Exploratory Assessment of Dolphinfish, *Coryphaena hippurus*, based on U.S. Landings from the Atlantic Ocean and Gulf of Mexico

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Abstract

The dolphinfish *Coryphaena hippurus* is a large, fast-swimming fish found worldwide in tropical and subtropical ocean waters. Dolphinfish are top-level predators that grow rapidly and mature in less than one year. The species supports both commercial and recreational fisheries in U. S. waters and in other national and international waters of at least 20°C. The current stock hypothesis, of one stock in the Gulf of Mexico and South Atlantic, plus a second stock ranging south in the Caribbean Sea from the Virgin Islands, was provisionally accepted for this report.

Through reanalysis of growth data and application of empirical methods, the annual rate of natural mortality M was estimated as about 0.68 to 0.80 per year. Such values are similar to those accepted for yellowfin tuna, another wide-ranging, fast-growing, predatory species found in warm ocean waters.

An index of relative abundance was developed on data from the U.S. longline fishery, and the index was used to fit a surplus production model. Model results include estimated MSY of about 12,000 mt/yr; estimated F_{MSY} of about 0.5/yr; and estimated stock status at the start of 1998 as above B_{MSY}. These results are plausible but uncertain; the uncertainty being due primarily to the abundance index, whose accuracy is unknown. A more fundamental source of uncertainty is the scarcity of information on stock structure.

For comparison, proxies for reference points were also computed. Based on the above estimates of M, the proxy estimate of F_{MSY} is about 0.5 to 0.8 per year. Based on an average of recent landings, a proxy estimate of MSY is about 7,200 to 8,100 mt/yr. It is not known whether the production-model estimates or these proxies are more accurate.

The benchmark and proxy estimates and the life history of dolphinfish suggest that it might be able to withstand a relatively high rate of exploitation. However, results are exploratory and uncertain, and no good index of relative abundance yet exists. In addition, U.S. data are unlikely to encompass the entire hypothesized stock.

The most important research needed to improve assessment includes studies of stock structure, studies of current vital rates, and modeling studies on abundance indices. A fishery-independent source of relative abundance information would be extremely valuable. International cooperation could potentially leverage U.S. efforts and improve data coverage of this transnational stock. With added research to rely on, future assessments of this resource could be more definitive.

1 Introduction

The dolphinfish[1] *Coryphaena hippurus* is a large, fast-swimming fish found worldwide in tropical and subtropical ocean waters. The species supports commercial and recreational fisheries in North Atlantic waters off the United States and in the Gulf of Mexico; those fisheries have been described by Thompson (1999). A synopsis of available biological information is provided by Palko et al. (1982), who describe the species thus: "dolphins are top-level predators, very agile, and capable of taking fast-moving prey."

The species is considered highly desirable for food, and it is widely sought by fishermen for food and recreation. Distribution is limited to the warm side of the 20°C isotherm, and dolphinfish are caught in suitable waters across the Atlantic basin, in the Gulf of Mexico, and in the Mediterranean Sea.

Accurate assessment of dolphinfish in U.S. waters is hindered by several factors. There is no statistics program in place specifically aimed at sampling the species, although records of dolphinfish appear in NMFS longline logbook, weighout, and MRFSS databases, and in data from other programs as well. However, the geographical sampling extents of those databases are not ideal for dolphinfish. Most (about 80% to 90%) of the landings are in recreational fisheries, which are usually more difficult to sample than commercial fisheries. The degree of dead discarding and live-release mortality is not well known. Stock structure is still uncertain, as discussed below. Most vital rates have not been reliably estimated, or the applicability of existing estimates is uncertain because of doubts about stock structure. Thus, it is doubtful that a meaningful catch-at-age matrix could be constructed. Recognizing this limitation, in this report a non-age-structured assessment model (surplus production model) is used for assessment purposes.

2 Stock Structure

Based on seasonal patterns in catch and on genetic observations, Oxenford and Hunte (1986) postulated a two-stock structure for dolphin in the western Atlantic. Under this hypothesis, a southern stock is found east and north of South America and extending northward to the Virgin Islands. Above the Virgin Islands, starting roughly at Puerto

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[1] The common name preferred by AFS (1980) is dolphin; others include mahi-mahi, dorado, and dolphinfish. The last is used here to avoid potential confusion with marine mammals,

Rico and extending north to North Carolina and north along the U.S. Atlantic coastline, the northern stock is found. Analyses in this report are made under this two-stock hypothesis and are concerned only with the northern stock.

Because the distribution of dolphin is basin-wide (given suitable temperatures), an analysis of fish caught off the United States is probably not sufficient to accurately characterize population dynamics of even this northern stock. At the least, data from Caribbean nations such as Cuba and Jamaica will be missing; if the stock extends to the eastern Atlantic, data from the eastern side of the basin will be missing. Furthermore, it is not known whether dolphinfish in the Gulf of Mexico should be considered part of the northern stock. In this report, they are so considered, but this assumption is made in the absence of data and so is an important source of uncertainty.

3 Vital Rates

The vital rates (growth, maturity, fecundity, mortality) of a stock offer insights into the degree of exploitation that it might endure without undue stock decline. As well as being used directly in data-intensive analyses such as spawning-stock biomass per recruit analysis, yield per recruit analysis, and sequential population analysis (VPA and similar analyses), information on vital rates and other life-history characteristics can be helpful in judging the permissible degree of exploitation in information-poor situations. From maturity, fecundity and growth patterns, one can form at least a qualitative impression of the likely response of a stock to exploitation. In addition one can compare a species to other species of similar life history about which more is known, or at least experience of which is more extensive.

In such a life-history approach, one generally expects that a relatively infecund, slow-maturing species can sustain a lesser degree of exploitation than a relatively fecund, early-maturing species. Examples of the former group would be most shark species; of the latter, species such as tropical tunas and menhadens. A notable exception to this general picture is that small, fast-growing, planktiverous species in coastal upwelling zones have been prone to drastic population crashes: a conspicuous example is the California sardine *Sardinops sagax* (MacCall 1979). However, fast-growing, early-maturing, predatory species that are more oceanic in distribution have not experienced such crashes, despite many decades of at least moderately intensive exploitation. This does not preclude the possibility of a crash under some excessive level of exploitation

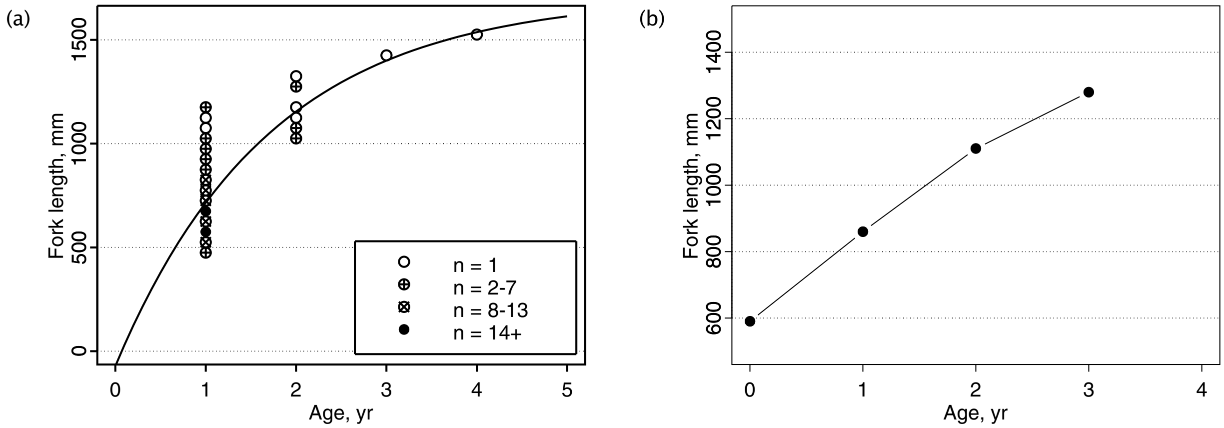

Figure 1. Data from published growth studies on dolphinfish with newly fitted von Bertalanffy growth functions. (a) Beardsley (1967); (b) Rose and Hassler (1968).

that might be reached in future.

3.1 Growth

Growth of dolphinfish is rapid. Beardsley (1967) examined 511 dolphin from waters off south Florida ranging in size from 475 to 1,525 mm fork length (FL). Of the 1-year-olds, the size range was 475 to 1,175 mm FL. No growth model was fitted in that study. In the present study, to provide values for use in empirical estimates of mortality rates (described in §3.3 below), a von Bertalanffy growth function

$$L_t = L_\infty \left(1 - \exp\left(-K(t - t_0)\right)\right) \tag{1}$$

was fit to the grouped length-at-age data of Beardsley (1967) as read from his Fig. 5. The resulting growth function is

$$L_t = 1710 \left(1 - \exp(-0.583[t - 0.07])\right), \tag{2}$$

and it appears to describe the sizes at age of those specimens reasonably well (Fig. 1a). Some of the dispersion apparent in Fig. 1a stems from the practice of reporting fish ages as integers, thus not accounting for growth increments less than one year; the scatter would presumably be less if ages were recorded to the nearest month or sizes were back-calculated to size at the time of formation of the last annulus.

A second relevant growth study was based on samples from the recreational charterboat fishery off Hatteras, North Carolina. Rose and Hassler (1968) examined 738 specimens during the 1961 through 1963 fishing seasons. Age determination was by scale reading; the oldest fish observed was 3 yr old (more precisely, under 4 yr old, as 3 but not 4 annuli were observed). Rose and Hassler (1968) fitted several models, including a length–weight model and a model relating body length to scale length, but they did not fit a standard growth model. As part of the present study, the grouped size-at-age data were read from their Fig. 3 and a von Bertalanffy model was fit. The resulting estimated growth function (Fig. 1b) is

$$L_t = 2459\left(1 - \exp(-0.158(t + 1.74))\right). \tag{3}$$

Statistical details for reanalysis of the two data sets were similar. Distribution of size at age was discernible from Beardsley (1967), but not from Rose and Hassler (1968), so for reanalysis of that study's data, a single size (the reported mean) was used for each age. In each reanalysis, recorded sizes were statistically weighted by sample sizes reported by the original authors.

Both reports truncated all ages to integer, without any attempt to estimate true age by examining growth since the last annulus or by considering month of collection. The effect of such truncation is loss of precision in the estimates of the von Bertalanffy growth parameters and likely bias in the estimate of t_0. The truncation would not be expected to bias estimates of K or L_∞ directly.

The growth curves corresponding to the two studies are somewhat different (Fig. 1. Because fish examined by Rose and Hassler (1968) were on average younger than those examined by Beardsley (1967), the former study may not describe size of older fish as well, and its estimate of asymptotic length L_∞ may not as closely reflect the overall maximum length of older fish in the stock.

The growth curves estimated here describe slower patterns of growth than that reported by Oxenford and Hunte (1983) from Barbados. That is not surprising, because fish in North Carolina and Florida waters are part of the presumed northern, rather than southern, stock, and they live in colder waters. For purposes of this report, the two sets of growth parameters estimated from U.S. waters seem more relevant.

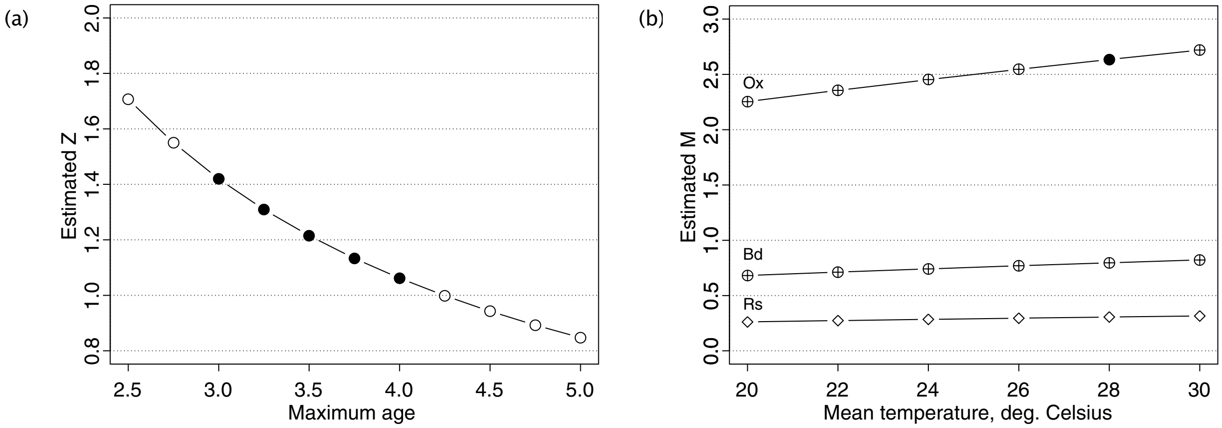

Figure 2. Empirical estimates of mortality rates for dolphinfish. (a) Estimates of total mortality rate Z from maximum observed age t_∞ by method of Hoenig (1983). Filled circles reflect range of t_∞ reported in literature. (b) Estimates of natural mortality rate M from growth parameters and average water temperature. Curve `Ox` is based on Oxenford and Hunte's estimates from Barbados; curve `Be` is based on growth data from Florida waters (Beardsley 1967) and reanalyzed here; curve `Rs` is based on growth data from NC waters, (Rose and Hassler 1968) and reanalyzed here.

3.2 Maturity and Fecundity

No analysis of reproductive biology was made for this report. Nonetheless, in considering the species' overall life history, a few key points from Beardsley (1967) will be summarized. In Florida waters, both sexes reach sexual maturity in the first year of life. The spawning season is extended, and multiple spawning may be common in both sexes. Total egg production per female is 240,000 to nearly 3 million eggs per year for a range of sizes from 500 mm to 1,100 mm FL. Rose and Hassler (1968) found that, of those they examined, few of the 2-year-old fish and none of the 3-year-old fish were females, but they attributed this sexual differential to "differential feeding habits of the sexes," leading to biased sampling (towards males) in their study, which used hook-and-line gear, rather than a population sex ratio different from unity. Other studies of reproductive biology are summarized in Palko et al. (1982).

3.3 Mortality Rates

Only one direct estimate of mortality rate was located in the literature. Bentivoglio (1988) used a Robson–Chapman estimator to estimate total mortality in the Gulf of Mexico Z at about 8.2/yr. That value does not seem feasible for dolphinfish in the Atlantic, where Beardsley (1967) found one 4-yr-old fish in a sample of 511. Assuming random

Table 1. Estimates of instantaneous rate of total mortality and corresponding annual survival fraction; method of Hoenig (1983).

Maximum age, yr	Total mortality rate Z	Survival fraction S
2.50	1.71	0.18
2.75	1.55	0.21
3.00	1.42	0.24
3.25	1.31	0.27
3.50	1.21	0.30
3.75	1.13	0.32
4.00	1.06	0.35
4.25	1.00	0.37
4.50	0.94	0.39
4.75	0.89	0.41
5.00	0.85	0.43

sampling, the probability of finding so old a fish in a sample of 511 is approximately $511e^{-8.2\cdot 4} = 2.9 \times 10^{-12}$, which can be considered very close to zero. The probability of finding a fish even 3 yr old would be about 1.1×10^{-8}. Thus, it is almost certain that either the estimate $\hat{Z} = 8.2$ is imprecise or inaccurate, that fish in the Gulf of Mexico have quite different vital rates from fish in the Atlantic, or that vital rates have changed dramatically through time. The following conclusion was reached by Bentivoglio (1988): "From all growth studies done in the Atlantic, the Gulf of Mexico dolphin population would seem to resemble the southern population as determined by Oxenford and Hunte (1986) [in having faster growth rates than fish in U.S. Atlantic waters.]."

Absent direct estimates, mortality rates are often estimated from other information using two empirical methods. The method of Pauly (1979) estimates natural mortality rate M from parameters L_∞ and K of the von Bertalanffy growth model and mean prevailing water temperature. The method of Hoenig (1983) estimates total mortality rate Z from the oldest age observed in a large sample, and is sometimes used to estimate M under the assumption that the sample comes from an unfished stock.

The two empirical methods were applied to approximate mortality rates of dolphinfish in the Atlantic (the northern stock). For the range of maximum ages reported in Beardsley (1967), Rose and Hassler (1968), and Oxenford and Hunte (1983) of 3 yr

Table 2. Estimates of instantaneous rate of annual natural mortality M as a function of growth parameters and mean water temperature; method of Pauly (1979). For key to study appreviations, see caption to Fig. 2.

Mean water temp, °C	M from study Ox	M from study Be	M from study Ro
20	2.254	0.681	0.262
22	2.355	0.712	0.273
24	2.452	0.741	0.285
26	2.545	0.769	0.295
28	2.634	0.796	0.306
30	2.719	0.822	0.316

to 4 yr, the Hoenig (1983) method provides estimates of total mortality rate Z from 1.42/yr declining to 1.06/yr as the maximum observed age increases (Fig. 2a, Table 1). If the maximum age of 4 yr is interpreted to mean a fish from age class 4, i. e., a fish on average slightly older than 4 yr, the estimate of Z would be less than 1.06/yr (Table 1). These are estimates of Z at the time the oldest ages were observed, i. e., at the time of the studies cited.

Estimates of M by Pauly's method are specific to growth parameters and water temperature assumed. Estimates were made for a a range of temperatures and three sets of von Bertalanffy growth parameters (Fig. 2b). The estimates based on the growth parameters of Oxenford and Hunte (1983) are presumably descriptive of the southern stock and are shown for comparison only. The two sets of estimates derived from growth parameters for the northern stock vary somewhat. Because the data of Beardsley (1967) included a wider range of sizes, a more even sex distribution, and resulted from more varied sampling techniques than the data of Rose and Hassler (1968), estimates from those data seem better suited to the purposes of this assessment.

Estimates of M based on the data of Beardsley (1967) are relatively high for such a large fish, but within the range of plausibility, given its high growth rate and early maturity. Over a range of mean water temperatures from 20° to 28°, corresponding estimates of M range from 0.68/yr to 0.80/yr (Fig. 2b; Table 2). For comparative purposes, this range of values is similar to accepted estimates of M for yellowfin tuna, another large, warm-water, wide-ranging, predatory fish. For that species, the values commonly used are $M = 0.8$ for ages 0 and 1 and $M = 0.6$ for older fish (ICCAT 1991).

4 Abundance Index

An index of relative abundance was estimated from the weighout database maintained at the NMFS Southeast Fisheries Science Center in Miami. This database contains records of fishing effort (number of hooks set) and landings in weight for numerous species caught in the U. S. longline fishery. That data base was selected because of its wide data coverage and because the relative lack of targeting on dolphinfish might result in approximately random sampling, which in turn would provide an unbiased index of relative abundance. (By comparison, using data from a fishery in which dolphinfish are strongly targeted might tend to underestimate changes in relative abundance, because targeting, especially on a schooling species, can cause catchability to increase with declining abundance.)

To construct the abundance index, the weighout data compiled by Goodyear (1999) for the South Atlantic Fishery Management Council were used; those data include years 1986 through 1997. In a data screening step, the following records were removed:

- Records with gear other than longline, as such records could not be used in generating a standardized abundance index
- Records from NMFS areas 10, 11, 12, and 13, which are south of the area occupied by the hypothesized northern stock of dolphinfish
- Records showing no hooks set, as being typographic errors or simply incomplete information
- Records believed to be from sets targeting dolphinfish, as being nonrepresentative of overall abundance trends; such records are few and mainly in the last few years

Following screening, data were accumulated on a trip basis (defined by unique combinations of vessel ID, number of hooks set, location and logbook date),[2] with total weight of dolphin landed and total number of hooks set as the major variables compiled for analysis.

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[2] Present practice is to apply a unique trip identifier in the weighout database. Because that practice was instituted only recently, other data were used here to define unique fishing trips.

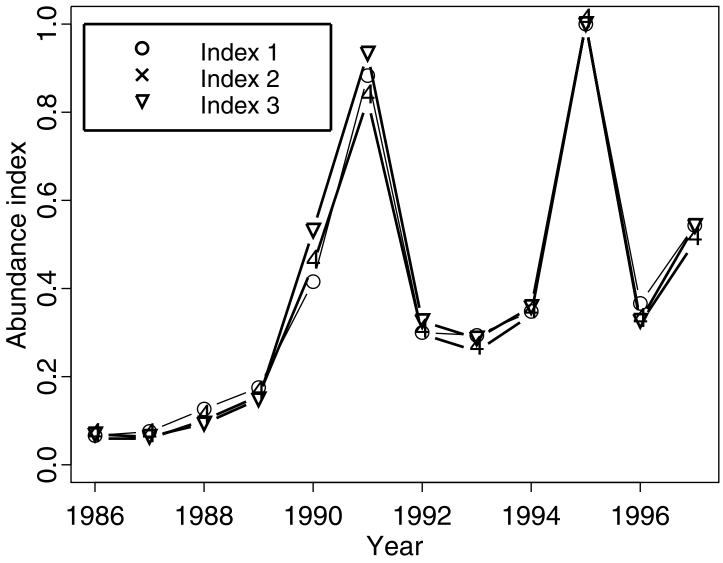

Figure 3. Preliminary indices of relative abundance of dolphinfish in U.S. waters. Indices vary by specific factors included in models. (See text for details.)

The abundance index itself was estimated through a statistical procedure similar to a linear model, but based on a delta-lognormal model (Lo et al. 1992; Zhou and Tu 1999). This procedure has been adopted in fisheries work for data sets with many cells with CPUE values of zero (Ortiz et al. 1999). Because the longline fishery is primarily directed at swordfish, not at dolphinfish, that was the case here.

Three indices were constructed, differing only in the effects estimated. Index #1 estimated effects only for year and general location of the catch (NMFS location code). Index #2 also estimated effects for an assigned *operation code* that classifies vessels into general groups by style and power of fishing. Index #3 omitted that operation code but added a seasonal effect (quarter of the year). The relative abundances (year effects) estimated by the three analyses were nearly identical (Fig. 3). Year effects from Index #1 were used in surplus production modeling (§5) and are given in the second column of Table 3.

Whether the estimated indices truly represent patterns of relative abundance is open to question: this analyst has limited confidence that they do. Inspection of Fig. 3 demonstrates that the estimated ratio between largest and smallest abundances within each index is about 15:1 and that the range of estimated abundances in recent years (1994–1997) is nearly 4:1. It is questionable whether dolphinfish have undergone such

Table 3. Data used in production model of dolphinfish *Coryphaena hippurus*. Relative abundance is in arbitrary units and derived from a delta–lognormal model; catch is the sum of commercial and recreational landings.

Year	CPUE	Catch, mt
1985	—	4,576.85
1986	0.06655	4,576.85
1987	0.07546	3,302.52
1988	0.12668	3,480.16
1989	0.17511	6,166.56
1990	0.41530	5,854.16
1991	0.88276	7,875.63
1992	0.30023	4,526.29
1993	0.29382	5,199.09
1994	0.34805	5,801.06
1995	1.00000	9,036.78
1996	0.36632	5,817.63
1997	0.54344	10,232.91

large and sudden changes in abundance; however the possibility cannot be dismissed. Moreover, the indices could be accurate (unbiased) but imprecise (noisy) because of poor representation of dolphinfish in the catch or for other reasons. With no corroborating evidence of population abundance patterns, one must say that uncertainty in the abundance indices is high.

5 Surplus Production Model

A surplus production model was fit to abundance index #1 and total landings as compiled by Goodyear (1999). Data used in modeling are given in Table 3. The model was fit with the computer program ASPIC (Prager 1995), which implements a non-equilibrium version of the logistic surplus production model of Lotka (1924) and Schaefer (1954, 1957) as revised by Pella (1967) and Prager (1994). Fits were also made with abundance indices #2 and #3, and because results were essentially the same, they are not presented here. The objective of fitting this model was to obtain estimates of stock status and reference points for management.

The surplus production model seems to fit the data reasonably well (Fig. 4a): it cap-

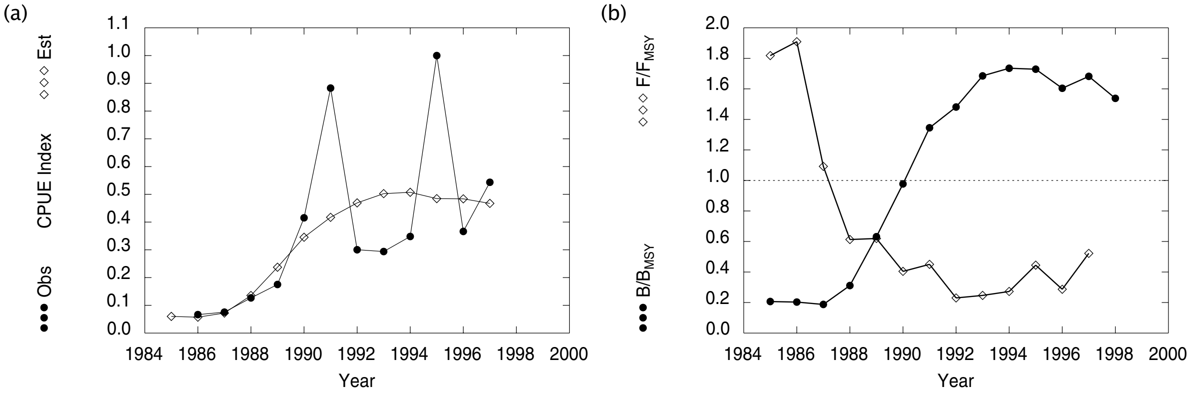

Figure 4. Surplus production model of dolphinfish, based on U.S. landings and long-line CPUE. (a) Fit of model to CPUE index. (b) Estimates of relative benchmarks B/B_{MSY} and F/F_{MSY} over time.

Table 4. Benchmark estimates from production model of dolphinfish in north Atlantic Ocean. Bias-corrected (BC) estimates shown, along with upper and lower bounds of nonparametric 80% confidence interval; all derived from bootstrapping.

Benchmark	BC estimate	80% LCB	80% UCB
MSY, mt/yr	12,241	8,506	21,110
F_{MSY}, proportion/yr	0.49	0.34	0.85
$B_{1998}/B_{\mathrm{MSY}}$	1.56	1.22	1.77
$F_{1997}/F_{\mathrm{MSY}}$	0.51	0.26	0.92

tures the overall pattern of change in the abundance index, though not the recent large fluctuations. Estimates from the model (Table 4) are plausible given the life history and catch record of the species. The confidence intervals in Table 4 should be regarded as minimum estimates; actual bounds of uncertainty are probably greater. Concern about uncertainty in these estimates springs from two related sources. First, as mentioned immediately above, the underlying abundance index is itself uncertain, and estimates from the production model can be no more certain than the data on which they are based. It is also notable that the model estimates low stock abundance at the start of the period (about 20% of B_{MSY} in 1985), followed by an increase of about 8×, to about 168% of B_{MSY} in 1997 (Fig. 4b). This pattern reflects that of the abundance index, although the model smoothes the variation somewhat. With no independent evidence at hand for comparison, it is difficult to know whether the estimate of low relative abundance in the mid

1980's is meaningful or an artifact. To judge sensitivity of the production model, additional runs were attempted with the first-year biomass fixed at higher fractions of B_{MSY} (fractions ranging from 0.2 to 0.6), but it was not possible to obtain estimates under that constraint. In summary, estimates from the production model seem plausible given the species' life history and recent landings, but can be considered no more certain than the estimated abundance indices upon which they are based.

6 Reference Points and Proxies

It has been recommended that limit reference points be specified as part of the information supplied for fishery management (FAO 1995; Restrepo et al 1998), and this approach has become increasingly important. The production model estimates above provide one set of estimates of limit reference points: MSY = 12,241 mt/yr and F_{MSY} = 0.49/yr (Table 4). Because of uncertainty in those estimates, it seems desirable to seek another set of reference points for comparative purposes.

In data-limited situations, the use of proxies for MSY and F_{MSY} has been suggested, along with the necessity of "bringing the knowledge base at least up to data-moderate standards" (Restrepo et al 1998). The same document suggests that suitable proxies for F_{MSY} can lie between $F = 0.75M$ and $F = M$. Given the range of estimates of M developed in §3.3 ($0.68 \leq \hat{M} \leq .80$), the corresponding range of proxies would be be $0.51 \leq F \leq 0.80$.

Restrepo et al (1998) also suggest that "if there is no reliable information to estimate fishing mortality or biomass reference points, it may be reasonable to use the historical average catch as a proxy for MSY, taking care to select a period when there is no evidence that abundance was declining." Using that approach, one could take an average of the last ten years' catch and arrive at a proxy for MSY of Y = 7,204 mt/yr. The choice of ten years is somewhat arbitrary, but the suggestion is to use a recent time period. If the last five years' catch are averaged, the proxy for MSY becomes Y = 8,089 mt/yr.

The benchmark estimates from the surplus production model and their proxy counterparts are comparable, but the production model estimates that a larger sustainable yield might be possible through application of a lower rate of fishing mortality. Unfortunately, current knowledge does not allow a scientific statement about which set of benchmarks is closer to the truth.

7 Summary of Stock Status

The life history of dolphinfish and the estimates generated here suggest that this species may be able to withstand a relatively high rate of exploitation. The abundance index indicates an increasing trend in stock size, and the surplus production model based on that index estimates that recent (start of 1998) stock status is above B_{MSY}. These positive indications are balanced by abundant uncertainty and reasons for caution:

1. Under excessive mortality rates, even a species resistent to exploitation may undergo geographically or temporally localized depletion or be exploited at suboptimal yield per recruit.
2. The current stock hypothesis is supported by only limited evidence.
3. The stock status of fish in the Gulf of Mexico is unknown. Here, they have been assumed to belong to the northern stock. Based on vital rates estimated for the two areas, that assumption may be incorrect (Bentivoglio 1988).
4. Under the current stock hypothesis, extent of the stock include waters of other nations, so that international cooperation in research, monitoring, and assessment appears necessary to obtain more complete catch records and to delineate stock boundaries.
5. Estimates of vital rates are several decades old.
6. The abundance index is quite uncertain and lacks corroboration.

8 Research Needs

Assessment of dolphinfish is limited by lack of information. Critical areas for futher investigation are

- Better definition of stock structure
- More research on vital rates
- Further research on appropriate indices of abundance

While research on these items can be conducted in parallel, it is a fundamental tenet that scientific assessment depends on proper definition of stock structure (Pitcher and Hart 1982). It is exceedingly difficult to interpret apparent changes in abundance when the fish under study may represent an unknown number of stocks, each of unknown extent.

All methods of assessment depend to some degree on estimates of vital rates. At the very least, yield per recruit cannot be estimated accurately without good estimates of growth and M; these are also needed for age-structured methods. Estimates of spawning potential and proxy estimates of F_{MSY} depend on knowledge of vital rates. Finally, even when they are not used directly in assessment models, comparison to current vital rates provides perspective to benchmark estimates.

Development of abundance indices for widely dispersed and poorly sampled species is not a simple endeavor. Development so far has been limited by time and manpower. More fundamentally, it is not certain whether the available data, which are mostly fishery dependent, are unbiased (for the population, not the catch) and have sufficient coverage. A fishery-independent measure of abundance would be a valuable tool, especially for a species such as dolphinfish, which tends to aggregate in surface waters and so is subject to targeting.

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