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THE BIOLOGY OF WAHOO (*ACANTHOCYBIUM SOLANDRI*) IN THE WESTERN CENTRAL ATLANTIC

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ABSTRACT This contribution summarizes aspects of the biology of the wahoo, *Acanthocybium solandri* (Scombridae), that are pertinent to assessment and management of this species in the western central Atlantic (WCA). In this region wahoo is a target species for both commercial and recreational fisheries, and annual landings appear to have increased steadily over the last 30 years to in excess of 2000 mt. Wahoo is believed to be migratory, but little is known of the migration patterns. Significant seasonal variation in catches within the region indicates that it is seasonally abundant in most locations. Periods of peak abundance occur from the fall through spring in the southeastern and northern Caribbean islands, and are restricted to the warmer months (late spring through early fall) in the more northerly locations (northern Gulf of Mexico, North Carolina, and Bermuda). Wahoo exhibits early sexual maturity (within the first year) and a spawning season that extends from at least May to October. Females are multiple batch spawners and are highly fecund. Limited age and growth studies indicate that it is a relatively fast-growing species, has high mortality, and probably lives for 5–6 years. Wahoo is primarily piscivorous, although some invertebrates including squids are eaten. A relatively small number of parasite species have been associated with it. There is no evidence of more than a single shared stock of wahoo in the WCA, and recent genetic studies, using RAPD markers, suggest that stock boundaries may extend beyond this region. The status of the wahoo resource in the WCA remains unclear. Reliable wahoo catch and fishing effort data from the entire WCA, improved knowledge of migration patterns, reproductive characteristics and critical habitat (e.g., preferred spawning areas), validation of age, growth and mortality estimates, and a more comprehensive analysis of stock structure for the entire Atlantic are needed for informed wahoo stock assessment and management.

INTRODUCTION

The wahoo, *Acanthocybium solandri* Cuvier, is classified in the family Scombridae. Johnson (1986) postulated that this species may be more closely related to the billfishes. However, a recent molecular study (Finnerty and Block 1995) confirms that wahoo is a scombrid, not an istiophorid, being closely related to the Spanish mackerels (Collette 1999, Collette et al. 2001).

Wahoo is a slender, streamlined, oceanic, epipelagic fish and is important to commercial and recreational fisheries throughout the western central Atlantic (WCA) (e.g., Goodson 1976, Collette 1978, in press, Mahon 1993, SAFMC 2000). Despite its importance to fisheries, wahoo remains unmanaged. Furthermore, the biological information needed to support management of this species is somewhat sparse and is scattered throughout the published and unpublished literature. In this paper we attempt to compile and review the biological information available for wahoo that is relevant to assessment and management of this species, at a time of increasing interest in addressing the management of shared pelagic stocks in this region (e.g., SAFMC 2000, CFRAMP 2001, FAO 2002a).

DISTRIBUTION, EXPLOITATION AND SEASONALITY

The wahoo has a circum-tropical distribution, occupying tropical and subtropical waters of the Atlantic (including the Mediterranean and Caribbean seas), Pacific and Indian oceans (Collette and Nauen 1983), and extending seasonally into temperate waters (Hogarth 1976). In the WCA, wahoo occurs from as far south as the northeast coast of Brazil (see Robins and Ray 1986) to as far north as Rhode Island in the USA (see Goodyear 1999 cited in SAFMC 2000). Wahoo is reported to be present year-round throughout much of the Caribbean and Gulf of Mexico, although its abundance, or availability to the fisheries, appears to have a seasonal pattern in most places (Table 1). Further north, in the Atlantic (off North Carolina and Bermuda), some wahoo appear to be present year-round, but abundance is highly seasonal, with the fish being far more abundant in the warmer months (Table 1).

Wahoo is caught by recreational and commercial fisheries in South America off Venezuela (Cervigón 1994) and in large numbers by commercial longliners off Brazil and the Netherlands Antilles in the southern Caribbean (ICCAT 2001, 2002, FAO 2002b). It is a target species of commercially important artisanal pe-

TABLE 1

Locations and approximate seasonality of highest catches of recreational and commercial fisheries for wahoo in the western central Atlantic.

Area	Location	Highest catches	Selected references
South America		?	FAO 2002b Cervigón 1994 ICCAT 2001, 2002
Southern Caribbean		?	ICCAT 2002
Southeastern Caribbean		Late fall–early summer	Mahon et al. 1982, 1990 Mahon 1993 George et al. 2001
Northern Caribbean	US Virgin Islands	Sep–Mar	Brandon 1987
	Puerto Rico	Sep–Mar	SAFMC 1998
	Jamaica	Feb–May	Harvey 1988
	Cuba	Winter	Rivas 1951
	Bahamas	Fall–Winter	Franks et al. 2000
Northern Gulf of Mexico 2000)		Spring–Fall	Goodyear 1999 (in SAFMC Franks et al. 2000
Eastern USA 2000)		Jul–Aug	Hogarth 1976 Manooch and Laws 1979 Manooch et al. 1981 Goodyear 1999 (in SAFMC
Atlantic	Bermuda	Apr–Sep	Luckhurst and Trott 2000

logic fisheries throughout the southeastern Caribbean islands of Grenada (Finlay and Rennie 1988), Barbados (Mahon et al. 1982), St. Lucia (Murray and St. Marthe 1991, Gobert and Domalain 1995), Dominica (Guiste et al. 1996), Martinique (Guillou and Lugin 2000), and Guadeloupe (Reynal et al. 1999). Although it is landed year-round in the southeastern Caribbean, catch rates for “kingfish” (an aggregate group composed primarily of wahoo and a small proportion of king mackerel) are lowest during the summer months (July–September) and show several low modes from November through June (e.g., Hunte 1987, Mahon et al. 1990, OECS 1996, George et al. 2001).

In the northern Caribbean, wahoo is caught by recreational and commercial artisanal fishers off the Cayman Islands (Barnes 1972 cited in Hogarth 1976), Jamaica (Aiken 1993, Mahon 1995, Harvey 1988), the northwest coast of Cuba (Rivas 1951, Collette 1978), the Dominican Republic (Brown 2001), Puerto Rico (Centaur Assoc. 1983), the US Virgin Islands (Hogarth 1976, Olsen and Wood 1983, Centaur Assoc. 1983, Brandon 1987), and the Bahamas (Hogarth 1976, Franks

et al. 2000). In general, highest catches in this region occur from the fall through early spring (Table 1), although Harvey (1988) noted that peak wahoo catches in Jamaica occur from February to May.

Wahoo is important to commercial and recreational fisheries in the northern Gulf of Mexico (Texas, Louisiana, Mississippi, Alabama, and western Florida), the Atlantic from the Florida Straits to North Carolina (Hogarth 1976, Goodyear 1999 cited in SAFMC 2000), and Bermuda (Luckhurst and Ward 1996, Smith-Vaniz et al. 1999). In the northern Gulf of Mexico, wahoo is caught year-round, although they are apparently more abundant during spring through fall (Franks et al. 2000). In the Atlantic, wahoo are reported off the east coast of Florida year-round and further north off South Carolina during the spring and summer (SAFMC 1998). Off North Carolina, there is some evidence that wahoo may be present in the Gulf Stream year-round, although they are only considered to be abundant from late July through August (Hogarth 1976, Manooch and Laws 1979, Manooch et al. 1981). In Bermuda, wahoo is taken year-round, but catches have a strong seasonal pattern

with 60–70% of the annual landings consistently occurring in the second and third quarters of the year (April–September) (Luckhurst and Trott 2000). Historically, there are spring (April–May) and fall (August–September) runs of wahoo in Bermuda which vary inter-annually in magnitude and to a lesser degree in timing (Luckhurst and Trott 2000). Wahoo landings are consistently lowest (5–8% of annual landings) in the first quarter which coincides with the lowest water temperatures (18–19°C) as well as reduced fishing effort.

Estimated annual landings of wahoo in the WCA are reported collaboratively by ICCAT and FAO, although slight differences are often found between the two data sets as a result of differences in the timing of required reporting and revisions (FAO 2002b). Records show a steady and rapid increase in wahoo landings from around 400 mt in the mid to late 1970s to an mean of 1,854 mt over the last three years for which there are data (1998–2000; Table 2). However, at least part of this increase is likely to represent an increase in reporting to ICCAT, rather than an actual increase in landings. For example, wahoo landings are shown from Grenada only since 1978, Barbados since 1979, USA since 1985, St. Vincent since 1988, Dominica and St. Lucia since 1990, and Trinidad and Tobago since 1991, although the fisheries in most of these countries have been taking wahoo for much longer periods of time. Wahoo catches are almost certainly under reported across the WCA. Many countries known to be taking wahoo, even if only in relatively small quantities, are not listed in the ICCAT (nor FAO) data records, while others have landings that are under reported (e.g., landings for US Gulf of Mexico and Atlantic coasts for 1984–1992 are far higher than reported in the ICCAT database (see Tables 2 and 3). One problem is that wahoo are aggregated with king mackerel (*Scomberomorus cavalla*) in national landings data of several countries (e.g., Hunte 1987, Mahon 1993) and cannot, therefore, be disaggregated into separate species in the ICCAT and FAO databases. Furthermore, statistics reported in the databases are biased by a country's capacity and willingness to accurately collect, process, and report fisheries data (FAO 2002a). Although recreational catches are likely to be quite substantial and often greatly exceed commercial landings (e.g., in the US Gulf, south Atlantic, and mid-Atlantic states: Goodyear 1999 cited in SAFMC 2000; in the US Virgin Islands: Brandon 1987), they frequently go unreported in this region (e.g., Franks et al. 2000, Luckhurst and Trott 2000). Garber et al. (2001) note with concern that increased recreational fishing in the US and Caribbean waters is putting additional harvest pressure on this species.

Wahoo landings have shown a slow but steady increase in many southeastern Caribbean countries from the 1970s through the 1980s (Mahon 1996), and particularly in St. Lucia from the mid 1990s (George et al. 2001). This reflects an increase in the number and fishing power of vessels and fishers (George et al. 2001). The US National Marine Fisheries Service (NMFS) records (1984–1997) reported by Goodyear (1999 cited in SAFMC 2000) indicate that wahoo landings in the US Gulf of Mexico have increased considerably since the mid 1980s, but show marked inter-annual variation (Table 3). These records also indicate a gradual increase in the commercial and recreational landings of wahoo for the US south Atlantic states (with the exception of an anomalously high year for the recreational fishery in 1986) (Table 3). In Bermuda, landings of wahoo have increased steadily over the 24 year (1975–1997) time-series, reflecting an increase in pelagic fishing effort and improvements to gear and fishing techniques over this time period (Luckhurst and Trott 2000).

MOVEMENTS AND MIGRATION

Little is known about the movements or migration patterns of wahoo in the WCA, although it is generally agreed (based on seasonality of landings by commercial and recreational fisheries) that they move seasonally, extending into cooler waters in the warmer months, and are migratory within and beyond the Exclusive Economic Zones (EEZs) of countries within the WCA region. Wahoo congregate in the vicinity of drifting objects including *sargassum* (e.g., NMFS 1997), and fishers have learned to rely heavily on these natural moving fish attracting devices (FADs) to catch wahoo and other large pelagics (e.g., Taquet 1998, Gomes et al. 1998, George et al. 2001). Wahoo are also caught around anchored FADs off Martinique and Guadeloupe (Laurans et al. 1999, Reynal et al. 1999).

There are a few on-going conventional tagging programs for wahoo in the WCA. A CFRAMP tagging program for large pelagic species commenced in 1996 (Singh-Renton 2001). To date, a total of 249 wahoo have been tagged in southeastern Caribbean waters, but no recaptures have been reported (Singh-Renton, pers. comm.). In Bermuda, a wahoo tagging program commenced in 1998 (Nash et al. 2002). To date, only 15 wahoo have been tagged and released. A single wahoo recaptured 10 months later, 64 km away from the point of release, may have remained in Bermuda waters during its liberty or returned there after a seasonal

TABLE 2

Estimated annual wahoo landings (mt) for countries within the western central Atlantic (data from ICCAT 2002).

Place	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Antigua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Aruba	100	100	115	115	115	115	115	115	115	115	120	90	80	80	70	60	50	50	125	40	50	50	50	50	50
Barbados	0	0	0	189	116	144	219	222	219	120	138	159	332	51	51	60	51	91	82	42	35	52	52	41	41
Brazil	9	3	6	69	1	1	0	0	0	21	141	133	58	92	52	64	71	33	28	1	16	58	40	0	0
Dominica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	43	59	59	59	58	58	58	58	50	50
Dominican Rep.	0	0	0	0	0	0	0	0	0	0	0	0	1	3	6	9	13	7	0	0	0	0	0	0	0
Grenada	0	0	35	31	25	23	41	94	50	51	82	54	137	57	54	77	104	96	46	49	56	54	54	82	82
Netherland Ant.	178	178	215	215	215	215	215	215	215	245	250	260	280	280	280	250	280	270	250	230	230	230	230	230	230
St. Lucia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77	79	150	141	96	80	221	223	223	310	310
St. Vincent	0	0	0	0	0	0	0	0	0	0	0	0	4	4	28	33	33	41	28	16	23	10	10	52	52
Trinidad & Tobago	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	118	1	0	0	0	0	1	1	1	2
USA	0	0	0	0	0	0	0	0	0	13	12	57	128	110	82	134	203	827	391	764	608	750	614	857	640
Bermuda	20	35	23	33	46	24	40	49	46	46	65	43	61	63	74	67	60	58	50	93	99	105	108	104	51
Venezuela	67	71	54	100	57	77	175	66	125	147	113	106	141	101	159	302	333	514	542	540	487	488	360	467	4
Totals	374	387	448	752	575	599	805	761	770	758	921	902	1222	841	971	1,296	1,408	2,187	1,697	1,913	1,883	2,079	1,800	2,244	1,512

TABLE 3

Recreational and commercial landings of wahoo (mt) from the US Gulf of Mexico and Atlantic coast states for the years 1984–1997. Data are from the US NMFS as presented by Goodyear (1999, cited in SAFMC 2000).

Year	Gulf of Mexico		South Atlantic		Mid-Atlantic		New England		Total
	Rec.	Com.	Rec.	Com.	Rec.	Com.	Rec.	Com.	
1984	9.1	2.4	187.7	11.4	0.0	0.0	0.0	0.0	210.6
1985	55.0	4.9	191.9	12.9	6.6	0.1	0.0	0.0	271.4
1986	92.0	11.0	1120.4	12.1	23.7	0.1	0.0	0.5	1259.8
1987	169.0	41.0	361.5	23.3	6.0	0.2	0.0	0.0	601.0
1988	198.4	103.4	378.0	23.7	0.0	0.5	0.0	0.0	704.0
1989	30.0	109.4	321.4	19.9	11.4	0.4	0.0	0.0	492.5
1990	67.6	51.2	195.1	26.4	0.0	0.8	0.0	0.0	341.1
1991	206.9	84.9	241.7	28.3	1.0	0.4	0.0	0.0	563.2
1992	157.5	134.0	292.3	29.4	0.0	0.9	0.0	0.5	614.6
1993	257.1	116.7	286.9	33.6	0.0	1.3	2.6	0.0	698.2
1994	61.0	71.0	350.5	30.6	18.9	1.7	0.0	7.6	541.3
1995	187.2	65.4	439.8	46.4	5.2	3.2	0.0	0.0	747.2
1996	148.6	65.8	384.8	36.2	5.4	1.1	0.0	0.1	642.0
1997	213.1	73.6	403.7	41.5	0.0	1.1	0.0	0.0	733.0

migration. It is possible that it may have followed a stable migratory route in the Atlantic, with the Bermuda Seamount as a seasonal feeding area, as has been postulated for yellowfin tuna (*Thunnus albacares*) and blackfin tuna (*Thunnus atlanticus*) in Bermuda (Luckhurst et al. 2001).

In the southeastern Caribbean, Neilson et al. (1999) suggested that the lack of a modal progression in length-frequency data is consistent with recruitment to the fishing grounds year-round and a highly migratory behavior. However, George et al. (2001) found a gradual increase in monthly mean size of wahoo taken from October through July and then a marked decrease through August to October, suggesting this might be due to migration of the older fish beyond the southeastern Caribbean region at the end of the peak fishing season. Neilson et al. (1999) suggested that the migration model for the southern stock of dolphin, *Coryphaena hippurus*, (wherein it is suggested that the fish move sequentially north through the waters of the Lesser Antilles countries, with a return migration south via the waters further to the east: see Oxenford and Hunte 1986) may also apply to wahoo. However, Hunte (1987) examined seasonality of the catch of “kingfish” (primarily wahoo) from several of the Lesser Antilles islands, and concluded that no clear pattern of movement could be detected. Furthermore, George et al. (2001) report a steady decrease northwards in mean length of wahoo caught around five islands in the southeastern Carib-

bean. This is contrary to the pattern seen in the mean size of dolphin landed up the island chain (Oxenford and Hunte 1986).

In the northern part of the WCA, wahoo is believed to migrate through the Florida Straits and along the Gulf Stream (Rivas 1951). Hogarth (1976) concurred with this when he suggested (based on seasonality of catches) that wahoo migrates northward from Florida waters during the spring with the peak of the migration occurring in late July and early August.

REPRODUCTIVE BIOLOGY

Sex ratio

Hogarth (1976) reported a strong female bias for wahoo caught in June through August by the recreational fishery (1964–1972) in North Carolina, with a consistent ratio of 3:1 females to males. He suggested that this skewed sex ratio may be a result of: different migration patterns between the sexes, a greater catchability of females resulting from differences between the sexes in preferred habitat, or a shorter lifespan in males such that there are few males in the size range taken by the fishery. Interestingly, a similar female biased sex ratio for dolphin landings is believed to result from inter-sexual differences in attraction to floating objects targeted by fishers (see Oxenford 1999).

Age and size at maturity

For wahoo from the northern Gulf of Mexico, preliminary estimates by Brown-Peterson et al. (2000) indicated that males reach maturity at one year of age and that 50% maturity is reached at < 935 mm fork length (FL). They also reported that females can reach sexual maturity as small as 850 mm FL but suggested a size of around 975 mm FL or larger for most females, 50% maturity at 1020 mm FL (approximately 2 years old) and 100% maturity at 1050 mm FL. Both males and females from North Carolina reach sexual maturity during their first year of life, at around 860 mm total length (TL) and 3.4 kg total weight for males and 1010 mm TL and 5.4 kg for females (Hogarth 1976). In Bermuda, preliminary data for wahoo suggest that size at maturity is around 1020 mm FL for males, while females are smaller (950 mm FL) (SAFMC 1998).

Fecundity and egg size

Most of the reproductive parameter estimates are from very small sample sizes and should be treated as preliminary. Examination of oocyte size-frequency data for wahoo from the northern Gulf of Mexico revealed that it is a multiple batch spawner with asynchronous oocyte development, with hydrated oocyte diameters ranging from 700–900 μm (Brown-Peterson et al. 2000). The few estimates of fecundity available vary widely (Table 4). This is in part due to the different definitions of fecundity, with some authors reporting total eggs in mature ovaries (e.g., Hogarth 1976, Collette and Nauen 1983, Collette in press) and others reporting batch and seasonal (annual) fecundity (Brown-Peterson et al. 2000). Mean relative batch fecundity for three wahoo from the northern Gulf of Mexico was estimated at 57.7 eggs per

g ovary-free body weight (Brown-Peterson et al. 2000). They noted an apparent increase in batch fecundity with size and age but no increase in the relative fecundity. Spawning frequency per ripe female was also estimated as every two to six days in June, based on histological examinations to determine the percentage of females in the late developing stage with ovaries containing postovulatory follicles. Annual fecundity estimates are based on this spawning frequency being maintained over the four-month spawning season (Table 4). Hogarth (1976) reported a fecundity-length relationship (fecundity = $0.0002 \text{ cm TL}^{4.849}$) for 87 females from North Carolina ranging in size from 1030–1800 mm TL (5.8–39.5 kg).

Gonad maturation, gonadosomatic indices and spawning season

Nine developmental stages of gonad maturation have been described for males and females from the Gulf of Mexico and Bimini, based on macroscopic and histological examination (Brown-Peterson et al. 2000). Four male maturity stages, which are easy to distinguish in the field, and six female stages, which are more difficult to distinguish, have been described for wahoo from North Carolina (Hogarth 1976).

Wahoo has a relatively low gonadosomatic index (GSI) as is typical for medium and large sized oceanic pelagic species (Oxenford 1985). In the northern Gulf of Mexico, the highest GSI value (9.5%) was for a female captured in June, while male GSI values rarely exceed 1.0% (Brown-Peterson et al. 2000). In Bermuda, the maximum GSI value recorded for a female was 5.85% for a fish weighing 24.9 kg and caught in July (Luckhurst unpubl. data).

TABLE 4

Fecundity estimates for wahoo in the western central Atlantic. ¹Total number of oocytes in mature ovaries, ²Number of hydrated oocytes in mature ovaries, ³Estimate of number of oocytes spawned per annual spawning season.

Location	Parameter	No. eggs	Fish size	N (no. fish)	Reference
Western central Atlantic	Fecundity ¹	6,000,000	1310 mm	1	Collette and Nauen 1983 Collette in press
Northern Gulf of Mexico	Mean batch fecundity ²	1,146,395 \pm 291,210 SE	1030–1630 mm FL	3	Brown-Peterson et al. 2000
	Annual fecundity ³	30,000,000– 92,800,000	(2–5 kg)		
North Carolina	Fecundity ¹	560,000– 45,340,000	1030–1800 mm TL (6.15–39.5 kg)	87	Hogarth 1976

TABLE 5

Spawning seasons for female wahoo in the western central Atlantic.

Location	Spawning season (peak activity)	Source of data	Reference
Straits of Yucatan	May–October (June)	Larval occurrence	Wollam 1969
Northern Gulf of Mexico	May–August (June)	Gonad analyses	Brown-Peterson et al. 2000
Straits of Florida	May–October (June)	Larval occurrence	Wollam 1969
North Carolina	June–August (June/July)	Gonad analyses	Hogarth 1976
Bermuda	May–August (?)	Gonad analyses	Luckhurst unpubl.

From relatively limited studies of reproduction, wahoo appears to have an extended summer (May–October) spawning season (Table 5). However, there have been no studies of spawning behavior from the southerly part of its range in the WCA, and evidence is insufficient to determine a preferred spawning environment. Fish larval collections in the WCA indicate that wahoo larvae are widespread in the Caribbean Sea and Gulf of Mexico but have been found only in very small numbers (Wollam 1969, Richards 1984, Richards et al. 1984). Collette and Nauen (1983) reported that wahoo in different maturity stages are frequently caught together and that spawning seems to extend over a long period. Bimini wahoo, sampled only in November, show slightly elevated female GSI values and a wide range of spermatogenic stages in males, suggesting at least some spawning activity during this month and a readiness to continue spawning in one to three months time (Brown-Peterson et al. 2000). Based on very limited larval collections, wahoo from the Straits of Yucatan and Florida have a spawning season extending from

May to October (Wollam 1969). In the northern Gulf of Mexico, Brown-Peterson et al. (2000) noted that only late development through spent stages were found and concluded from monthly GSI values (Figure 1) and from histological examination of gonads that females have a 4-month (May–August) spawning season, with peak spawning in June, while males have a slightly more extended spawning season into September. They also suggested that there may be two temporally different spawning groups of female wahoo, since 10% of females sampled in the peak spawning month (June) had regressed ovaries. In the Gulf Stream off North Carolina, Hogarth (1976) concluded from monthly gonadosomatic indices (Figure 1) and frequency of occurrence of mature, ripe, and spent fish, that wahoo spawns from late June through August with peak activity occurring in June and July. He reported the highest frequency of mature and ripe females in June, a mixture of mature, ripe, and spent females in July and August, and spent females in September and October. He noted that few immature males are caught off North Carolina.

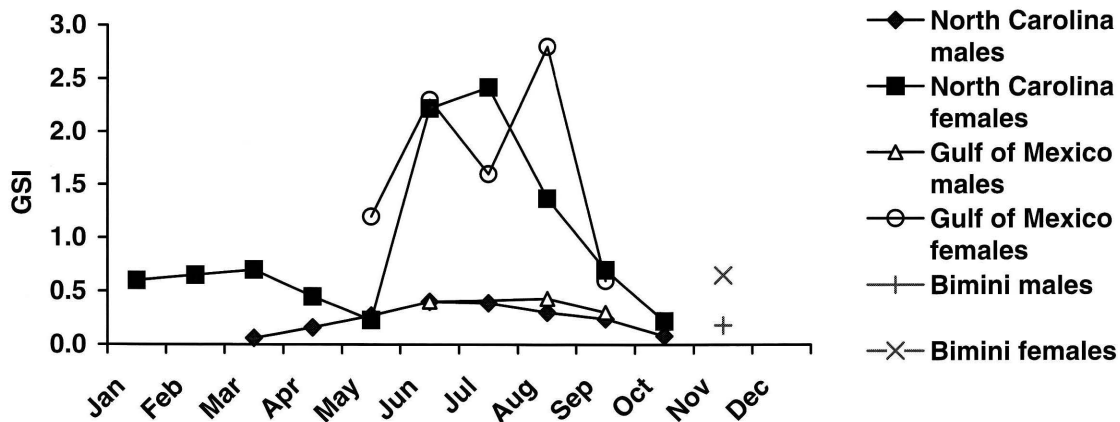


Figure 1. Monthly mean gonadosomatic indices (GSI) for male and female wahoo from the northern Gulf of Mexico ($n = 52$ females, 19 males, collected from May–September) and Bimini in the Bahamas ($n = 13$ females, 19 males, collected in November) (from Brown-Peterson et al. 2000), and North Carolina ($n = 617$ females, 178 males) (from Hogarth 1976).

In Bermuda, based on macroscopic evaluation of gonadal condition, females appear to spawn from May through August, while males apparently have an extended period of sperm production, since a running ripe male was sampled in September, beyond the period when females are reproductively active (Luckhurst unpubl. data).

MORPHOMETRICS, AGE, AND GROWTH

Length and weight

Numerous length and weight measures have been recorded for wahoo across the WCA, and the various relationships between length, weight, girth, caudal fin span, otolith size, dorsal fin spine size and growth checks (Table 6) show little variation in equivalent relationships among localities. For the length-weight relationships, this is evidenced by the similar estimated weights for an 1100 mm fish (Table 6).

Length-frequencies

Length-frequency data are available from landings of hook and line troll fisheries in a number of locations across the WCA. Most data sets show a similar wide size-range of wahoo, a unimodal size structure, and little indication of a modal progression in the size frequency over time. This latter observation has constrained attempts to use length-based methods to determine growth and mortality rates in particular for this species.

In St. Lucia, 11 years of wahoo size-frequency data from the artisanal fishery landings indicate an essentially unimodal size structure with a size range of 325–2125 mm FL and modal size classes in the range 775–975 mm FL (Neilson et al. 1999). The authors reported two closely spaced modes in the annual length-frequency distributions and suggested that they could represent either year classes or sexes if growth rate is sexually dimorphic, as is the case with some other scombrids. Neilson et al. (1999) also noted differences in the monthly mean size of wahoo landed but no clear modal progression. Note that parts of this same data set are also given in Murray and Sarvay (1987), Murray (1989), Murray and Nichols (1990) and Murray and Joseph (1996).

Beardsley and Richards (1970) provided size-frequencies from the recreational fishery in Florida sampled at a taxidermist. Although they acknowledged that the sample was likely biased towards larger specimens, they felt that it was reasonably representative of the wahoo caught, since a high proportion of the catch was

retained for mounting by the recreational fishers. The size range for these Florida samples was 510–1750 mm FL, and there was no clear quarterly progression of the size frequency over a year.

In North Carolina, Hogarth (1976) reported that wahoo landed by the recreational fishery ranged in size from 760–2050 mm TL with the majority occurring in the 1110–1600 mm TL range. He reported some seasonal variation in size: first quarter (winter) fish ranged from 760–1650 mm TL (modal range: 1310–1500 mm TL), second quarter (spring) fish ranged from 860–1700 mm TL (modal range: 1010–1300 mm TL), and fall quarter fish modal range from 1210–1300 mm TL. There was no clear modal progression of size-frequency over the year. Wahoo landed in Bermuda had a unimodal size structure with a size range of 720–1800 mm FL and a modal size for both sexes combined of 1180 mm FL (Luckhurst and Trott 2000).

Age, growth, and longevity

There is uncertainty involved in aging wahoo, as scales are unreadable and vertebrae annuli are inconsistent (see Hogarth 1976). Furthermore, otolith microstructure is complex, and there has been no successful validation of presumed annuli or daily growth checks in otoliths to date, although oxytetracycline (OTC) injections are part of a tagging program in Bermuda (see Nash et al. 2002). The few studies that have been conducted concur that wahoo is a relatively fast-growing species, particularly in the first year, and estimated size-at-age for wahoo from several locations and/or using different aging techniques are similar (Table 7). Most studies agree that wahoo probably has a life-span up to or in excess of 5–6 years.

In the southeastern Caribbean, Murray (1989) reported putative daily growth checks visible in a small number of whole sagittal otoliths ($n = 9$) from St. Lucia. Murray and Nichols (1990) noted that the otolith-based age estimates in the St. Lucia wahoo are probably erroneous. Sagittal otoliths ($n = 450$) from Barbados, St. Lucia, St. Vincent and Trinidad, and Tobago were examined for annual growth checks by Kishore and Chin (2001). Although sectioned otoliths have inconsistent growth checks, whole otoliths reveal relatively clear and consistent checks (presumed to be annuli) in most specimens from which size at age one year is estimated (Kishore and Chin 2001) (Table 7). These same authors reported 10 presumed annuli in the sagittae of the largest specimens, suggesting a longevity of up to 10 years.

TABLE 6

Morphometric relationships for wahoo from the western central Atlantic region. S_R = sagittal radius, SP_A = dorsal spine annuli, SP_L = dorsal spine length, SP_W = dorsal spine weight, SP_D = dorsal spine diameter.

Area	Location	Relationship (units)	Sex	Sample	Equation	Est. kg at	Reference	
				size (n)		1100 mm		
Southeastern	Trinidad & Tobago	Length-whole weight (Wt in kg, L in cm)	All	391	$Wt = 8.9 \times 10^{-8} \times FL^{3.862}$	6.8	Kishore and Chin 2001	
Caribbean	St. Lucia	Length-gutted weight (Wt in g, L in mm)	All	195	$Wt = 1.039 \times 10^{-6} TL^{3.206}$	5.9	Murray 1989, Murray 1999	
				36	$Wt = 2.991 \times 10^{-6} FL^{3.072}$	6.6		
				?	$Wt = 4.06 \times 10^{-6} FL^{3.028}$	6.2		George et al. 2001
			All	75	$FL = 1.086 + 0.950 TL$	-	Murray 1989, Murray 1999	
		Length-sagittal radius (mm)	All	9	$TL = 16.56 S_R^{1.929}$	-	Murray 1989	
Northern Caribbean	Bahamas	Length-whole weight (Wt in kg, L in cm)	All	25	$Wt = 1.741 \times 10^{-6} \times TL^{3.221}$	6.5	Hogarth 1976	
				57	$Wt = 4.691 \times 10^{-5} \times TL^{2.567}$	8.2		
				91	$Wt = 2.037 \times 10^{-6} \times TL^{3.201}$	7.0		
	?	Length-dorsal spine annuli (mm)	All	22	$FL = 748.406 + 214.69 SP_A$	-	Franks et al. 2000	
Gulf of Mexico	Northern	Length-dorsal spine length (mm)	All	59	$FL = 452.736 + 12.852 SP_L$	-	Franks et al. 2000	
		Length-dorsal spine wt (L in mm, Wt in g)	All	63	$FL = 862.358 + 704.691 SP_W$	-		
		Length-dorsal spine diameter (mm)	All	63	$FL = 365.683 + 277.002 SP_D$	-		
		Length-dorsal spine annuli (mm)	All	63	$FL = 735.151 + 186.01 SP_A$	-		
		Dorsal spine diameter-dorsal spine annuli (mm)	All	55	$SP_D = 1.610 + 0.561 SP_A$	-		
Eastern USA	Florida	Length-whole weight (Wt in kg, L in cm)	?	?	$Wt = 3.647 \times 10^{-6} \times TL^{3.082}$	8.2	Beardsley and Richards 1970	
			All	746	$Wt = 1.544 \times 10^{-6} \times FL^{3.294}$	7.1		Hogarth 1976
	North Carolina	Length-whole weight (Wt in kg, L in cm)	All	795	$Wt = 1.845 \times 10^{-6} \times TL^{3.218}$	6.87		
Female			617	$Wt = 2.113 \times 10^{-6} \times TL^{3.192}$	7.0			
Male			178	$Wt = 2.157 \times 10^{-6} \times TL^{3.181}$	6.7			
			Length-length (cm)	All	795	$TL = 2.452 + 1.016 FL$	-	
			Length-caudal fin span (cm)	All	795	$TL = 2.832 + 1.016 CF$	-	
			Length-girth (cm)	All	795	$TL = 0.656 + 1.020 G$	-	
			Weight-girth (Wt in kg, L in cm)	All	795	$Wt = 16.765 + 0.644 G$	-	
			Length-sagittal radius (mm)	?	?	$TL = 34.14 + 0.599 S_R$	-	
	Maryland	Length-whole weight (Wt in kg, L in cm)	All	32	$Wt = 1.517 \times 10^{-6} \times TL^{3.247}$	6.4		
Atlantic	Bermuda	Length-whole weight (Wt in kg, L in cm)	All	72	$Wt = 0.446 \times 10^{-6} \times TL^{3.502}$	6.3	Hogarth 1976	

TABLE 7

Estimated mean lengths at age for wahoo from the western central Atlantic obtained using unvalidated growth checks in hard parts. For ease of comparison total lengths for wahoo from Trinidad and Tobago and North Carolina have been converted to fork lengths (using the length-length conversion equations given for wahoo in the same geographical area).

Location	Length (mm FL)						Reference
	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	
Trinidad & Tobago	847	-	-	-	-	-	Kishore and Chin 2001
Bahamas	961	1179	1391	-	-	-	Franks et al. 2000
Gulf of Mexico	937	1081	1325	1536	1690	1749	Franks et al. 2000
North Carolina	1105	1216	1368	1569	-	-	Hogarth 1976

Wahoo from the northern Gulf of Mexico ($n = 63$) and from Bimini in the Bahamas ($n = 22$) have been tentatively aged using unvalidated annuli in thin-sectioned dorsal fin spines (Franks et al. 2000) (Table 7). Although the first five dorsal fin spines were examined, only the first (largest) spine appeared to have unambiguous translucent bands (presumed annuli). From Bimini, there was no difference between the sexes in size-at-age estimates. From the northern Gulf, up to six annuli were detected in the largest specimens, and again there was no difference in size-at-age estimates between males and females. Sagittal otoliths were also examined from the same fish specimens by Franks et al. (2001) who attempted to enhance the contrast and visibility of vague presumed annual growth checks using a variety of stains and etching techniques. However, since bands were not reliably enhanced in the majority of specimens, they concluded that this was not a useful technique for this species.

For wahoo off the lower Florida coast, Beardsley and Richards (1970) suggested a summer growth rate of 30–40 mm FL per month, based on modal progression of wahoo size-frequency data from a taxidermist. Hogarth (1976) aged wahoo from North Carolina using presumed annuli in whole sagittal otoliths. He used back calculation of lengths at annulus formation (using the otolith radius to body length relationship) to estimate length-at-age and suggested a five year life-span, but noted that the majority (78%) of individuals sampled were less than three years old.

Presumed annuli as well as apparent daily growth checks are clearly visible on the sagittal otoliths from Bermuda, under a scanning electron microscope (Luckhurst et al. 1997). However, they do not provide any size-at-age data in this preliminary study and indicate that validation of the periodicity of the growth

checks will be attempted with an otolith marking (OTC) tag-recapture program in Bermuda. This has not yet yielded any validation results, but a single recapture indicated rapid growth from 5 to 15 kg in an individual at liberty for 10 months (Nash et al. 2002).

Growth parameters

Von Bertalanffy growth parameters have been estimated for wahoo from several locations across the WCA using unvalidated growth marks in hard parts and/or length-frequency data to estimate size-at-age over a range of size classes (see Murray 1989, Murray and Sarvay 1987, Murray and Joseph 1996, Kishore and Chin 2001, George et al. 2001, SAFMC 2000). Asymptotic length (L_{∞}) estimates range from 1410 mm TL to 2210 mm FL, and instantaneous growth (k) estimates vary widely from 0.152–3.93 (on an annual basis). Given the stated uncertainties in all of the estimates and the fact that there is a wide range in estimates, even for wahoo from the same location (e.g., Murray 1989), they should be considered as highly preliminary.

MORTALITY

There have been a few estimates of mortality rates for wahoo from the WCA. Off St. Lucia in the southeastern Caribbean, preliminary estimates place total mortality between 69 and 90% annually, natural mortality between 38 and 44% annually, and fishing mortality between 46 and 83% annually (Murray and Sarvay 1987, Murray 1989 and Murray and Joseph 1996). However, these mortality estimates are likely to be biased due to the lack of modal progression in the length-frequency distributions (Neilson et al. 1999). George et al.'s (2001) estimates of annual total mortality (99%), natural mortality (47%) and fishing mortality

(98%) are likely to be unrealistically high, given the possibility that the larger fish may be migrating out of the sampling area. Hogarth (1976) estimated total mortality for wahoo collected off North Carolina at between 35 and 38% annually. Like the growth rate parameters, these mortality estimates from the WCA should be considered as highly preliminary, given the high variation in estimates even for fish from the same location and the general lack of modal progression in the length-frequency data on which they are based.

FOOD AND FEEDING HABITS

There have been a few studies of wahoo diet and feeding habits in the WCA which indicate that it is primarily piscivorous, with fishes accounting for more than 70% of the total number of food items (Figure 2) and more than 90% of the total volume and occurrence of prey items in the northern Gulf of Mexico and the US south Atlantic states (Table 8) (see Hogarth 1976, Manooch and Hogarth 1983). Collette and Nauen (1983) and Collette (in press) list tunas (Scombridae), flyingfishes (Exocoetidae), herrings and pilchards (Clupeidae), scads (*Decapterus* spp.), and lanternfishes (Myctophidae) as common prey of wahoo in the WCA. In Bermuda, little tunny (*Euthynnus alletteratus*) and flyingfishes are common vertebrate prey (Luckhurst unpubl. data from 150 wahoo caught Sep–Oct). Invertebrate prey, comprising mostly squids, varies in importance with location and accounts for between 2.6 and 26.3% of all food items consumed by wahoo from the northern Gulf of Mexico (Manooch and Hogarth 1983) and the US south Atlantic states (Hogarth 1976, Manooch and Hogarth 1983) (Figure 2). Squids are also listed as important prey items for wahoo from the WCA (Collette and Nauen 1983, Collette in press) and Bermuda (Luckhurst unpubl. data). The groups of key importance to the diet are similar among locations and comprise fast swimming pelagic families (scombrids, exocoetids, clupeids, and cephalopods) as well as those which are generally associated with floating material (stromateids, juvenile carangids, diodontids, and balistids) (Figure 2). This indicates that wahoo forages in open water as well as below floating material. Manooch and Hogarth (1983) note that small items do not feature in the diet, probably because wahoo lack gill rakers, and there is no apparent relationship between predator and prey size since wahoo can bite large prey into pieces. Wahoo is one of the fastest pelagic species, attaining bursts of speed exceeding 75 km per hour (Joseph et al. 1988). Consequently it is able to capture a wide range of

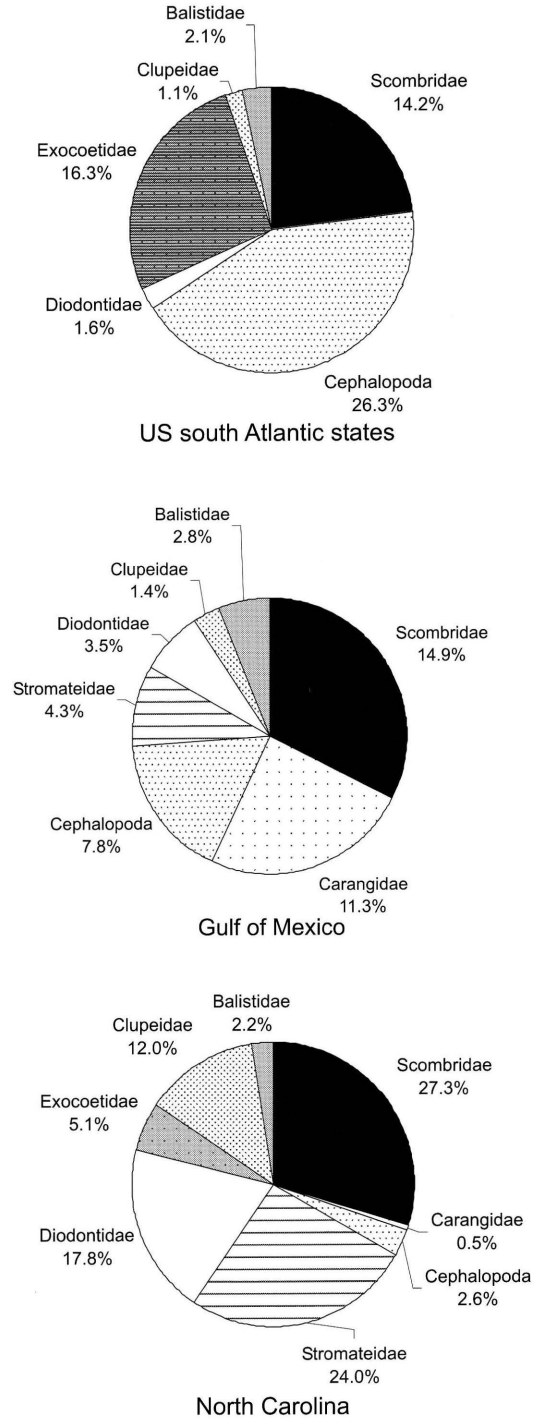


Figure 2. Comparison of the diet of wahoo from the western central Atlantic based on numerical abundance of major prey items in stomachs. Data from the Gulf of Mexico ($n = 95$ fish from northwest Florida, Louisiana and Texas) and the US south Atlantic states ($n = 172$ fish from North Carolina, South Carolina, Georgia, east coast of Florida and Florida Keys) were collected in 1980–1981 and are from Manooch and Hogarth (1983). Data from North Carolina ($n = 645$ fish) were collected in 1964–1971 and are from Hogarth (1976).

TABLE 8

Diet of wahoo from the northern Gulf of Mexico and the US south Atlantic states (1980–1981) showing the relative importance of prey families or higher taxa assessed by percent frequency of occurrence in stomachs containing food and by percent of total volume of prey items. Data are extracted from Manooch and Hogarth (1983).

Location	US Gulf of Mexico		US south Atlantic states	
Total no. fish examined	95		172	
Total no. fish prey species	13		11	
Total stomachs w. food	71		123	
Total prey volume (ml)	3717		7543	
Freq. of occurrence	% occurrence	Rank	% occurrence	Rank
Fish	91.5	.	90.2	.
Unid. fish	59.2	.	47.2	.
Clupeidae	2.8	.	1.6	5
Exocoetidae	0.0	.	21.1	2
Echeneidae	1.4	.	0.0	.
Carangidae	15.5	2	0.0	.
Coryphaenidae	1.4	.	0.0	.
Scombridae	22.5	1	19.5	3
Stromateidae	1.4	.	0.0	.
Bothidae	0.0	.	0.8	.
Balistidae	4.2	5	1.6	5
Diodontidae	5.6	4	2.4	4
Invertebrates	14.1	.	?	.
Cephalopoda	14.1	3	25.2	1
Crustacea	0.0	.	0.8	.
Volume	% volume	Rank	% volume	Rank
Fish	99.2	.	91.9	.
Unid. fish	19.7	.	19.9	.
Clupeidae	2.3	.	0.5	.
Exocoetidae	0.0	.	22.4	2
Echeneidae	0.4	.	0.0	.
Carangidae	15.4	2	0.0	.
Coryphaenidae	5.0	.	0.0	.
Scombridae	51.7	1	44.6	1
Stromateidae	3.5	3	0.0	.
Bothidae	0.0	.	0.1	.
Balistidae	0.2	.	1.9	5
Diodontidae	1.1	4	2.5	4
Invertebrates	0.5	.	8.0	.
Cephalopoda	0.5	5	8.0	3
Crustacea	0.0	.	0.0	.

prey species while foraging in the water column. Interestingly, although Scombridae is one of the most important prey families overall (Figure 2, Table 8), there have been no reported incidences of cannibalism.

PARASITES

Although there have been relatively few studies of wahoo parasites from the WCA, Hogarth (1976) and Manooch and Hogarth (1983) found that 80.5% of stomachs from North Carolina, the US south Atlantic states, and the Gulf of Mexico contain 1–13 (average 2) large digenetic trematodes (tentatively identified as *Hirudinella ventricosa*). Levels of infection are the same for males and females, independent of host size, and there is no discernible effect of the parasites on the condition of individuals (Manooch and Hogarth 1983). However, geographical differences in the level of infestation are evident, with wahoo from the east and south coasts of Florida having the lowest levels. Wahoo from the Bahamas and North Carolina are also occasionally infested with a monostome (tentatively identified as *Didymocystis coastesi*) in the eye muscle (Manooch and Hogarth 1983). In Bermuda, Luckhurst (unpubl.) examined wahoo stomachs ($n = 150$) and found that 94% contained between 1–12 (average 2) large digenetic trematodes. He also reported parasitic copepods attached close to the caudal fin of some Bermuda wahoo. The total parasite fauna of wahoo is low, with only 11 different parasites (including a copepod worm, a fluke, a tissue fluke, 2 gill worms, 3 tapeworms, and 3 copepods) from western Atlantic specimens. Cressey and Cressey (1980) and Cressey et al. (1983) list seven species (6 genera) of parasitic copepods from wahoo (locations of samples not specified), with infestation rates being highest for *Brachiella thynni* (61%), *Gloiopotes hygomianus* (42%), and *Caligus productus* (17%).

STOCK STRUCTURE

Several authors have commented generally on the possible nature of the stock structure of wahoo in the WCA (e.g., Hunte 1987, Mahon 1990, 1996, Neilson et al. 1999), based on sparse length-frequency and seasonality data. All agree that the data are insufficient to draw any firm conclusions but consider it reasonable to assume that wahoo is likely to have a shared-stock status within the WCA, either straddling or migrating between the EEZs of two or more countries. Manooch and Hogarth (1983) speculate that differences in levels of

infestation of wahoo by the giant trematode, observed between the east and south coasts of Florida and the rest of the US south Atlantic states and the northern Gulf of Mexico, may indicate separate stocks. However, they conclude that it is more likely caused by slight geographical differences in diet. Lacking any substantive data suggesting otherwise, the SAFMC (1998, 2000) is using a working hypothesis of a single-stock model for preparation of a management plan for wahoo.

More recent genetic data concur with earlier suggestions that wahoo in the WCA probably comprise a single unit stock. A preliminary study of genetic variation, using genomic DNA of 78 wahoo from across the WCA (Bermuda, Gulf Coast of the USA, Dominica, and Tobago) and just two RAPD (Random Amplified Polymorphic DNA) primers, indicates genetic homogeneity consistent with a single stock (Collymore 2000). A follow-up study by Constantine (2002) tested the single-stock hypothesis, using RAPD markers obtained from five primers to examine 114 wahoo from six locations in the WCA (Bermuda, Gulf Coast of the USA, Dominica, St. Lucia, Barbados, and Tobago) and an outgroup sample ($n = 33$) from the mid-Atlantic (Rocedos São Pedro e São Paulo, off Brazil). A high level of genetic variation within and among samples from different locations in the WCA, but with no clear separation, supports the single-stock hypothesis. Furthermore, a lack of genetic separation between the WCA and the mid-Atlantic samples suggests that the stock boundary extends beyond the WCA (Constantine 2002).

Garber et al. (2001) provide a molecular characterisation of the mtDNA control region of the wahoo genome, including the structure and sequence of the flanking tRNA genes and identification of a hypervariable segment at the 5' end of the control region. This will be useful in future studies for designing specific primers and selecting appropriate restriction enzymes for this portion of the genome, to further test the null hypothesis of a single stock.

STATUS OF THE RESOURCE

Although ICCAT monitors landings of wahoo throughout the Atlantic, they have not yet attempted to conduct any assessments nor to manage this species. There has been no region-wide stock assessment in the WCA and, as such, the status of the resource remains uncertain. A sub-regional assessment of wahoo in the southeastern Caribbean, using a combination of length-based models (length-based catch curve and length-based virtual population analysis) suggests an annual

maximum sustainable yield (MSY) of 2,137 mt corresponding to a fishing mortality of 29% annually ($F_{msy} = 0.34 \text{ y}^{-1}$) (George et al. 2001). The stock was deemed severely overfished, given that their estimates of current annual fishing mortality greatly exceeded F_{msy} . They also estimated maximum yield per recruit (YPR) to occur at an annual fishing mortality of 66% ($F_{max} = 1.09$) (for the present size-at-first capture of 900 mm FL) and annual fishing mortality rates of 49 and 37% ($F_{max} = 0.68$ and 0.47) to maintain the stock at 30 and 40% of its initial biomass per recruit (BPR) respectively. Again, the indication is of severe overfishing currently taking place. However, the results of this assessment are highly uncertain and dependent on dubious growth parameters. They are also likely to be biased, because there is strong indication that the southeastern Caribbean population is not a separate stock from that present in the rest of the WCA; therefore, the catch data used only represent about 20% of the total catch from the WCA stock. Moreover, the classification of the stock as severely overfished is based on current mortality estimates that are highly uncertain (George et al. 2001).

The Gulf of Mexico Fishery Management Council uses estimates of mean annual landings as a proxy for MSY and current estimates oscillate between 650 and 750 mt (FAO 2002a). Again, this is unlikely to be a realistic MSY for the stock, given that the Gulf of Mexico population is probably not a separate stock. The US NMFS has not done any assessment or defined stocks of wahoo in US waters.

There have been a number of studies examining local or sub-regional time-series of wahoo catch and effort data as possible indicators of declines in stock abundance. None of these studies have found any evidence of decline, but there is some question as to whether the available catch per unit effort (CPUE) data sets are suitable as abundance indicators for wahoo, since increases in fishing power may not have been adequately accounted for in the unit of effort used (e.g., catch per trip). Furthermore, wahoo is often part of a multi-species catch per trip and not necessarily the primary target. For example, in the southeastern Caribbean island of Barbados, the average annual catch per trip for "kingfish" (primarily wahoo) shows an increase over the years 1960–1982 which is attributed to increased fishing power per trip, rather than an actual increase in the abundance of wahoo (Hunte 1987). Mahon et al. (1990) examined CPUE (catch per trip) data series from several islands in the southeastern Caribbean chain ranging from 32 years (1958–1989) in

Barbados, 11 years (1979–1989) in St. Vincent, 8 years (1982–1989) in Grenada, to 5 years (1985–1989) in St. Lucia. No declines were evident, but they reported significant inter-annual variability in the mean CPUE and a lack of synchrony in the annual abundance indices among islands. They concluded that wahoo have a patchy distribution in this sub-region which varies from year to year but has not declined overall, or that the CPUE indices used are not a good index of wahoo abundance. In the US Virgin Islands, CPUE data from the recreational fishery for the years 1967–1979 showed no net long-term change in catch per trip over this 12-year period (Hunte 1987). In North Carolina a CPUE time-series from the recreational fishery off Hatteras and Oregon Inlet, showed a steady increase from around 0.12 fish per trip in the mid 1960s to 0.35 fish per trip in the early 1970s and a slight concomitant increase in fishing effort (number of trips) (Hogarth 1976). This he attributed to improved fishing techniques, rather than a real increase in the abundance of wahoo in the Gulf Stream over the 9-year (1964–1972) period. In Bermuda, where wahoo is the primary target, mean annual CPUE data show no trends over the period 1987 to 1996, suggesting no marked changes in the abundance of wahoo in Bermuda's waters over 11 years (Luckhurst and Trott 2000).

DATA NEEDS

Based on the one-stock hypothesis for wahoo in the WCA, a regional approach to stock assessment and management will be required. Recreational and commercial fishing pressure on wahoo is continuing to rise throughout much of the region and there is concern that the stock is, or soon will be, negatively impacted and should be managed. However, assessment and management attempts will be constrained by the current lack of knowledge in several key areas. Significant improvements in wahoo catch and effort data collection and reporting are needed to include all countries participating in the fishery and to obtain reliable abundance estimates and exploitation trends for this stock. Wahoo migration and movement patterns are inadequately known. These data are necessary for determining critical habitats (e.g., important spawning areas), determining relative spatial and temporal distribution of the resource among the EEZs of the countries in the WCA, and improving the interpretation of genetic stock structure data. Uncertain age and growth estimates and a general lack of modal progression of fishery-dependent length-frequency data over time are a significant con-

straint to using age and length-based approaches to stock assessment and to determining current mortality and exploitation rates. Data on reproductive characteristics (e.g., fecundity-length relationships, age and size at maturity, spawning season) are required from a larger sample size and for a greater geographical area to improve confidence in attempts to assess the impacts of management actions on spawning stock biomass and for assisting in the appropriate choice of minimum harvest sizes and closed seasons. A more comprehensive analysis of genetic stock structure is required to determine the relationship between wahoo from the WCA and the entire Atlantic Ocean and thus whether assessment and management of this species will need to be expanded to a broader geographical area.

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