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Wreckfish Polyprion americanus in the North Atlantic: Fisheries, Biology, and Management of a Widely Distributed and Long-Lived Fish

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Abstract.—The wreckfish Polyprion americanus is a long-lived, globally distributed species that supports fisheries on both sides of the Atlantic Ocean, in the Mediterranean, and in the western South Pacific. Wreckfish in the western North Atlantic have a life history that includes an extended (perhaps for two years) pelagic juvenile stage that drifts in the North Atlantic gyre; slow growth rates after assuming demersal existence; recruitment to the American fishery resulting from migration to the grounds at an advanced age (four years); and a long life (31 years at 1460 mm total length and 47 kg total weight). Experience with wreckfish in isolated geographic habitats such as Bermuda indicates that wreckfish can be quickly overfished as fishing technology develops to target the species. Because of its life

1Coauthors listed alphabetically.
The wreckfish, *Polyprion americanus* (Schneider 1801), is widely distributed and occurs on both sides of the Atlantic Ocean; on the Mid-Atlantic Ridge and Atlantic islands (Bermuda, Azores, Madeira, Canaries, Tristan da Cunha, Gough); on Atlantic seamounts with appropriate depths (e.g., Vema); in the Mediterranean; in the southern Indian Ocean (St. Paul and Amsterdam Islands); and in the western South Pacific (southern Australia and New Zealand and nearby banks) (Heemstra 1986; Sedberry et al. 1994; Sedberry 1995) (Figure 1). Wreckfish are large (2 m length), presumably long-lived, demersal fish that have an extended pelagic juvenile stage (to 60 cm length) that associates with floating debris, the habit responsible for their American common name. In the Atlantic, wreckfish occur in the landings of the southeastern United States, Bermuda, the Azores, Madeira, and southwestern Europe (including Mediterranean countries) (Sedberry, personal observation; FAO 1994). There is a small sportfishery for wreckfish in the Bahamas (Carlin, personal observation). There is a very large but poorly-documented fishery for wreckfish in Brazil (Sedberry, personal observation). They are landed incidentally in multispecies long-line and trawl fisheries in southern Africa and nearby seamounts and banks, including Gough Island and Vema Seamount (D. Japp, Sea Fisheries Research Institute, personal communication). In the western South Pacific, wreckfish are caught incidentally to other species in long-line fisheries on seamounts and continental slopes. In Australia, the fishery operates off Tasmania and the southern mainland, utilizing demersal longlines in 200–600 m of water (Sedberry, personal observation). This fishery targets gemfish *Rexea solandri*; deepsea trevalla or blue-nose *Hyperoglyphe antarctica*; and groper or hapuku *Polyprion oxygeneios*, although it also catches large numbers of *P. americanus* on vertical longlines. In New Zealand, wreckfish are caught on demersal fishery, off the northem South Island (Cook gears are used (ventral horizontal off-bottom seine, and hapuku. fishery for *Polyprion with chartered fish fishing magazines.

In the mid-1980s it was found that wreckfish, sidered rare in the western Pacific (Ray 1986). A very specific habitat range has been managed co-management and individual fishing plan (SAPMC 1998). The fishery was managed to maintain the fishery would satisfy the fishermen and the environment.

Wreckfish Distribution Records (+)

![Wreckfish Distribution Records](image_url)

**FIGURE 1.** Distribution of wreckfish, *Polyprion americanus*. + = demersal or habitat unstated; p = captures of pelagic juveniles.
caught on demersal longlines from vessels working off the northern ends of the North Island and South Island (Cook Strait). A variety of long-line gears are used (vertical, horizontal on-bottom, horizontal off-bottom), and target gemfish, blue-nose, and hapuku. There is also a recreational fishery for Polypriion species in New Zealand, with chartered fishing trips advertised in sport-fishing magazines.

In the mid-1980s an American fishery developed for wreckfish, a species that had been considered rare in the western North Atlantic (Robins and Ray 1986). Because of its perceived rarity and very specific habitat requirements, wreckfish has been managed conservatively. Sedberry et al. (1994) reviewed development of the fishery from its establishment through the first management plans (SAFMC 1990, 1991a). Since that time additional management measures have been established to maintain catch and price levels that would satisfy the concerns of vested wreckfishermen and management agencies (SAFMC 1991b). Also, additional life history data have been published (Sedberry et al. 1996) or collected (this study). Management measures in the United States included a total allowable catch (TAC), individual transferable quotas (ITQs), gear restrictions (no longlines), and a spawning season closure of the fishery (SAFMC 1991b). Such intensive management was previously unheard of in a southeastern U.S. fishery, but was supported by the fishermen who developed the fishery and by the South Atlantic Fisheries Management Council (SAFMC). When the management plan began to be developed, little was known of the biology of wreckfish, but it has since been determined that there is a single genetic stock of wreckfish in the North Atlantic and Mediterranean that is distinct from wreckfish from other parts of the world (Sedberry et al. 1996). In addition, preliminary age-length keys and data on reproductive biology have been used in an annual assessment to set the quota (Anonymous 1997; Manooch, Sedberry and Ulrich, personal observation).

We now know that the wreckfish is a long-lived species that has a wide geographic distribution. A single genetic stock of wreckfish extends from the only documented North Atlantic wreckfish spawning grounds off South Carolina to the Madeira archipelago and Mediterranean Sea (Sedberry et al. 1996). Mechanisms for maintaining gene flow and the patterns of recruitment of juveniles and adults are poorly understood, but some active adult migration or drifting of pelagic juvenile phases must be involved (Sedberry et al. 1996). Because the species is long-lived, widely distributed, possesses an extended pelagic stage, and is fished by several North Atlantic nations, it presents a management problem. The purpose of this report is to review the recent developments in our knowledge of the biology of the species throughout its North Atlantic range, to summarize management strategies that are in place, and to suggest management solutions.

Methods

We obtained biological and fisheries data on wreckfish from sampling the landings in our respective countries and by compiling data collected by our employing fishery research and management agencies. Samples for life history and genetic study and observations of length frequency, fishing methods, and catch rates were made during port sampling, research cruises, and fishing voyages. The development and prosecution of wreckfish fisheries were described by observing vessels and landings and by interviewing wreckfishermen.

 Sagittae for aging of wreckfish came exclusively from American fish caught from 1989 to 1993 on the Blake Plateau (approximately 32°N, 79°W), and were sampled by research vessel or from commercial landings. Sagittae were removed from the cranial by chiseling through the otic capsule, and were stored dry in envelopes. Total length (TL) and total uncut length (TW, when available) were measured on each fish. Sectioned sagittae (N = 790) were used to obtain ages by viewing under a dissecting microscope fitted with a video camera and monitor. Lateral measurements from the kernel to opaque rings and to the margin were recorded. For back-calculated length at age, measurements to opaque rings were made on 534 ooliths.

Marginal increment analysis was used to validate the annual natural rate of oolites on ooliths. We plotted, by month, percent of ooliths where marginal increments were zero, that is, the period when opaque zones were formed. Francis et al. (in press) determined that oolite rings on the sectioned ooliths of hapuku P. oxygynaeus, were laid down annually, based on injection of tagged fish with oxytetracycline.

Growth parameters, $L_a$ (asymptotic length), $k$ (growth coefficient) and $t_e$ (age at beginning of
growth) were estimated from the von Bertalanffy equation:

\[ L_t = L_\infty (1 - \exp[-k(t - t_0)]) \]

a widely-used growth model fitted to back-calculated length-at-age data (Ricker 1975; Everhart et al. 1981). Growth parameters were estimated using SAS PROC NLIN with the Marquardt Option (SAS Institute 1982); data were weighted by the number of fish sampled at each age.

Tissue samples for genetic study were collected from port sampling in Charleston, South Carolina, United States, Horta (Azores, Portugal), Funchal (Madeira, Portugal), Bermuda, and Itajaí (Brazil); or by participation in research cruises or fishing trips aboard commercial long-line vessels operating on the Mid-Atlantic Ridge, in Majorca (Mediterranean Spain), Brazil, Australia, and New Zealand (see Sedberry et al. 1996 for additional details of genetic sampling). Samples for genetic analysis included those collected and analyzed by Sedberry et al. (1996) and additional materials collected from Bermuda and by Faroese research vessels operating on various locations on the Mid-Atlantic Ridge. Investigation of genetic population structure was conducted by examining restriction fragment length polymorphisms (RFLPs) in mitochondrial DNA (mtDNA) amplified via the polymerase chain reaction (PCR). Details of DNA isolation, storage, restriction enzyme digestion, and elucidation of fragment length polymorphisms can be found in Sedberry et al. (1996). Sedberry et al. (1996) obtained nine restriction fragment length profiles from a PCR-amplified fragment (approximately 1,500 base pairs) of the ND1 mitochondrial gene from 179 wreckfish from seven localities (Blake Plateau, Azores, Madeira, Majorca, Brazil, Australia, and New Zealand). Two enzymes, Hae III and ScrFI, were informative and indicated no stock separation between eastern North Atlantic/Mediterranean (Azores, Majorca, Madeira), and western North Atlantic (Blake Plateau) wreckfish, but separated western South Atlantic wreckfish from the North Atlantic. South Atlantic wreckfish share restriction-site similarities with western Pacific wreckfish that were not shared with North Atlantic wreckfish.

For the present paper, we obtained samples from four additional locations. These included:

1. Bermuda \((N = 11)\),
2. the Mid-Atlantic Ridge north of the Azores ("North Azores") \((N = 20)\),
3. the Mid-Atlantic Ridge southwest of the Azores ("Southwest Azores") \((N = 6)\), and
4. seamounts west of Madeira ("West Madeira") \((N = 5)\).

These additional samples were analyzed according to the methods of Sedberry et al. (1996) for the two informative enzymes (Hae III and ScrFI) and the resulting RFLPs compared to the results obtained in that paper.

Results and Discussion

The U.S. Fishery

Sedberry et al. (1994) reviewed development of the U.S. wreckfish fishery, and their results will be summarized here. The fishery for wreckfish developed in the mid 1980s, shortly after biologists from the South Carolina Department of Natural Resources observed (from submersible) wreckfish associated with coral mounds on the western edge of the Blake Plateau. At about that time, pelagic long-liners working on the Blake Plateau southeast of Charleston landed a few wreckfish they had caught on longlines lowered to coral pinnacles on the bottom, on fish marks noted on echosounders. The presence of concentrations of wreckfish in the western North Atlantic that could support commercial fisheries was virtually unknown until 1987, when a hook-and-line fishery developed on an area of the Blake Plateau known as the Charleston Bump \((32^\circ N, 79^\circ W)\) characterized by an extensive ridge having approximately 100 m of relief, in depths ranging from 450 to 600 m (Figure 2). This topographic feature deflects the Gulf Stream offshore, resulting in upwelling (Brooks and Bane 1978) and perhaps increased productivity that supports a population of a large fish, in depths that are relatively food limited.

Following the early landings, additional boats entered the fishery. The early boats, as well as subsequent entrants in this fishery, ranged from 13 to 23 m in length. These boats were mainly vessels utilized in the southeastern U.S. snapper-grouper fishery, and included some swordfish long-line boats and shrimp trawlers. The latter groups participated part-time, alternating between the swordfish or shrimp and wreckfish fisheries.

The vessels fished 2–4 heavy-duty hydraulic reels or long-line reels spooled with 3.2 mm cable, and a terminal rig consisting of 30–50 kg of weight and 8–12 large hooks (#3 tuna circle) bailed with squid bottom and fish by wreckfish caught of the depth. fish hooked before the fishing was done frable habitat, was often difficult for fishermen to locate even on the near surface due to stable position, extensive vertical although fish were hard bottom. Fishing on the near bottom easy to locate.
WRECKFISH IN THE NORTH ATLANTIC: FISHERIES, BIOLOGY, AND MANAGEMENT

Discussion

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and perhaps in-
are relatively food

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heavy-duty hydraulic with 3.2 mm consisting of 30–50 kg and hooks (#3 tuna circle)

baited with squid. The gear was lowered to the bottom and fished just above the bottom. Strikes by wreckfish could be felt at the surface, in spite of the depth, and several fish were usually hooked before the gear was retrieved.

During the first two years of the fishery, fishing was done from vessels anchored over suitable habitat, located by fathometer. Anchoring was often difficult in Gulf Stream currents and fishermen began to maintain vessel headway without anchoring, to counteract the velocity of the surface current and to maintain a relatively stable position. Gear was fished over areas of extensive vertical relief on the Charleston Bump, although fish were sometimes caught over flat hard bottom. Fishermen seemed to prefer fishing on the nearly vertical scarp, because it was easy to locate, and because catches remained high, giving little incentive to explore other sites. Submersible observations indicated that wreckfish were especially concentrated near the high-relief scarp on the Charleston Bump, relative to flat hard bottom. Because of upwelling on the Charleston Bump, bottom temperatures were highly variable (Table 1). We have recorded bottom temperatures on the Charleston Bump ranging from 6.2°C to 16.3°C, with temperature fluctuations of 7°C at the same site over a few days. Wreckfish catches occurred throughout this range, with a decline in fishing success in waters below 9.0°C.

Initial catch rates in the newly-established fishery were high, with some boats catching between 1.4 and 3.6 metric tons per 7–8 d trip. Monthly landings increased from around 4 metric tons per month in 1987 to 9–36 metric tons.
per month in 1988, to about 14–100 metric tons per month in 1989 up to a maximum of 454 metric tons in March of 1990. The fishery expanded rapidly from 1987 to 1989 (Figure 3), as fishing methods improved and more fishermen joined the fishery, causing concern among fishermen and management agencies. Monitoring of annual commercial landings indicated that catch rates went from less than 400 kg annually in 1984 through 1986 to 13 metric tons in 1987, 200 metric tons in 1988, to about 1,900 metric tons in 1989 (Figure 3). In 1988, 11 vessels participated, making 63 trips. By 1989, 39 vessels targeting wreckfish made 383 trips. In early 1990 a commercial fisherman estimated that there were at least 40 boats participating in the fishery. In June 1990 the SAFMC imposed a 2-million pound (907 metric ton) TAC; the quota was projected to be reached by the end of July and the fishery was closed on 8 August. Before closure, vessel catch rates (74 vessels) ranged between 2.7 and 5.0 metric tons for a 7–8 d trip. One extended trip (10 d) by a larger vessel resulted in landings of greater than 13.6 metric tons. In 1990, the number of direct participants ranged to range 1.

After the collapse of the fishery, management measures and price levels of vested wreckfish agencies. The fishery management plan was implemented to ensure (507.2 sure) (15 Januar spawning period) fish in 1992, but most of the catch (19 boats participated 1994 (17 boats) vessels landed in 1997.

In 1990, the 395–550 Balearic Islands Sedberry, personal observation

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Depth (m)</th>
<th>Location</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.2–16.3</td>
<td>450–600</td>
<td>Blake Plateau</td>
<td>Sedberry et al. (1994), Sedberry and Ulrich, personal observation</td>
</tr>
<tr>
<td>6.0–15.0</td>
<td>214–450</td>
<td>SE Brazil Slope</td>
<td>Haimovici et al. (1994), Sedberry, personal observation</td>
</tr>
<tr>
<td>10.5</td>
<td>44–300</td>
<td>New Zealand</td>
<td>Sedberry and Ulrich, personal observation</td>
</tr>
<tr>
<td></td>
<td>219–732</td>
<td>Madeira and Salvage Island</td>
<td>Sedberry, personal observation</td>
</tr>
<tr>
<td></td>
<td>295–550</td>
<td>Balearic Islands</td>
<td>Sedberry, personal observation</td>
</tr>
</tbody>
</table>

![U.S. Wreckfish Landings](image)

**Figure 3.** Annual landings (metric tons), catch per trip, and Total Allowable Catch (TAC) for wreckfish caught on the Blake Plateau and landed in the United States.
number of direct participants in this fishery was estimated to range between 125 and 175.

After the closure of the fishery in 1990, the fishery reopened in 1991 with additional management measures established to maintain catch and price levels that would satisfy the concerns of vested wreckfishermen and management agencies. The fishery is now managed with an individual transferable quota system, using the same TAC (907.2 metric tons), and includes a closure (15 January–15 April) during the main spawning period. About 46 boats landed wreckfish in 1992, but fewer than 10 accounted for most of the catch. Participation declined in 1993 (19 boats participated), and declined slightly in 1994 (17 boats) and 1995 (13 boats). Only nine vessels landed wreckfish in 1996 and seven in 1997.

In 1990, the SAFMC acted to place restrictions on the fishery because expansion at the time concerned biologists, fishermen, and the management council, as similar developments caused overfishing very quickly in the tilefish Lopholatilus chamaeleonticeps and snowy grouper Epinephelus niveatus fisheries in the southeastern United States (Barans and Stender 1993; Wanasiki et al., in press). There were few data available on the life history of the species on which to develop a management plan, and annual examination of length frequency (Figure 4) and catch per unit effort (CPUE, Figure 3) showed no change indicative of stock decline. However, we believed that wreckfish were recruited to the grounds at a large size, since submersible observations indicated only large mature fish present on the Blake Plateau, and fishing records indicated that localized fished out areas were replenished with large fish (Sedberry et al. 1994; Ulrich, personal observation). Because fish are apparently recruited to the grounds at a large size, a decline in lengths may not occur or it may take several years before fishing pressure could be reflected in decreasing size of fish. The presence of fish hooks not used on the local grounds, in fish that were caught there, indicated that perhaps fish were being recruited at large size from distant areas (Sedberry et al. 1996). If so, it would take several years before decline in fish length or CPUE would show up in the landings. By that time, it would be too late to initiate a management plan. For now, it appears as though the stock can be maintained with the current level of effort, provided there are not significantly increased removals of fish from other areas of the stock’s range.

The rapid development in this fishery caused concern among state and federal fisheries biologists and fishermen, as the expansion already exhibited by this fishery by the end of 1989 was expected by the SAFMC to accelerate in 1990. As stocks of shelf species have declined (e.g., Collins and Sedberry 1991; Zhao et al. 1997), fishermen have moved to deeper water to exploit tilefishes (Malacanthidae) and deep-water groupers (Serranidae). In 1990, offshore fishermen anticipated additional limitations on swordfish and shark fisheries, and the rapid escalation in the wreckfish fishery that occurred in 1989 and 1990 was expected to continue as many of the fishermen licensed to fish for swordfish and sharks switched to wreckfish.

In response to fishermen’s concerns, this rapid growth, and potential vastly increased effort, the SAFMC developed three amendments to the Fishery Management Plan for the Snapper/Grouper Fishery of the South Atlantic Region (SAFMC 1990, 1991a, 1991b). These amendments had the following objectives:

1. add wreckfish to the snapper grouper unit, so that plans and regulations could be developed;
2. define parameters that could be used to establish optimum yield and overfishing;
3. establish permitting regulations;
4. collect data needed for management;
5. establish a control date for inclusion of participants in a potential limited entry;
6. establish a fishing year starting on 16 April;
7. establish a process whereby TAC would be set, initially at 907 metric tons, and with a temporary 4.5-metric-ton trip limit;
8. establish a spawning season closure, from 15 January through 15 April;
9. ban the use of longlines in the wreckfish fishery;
10. adjust the 1990 TAC to 1,361 metric tons, to be released at the rate of 434 metric tons per quarter (16 April–15 July, 16 July–15 October, 16 October–15 January, with the same spawning season closure (15 January–15 April); and
11. establish an ITQ for the wreckfish fishery.

The control date was later extended to include all fishermen in the fishery or geared up to
FIGURE 4.—Length frequency distributions of wreckfish caught on the Blake Plateau and landed in South Carolina, USA, from 1989 to 1997.

Fish by 8 August 1990. Fishermen in the fishery by that date could obtain a permit to fish, in case of future imposition of a limited entry. The initial TAC was based primarily on previous catches and was aimed at maintaining a fishing level and acceptable price structure that would be similar to 1988. In 1990, the first year of the TAC, it was determined that about 880 metric tons had been harvested by 31 July 1990, and on 8 August, the fishery was closed. The subsequent spawning season closure was based on preliminary data obtained by D. Wyanski (SCDNR, unpublished data).

The TAC was adjusted in 1991 to 1,361 metric tons, to be released at the rate of 454 metric tons per quarter. The third-quarter 454-metric-ton release was contingent upon no signs of overfishing (i.e., no decline in mean size or CPUE). The quota tracking and assessment was incomplete because of lack of data, and the third portion of the quota was not released that year. The TAC has remained at 907 metric tons per fishing year since then, based on an annual assessment conducted by the SAFMC.

The ITQ divided the TAC into 100 shares, with half of the eligible fishermen maintaining 50% of the eligible fishermen on the fishery; the remaining fishermen were then allowed to divide the remaining landings from July 1990, and landed 1.27 metric tons per annum and 24 September share plus pro rata share after the wreckfish have dealt with tem and tracks. Catches were greater from the big year of 1990/1991 compared to the smaller year of 1993/1994. A small area of the managed area was shown to increase in size of fish (Fig. C. Initial inc...
with half of the shares distributed so that each eligible fisherman received shares, and the remaining 50% of shares to be distributed among eligible fishermen, on a pro rata basis, dependent on the fisherman's catching history. Eligible fishermen were those with documented wreckfish landings from 1 January 1989 through 24 September 1990, and who could document having landed 1.27 metric tons between 1 January 1987 and 24 September 1990. No initial share (equal share plus pro rata share) could be greater than 10% of the 100 available shares. Other aspects of the wreckfish management plan amendments have dealt with how to administer the quota system and track the quota.

Catches with the quota in place are down from the big year in 1989 (Figure 3), and CPUE is lower compared to the peak but is relatively stable. A small downward trend in CPUE occurred from 1994 to 1996. Because the fishery is managed with a quota, CPUE may not be a good measure of abundance, but monitoring of length frequency has given no indication of decreasing size of fish (Figure 4).

Initial increases in CPUE and landings, which occurred while maintaining size stability of landed fish, indicated that the resource may be large enough to support the fishery. However, current management in the United States assumes a single stock in U.S. waters, and no fishing pressure on that stock beyond that exercised by the small fleet working the Blake Plateau grounds. These assumptions may not be true, and sources of recruits to the Blake Plateau grounds remain unknown.

The Bermuda Fishery
Demersal fisheries in Bermuda have historically targeted shallow reef species, especially groupers and snappers, with fish pots being the primary gear type (Luckhurst 1996). The development of the fishery for wreckfish was coincident with, and partially a result of, the decline in the traditional shallow-water grouper fishery of Bermuda, as documented by Luckhurst (1996). As a result of intense fishing pressure, especially on spawning aggregations, several grouper species became commercially extinct during the period 1975 to 1981. The fish pot ban of 1990 caused a major shift in fishing effort to line fishing (which had been a limited effort dating back to the late 1960s), including vertical long-lining in deeper water. As in the United States, fishermen in Bermuda moved progressively into deeper water as the stocks of shallower reef fishes became depleted. Anecdotal information indicated that the first wreckfish was caught in Bermuda in the early 1970s.

Fishing intensity was initially low for wreckfish, but it rapidly increased. Most of this increased fishing effort was the result of the introduction of a technological innovation (vertical longlines) to the Bermuda deep-reef fishery in 1980. Many fishermen invested in this new gear type when they witnessed the initial high catches of snappers from the shallower deep-reef strata (215–325 m). The directed fishery for wreckfish was initiated by one fisherman (Bobby Doe), who had initially started snapper reel fishing in the shallower depth strata on the slopes of the Bermuda seamount. As abundance of fishes in these depths declined, he probed greater depths which had not been fished. He perfected the technique of catching wreckfish using stainless steel wire (54 kg test) on a snapper reel. He caught wreckfish in the depths from 360 to 684 m (similar to depths on the Blake Plateau), and found that they peaked in abundance at 650 m. When wreckfish were discovered in numbers at these greater depths in the late 1970s, they became the target species, replacing the misty grouper Epinephelus mystacinus.

Recollections of fishermen and observers indicate that mean sizes and catch rates in the early stages of the fishery were high, as would be expected for a virgin stock, and as was true in the U.S. fishery which developed 10 years later. As fishing intensity rapidly escalated with a greater number of fishermen setting vertical longlines in these depths for wreckfish, catches increased dramatically (Figure 5). However, these high catches were sustained for only about two years. Following these peak years, catches declined precipitously to low levels and fishing effort dropped as it was no longer economically viable to target wreckfish (Figure 5). There has been limited and intermittent fishing for wreckfish since the early 1980s, but catches have not risen above incidental levels on an industry-wide basis (Division of Fisheries 1996). Unlike the catch histories of other island states in the Atlantic where wreckfish fisheries were sustained for several years (see below), Bermuda appears to provide an example of the effects of growth overfishing of a limited resource on a small oceanic island. There was a decline in mean size from the commencement of the fishery for a four-year period (1979–1982; Table 2). Despite the small sample sizes in 1979–
1980 and the anecdotal nature of the data, it appears as if the mean size declined by about 50% in this short time period. In contrast, recent sampling (1996–1997) by one of us (Luckhurst) shows an increase in mean size; however, interpretation is limited by the small sample sizes.

Active fishing for wreckfish began again in late 1995 by the same fisherman (Bobby Doe) who had originally developed the fishery. Through this fisherman it has been possible to examine every specimen caught (N = 16) and to obtain tissue samples to contribute to the broad-scale genetic analysis of wreckfish being undertaken (this paper). In spite of efforts directed at wreckfish, catches have been very small since 1995, indicating a lack of recovery in the Bermudian wreckfish population. The largest specimen examined since directed sampling effort for DNA samples began, was a ripe female (133.5 cm FL) caught on 1 October 1995 which weighed 45.5 kg whole weight. Both specimens were taken from the same area off the east end of the island and from the same depth (650 m). The size of the smallest specimen and its depth of capture give an indication of the size at which juvenile stages of wreckfish descend to the bottom.

**The Portuguese Islands Fishery**

During this study, Portuguese fisheries operated from and around the Macaronesian islands of the Azores and Madeira archipelagos, and from mainland Portugal. Landings on the mainland and the islands were usually from fish caught in their respective geographic area. Mainland landings included some fish caught off North Africa (Morocco). Our work concentrated on the island fisheries that supplied about half of Portugal's wreckfish landings in recent years (Figure 6).

Wreckfish has been the most expensive demersal fish in the Azorean market, where it often fetched about twice as much as does in the

**Table 2. Mean sizes and size range of wreckfish from the Bermuda fishery.** Data from 1979–1982 are from fishermen's records. Data from 1996 and 1997 were collected by Luckhurst.

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>Mean weight (kg)</th>
<th>Size range (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>25</td>
<td>26.3</td>
<td>15.9–37.2</td>
</tr>
<tr>
<td>1980</td>
<td>14</td>
<td>28.6</td>
<td>11.3–53.0</td>
</tr>
<tr>
<td>1981</td>
<td>368</td>
<td>14.0</td>
<td>10.9–43.1</td>
</tr>
<tr>
<td>1982</td>
<td>311</td>
<td>12.4</td>
<td>8.6–20.9</td>
</tr>
<tr>
<td>1996</td>
<td>6</td>
<td>19.5</td>
<td>10.5–31.5</td>
</tr>
<tr>
<td>1997</td>
<td>9</td>
<td>19.2</td>
<td>5.5–33.5</td>
</tr>
</tbody>
</table>

**Figure 5.** Annual landings (metric tons) of wreckfish in Bermuda, 1979–1996.

**Figure 6.** Case value of wreckfish in the Azores.

**Figure 7.** Average exchange rate. The
specimens were taken at the east end of the island depth (650 m). The size and its depth of capture of the size at which wreckfish descend to the

sherry
Colonial fisheries off the Macaronesian islands archipelagos, rugal. Landings on the islands were usually from fish geographic area. Mainly some fish caught off Our work concentrated on fish stocks in the recent years

the most expensive deep-water market, where it sells as much as it does in the

Data from 1979–1982 are

| Size range (kg) | 15.9–37.2 | 11.3–33.0 | 10.9–43.1 | 8.6–20.9 | 10.5–31.5 | 5.5–33.5 |

United States (Figure 7). In spite of the high exvessel value per fish, it ranked second in total economic value among demersal species caught in the Azores, after the blackspot seabream (Pagellus bogaraveo, family Sparidae). Blackspot seabream was the target species of the Azorean demersal long-line fishery that caught wreckfish, and average annual landings of blackspot seabream in recent years were about 900 metric tons, far exceeding the catches of wreckfish. Average size of blackspot seabream has been between 25 and 30 cm in recent years, and its depth range was from less than 50 down to 600 m (Krug 1994; Silva et al. 1994; Silva and Krug 1995; Anonymous 1996). Because the demersal long-line fishery targeted a smaller and shallower-living species than wreckfish, it landed few wreckfish relative to the target species. Catches

![Graph showing Portugal Wreckfish Catch by Year](image)

**Figure 6.** Catch of wreckfish (metric tons) in Portugal, by region and year.

![Graph showing Portugal & U.S. Wreckfish Value by Year](image)

**Figure 7.** Average annual exvessel price of wreckfish in Portugal, by region, and in the United States. The average exvessel price for wreckfish in 1997 in the United States was US$4.78/kg, using the July 1997 exchange rate. The exchange rate for US$10.00 was that of 27 July 1998.
of wreckfish were an order of magnitude less than catches of other demersal species in the fishery (Figure 8).

The development of the Azorean fishery for wreckfish paralleled the development of the mixed-species demersal long-line fishery, expanding rapidly during the mid-1980s (Figure 8). Between 1980 and 1994 catches of demersal fishes increased nearly 500%, from 986 metric tons in 1980 to 4,741 metric tons in 1995. This increase was due to a change in fishing technology, with the development of the demersal longline fishery in the Azores. Before 1980, fishing was done primarily by artisanal vessels (dories) fishing handlines. In more recent times long-liners (e.g., about 56 vessels in 1997) landed 85–90% of the demersal fish catch. With the new boats came a shift to new fishing grounds, which included more remote seamounts and deeper grounds. From 1989 to 1994 about 75% of the demersal Azorean fish catch came from the seamounts. Larger vessels, improvements in navigation, bottom sounding, and mechanization of the gear have allowed fishermen to fish farther from home ports, and in deeper waters.

Two main types of fishing gear were used in the Azores to catch wreckfish. One was a modified longline, designed specifically to fish on steep slopes where wreckfish occur (Figure 9). This gear can change slightly from island to island and from boat to boat. It was designed to place hooks near the bottom by using a series of weights (stones), while keeping the hooks from fouling on the bottom by suspending them from a guy line above the bottom. The guy line also allows retrieval of fish in case the ground line hangs on the rocky bottom.

The other gear that caught wreckfish in the Azores was the normal bottom longline used in the mixed-species demersal long-line fishery (Figure 10). In this fishery the target species was the blackspot seabream; however many other species were caught (other sparids, especially red porgy Pagrus pagrus; blackbelly rosefish Helicolenus dactylopterus; other scorpeneids, Scorpaena species; alfonsoins, Beryx species; deepwater gadids, Phycis species; and wreckfish). Many of these species are caught in significant amounts and the fishery is multispecific.

Because the Azorean demersal fishery is multispecific and wreckfish are caught with these two primary gear types (or various modifications), often fished from the same boats, it is difficult to define fishing effort toward any one species, as can be done with wreckfish in the United States. The Departamento de Oceanografia e Pescas (DOP), Universidade dos Açores, is initiating an effort to improve the quality of the catch and effort database by interviewing vessel captains and by port sampling of landings for species composition and length frequency.

Stock assessments on blackspot seabream have indicated that the species is severely overfished in the Azores (Krug 1994; Silva et al. 1994; Silva and Krug 1995; Anonymous 1996). Due to the urgent need to reduce the fishing mortality of blackspot seabream and other demersal species caught in the Azores, "significant amount..."
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in the Azores, management imposed to restore
stocks of blackspot seabream will influence the
catches of several other species including a sig-
nificant amount of wreckfish catch. Because of
this, several specific preliminary TACs for the
Azores have been proposed, including an annual
TAC for the wreckfish of 280 metric tons. This
proposal was based on the ratio of catches of
blackspot seabream and wreckfish (Silva et al.
1994). As of August 1998, this TAC had not been

![Diagram](image)

**Figure 9.**—Longline used in the Azores for deep-water fishing on rocky bottom, modified specifically for catching wreckfish.

![Diagram](image)

**Figure 10.**—Demersal longline used in the Azores for deep-water fishing on rocky bottom for blackspot seabream and other smaller demersal species.
implemented. Additional biological data need to be collected to support the implementation of the TAC and other management measures.

Fishery-independent abundance surveys have been implemented (in 1993, 1995, and 1996) by the DOP to assess the size of the Azorean wreckfish stock, to collect biological data needed for management, and to evaluate fishing and sampling methods. Catches of wreckfish during the survey cruises have been low; however, the data are being analyzed to determine factors (geographic area, depth, time, season, hook size) associated with wreckfish catches. Future surveys will concentrate on areas, times, and gear that produce the best wreckfish catches (Silva et al. 1996; Silva and Menezes, in press).

The development of the demersal fishery of the Madeiran archipelago proceeded in a fashion similar to that of the Azores; however, there are some important differences, particularly in some of the species sought. The earliest published record of wreckfish in Madeira was that in Lowe's *A History of Fishes from Madeira, Volume I*, published in separate between 1843 and 1860. Wreckfish are commonly found in the fish market in Funchal, and has undoubtedly been known from Madeira waters long before Lowe's (1843) account. Wreckfish was often referred to by other travelers passing by Madeira as part of the list of species commonly found at the fish market. While seen in the market there, wreckfish has never supported a big fishery in Madeira, and in 1996 it represented only 0.24% of the total weight of the landings. It is a component of a long list of demersal species that was caught by the traditional fleet, on island slopes, from 200 to 450 m depth (about 0.8-1.6 km off the coast). The fishery landings for wreckfish (Figure 6) and other demersal fishes in the mixed-species demersal fishery in Madeira was substantially below the level caught in the Azores and off the mainland. The Madeira archipelago has virtually no platform and thus limited demersal fishing resources. Most of the local fleet has concentrated on the pelagic tuna fishery and on the bathypelagic black scabbardfish *Aphanopus carbo*. Black scabbardfish supported a fishery of about 3,000 metric tons per year (1993-1996) from the waters around Madeira (compared to 29-67 metric tons of wreckfish for the same years) and with the tuna fishery accounted for 80% of the total fishery landings of Madeira. Perhaps as a result of the relatively low importance of wreckfish in the landings (ranging from 0.3 to 0.6% of the total landings from 1993 to 1996), there has been no management for the wreckfish fishery.

As in the Azores, the value of the wreckfish fishery in Madeira stemmed from its high market price. It was by far the most valuable fish in the local market with an average exvessel price in 1996 of US$9.00/kg at the auction (at $US1.00 = 170 PTE) and a total value of landings of about $260,375 for that year. By comparison, the average price in 1996 for total Madeiran demersal species was $1.13/kg. In the local supermarkets wreckfish were sold for 2-3 times the exvessel price.

The demersal fishing boats were mostly open deck, 7-11 m long with a crew of 6-10 men. The boats made 4-5 d trips, usually departing the docks on Monday. There was also a number of small "canoes" (4-5 m long with 2-3 men aboard) that occasionally caught wreckfish (their catches are included in the landings, but not our CPUE analysis). In recent times, the fishing gear has changed to bottom longlines with 1,500-2,500 hooks. The gorazela, a handline or hand powered reel with 9-11 hooks, is now rarely used. The gorazela and other handline gear were common practice until the seventies (Nunes 1974).

Because the vessels and gear used in Madeira were simpler and fewer than in the Azores, CPUE was estimated for the Madeira wreckfish fishery from 1988 to 1996. We examined catch records from total landings (the entire demersal fleet) and also records from the boats that target wreckfish. The peaks of the local wreckfish catch often occurred for a few months a year from March to June (Figure 11). Since the boats make a trip each week, we defined the boats targeting wreckfish as those that land wreckfish from at least 12 trips a year.

The data showed an increase of landings of wreckfish in Madeira in the 1990s with a peak in 1994. Landings were under 10 metric tons/year up to the late 1980s and were more than 20 metric tons/year in the 1990s. The increase in total landings corresponded to an increase in fishing effort (number of trips) by the fleet, and also to a slightly increased CPUE (Figure 12). The increased CPUE was due to changes in the fleet and fishing gear used. In the early 1990s new boats that sought wreckfish joined the fishery. These boats landed 60% of the wreckfish catch in 1988, which increased to 90% of the landings in 1995. Since these newer boats spent more effort on wreckfish, their share of the total landings has increased in recent years.
WRECKFISH IN THE NORTH ATLANTIC: FISHERIES, BIOLOGY, AND MANAGEMENT

Mean length of wreckfish from Madeira remained fairly constant from 1993 through 1997 (Figure 13). Wreckfish landed in Madeira were smaller than those landed in the United States, and there was a larger variance associated with the mean, indicating a larger range of sizes of wreckfish in Madeira than in the United States (Figure 13). Wreckfish mean lengths and CPUE have not changed much in Madeira in recent years, although there has been a decrease in landings. These trends should be monitored to determine if overfishing becomes a problem in Madeira.

Little is known of the ecology of wreckfish around Madeira. Juveniles have been observed at the surface from February through September (Andrade, personal observation). As in the Azores, wreckfish that dominate the demersal long-line

![Graph](image1.jpg)

**Figure 11.**—Monthly landings of wreckfish (metric tons) in Madeira, 1984–1993.

![Graph](image2.jpg)

**Figure 12.**—Annual landings (metric tons), effort (number of trips), and catch per unit of effort (catch/trip, kg) for boats targeting wreckfish in Madeira.
catches are smaller than those that dominate the catches in the western North Atlantic. Aggregations of preadult fish (450–700 mm) in the traditional Madeiran fishing grounds (Madeira and Desertas Islands and seamounts north of Porto Santo) occur during winter between 200 and 350 m depth, resulting in higher CPUE and landings in the coldest (2–3) months. Due to the higher number of fish of this smaller size, the mean length of fish drops at this time of year (Andrade, personal observation). Preadult fish of the same size are only occasionally caught from these fishing areas and depths at other times of the year (Andrade, personal observation).

There is no management plan for wreckfish in Madeira. As demersal fish catches are increasing along with the resident and tourist human population of the archipelago, additional life history data should be collected on Madeiran wreckfish, and appropriate management plans developed.

Other Localities

Wreckfish are also caught in the Mediterranean, and Food and Agriculture Organization of the United Nations (FAO) catch statistics for FAO Area 37 indicated average annual landings of 32.4 metric tons/year from 1974 to 1994, all Mediterranean countries combined. In Majorca, where one of us (Sedberry) obtained tissue samples for genetic study, there was one fisherman who targeted wreckfish in 1994. He used bottom longlines similar to the Azorean bottom (not modified) longline. Although not documented, he reported that his catches have steadily declined over the past 20 years, in numbers and mean size. Mean size of wreckfish caught during a trip aboard his boat was 823.9 mm TL (N = 20; range = 500–1370 mm), which was larger than Madeiran wreckfish we measured, but smaller than American (Figure 13). He believed that a large number of pelagic juveniles are caught in drift-net fisheries.

Exploratory fishing in October–November 1996 by the Fisheries Laboratory of the Faroes on the Mid-Atlantic Ridge outside of the Azorean territorial sea produced small catches of large wreckfish (Figure 14) from north and south of the Azores EEZ. Most of these fish were large enough to be sexually mature (mean TL = 1107 mm), and the sex of most of the specimens (except for the very smallest four individuals) could be easily determined by macroscopic examination of the gonads. As these wreckfish were caught in October before the spawning season, it could not be ascertained if there was spawning in this region at that time. However, during previous exploratory fishing in the same region in November of 1995, 35% of 118 wreckfish were found to be running ripe, but this was not thought to constitute a large spawning aggregation (Thomsen, personal observation). Spawning of wreckfish in the Atlantic has been observed to occur in the Blake Plateau area, but 600 spawners were detected in the Central Atlantic. Wreckfish, S. seviosus, a member of the family Syngnathidae, is a pelagic species that spends its early stages in the open ocean before settling to the sea floor. A common feature is that they have a keen sense of smell and are able to find their way back to the ocean after spending time on land. They are known to be able to change their color and texture to blend in with their surroundings, a behavior that has earned them the nickname "the master of disguise."
Atlantic has been thoroughly documented on the Blake Plateau; however, examination of more than 600 specimens from Madeira has not detected a mature wreckfish in those waters (D. Wyanski, SCDNR, unpublished data).

A commercial fishery on the Mid-Atlantic ridge, operated from distant ports, does not appear to be economically feasible. In spring of 1996, a commercial fishing vessel (the same one used for the Faroese experimental fishing) caught 333 wreckfish ($6,230 \text{ kg}$) in 37 days of fishing (1,350 nautical miles from port) (Thomsen, personal observation).

### Life History and Population Genetics

Of the 790 otoliths examined, 730 (92.4\%) could be aged, and 543 (74.4\% of those aged) were measured for back calculations. Marginal increment analysis indicated that opaque rings were laid down annually in April (Figure 15); however, sample sizes from other months were smaller, and this analysis should be considered preliminary. Based on this marginal increment analysis, and the annual nature of rings documented by Francis et al. (in press) for $P.\ oxy-
genetos$, we believe that the rings are annual.

Wreckfish from the Blake Plateau fishery ranged in age from 4 to 31 years (Table 3; Figure 16). The oldest fish was 1460 mm TL and weighed 47 kg. Most fish harvested by the American fishery were 8–12 years old. At this size and age, wreckfish on the Blake Plateau are mature (D. Wyanski, SCDNR, unpublished data), and submersible observations, along with landings, indicated that nearly all fish on the Charleston Bump are large, mature fish (Sedberry et al. 1994). It may be that smaller wreckfish are present on the grounds and may be excluded by the hook and line fishery. This does not seem likely since the fishery catches small individuals of other species (e.g., blackbelly rosefish, alfonso s Beryx splitens, Cuban dogfish Squalus cubensis, chain dogfish Scyliorhinus retifer), small demersal wreckfish have a large mouth and are capable of taking the hooks used, and no small wreckfish have been observed from submersible. Wreckfish less than 4 years old may inhabit the surface waters "downstream" from the spawning grounds on the Charleston Bump (none have been observed on the grounds) or are demersal but not present on the grounds.

Mean back-calculated lengths at age ranged from 340 mm TL at age one to 1458 mm TL at age 31 (Table 3; Figure 16). Back-calculated lengths from the last annulus for each age-group (Vaughan and Burton 1994) yielded the following von Bertalanffy growth equation:

$$L_t = 1517 (1 - e^{-0.673t + (-3.726)})$$
Figure 15.—Marginal increment analysis of Blake Plateau wreckfish, plotted as percent of otoliths which had marginal increments of zero, by month. Of 536 measured increments, 129 equaled zero, and most of these occurred in April. The number over each bar is the number of marginal increments equal to zero, followed by (after slash) the number of otoliths measured for marginal increment, for that month.

The 95% confidence intervals for $L_0$, $k$, and $t_0$, respectively, were: 1510–1524, 0.072–0.074, and -3.825 to -3.628.

Compared to hapuku $P. oxygeneios$, wreckfish mature earlier (8–10 years versus 10–13 years) and do not live as long (31 years versus 60 years), even though maximum sizes are similar (Francis et al., in press). Wreckfish are still relatively slow growing and long-lived.

Hapuku switch from pelagic to demersal habitat at around 5° (Francis et al., in press) tagged in the Azores on the bottom in 254 at 50.1 cm TL (Sedberry also apparently take about 50 cm. We his small, but data from fish may be more theoretical and back-cal culate that these fish are (Figure 16).

Sedberry et al. population structure analysis of PCR-ampl informative restrict a dominant component North Atlantic, which amalyzed from the A: (Table 4). It was also type found in wreckfish. Wreckfish from the onstated a complete genetotype (BB), with di both informative examples collected from composite haplotypes from Bermud a Ridge southwest of the small sample. Addition haplotype samples from addi confirm the genet-Atlantic wreckfish hemisphere found occurrence of the from Bermuda and west of the Azores structuring within Geyer. Addition additional loci are in pro.

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habitat at around 50 cm TL and 3–4 years old (Francis et al., in press). A pelagic wreckfish tagged in the Azores at 49 cm TL was recaptured on the bottom in 254 m depth three months later at 50.1 cm TL (Sedberry et al. 1996). Wreckfish also apparently take up the demersal habitat at about 50 cm. We have not aged wreckfish this small, but data from hapuku suggest that these fish may be more than a year old, and our theoretical and back-calculated lengths at age indicate that these fish may be two years old or older (Figure 16).

Sedberry et al. (1996) reported on genetic population structure in wreckfish based on RFLP analysis of PCR-amplified mtDNA. Based on two informative restriction enzymes, they reported a dominant composite haplotype (AA) for the North Atlantic, which was found in all fish examined from the Azores, Majorca, and Madeira (Table 4). It was also by far the dominant haplotype found in wreckfish from the Blake Plateau. Wreckfish from the southern hemisphere demonstrated a completely different composite haplotype (BB), with different restriction profiles for both informative enzymes. With the additional samples collected for the present paper, a third composite haplotype was found in three specimens from Bermuda (N = 2) and the Mid-Atlantic Ridge southwest of the Azores (N = 1). Because of the small sample sizes, the significance of this additional haplotype is unknown. However, the samples from additional North Atlantic locations confirm the genetic distinctiveness of the North Atlantic wreckfish from those in the southern hemisphere found by Sedberry et al. (1996). The occurrence of the new haplotype only in fish from Bermuda and the Mid-Atlantic Ridge southwest of the Azores may indicate population substructuring within the North Atlantic Subtropical Gyre. Additional samples and examination of additional loci are needed to confirm this, and this work is in progress.

Based on existing records of juvenile wreckfish, it was suggested the juveniles of American wreckfish drift to the eastern Atlantic islands at the surface with the North Atlantic currents (Sedberry et al. 1996). However, as suggested by Sedberry et al. (1996), passive drift may not be the only mechanism contributing to a single wreckfish stock in the North Atlantic. The frequent occurrence of European fish hooks in American wreckfish indicates migration of large wreckfish across great distances. Length frequency, seasonality of landings, and the finding of foreign fish hooks in American wreckfish suggest the recruitment of mature adult fish to North America from other fishing areas. Sedberry et al. (1996) concluded that RFLP analysis of mtDNA indicated a single stock of wreckfish in the North Atlantic. The international basin-wide distribution and movements of wreckfish in this stock must be considered in management plans.

Management Considerations

The complexity of the life history of North Atlantic wreckfish includes adult life and spawning in deep water over rocky bottom off the North American coast, a pelagic development with drift of juveniles with the dominant oceanic circulation, descent to the bottom at about 50 cm TL, formation of spawning aggregations, late maturity, and a long life. Wreckfish are intensely managed in American waters, and the U.S. fishery has continued to produce acceptable yields. However, the American fishery is somewhat self-regulating, in that considerable skill is needed to fish from small boats, in deep water, at a great distance from shore, in swift currents, in areas prone to fierce winter storms and summer tropical cyclones. Although the American fishery has a limited entry, most of the fish were caught by a relatively few highly skilled fishermen before the limited entry, and those fishermen continue to be the high producers. The fleet continued to shrink after the imposition of the limited entry, indicating that more skill is required to catch wreckfish now than initially.

In contrast to the U.S. fishery, wreckfish in other parts of the North Atlantic range can be fished relatively close to shore, by artisanal and sophisticated fleets. Those fleets may not have exerted too great a fishing pressure so far, but there is potential for increased demand, as resident and tourist human populations increase on the islands. The experience of Bermuda indicates that increased fishing pressure on wreckfish, enhanced in that case by a sudden relative improvement in local fishing technology, can cause commercial extinction of wreckfish in island habitats. Because of the specific habitat requirements of demersal wreckfish, their range consists of insular slopes and continental slope habitats which are effectively islands (i.e., the Charleston Bump). Fishing technology is improving in the Azores and Madeira, and hydraulically-powered demersal long-line gear is replacing handlines and hand winches. The improved technology may result in declines
TABLE 3.—Mean back-calculated lengths (TL, mm; N = 543) for wreckfish from the southeastern United States (WMTL = weighted mean total length; INCR = size increment).

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such as those observed in Bermuda. Considerably more habitat exists around the Azores (about 6,500 km² of bottom between 200 and 600 m depth) and other islands that are on the Mid-Atlantic Ridge and associated transverse ridges than exists in Bermuda (about 370 km² for the same depths). Combined with the multispecies nature of the Portuguese fishery, increased habitat may account for the sustained deepwater fishery in the Azores and Madeira (500 km² of habitat), relative to the experience in Bermuda. However, the rapid improvements in fishing technology that is developing throughout the world have not bypassed the Portuguese islands. We expect increased fishing pressure on wreckfish, particularly as declines occur in traditional mainstays of the demersal fishery, such as the blackspot seabream.

In addition to demersal fisheries that catch wreckfish, the juveniles of this species are subject to bycatch in pelagic tuna drift-net fisheries in the eastern North Atlantic (Goujon et al. 1993). Several thousand juvenile (<70 cm TL) wreckfish were taken each year in 1992 and 1993 (9,000 total individuals, at 13 metric tons), and these catch rates may be continuing, although they have not been documented since that time (Goujon et al. 1993). Estimates based on observer programs and expanded to the entire fleet indicate that about 17,500 pelagic juvenile wreckfish were caught by the French tuna drift-net fleet operating in the northeast Atlantic (43–52°N, 6–21°W) in 1992–1993 (Goujon et al. 1993). By comparison, 38,205 and 33,803 wreckfish were landed in the American fishery in 1992 and 1993. The impact of the pelagic bycatch is unknown, but these fish are immature potential spawners that are caught before reaching optimum market size and before they have other bycatch rates into man.

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WRECKFISH IN THE NORTH ATLANTIC: FISHERIES, BIOLOGY, AND MANAGEMENT

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Before they have spawned. The impact of this and other bycatch should be evaluated and incorporated into management plans.

In addition to fisheries within territorial seas, wreckfish apparently occur in extraterritorial waters over the Mid-Atlantic Ridge (Ryall and Hargrave 1984; present study). Our data indicate that large wreckfish may be common there and this area may constitute an undocumented spawning ground. Wreckfish on the Mid-Atlantic ridge need further research, and the existence of this group of fish should be taken into account when defining a management plan for the North Atlantic.

Because of the life history of wreckfish in the North Atlantic (Sedberry et al. 1996; this paper), management of this species will require efforts on both sides of the Atlantic. There is a lesson in the wreckfish fishery in Bermuda. Although wreckfish do not have the economic value of highly migratory species such as bluefin tuna, or the scientific and public concern for conservation such as that for loggerhead turtle Caretta caretta, the wreckfish shares life history characteristics with these species, and has been exploited during vulnerable life history stages (bycatch as juveniles; and fished on the spawning grounds as adults), and should be considered for management by international fisheries management organizations. Such a management plan should include:

1. Total allowable catch. This has worked well in the United States.
2. Gear restrictions. Although the magnitude is not well documented, drift nets catch wreckfish before they reach an optimal market size, and before they reach maturity. Drift nets
should be regulated in areas where pelagic wreckfish are common, or undersized wreckfish should be released if in good condition. This should be coordinated to reduce bycatch on other species as well. Longlines have been banned in the U.S. fishery, but Portuguese long-liners have produced markedly increased catches in the Azores and Madeira. Long-line fishing should be monitored to determine its effect on wreckfish populations.

3. **Limited entry**, while controversial, has worked in the U.S. wreckfish fishery, and has resulted in an efficient, profitable fishery.

4. **Closed season**. The spawning season closure in the United States protects the Blake Plateau spawning aggregation during the spawning season, when fish are apparently aggregated on the grounds. If additional spawning areas and aggregations are documented, they should also be closed during the spawning season, since fishing of spawning aggregations can have serious deleterious effects (Coleman et al. 1999, this volume).

As noted by Sedberry et al. (1996) wreckfish and loggerhead sea turtles have similar life histories, with progeny originating off the southeastern United States, drift of juveniles around the North Atlantic gyre, and migration of adults to reproductive areas. Both species are also slow-growing and late maturing, and for these and other reasons, loggerhead turtles have been afforded international protection. Because of increasing exploitation of wreckfish, international management efforts are needed to ensure a future fishery. There are, perhaps, additional demersal species whose life histories are similar, and should be considered in such a plan.

As management plans are developed, continued assessment of the status of the North Atlantic wreckfish stock should be done periodically. As part of the management of wreckfish in the United States, an annual assessment, including virtual population analysis (VPA), is done to set the quota (Anonymous 1997). The SAFMC Wreckfish Assessment Group has also recently reviewed the extent of our knowledge of the biology of wreckfish, and has outlined remaining research needed to refine VPAs and evaluate the present quota (Anonymous 1997). Additional research needs include:

1. continued collection of length frequency and catch statistics, by sex, for the U.S. fishery and for FAO Fishery Areas 27 and 37 (where historical data are also needed);
2. collections of otoliths, by sex, for continued development of age length keys;
3. sociological data on the fishery in relation to the TAC;
4. stock identity resolution for North Atlantic wreckfish, to include tagging and characterization of eastern Atlantic fisheries;
5. continued collection of smaller female fish (60-90 cm TL) to determine size and age at maturity; and
6. an economic survey of wreckfish ITQ holders; and
7. an international workshop on deepwater fisheries, with emphasis on wreckfish.

These research needs require cooperation among countries that fish for wreckfish and should be incorporated into an international management plan. With additional research and development of management based on this research, it is hoped that North Atlantic wreckfish fisheries can be sustained.

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WRECKFISH IN THE NORTH ATLANTIC: FISHERIES, BIOLOGY, AND MANAGEMENT

NA27FD0052-01, G. Ulrich, Principal Investigator. This is Contribution No. 412 from the South Carolina Marine Resources Center.

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