

## Summary of stock assessment of *Hirundichthys affinis*

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### INTRODUCTION

This paper summarises efforts to pursue assessment of the eastern Caribbean flyingfish (*H. affinis*) stock as a basis for management advice. The paper covers the period through to the end of the Eastern Caribbean Flyingfish Project (ECFFP). It discusses the results of the efforts and their applicability for management given the biological characteristics of the species. Efforts subsequent to the ECFFP are summarised in the final chapter of this book.

### APPROACHES TO ASSESSMENT

#### Yield-per-recruit

Yield-per-recruit (Y/R) analyses use growth rate, natural mortality and age of recruitment of fish to the fishery to estimate the Y/R corresponding to various levels of fishing mortality (F). It is also possible to explore the probable effects of changes in the fishery which would result in changes in recruitment age (e.g. gear selectivity). If current levels of F are known, the analysis will indicate whether the manager should implement measures to increase or decrease F and/or change gear selectivity to alter age at recruitment in order to optimise Y/R.

All the necessary input data for flyingfish were not available prior to the meeting. However, subsequent to the workshop, an exploratory Y/R analysis was carried out. A growth curve fitted to otolith daily ring counts for fish in the size range 5-140 mm FL, and adjusted on the basis of estimated size-at-age for larger fish, was used to estimate size-at-age. Natural mortality was estimated from the multiple regression equation of Pauly (1984). Y/R was examined for two harvesting options. In the first Option a harvesting strategy which approximates the current fishery situation was assumed, i.e. recruitment to the fishery was considered to be knife-edged at maturity. In the second option, recruitment was considered to be complete at the youngest age, i.e. at one month. The

purpose of exploring the second option was to examine the situation which might develop if the fishery changed from exploiting fish which are aggregated for spawning, to targeting immature fish.

On the basis of information which became available at the Final Workshop of the ECFFP, a yield-per-recruit (Y/R) analysis was carried out for *H. affinis* in the eastern Caribbean, in order to determine the feasibility of optimising Y/R as a management objective. Owing to the uncertainties in the input parameters, in particular natural mortality, the analysis should be viewed as exploratory. However, even with the uncertainties, the analysis clearly indicates that Y/R is unlikely to be useful as a tool for providing advice on flyingfish to fishery managers.

Oxenford *et al.* (1994) estimated von Bertalanffy growth parameters for juveniles from otolith daily increment counts. However, the largest individual used was 14 cm FL, and their growth curve did not reach its asymptote as quickly as was indicated by the estimates of size-at-age for adult fish provided by Storey (1983) and Khokiattiwong *et al.* (2000) (Table 1). Therefore,  $t_0$ ,  $k$  and  $L_{\infty}$  were adjusted slightly in this study to allow the growth curve to better fit the data for the adult fish (Figure 1). The original values for the growth parameters, for time in days, were:  $L_{\infty} = 24.5$  cm FL,  $k = 0.00854$ ,  $t_0 = 2.85$  days. The adjusted values are:  $L_{\infty} = 23.2$  cm FL,  $k = 0.010$ ,  $t_0 = 4$  days.

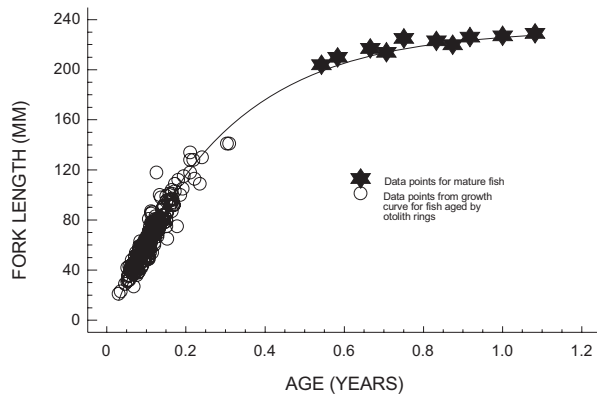
The adjusted growth curve was used to predict lengths for ages 1-18 months. Corresponding weights-at-age were estimated using the weight-length relationship provided by Khokiattiwong *et al.* (2000) for males and females combined:  $W = 0.01160 L^{3.01}$ .

Natural mortality was calculated as 4.4 from the multiple regression equation of Pauly (1984):  $\log M = -0.0066 - 0.279 \log L_{\infty} + 0.6543 \log K + 0.4634 \log T$ , using the growth parameters above, and a water temperature of 27°C which the analysis by Podesta and Brown (1990) indicates as appropriate.

**Table 1. Mean size-at-age for adult *H. affinis* from data of Storey (1983) and Khokiattiwong (1988). The ages are estimated assuming an average birth date of March 1st.**

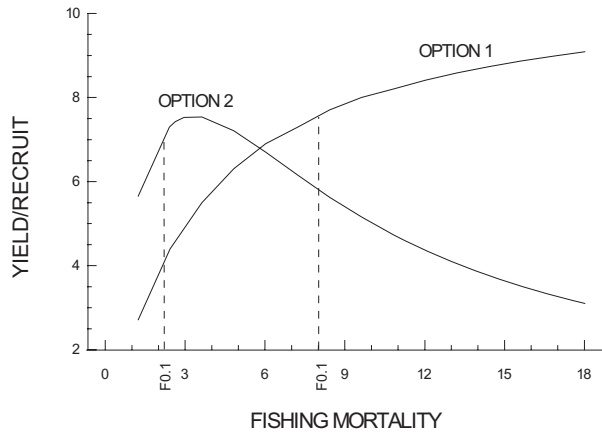
Age (days)	198	258	319	213	243	274	304	335	365	395
Length (mm FL)	204	214	220	210	217	224	223	226	227	229

Two Y/R analyses were carried out using the method of Thompson and Bell as described by Rivard (1982). In the first analysis (Option 1), recruitment was set as occurring at age seven months (the approximate average age of maturity), based on the observation that the present fishing method depends on the aggregation of spawning fish. Although it is unlikely that an economically viable way can be found to harvest flyingfish before they aggregate for spawning, this possibility cannot be discounted. Therefore, in the second analysis (Option 2), full recruitment was set at age 1 month, to explore the Y/R scenario which might result if a fishing method was developed which could harvest immature fish.

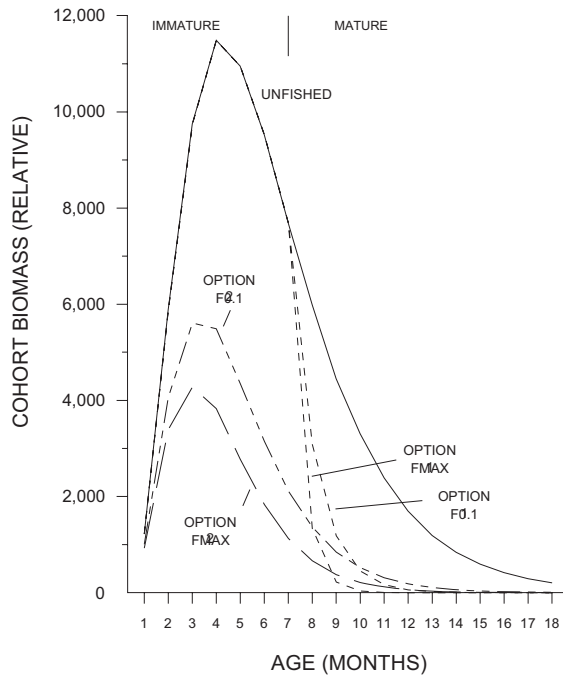


**Figure 1. Adjusted growth curve for *H. affinis* in the eastern Caribbean.**

The inputs to, and results of the analyses are shown in Table 2, and Figures 2 and 3. Figure 2 shows Y/R values at different fishing mortalities (F) for Options 1 and 2. The figure indicates that for Option 1, Y/R is maximised at an annual F which is in excess of 18.0, whereas for Option 2 it is maximised at an annual F of 3.3. Figure 3 shows the distribution of biomass at age for an unfished cohort, and for  $F_{MAX}$  and  $F_{0.1}$  in each option. It shows that due to the relatively high M, and the levelling off of growth at ages six-seven months, biomass in an unfished cohort peaks very sharply at age four months.



**Figure 2. Yield-per-recruit of *H. affinis* at various levels of F. Age at first capture for Option 1 is taken as 7 months and for Option 2 as 1 month.**



**Figure 3. Distribution of biomass at age for fished and unfished cohorts.**

**Table 2. Relative cohort biomass estimates for *H. affinis* at  $F_{0.1}$  and  $F_{Max}$  for the two fishing options (Option 1 = full recruitment at age of first maturity -- seven months; Option 2 = full recruitment at age 1 month). Population size at age 0 was taken as 1,000 fish.**

Age (months)	Length (cm)	Weight (g)	Unfished number of individuals	Relative cohort biomass-at-age				
				Unfished	Option 1 $F_{Max}$	Option 2 $F_{Max}$	Option 1 $F_{0.1}$	Option 2 $F_{0.1}$
1	5.3	1.8	693.05	1217	1217	925	1217	1012
2	10.1	12.2	480.32	5875	5875	3392	5875	4061
3	13.5	29.3	332.88	9751	9751	4279	9751	5605
4	16.1	49.8	230.70	11483	11483	3829	11483	5488
5	17.9	68.5	159.89	10949	10949	2774	10949	4350
6	19.3	85.9	110.81	9518	9518	1833	9518	3145
7	20.3	100.0	76.80	7680	7680	1124	7680	2110
8	21.1	112.3	11.88	5979	1334	665	3087	1366
9	21.6	120.5	1.84	4447	221	376	1185	844
10	22.1	129.1	0.28	3302	37	212	454	521
11	22.4	134.5	0.04	2383	6	116	169	313
12	22.6	138.1	0.01	1696	1	63	62	185
13	22.7	140.0	<0.01	1191	0	34	23	108
14	22.8	141.9	<0.01	837	0	18	8	63
15	22.9	143.7	<0.01	588	0	10	3	37
16	23.0	145.6	<0.01	413	0	5	1	22
17	23.1	147.5	<0.01	290	0	3	0	13
18	23.1	147.5	<0.01	201	0	1	0	7
<b>Average mature biomass</b>				2417	773	219	1056	466
<b>Percent of unfished biomass</b>					32%	9%	44%	19%

In Option 1, fishing at  $F_{Max}$  would result in virtually all of the fish being caught at age seven months (Figure 3). Thus Y/R optimisation would lead to removal of most fish as soon as they mature, before they have had the opportunity to spawn. In this situation, the average mature biomass of a cohort would be about 32% of that for an unfished cohort. Using  $F_{0.1}$  as a reference fishing mortality the average mature biomass of a cohort would be 44% of that for an unfished cohort. Such reductions in mature biomass are likely to be detrimental to recruitment, but the potential effects have not been quantified.

In Option 2, fishing at  $F_{Max}$  would result in virtually all the fish being caught between ages 3-6 months. Thus Y/R maximisation would lead to the removal of most fish before maturity. In this situation the average mature biomass is reduced to 9% of that for an unfished cohort (Table 2). The use of  $F_{0.1}$  as a reference fishing mortality results in an average mature biomass which is 19% of that for an unfished cohort.

The conclusion from these exploratory analyses is that maximisation of Y/R is not an appropriate management objective for the flyingfish fishery in the eastern Caribbean. Management strategies which use Y/R

as a management criterion, even through the most conservative approach used in this study (Option 1,  $F_{0.1}$ ), will permit the reduction of spawning stock to a level likely to result in recruitment failure. Should an economically viable way be found to harvest immature flyingfish, i.e. before they aggregate for spawning (Option 2), recruitment overfishing would be a major concern. Any extensive change in the nature of the fishery towards harvesting fish before they aggregate for spawning should therefore be discouraged.

These analyses coupled with knowledge of the basic characteristics of the fishery indicate that even using the conservative  $F_{0.1}$  as a reference fishing mortality, Y/R optimisation is unlikely to be a useful criterion for managers. This is primarily because recruitment overfishing is very likely to result if Y/R is used as a management criterion.

### Surplus production

A surplus or general production approach to stock assessment directly models the yield produced by a stock at various levels of fishing mortality, using time-series of fishing effort and yield, without considering details of growth and recruitment. However, it does require that

fishing must have had a significant impact on stock abundance at some point in the time-series.

In the case of an annual species such as flyingfish, where the yield in each year is the surplus recruitment from the previous year, annual surplus production and surplus recruitment are virtually the same. The only difference between the two would arise in the event that density-dependent growth affected the yield in weight at various levels of recruitment.

### Stock-recruitment analysis

Even if there is a fundamental change in the present method of harvest, growth overfishing is unlikely due to the rapid growth rate and high natural mortality of flyingfish. Therefore, the primary management concern is the possibility that increased exploitation of spawning fish (many of which are taken before they have spawned), or immature fish, will lead to reduced recruitment. An analysis of the relationship between stock and recruitment using catch and effort data from the northwest of Barbados, suggests that there may be a reduction in recruitment at the lowest observed levels of parent stock (Mahon 1989) (Figure 4). The analysis is based on flyingfish being essentially annual, such that there is no overlap between cohorts in the fishery and the fishable stock in each year consists entirely of new recruits.

Two issues arise in connection with the analysis. First is the validity of the catch per trip as an index of abundance. Second is the extent to which an analysis based on a CPUE time-series from one location can be considered as representative of the entire stock. As tagging data now indicate that a single shared stock of flyingfish throughout the south-eastern Caribbean region is the most likely stock structure, data collected at one location only may adequately reflect of the behaviour of the entire stock.

One feature of the stock-recruitment relationship in Figure 4 is the high degree of variability in recruitment around the estimated stock-recruitment curve. A high degree of interannual variability is characteristic of many pelagic fishes in the eastern Caribbean (Mahon *et al.* 1990). The observed variability makes it impossible to use the stock-recruitment relationship for flyingfish to predict surplus recruitment (i.e. yield) in any year on the basis of CPUE in the preceding year with sufficient accuracy to be useful for management. However, if recruitment variability in flyingfish is closely related to environmental factors which can be identified and quantified, then it might eventually be possible to predict recruitment, and thus to estimate surplus recruitment with acceptable accuracy for use in management.

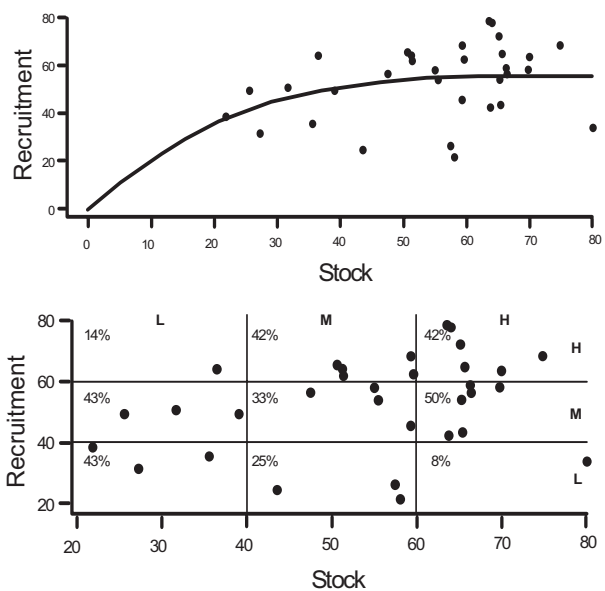


Figure 4. Stock-recruitment analysis for flyingfish (from Mahon 1990).

An analysis of the correlation of the residuals around the stock recruitment relationship with various environmental variables did not reveal any strong environmental influences on recruitment (Mahon 1989). However, several points should be noted. The environmental data which were available for input into the analysis were primarily climatic rather than oceanographic. Although the latter are related to the former, oceanographic influences on recruitment cannot be discounted until more proximate variables have been used in the analysis. Unfortunately, there are few time-series of oceanographic data for the eastern Caribbean, and the data which do exist are in raw form and will therefore require considerable preselection and analysis before they can be used. A further complication is that the early life-history of flyingfish is not sufficiently well known to allow a close match between the time and location at which a particular life history stage occurs and the corresponding environmental conditions.

Predation mortality may also be an important factor determining recruitment success in flyingfish. Such an analysis would require information on inter- and intra-annual variation in the abundance of potential predators. Fishery data on relative abundance of known predators, such as adult dolphinfish exist, but there are no data on the juveniles of these predatory fish which may be more important predators of flyingfish than the adults.

In conclusion, it does not appear likely that in the foreseeable future, there will be data that will allow the

development of predictive models of flyingfish recruitment, and thus of surplus recruitment yield.

### Risk assessment

The fact that there is considerable inter-annual variability in flyingfish recruitment and that yield in any year cannot be accurately predicted, indicates that the most effective approach to estimating appropriate levels of harvesting is to use the stock recruitment relationship, and the observed variability to simulate the risk of stock collapse, and other undesirable fishery characteristics at various levels of exploitation. On this basis, managers can select a level of exploitation at which the risks are acceptable. The meeting reviewed the conclusions of the study by Mahon (1989) which conducted such an analysis using the data from the Barbados fishery up to 1986. The analysis sought to identify the risks of stock collapse, and periodic low catches, as well as increased inter-annual variability in catch rates which would accompany increased exploitation.

The final workshop of the ECCFFP concluded that risk assessment based on the approach used by Mahon (1989), remained the best assessment approach for the flyingfish fishery at the present time. However, there are no absolute reference points regarding appropriate levels of risk. These would have to be agreed upon by the fishing industry, by managers and by consumers, all of whom have interests in appropriate management of the resource.

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