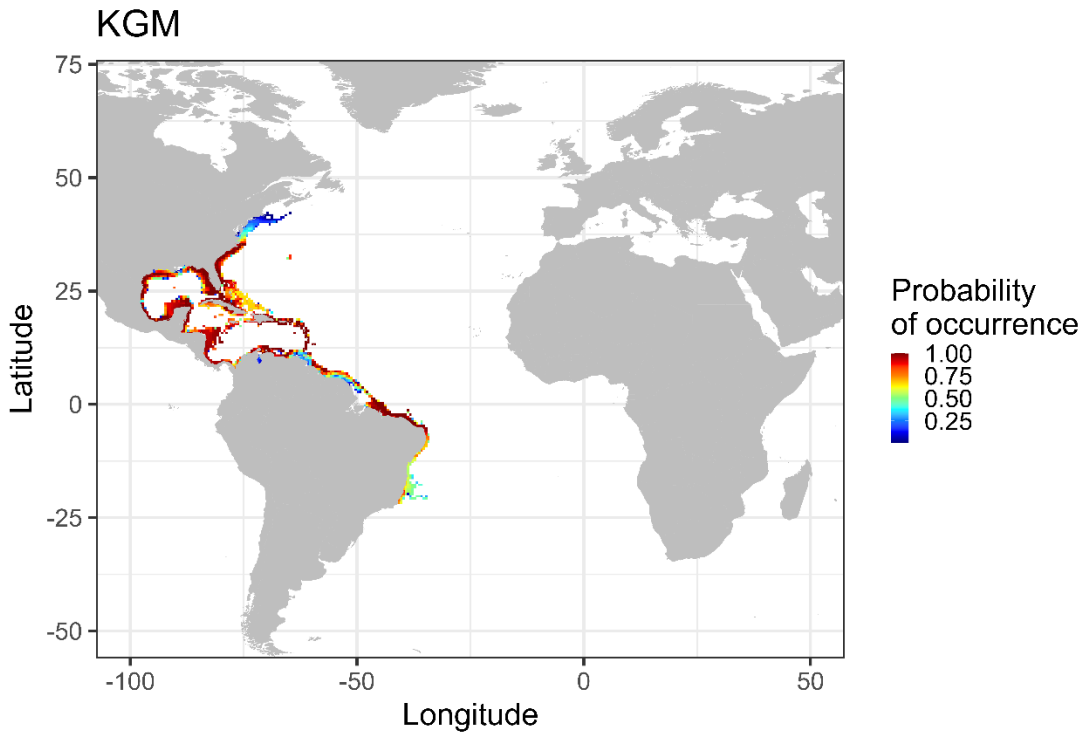

Figure 3. Native spatial distribution map for king mackerel based on data available on aquamaps.org website. Distribution range colours indicate degree of probabilities of occurrence.

3.b. Habitat preferences

King mackerel is an epipelagic and neritic fish occurring in coastal waters within the 20°C isotherm in both hemispheres. Often found in outer reef areas.

Larvae are encountered in surface waters of 26.3° to 31°C (McEachran *et al.*, 1980).

3.c. Migrations

King mackerel show a cyclical pattern of movement along the coasts of the southeastern United States and Gulf of Mexico. Large schools migrate over considerable distances along the Atlantic US coast depending on water temperature. They migrate off west-central Florida from April to May and from October to November, remaining within coastal ocean temperatures of 20–26ºC (Manooch, 1979). Some fish may be residents in southeastern Florida waters (Sutter *et al*., 1991a). Cyclical tag return patterns were noted along eastern Florida and in North Carolina. The proportion of mixing of stocks along eastern Florida may vary yearly (Fable *et al*, 1987; Schaefer and Fable, 1994).

In Gulf of Mexico, a western stock migrates northward along the Mexico-Texas coast during the spring and early summer from its winter grounds at Yucatan Peninsula, and an eastern stock migrates at the same time northward along the eastern coast of the Gulf of Mexico from its winter grounds in South Florida. Both stocks migrate simultaneously into the northern Gulf of Mexico and mix at varying degrees in the northern summering grounds (Johnson *et al*., 1994).

King mackerel appears to be present throughout the year off Louisiana and off the state of Ceará in northeastern Brazil.

4. Biology and life history parameters

For this manual and species, two stocks unit areas, previously defined by ICCAT for data collection and management purposes, were considered to summarize results: Southwest Atlantic (SW) and Northwest Atlantic. Aspects of the biology of the king mackerel for both Northwest and Southwest Atlantic are available and, overall, for K, $L\infty$, L_{50} and T_{MAX}, estimates for both areas may be considered similar.

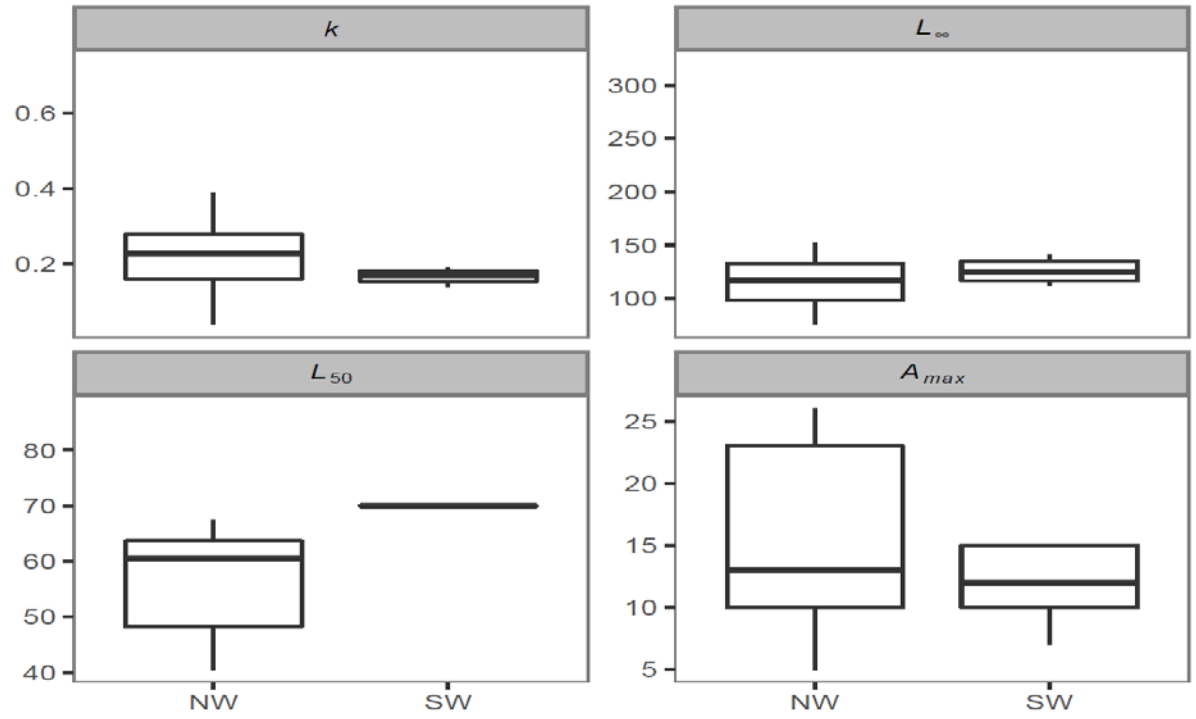

Figure 4. Life history parameters for King Mackerel by ICCAT area. Von Bertalanffy body growth coefficient (k), Von Bertalanffy asymptotic length ($L\infty$), length at 50% maturity (L_{50}), Maximum Age (A_{MAX}, years). Fork Length in cm.

4.a. Growth

Estimates of growth parameters for the king mackerel date back to the 1970s. The most recent estimates for the Northwest Atlantic (Shepard *et al*., 2010), consider the growth parameters by Northwest area and sex (**Table 1**). For the Southwest Atlantic, the most recent estimated were also obtained by sex but also by males and females combined (Nóbrega and Lessa, 2009). The growth parameters may differ between males and females. Females have slower growth and higher asymptotical length (116.8 cm (L∞) and 0.190 y^{-1} (k) for males; 132.7 cm (L∞) and 0.159 (k) y^{-1} for females; Nóbrega and Lessa, 2009). Maximum age reported is 26 and 15 y^{-1} for the Northwest and Southwest Atlantic respectively (Ortiz and Palmer, 2008; Nóbrega and Lessa, 2009).

Table 1. Growth parameters for king mackerel (L∞ in cm, K in y^{-1}, to in y). NW – Northwest Atlantic. SW – Southwest Atlantic. GOM – Golf of Mexico.

Growth parameters							
L∞	K	to	Area	Country	Reference	Sex	Method
137	0.15	-0.13	SW	Brazil	Carneiro Ximenes et al., 1978	All	Otoliths
140	0.15	-1.52	NW	Trinidad Tobago	de Sturm and Salter, 1990	All	Otoliths
140	0.19	-0.54	NW	Mexico	Arreguin-Sanchez, 1995	All	Length
107	0.21	-1.39	NW	USA	Johnson et al., 1980	Males	Otoliths
147.8	0.115	-	NW	USA	Manooch et al., 1987	All	Otoliths
112.7	0.213	-	NW	USA	Collins et al., 1988	All	Otoliths-whole
127.7	0.087	-	NW	USA	Collins et al., 1988	All	Otoliths-section
132.6	0.127	-	NW	USA	Sutter et al., 1991b	All	Mark-recapture
152	0.07	-	NW	USA	Sutter et al., 1991b	All	Mark-recapture
114	0.245	-0.16	NW	USA	Ortiz et al., 2008	All	Otoliths
121.6	0.228	-0.16	NW	USA	Ortiz et al., 2008	Females	Otoliths
98.2	0.316	-1.34	NW	USA	Ortiz et al., 2008	Males	Otoliths
124.5	0.256	-0.173	NW (GOM)	USA	Shepard et al., 2010	Females	Otoliths
92.2	0.353	-0.166	NW (GOM)	USA	Shepard et al., 2010	Males	Otoliths
111.6	0.464	0.506	NW	USA	Shepard et al., 2010	Females	Otoliths
98.6	0.51	0.502	NW	USA	Shepard et al., 2010	Males	Otoliths
124.9	0.165	0.27	SW	Brazil	Nóbrega and Lessa, 2009	All	Otoliths-section
132.7	0.159	0.387	SW	Brazil	Nóbrega and Lessa, 2009	Females	Otoliths-section
116.8	0.19	0.377	SW	Brazil	Nóbrega and Lessa, 2009	Males	Otoliths-section

No information on conversion factors is available for this species.

4.b. Length-weight relationship

Published length-weight relationships for several geographical areas in Atlantic are showed in **Table 2**. Except for some estimates, most equations point the relationship as isometric (b ≈3).

Table 2. Published king mackerel length-weight relationships. NW – Northwest Atlantic. SW – Southwest Atlantic.

Equation	N	FL range (cm)	Sex	Area	Country	Reference
$W=0.000025 \times FL^{2.83}$	480	42 - 123	All	NW	Mexico	Medina-Quej and Domínguez, 1997
$W=0.0157 \times FL^{2.87}$	311	46 - 105	-	NW	Cuba	León and Guardiola, 1984
$W=0.015 \times FL^{2.893}$	186	46 - 105	-	NW	USA	Finucane et al., 1986
$W=0.0102 \times FL^{2.93}$	335	39 - 159	Female	SW	Brazil	Nomura and de Sousa Rodriguez, 1967
$W=0.0091 \times FL^{2.96}$	338	35 - 155	Male	SW	Brazil	Nomura and de Sousa Rodriguez, 1967
$W=0.0133 \times FL^{2.94}$	237	46 - 115	Male	NW	USA	Beaumariage, 1973
$W=0.0039 \times FL^{3.13}$	293	39 - 159	Female	NW	USA	Beaumariage, 1973
$W=0.0084 \times FL^{2.99}$	2821	35 - 155	-	NW	USA	Johnson et al., 1983
$W=0.0068 \times FL^{3.02}$	666	46 - 115	-	SW	Brazil	Nomura and Costa, 1966
$W=0.0027 \times FL^{3.23}$	197	58 - 150	-	NW	USA	Beardsley and Richards, 1970
$W=0.00005 \times FL^{2.78}$	696	-	-	NW	México	Aguilar-Salazar et al., 1990
$W=0.00001 \times FL^{2.95}$	452	≈ 34 - 120	All	SW	Brazil	Lessa et al., 2004

4.c. Reproduction

- *Spawning*

Spawning takes place from May through September in the western Gulf of Mexico (Finucane *et al*., 1986), particularly in September at depths between 35 and 180 m over the middle and outer continental shelf (McEachran *et al*., 1980), peaking in July and August in the northeast Caribbean (Erdman, 1977). In northeast Brazil, the species is reported to spawn all over the year (Fonteles-Filho, 1988), but mainly from October to March (spring and summer) (Gesteira and Mesquita, 1976). In Trinidad Tobago, spawning takes place throughout the year around the island, with peak spawning from October through March (de L. Sturm and Salter, 1990). Recent evidence for king mackerel in Gulf of Mexico and U.S. South Atlantic indicates that this species are indeterminate spawners, with the possibility of multiple spawning events over a protracted (months long) reproductive season. The highest spawning fraction were observed in May and June in the US Atlantic coast, and June in the Gulf of Mexico (Fitzhugh *et al*., 2008). In Puerto Rico, the spawning season for *S. cavalla* is also extended, although limited or no activity was detected between September and March (Figuerola-Fernández *et al*., 2007) (**Table 3**).

Table 3. Period of main spawning activity for the king mackerel off the Atlantic Ocean (grey). NW – Northwest Atlantic; SW – Southwest Atlantic.

Location	*J*	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*	*Reference*
AT-NW (Gulf of México)													Finucane *et al*., 1986
AT-NW (northeast Caribbean)													Erdman, 1977
AT-SW (Brazil)													Gesteira and Mesquita, 1976
AT-NW (Trinidad Tobago)													de Sturm and Salter,1990
AT-NW (Puerto Rico)													Figuerola-Fernández *et al*., 2007
AT-NW (US coast)													Fitzhugh *et al*., 2008
AT-NW (Gulf of México)													Fitzhugh *et al*., 2008

- *Maturity*

Length at first maturity may vary among areas for the species. Fork length at first maturity off Florida is 73 cm in males and 84 cm in females (Beaumariage, 1973). All females were mature at 85-89.9 cm fork length at Gulf of Mexico and USA waters (Finucane *et al*., 1986). In Brazil, females reach their first sexual maturity around 63 – 70 cm and 4 years old (Gesteira and Mesquita, 1976; Lessa *et al*., 2004). In Trinidad, first spawning takes place at ages 1-2 for both sexes (de Sturm and Salter,1990). In Puerto Rico, males mature at 450 mm FL, whether females do so at 585 mm FL; all males and females larger than 550 and 750 mm FL, respectively, were mature (Figuerola-Fernández *et al.*, 2007). Average generation length across the species range has been estimated at nine years (Collette et al., 2011).

Table 4. Published king mackerel maturity studies off the Atlantic Ocean. NW – Northwest Atlantic; SW – Southwest Atlantic.

L_{50} (cm)	***Sex***	***Location***	***Reference***
73	Males	AT-NW (Florida)	Beaumariage, 1973
84	Females	AT-NW (Florida)	Beaumariage, 1973
70	Both	AT-SW (Northeast Brazil)	Lessa *et al*., 2004
63	Both	AT-SW (Northeast Brazil)	Gesteira and Mesquita, 1976
45	Males	AT – NW (Puerto Rico)	Figuerola-Fernández *et al.*, 2007
58.5	Females	AT – NW (Puerto Rico)	Figuerola-Fernández *et al.*, 2007

- *Sex ratio*

Sex ratio is unbalanced with a predominance of females in Ceará, Northeast Brazil (Fonteles Filho, 1988), however, the opposite was reported for the overall coast of the region (3:1; favourable to males). This could be related to the low depth of the catches (mean of 18 m) suggesting a differential distribution by sexes (Lessa *et al*., 2004). In Trinidad, fishery females predominate in all size groups, with the proportion of males increasing during the peak spawning season (de Sturm and Salter, 1990). Females dominated catches in most months and comprised a greater portion of the recreational than the commercial landings in USA. Female percentage was usually lower in the warmer than in the colder months and, in general, female percentage increased with an increase in fish size (Trent *et al*., 1987).

- *Fecundity*

In Brazil, the fecundity of 63 to 123 cm long females ranges from 345 000 to 2 280 000 eggs (absolute fecundity per total length: $F=(-18.763+0.321\ L) \times 10^5$) (Ivo Correa, 1974). The eggs-length relationship used in the Gulf of Mexico and Northwest Atlantic is $Eggs = 0.0000073141*Length^{3.0087053}$ (SEDAR, 2020a, b).

Estimates of fecundity on the south Atlantic and Gulf of Mexico coasts of the United States, ranged from about 69,000 to 12,207,000 eggs for fish from 446 to 1,489 mm fork length (Finucane *et al*., 1986). More recent estimates observed that batch fecundity was lower in East Florida (Atlantic) than in Northwest Florida (NE Gulf of Mexico), but it indicated that king mackerel have a greater reproductive potential than previously reported: a single batch should equal 560,000 ova for, for example, a 800 mm female, and thus three spawning events could exceed the egg production of the earlier estimate of Finucane *et al*. (1986) (Fitzhugh *et al*., 2009).

4.d. First life stages

- *Eggs and larvae*

Eggs are pelagic, 0.90-0.98 mm in diameter and with one oil globule (0.30-0.32 mm in diameter). The yolk is homogeneous. Larvae present pigmentation on forebrain, midbrain, over gut, cleithral symphysis, ventral margins of tail, distinct patch on each side of tongue (Richards, 2005). Larvae of the king mackerel seem to grow from 0.54 to 1.33 mm per day (De Vries *et al*., 1990). Larvae are encountered in surface waters of 26.3–31°C and 26.9–35ppm (Collette *et al*., 2011).

4.e. Diet

The species have sharp, non-serrated, laterally compressed teeth (Morgan and King, 1983), suited for cutting soft-bodied prey (Wall *et al*., 2009). King mackerel attain high strike velocities resulting in forward forces being exerted on their prey during ram feeding (Ferguson *et al*., 2015). It can reach high swimming speeds to chase prey and use sharp teeth to impart high bite pressure, factors which apparently alleviate the need for high bite forces.

King mackerel are opportunistic feeders like other members of the tuna and mackerel family (Scombridae) (Wall *et al*., 2009). It feeds primarily on fishes, especially clupeids (*Opisthonema, Harengula, Brevoortia, Sardinella*) with smaller quantities of penaeid shrimps and squids (Menezes, 1969; Devane, 1978; Naughton and Saloman, 1981).

4.f. Physiology

There is a lack of information on this topic.

4.g. Behaviour

This species makes large schools of similar sized individuals.

4.h. Natural mortality

In Gulf of Mexico, the natural mortality was estimated to be M = 0.4 (Arreguin-Sanchez *et al.*, 1995). According to SEDAR (2020a, b), M varies according to age – from 0.657 (age 0) to 0.157 (Age 11+). In Northeast Brazil, M was obtained as 0.2 (Lessa *et al*., 2004)

4.i Stock structure

Tagging efforts in the 1970s and 1980s indicated that there are three migratory groups of king mackerel in United States waters: a Western Gulf of Mexico, Eastern Gulf of Mexico, and Atlantic (Johnson *et al*., 1994, Shepard *et al*. 2010). However, since there are no genetic differences between the two Gulf of Mexico populations, the species is managed as two migratory stocks: Gulf of Mexico and the southeastern US coast (Gold *et al*., 2002). De Vries *et al*. (2002) have estimated stock composition in the mixed-stock fishery which operates off southeast Florida in winter when stocks mix (De Vries *et al*., 2002). Studies carried out in North and Northeast Brazil revealed that there is only one panmictic population, and low levels of genetic variability were verified (Santa Brígida *et al*., 2007).

5. Description of fisheries

5.1. Catch composition

It is an important species for recreational, commercial, and artisanal fisheries throughout its range. *Scomberomorus* species are caught with drift (gill) nets, trolling lines, hook lines, baited handlines, beach seines, bamboo stake traps, set nets and various other gear, including sport gear in the charter boat industry. Driftnet and trawl shrimp fisheries capture juveniles of king mackerel as bycatch (Harris and Dean, 1996; Trent *et al*., 1997).

Total catch is probably underestimated due to reporting of unclassified *Scomberomorus* species captures as well as the probably inadequate reporting of artisanal and recreational catches (Manooch, 1979). ICCAT annual catches reported, from 1950 to 2019, a mean catch of 9841 MT, with a peak of 19,815 MT in 1996. Considering each region, king mackerel is mainly caught by rod and roll in the Northwest Atlantic and by longline in the southwestern Atlantic, however most catches are from unknown gear (**Figure 5**).

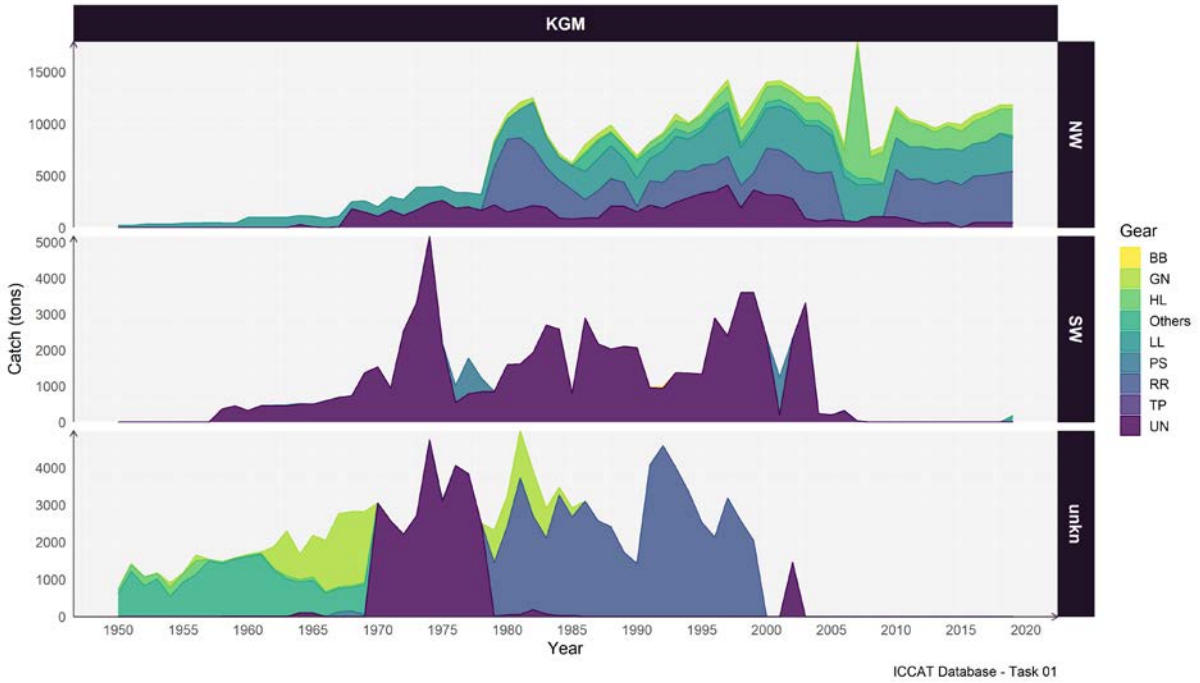

Figure 5. Catch distribution by gear and region of king mackerel in the Atlantic Ocean from 1950 to 2019 (MT). TP: traps. RR: rod and reel. PS: purse seine. LL: longline. HL: handline. GN: gillnets. BB: baitboat. UN: unknown. Others includes trawl (TW), trolling (TR), haul seine (HS), trammel net (TN), sport (SP), tended line (TL), and harpoon (HP).

USA sport fishing with hook-and-line is carried out from April to December (but mostly in spring and fall) in North Carolina, and all year round (with local seasonal peaks) in Florida. Commercial fisheries operate in the same areas, as well as off Louisiana and Mississippi.

5.2. Length and age composition

In Northeast Brazil (Southwest Atlantic), individuals from 4 to 6 years are mainly caught (56.6% of the catch) and those more than 11 years old are hardly caught (4.8% of total catches) (Lessa *et al.*, 2004).

According to data from ICCAT Task 2 size, size data are only available for Northwest Atlantic (**Figure 6**). For this area, from 1986 to 2019, the mean fork length of individuals caught was 104.96 cm.

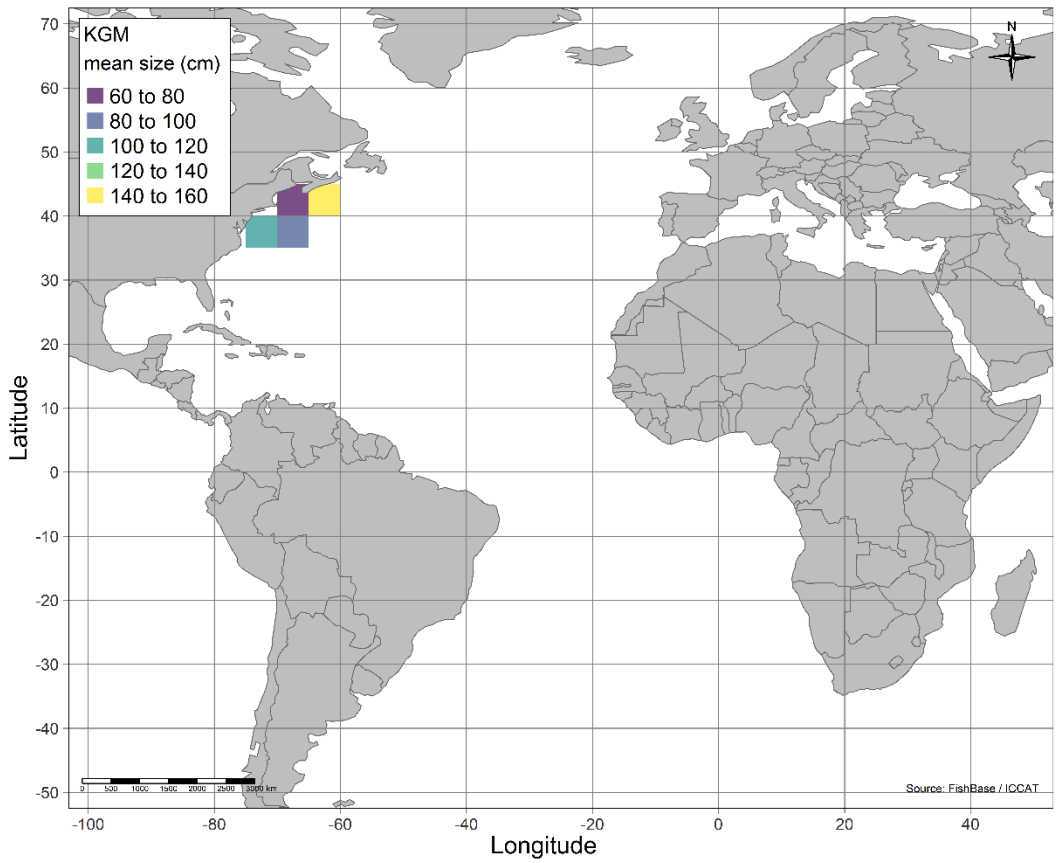

Figure 6. Mean size of king mackerel in each quadrant of 5x5° between 1979 and 2019.

There are no estimates of catch-at-size or catch-at-age for king mackerel.

6. Stock assessment

Using a semi-quantitative risk assessment (Productivity and Susceptibility Analysis PSA), among small tunas, king mackerel in the North Atlantic was considered highly vulnerable (Lucena-Frédou *et al*., 2017a). Preliminary stock assessment efforts in Trinidad conclude that the stock may be overfished (Hogarth and Martin, 2006).

This species is only managed in the USA under the Fishery Management Plan for Coastal Migratory Pelagic Resources. The management bodies are the South Atlantic Fishery Management Council (SAFMC) and the Gulf of Mexico Fishery Management Council (GMFMC). In the USA, prior to the 1980s, king mackerel fisheries were essentially unregulated and became depleted. Regulations were implemented in 1983 to control harvest and rebuild declining stocks of king mackerel, and today these stocks have been restored to target population levels. Currently, many regulations are in course either in the Gulf of Mexico and Atlantic. These include size and trip limits; limited incidental catch allowance; Annual Catch Limit, closed seasons and gear limitation (https://safmc.net/regulations/regulations-by-species/king-mackerel/; https://gulfcouncil.org/fishing-regulations/king-mackerel-scomberomorus-cavalla/). Integrated assessments have been performed for king mackerel in the western Atlantic Ocean, in particular on the South coast of the USA and Gulf of Mexico, using Stock Synthesis (SS) model (Methot and Wetzel, 2013). These assessments include life history information, landings (from different fleets) since the 1900s, discards, length and age composition data, as well as fishery dependent and independent indices of abundance. Neither the king mackerel in the South USA nor in the Gulf of Mexico were found to be overfished or undergoing overfishing (SEDAR, 2020a, b).

South Atlantic *S. cavalla* was considered at moderate/high risk by PSA (Lucena-Frédou *et al*., 2017a, b) and was considered fully or near full exploitation by using length-based methods with data collected up to 2000 (Lucena Frédou and Asano Filho, 2006; Lessa *et al*., 2009; Nóbrega and Lessa, 2009). Considering the assessment carried out by the International Union of Conservation of Nature (IUCN), through its Red List of Threatened Species, the category of Least Concerned (LC) has been assigned in global and regional assessments (Gulf of Mexico) (see https://www.iucnredlist.org/; Collette *et al*., 2011).

Lucena-Frédou *et al*. (2021) has found that there are many gaps in knowledge within species of small tunas, *S. cavalla* included. At the moment, except for the USA, datasets required for these "classical" stock assessments are unavailable for king mackerel and "data-poor" or "data-limited" approaches are currently the most recommended. Overall, length-based methods show a more promising applicability than any other assessment methods to estimate proxies for stock status for small tunas, since collecting length measurements from a portion of the catch might be more feasible than collecting total landings data (Pons *et al*., 2019), which are clearly underestimated in the Atlantic.

7. List of references

Aguilar-Salazar, F.A., Salas-Márquez, S., Cabrera-Vázquez, M.A., Martínez-Aguilar, J.D. 1990. Crecimiento y mortalidad del carito *Scomberomorus cavalla*, en la zona de la costa norte de la Península de Yucatán. Ciencia Pesquera, 8:71-87.

Arreguin-Sanchez, F. Cabrera, M.A. Aguilar, F.A. 1995. Population dynamics of the king mackerel (*Scomberomorus cavalla*) of the Campeche Bank, Mexico. Scientia Marina, 59(3-4).

Beardsley, G.L. and Richards, W. J. 1970. Size, seasonal abundance, and length-weight relation of some scombrid fishes from southeast Florida. Washington D. C.

Beaumariage, D.S. 1973. Age, growth and reproduction of king mackerel, *Scomberomorus cavalla*, in Florida. Fla.Mar. Res.Publ., (1):45 p.

Carneiro Ximenes, M.O., Ferreira de Menezes, M., Fonteles-Filho, A.A. 1978. Idade e crescimento da cavala, *Scomberomorus cavalla* (Cuvier), no estado do Cearã (Brasil). Arquivos de Ciências do Mar, 18: 73-81.

Collette, B.B. and Nauen, C.E. 1983. FAO species catalogue. Vol. 2. Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. FAO Fish. Synop. 125(2). 137 pp.

Collette, B., Amorim, A.F., Boustany, A. Carpenter, K.E., de Oliveira Leite Jr, N., Di Natale, A. Fox, W., Lucena-Frédou, F.L. Graves, J. Viera Hazin, F.H. Juan Jordá, M., Minte Vera, C., Miyabe, N., Nelson, R., Oxenford, H., Teixeira Lessa, R.P., Pires Ferreira Travassos, P.E, 2011. *Scomberomorus cavalla*. The IUCN Red List of Threatened Species 2011: e.T170339A6755835. http://dx.doi.org/10.2305/IUCN.UK.2011-2.RLTS.T170339A6755835.en

Collins, M.R., Schmidt, D.J., Wayne-Waltz, C., Pickney, J.L. 1988. Age and growth of king mackerel, *Scomberomorus cavalla*, from the Atlantic coast of the United States. Fishery Bulletin, 87: 49-61.

De Sturm, M.G, Salter, P. 1990. Age, growth, and reproduction of the king mackerel *Scomberomorus cavalla* (Cuvier) in Trinidad waters. Fishery Bulletin, 88(2):361-370.

Devane, J.C. 1978. Food of king mackerel, *Scomberomorus cavalla*, in Onslow Bay, North Carolina. Trans.Am.Fish.Soc., 107(4):583-6.

De Vries, D.A., Grimes, C., Lang, K.L., White, B.W. 1990. Age and growth of king and Spanish mackerel larvae and juveniles from the Gulf of Mexico and U.S. South Atlantic Bight. Env. Biol. Fish 29: 135–143.

De Vries, D.A., Grimes, C.B., Prager, M.H. 2002. Using otolith shape analysis to distinguish eastern Gulf of Mexico and Atlantic Ocean stocks of king mackerel. Fish. Res., 57(1):51-62.

Erdman, D.S. 1977. Spawning patterns of fish from the northeastern Caribbean. FAO Fish.Rep., (200):145-69.

Fable, W.A. Jr., Trent, L., Bane, G.W., Ellsworth, S.W. 1987. Movements of king mackerel, *Scomberomorus cavalla*, tagged in Southeast Louisiana, 1983-85. Mar. Fish. Rev., 49(2):98-101.

Ferguson, M., Huber, D.R. Lajeunesse, M.J., Motta, P.J. 2015. Feeding Performance of King Mackerel, *Scomberomorus cavalla*. J. Exp. Zool. 323A:399–413.

Figuerola-Fernández, M., Torres-Ruiz, W., Peña-Alvarado, N. 2007. Sexual maturity and reproductive seasonality of king mackerel (*Scomberomorus cavalla*) and cero (*Scomberomorus regalis*) in Puerto Rico. Proc. Gulf Caribb. Fish Inst. 58:251–261.

Finucane, J.H., Collins, L.A., Brusher, H.A., Saloman, C.H. 1986. Reproductive biology of king mackerel, *Scomberomorus cavalla*, from the southeastern United States. Fish. Bull., 84(4): 841-850.

Fitzhugh, G., Fioramonti, C., Walling, W., Gamby, M., Lyon, H., De Vries, D., Ortiz, M. 2008. Batch fecundity and an attempt to estimate spawning frequency of king mackerel (*Scomberomorus cavalla*) in U.S. waters. In: Proceedings of the 61st Gulf and Caribbean Fisheries Institute. 30–37 pp.

Fonteles-Filho, A.A. 1988. Sinopse de informacoes sobre a cavala, *Scomberomorus cavalla* (Cuvier) e a serra, *Scomberomorus brasiliensis* Collette, Russo and Zaval-Camin (Pisces: Scombridae), no estado do Ceara, Brasil. Arq. Cien. Mar. 27:21-48.

Gesteira, V.C.T. and Mesquita, L.L., 1976. Época de reprodução, tamanho e idade na primeira desova da cavala e da serra, na costa do estado do Ceará (Brasil). Arq. Ciên. Mar, Fortaleza, 16(2): 83-86.

Gold, J.R. Pak, E., De Vries, D.A. 2002. Population structure of king mackerel (*Scomberomorus cavalla*) around peninsular Florida, as revealed by microsatellite DNA. Fish. Bull., 100(3): 491-509.

Harris, P.J. and Dean, J.M. 1996. The catch of king mackerel and Spanish mackerel in the commercial shrimp fishery of South Carolina. Symp. on the Consequences and Management of Fisheries Bycatch, Dearborn, MI (USA), 27-28 Aug 1996.

Hogarth, D. and Martin, L. 2006. Stock Assessment and Management Advice for the King Mackerel (*Scomberomorus cavalla*) Fishery of Trinidad and Tobago. Proceedings of the 59th Annual Gulf and Caribbean Fisheries Institute (Book of Abstracts).

Ivo Correa, C.T. 1974. Sobre a fecundidade da cavala, *Scomberomorus cavalla* (Cuvier), em aguas costeiras do Estado do Ceara (Brasil). Arq. Cienc. Mar. Vol., 14(2):87-89.

Johnson, A.G., Fable, W.A. Barger, L. E., Williams, M. L. 1980. Preliminary report on the age and growth ok king mackerel (*Scomberomorus cavalla*) from the United Sates. Collective Volume of Scientific Papers, ICCAT, 9:722-733.

Johnson, A.G., Fable, W.A. Jr, Williams, M.L., Barger, L.E. 1983. Age, growth, and mortality of king mackerel, *Scomberomorus cavalla* from the southeastern United States. Fishery Bulletin, 81(1): 97-106.

Johnson, A.G., Fable, W.A., Grimes, C.B., Trente, L., Perez, J.V. 1994. Evidence for distinct stocks of king mackerel, *Scomberomorus cavalla*, in the Gulf of Mexico. Fish. Bull., 92(1): 91-101.

León, M.E. and Guardiola, M. 1984. Caracterización biológico-pesquera del género *Scomberomorus* de la zona suroriental de Cuba. Rev. Cuba Investig. Pesq., 9:1-26.

Lessa, R.P., Nóbrega, M.F., Bezerra-Junior, J.L. 2004. Dinâmica de populações e avaliação de estoques dos recursos pesqueiros da região nordeste. Subcomitê Regional Nordeste (Score-NE), Recife. 246 pp.

Lessa, R. Nóbrega, M., Lucena-Frédou, F., Santos, J.S. 2009. Espécies Pelágicas, *Scomberomorus cavala*. In: Lessa R., Nóbrega M.F., Bezerra Jr J.L., (Eds.), Dinâmica de Populações e Avaliação dos Estoques dos Recursos Pesqueiros do Nordeste. Martins & Cordeiro LTDA, Fortaleza. 76–89 pp.

Lucena-Frédou, F. and Asano-Filho, M. 2006. Recursos pesqueiros da região norte. In: Jablonski S, Rossi-Wongtschowski C.L.D.B., Haimovici, M; Lessa, R.P; Martins, A; Ávila, R. and Lucena-Frédou, F. (Eds.), Programa REVIZEE – Relatório Executivo. Ministério do Meio Ambiente, Brasília 121–152.

Lucena-Frédou, F., Frédou, T. Ménard, F. 2017a. Preliminary Ecological Risk Assessment of small tunas of the Atlantic Ocean. Collect. Vol. Sci. Pap. ICCAT, 73:2663–2678.

Lucena-Frédou, F., Kell, L. Frédou, T., Gaertner, D., Potier, M., Bach, P., Travassos, P., Hazin, F., Ménard, F. 2017b. Vulnerability of teleosts caught by the pelagic tuna longline fleets in South Atlantic and Western Indian Oceans. Deep–Sea Research Part II, 140:230–241.

Lucena-Frédou, F., Mourato, B., Frédou, T., Lino, P.G., Muñoz-Lechuga, R., Palma, C. Soares, A., Pons, M. 2021. Review of the life history, fisheries, and stock assessment for small tunas in the Atlantic Ocean. Rev. Fish Biol. Fish. 31, p.p. 709–736.

Lubbock, R. and Edwards, A. 1981 The fishes of Saint Paul's Rocks. J. Fish Biol, 18:135-157.

Manooch, C.S. 1979. Recreational and commercial fisheries for king mackerel, *Scomberomorus cavalla*, in the South Atlantic Bight and Gulf of Mexico, USA. In Proceedings of the Colloquium on the Spanish and King Mackerel Resources of the Gulf of Mexico. Edited by E.L. Nakamura and H.R. Bullis, Jr. Publ. Gulf States Mar. Fish. Comm., (4):33-41.

Manooch, C.S. Naughton, S.P., Grimes, C.B, Trent, L. 1987. Age and growth of king mackerel, *Scomberomorus cavalla*, from the U.S. Gulf of Mexico. Mar. Fish. Rev.,49(2): 102-108.

McEachran, J.D., Finucane, J.H., Hall, L.S. 1980. Distribution, seasonality and abundance of king and Spanish mackerel larvae in the northwestern Gulf of Mexico (Pisces: Scombridae). Northeast Gulf Sci.,4(1):1-16.

Medina-Quej, A. and Domínguez-Viveros, M. 1997. Edad y crecimiento del *Scomberomorus maculatus* (Scombriformes: Scombridae) en Quintana Roo, México. Revista de Biología Tropical, 45: 1155-1161.

Menezes, M.F. 1969. Alimentação da cavala *Scomberomorus cavalla* (Cuvier) em águas costeiras do estado do Ceará. Arq. Cien. Mar., 9(1): 15-20.

Methot, R.D. and Wetzel, C.R. 2013. Stock synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fish. Res., 142:86–99.

Morgan, E.C. and King, W.K. 1983. Tooth replacement in king mackerel, *Scomberomorus cavalla* (Pieces: Scombridae). Southwest Nat., 28:261–269.

Naughton, S.P. and Saloman, C.H. 1981. Stomach contents of juveniles of king mackerel (*Scomberomorus cavalla*) and Spanish mackerel (*S. maculatus*). Northeast Gulf Sci., 5(1): 71-74.

Nóbrega, M.F. and Lessa, R.P. 2009. Age and growth of the king mackerel (*Scomberomorus cavalla*) off the northeastern coast of Brazil. Braz. J. Oceanogr. 57:273–285.

Nomura, H. and de Sousa Rodrigues, M.S. 1967. Biological notes on king mackerel, *Scomberomorus cavalla* (Cuvier), from northeastern Brazil. Arquivo da Estação de Biologia Marinha, Universidade Federal Ceara, 7: 79-85.

Nomura, H. and da Costa, R.S. 1966. Sobre o comprimento e o peso da cavala e da serra das aguas cearenses. Arq. Est. Biol. Mar. Univ. Fed. Ceará, 6(1): 11-13.

Ortiz, M. and Palmer, C. 2008. Review and estimates of von Bertalanffy growth curves for the king mackerel Atlantic and Gulf of Mexico stock units. Sustainable Fisheries Division Contribution SFD-2008-006, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, Florida, 20 p.

Pons, M., Kell, L., Rudd, M.B., Cope, J.M., Lucena-Frédou, F. 2019. Performance of length-based data-limited methods in a multifleet context: application to small tunas, mackerels, and bonitos in the Atlantic Ocean. ICES Journal of Marine Science, 76(4): 960–973. doi: 10.1093/icesjms/fsz004.

Richards, W.J., (ed.) 2005. Early Stages of Atlantic Fishes: An identification guide for the western central North Atlantic. CRC Press, Taylor and Francis Group, Boca Raton, FL, 2640 pp.

Santa Brígida, E.L. Cunha, D.B., Rego, P.S., Sampaio, I., Schneider, H., Vallinoto, M. 2007. Análise populacional de *Scomberomorus cavalla* (Cuvier, 1829) (Perciformes, Scombridae) da costa Norte e Nordeste brasileira. Braz. J. Biol., 67 (4): 919-924.

Schaefer, H.C. and Fable, W.A. 1994. King mackerel, *Scomberomorus cavalla*, mark-recapture studies off Florida's east coast. Mar. Fish. Rev., 56(3):13-23.

SEDAR, 2020a. SEDAR 38 – Update: South Atlantic King Mackerel Stock Assessment Report. SEDAR, North Charleston SC. 66 pp.

SEDAR, 2020b. SEDAR 38 – Update: Gulf of Mexico King Mackerel Assessment Update Report. SEDAR, North Charleston SC. 72 pp.

Shepard, K.E., Patterson III, W.F. De Vries, D.A., Ortiz, M. 2010. Contemporary versus historical estimates of king mackerel (*Scomberomorus cavalla*) age and growth in the U.S. Atlantic Ocean and Gulf of México. Bull. of Mar. Sci. 86(3): 515–532.

Sutter, F.C. III, Williams, R.O., Godcharles, M.F. 1991a. Movement patterns and stock affinities of king mackerel in the southeastern United States. Fish. Bull., 89(2):315-324.

Sutter, F.C III, Williams, R.O., Godcharles, M.F. 1991b. Growth and mortality of king mackerel *Scomberomorus cavalla* tagged in the southeastern United States. Fish. Bull., 89(4):733-737.

Trent, L. Parshley, D.E., Carlson, J.K. 1997. Catch and bycatch in the shark drift gillnet fishery off Georgia and East Florida. Mar. Fish. Rev., 59(1):19-28.

Trent, L., Fable, W.A. Jr., Russell, S.J., Bane, G.W., Palko, B.J. 1987. Variations in size and sex ratio of king mackerel, *Scomberomorus cavalla*, off Louisiana, 1977-85. Mar. Fish. Rev., 49(2):91-97.

Wall, C.C., Muller-Karger, F.E. Roffer, M.A. 2009. Linkages between environmental conditions and recreational king mackerel (*Scomberomorus cavalla*) catch off west-central Florida. Fish. Ocean., 18:185–199.