



GRENADA LONGLINE BAIT USAGE ASSESSMENT

Consultancy to Develop a
National International
Commission for the
Conservation of Atlantic Tunas
(ICCAT) Strategy and to Conduct
Key Activities from the Fishery
Improvement Plan for Grenada

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ACRONYMS AND ABBREVIATIONS

BET	Bigeye Tuna
BUM	Blue Marlin
FAO	Food and Agriculture Organization of the UN
HCRs	Harvest control rules
ICCAT	International Commission for Conservation of Atlantic Tunas
LL	Long Line
SAI	Sailfish
SKJ	Skipjack Tuna
YFT	Yellowfin Tuna

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1 GRENADA LONGLINE BAIT USAGE ASSESSMENT

1.1 GRENADA BAIT USAGE

The three main bait species used in the Grenada longline (LL) fishery are flying fish (*Hirundichthys affinis*), bigeye scad (*Selar crumenophthalmus*) and Atlantic threadfin herring (*Opisthonema oglinum*). Flyingfish have been the traditional bait used, which occurs seasonally in Grenadian waters during the period of October through June. Longline fishers also purchase imported threadfin herring (Gentner et al. 2018) used as chum to catch flyingfish or (infrequently) as bait, themselves. Alternatively, fishers may deploy drifting gillnets during longline fishing trips to catch flyingfish. If flyingfish are unavailable, longline fishers purchase bigeye scad caught in the local inshore beach seine fishery and kept alive in seapens. There is a local market for flyingfish and bigeye scad and, thus, landings of those species for that market are recorded to some extent. However, there is no monitoring in place for any of these bait fisheries. The amount of bait use varies significantly between longline operators ranging from 200 fish per day on the smaller vessels to 900 fish per set on the larger ones (Sieben and Gascoigne 2021). They also note that "...bait use in longline fisheries tends to make up a significant proportion of the total longline catch, likely exceeding the 5 percent threshold applied by MSC to 'main' species." In the following section, we provide some quantification of the likely scale of annual bait usage in the Grenada longline fishery.

The basic approach to estimating annual bait usage is to estimate the number of hooks set per year and then multiplying by the average weight of a baitfish set on each hook. A simple method to estimate annual hooks set is to divide the annual catch of YFT of the Grenada LL fishery (or annual catch of pelagics) by the catch per hook of YFT (or pelagics). Alternatively, hooks per year might be estimated more directly (sets/trip, hooks/set, trips/year and number of vessels for each of the main three LL vessel types). In the latter case, there is information available on the average number of hooks per set by vessel type and number of vessels by type (Rennie 2024 pers comm). But this method requires information on the number of sets per trip and per year for each vessel type and that data is not available. However, there was a project (Samalsingh et al. 2005) that provided catch of YFT and pelagics per set and per hook in the developing Grenada longline fishery. These catch rates may be used to estimate hook usage. Thus, we have opted to use the former approach (annual YFT catch/annual catch per hook of YFT times baitfish weight). This method uses the current yellowfin catches it is estimating the current annual bait usage. The number of hooks used per year is estimated by dividing the kg of yellowfin catch per hook (from Samalsingh et al. 2005) by the annual catch kg of yellowfin. Then the number of hooks is multiplied by the weight of a baitfish on each hook resulting in the aggregate annual baitfish usage.

First consider the expected weight per fish for each of the three baitfish species. The common metric for flyingfish is "3 per pound" (Medley et al. 2010) which equates to 0.15 kg/fish. This is consistent with a 23 cm fish (Fishbase). Additionally, 0.15kg/fish is consistent with estimates for comparable length fish of bigeye scad and Atlantic threadfin herring (Fishbase). Thus, as an initial estimate, that metric is used for kg/fish for all bait species. Second, Samalsingh et al. (2005) reported on the developing longline fishery in Grenada, following that progress from 1982-93. They reported on the catch per trip of YFT and YFT, BUM and SAI combined, as well as the number of hooks per trip for several stages of the project. From their Table 1 there were three stages of the project with differing vessel characteristics: stage one wooden vessels with box and line gear type setting an average of 45 hooks/set; stage two fiberglass, box and line, 45 hooks per set; and stage 3 fiberglass, line and reals, 110 hooks per set. The catch (kg) per hook of "targeted" species (YFT, BUM and SAI) and for YFT alone are in their Figure 8. Recent landings of YFT, BUM and SAI from Grenada come from the Task 1 database of ICCAT. The mean over the three stages of catch per hook of YFT+BUM+SAI from these data was 1.138 kg/hook (standard deviation 0.187. The aggregate usage (Table 1) is for all bait species and no attempt was made to disaggregate the estimates into the three bait species.

Year	Task 1 Grenada Catch of YFT ICCAT (mt)	Task 1 Grenada Catch of YFT, BUM, SAI ICCAT (mt)	Est Annual Bait Usage (mt)	Estimated hooks set/yr (x 10 ³)	kg YFT/kg bait
2015	1108	1369	180	663	6.14
2016	1535	1721	227	833	6.77
2017	1177	1384	182	670	6.45
2018	1297	1492	197	722	6.60
2019	708	874	115	423	6.15
2020	739	876	115	424	6.40
2021	287	366	48	177	5.95
2022	957	1034	136	501	7.02
Approx mean			150		
Approx Coefficient of Variation			40%		

Table 1 - Approximate estimates of bait usage in the Grenada longline fishery. Grenada Catch of YFT, BUM, SAI (mt). Catch of YFT, BUM and SAI from ICCAT Task 1 database; Catch per hook of YFT+BUM+SAI from Samalsingh et al. 2005 (mean 1.138/hook standard deviation 0.187).

These estimates are meant to provide a broad understanding of the scale of bait usage in the LL fishery, thus less confidence can be placed on individual annual estimates. The statistics make a number of assumptions:

that size of individual bait fish is around 0.15 kg;

that the current catch of target species per hook has not deviated much from the 1990's and that it does not deviate much between vessel types;

that there is one baitfish used for each hook that is set (ignores when fishers have fewer baitfish than hooks or when there are more baitfish than hooks and the excess baitfish are discarded);

that there has been relatively little variation in hooks/set over time within a vessel type; and other issues.

Of these the assumption of ~1.138 kg of target species catch per hook is probably (assumption 2) is the most suspect for at least two reasons. One reason is that the original Samalsingh report does not indicate if the catches that are recorded were in whole weight or gilled and gutted weight. We have assumed they were in whole weight. However, the report describes the gutting at sea, so it is unclear if the conversion to whole weight was made. If, in fact, the catches were in gutted weight, then the estimates of bait usage would increase by about 20% (the conversion rate to whole fish). The second reason is that the Samalsingh study took place in the 1990's and catch efficiencies may have changed since then. In the future, if bait usage is to be quantified more precisely, there needs to be a concerted effort to associate hook usage with individual catches and trips (perhaps through a logbook or more usefully, an electronic logbook associated with a phone app). Thus, we suspect that the coefficient of variation is underestimated. Nevertheless, these results indicate a "rule of thumb" that at least 1 kg of baitfish is needed to realize a catch of 6-7 kg of yellowfin. Also, results indicate that baitfish usage likely exceeds 5% of the yellowfin catch and of the aggregate of YFT, BET, SKJ, BUM and SAI. Nevertheless, these data provide a basis for evaluating likely impacts of the fishery on regional and national baitfish resources.

1.2 REGIONAL CARIBBEAN BAIT USAGE

In order to evaluate the possible usage of bait in the Caribbean region Table 2 gives the recent reported catches of YFT for six Caribbean countries including Grenada. If all of the YFT catch from these countries were obtained from similar gears and baiting practices, then using a “6-7 kg rule of thumb” implies that average annual YFT catches of 2958 mt are supported by annual bait usage of 423-493 mt. However, it is unclear what baiting practices occur, especially for the Trinidad and Tobago catches. In any case, this implies a regional usage of less than 700 mt annually. (the highest entry in Table 2 is 3797 mt total YFT catch divided by 6 is less than 700 mt). As discussed previously, these estimates rely on a number of assumptions. Nevertheless, the estimates provide a first approximation of usage.

Year	Barbados	Dominica	Grenada	Saint Kitts and Nevis	Saint Vincent and the Grenadines	Saint Lucia	Trinidad and Tobago	Total	Bait Usage (mt) using rate 6	Bait Usage (mt) using rate 7
2015	262	194	1167	1	153	175	1179	3131	522	447
2016	324	179	1607	5	434	191	1057	3797	633	542
2017	270	209	1257	29	772	232	890	3659	610	523
2018	248	116	1391	13	373	199	1214	3555	593	508
2019	121	180	818	1	105	172	982	2379	396	340
2020	173	120	784	6	226	190	973	2471	412	353
2021	213	75	287	0	104	156	1244	2078	346	297
2022	202	75	957	0	104	174	1080	2592	432	370
Average	227	143	1033	7	284	186	1077	2958	493	423

Table 2 - Reported catch of yellowfin tuna from Caribbean countries. Rates of usage of 6 or 7 kg of YFT per kg of bait are presented as examples

1.3 OTHER CARIBBEAN REGIONAL SOURCES OF MORTALITY ON BAIT SPECIES

Reported landings of the flyingfish and bigeye scad species within the Caribbean region from the FAO database (FishStatj) are shown in Figure 1. Note that these data are reported landings and some countries might not fully report. For example, there are no reported catches of flyingfish from Trinidad and Tobago in this database (although they do report a large catch of aggregated species). However, persistent conflicts between Barbados and Tobago fishers over flyingfish access (Fraser 2024) suggests that Trinidad and Tobago would have been exploiting the flyingfish resource to some extent. Also, it is unlikely that bait usage is being fully reported or reported at all. Additionally, it has been noted in multiple publications (e.g. Gentner et al 2018, Fraser 2024, Sieben and Gascoigne 2021, CRFM 2014, 2018) that the catch of targeted fisheries for flyingfish (primarily from Barbados) has declined substantially. Hypotheses for the cause of this includes a shift in the flyingfish distribution and/or the interaction of the fishers and their gear with the proliferation of Sargassum throughout the Caribbean.

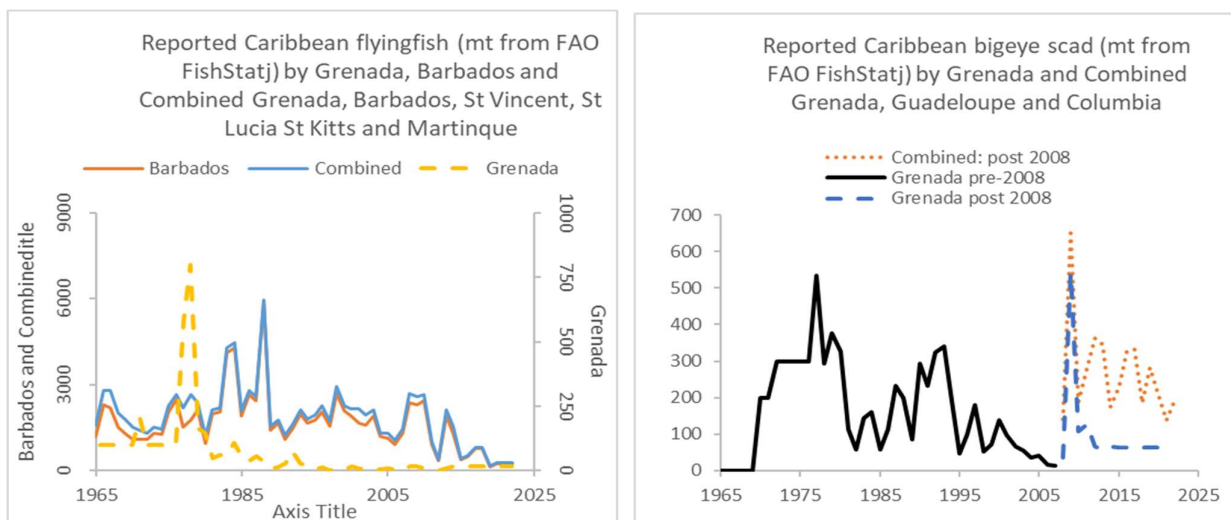


Figure 1 - Reported Caribbean catches of flyingfish and bigeye scad

From Figure 1, the directed flyingfish fishery experienced annual catches of approximately 2500 mt for more than four decades. The decline in catches since ~2008 may have been accompanied by an increased usage of flyingfish as bait in the regional longline fisheries as that fishery developed. However, it has been noted previously that that usage has decreased. Thus, even if all the bait usage now were flyingfish (which it is not; most of the bait used now is bigeye scad, Gentner et al 2018) and given the likely bait usage in the region (Table 2), it is very unlikely that current annual fishing mortality exceeds the 2500 mt that the directed fishery experienced in the past over many years.

The statistics on bigeye scad are more equivocal (Figure 1 right panel). Reported catches seem to be more ad hoc with reports from most Caribbean countries not appearing in the database. Grenada reported annual catches have declined over the years.

1.4 ASSESSMENT OF BAIT SPECIES

1.4.1 FLYINGFISH

Medley et al. 2008 assessed the regional status of flyingfish through a working group of regional experts on the fisheries and flying fish biology. Total catches were compiled from Barbados, Dominica, Grenada, Saint Lucia, Saint Vincent, and Tobago. These catches were considered to be the best estimates available, but were probably not highly accurate. In particular, it was noted that catches used for bait were poorly recorded but preliminary estimates were made by the working group based on the available data and their local knowledge. Catch and effort data were available from Barbados, Tobago and Saint Lucia. These data were combined into a single standardized index of abundance using a generalized linear model. The index covered 1988-2008, whereas the catch data at that time extended from 1950 to 2008.

Medley et al. 2008 provided a synopsis of the biology of the four wing flyingfish as it relates to the construction of stock assessment analyses which is summarized here. The flyingfish is a short-lived, essentially annual species with a maximum age of around 18 months and grows relatively fast (best estimates of standard von Bertalanffy growth parameters are: $L = 24.5$ cm FL, $k = 0.01$ per day, $t_0 = 2.85$ days. They reach first maturity as small as 18.0 cm FL (around five months of age). The majority of fish are mature by 20.3 cm FL (around seven months of age). Individual fish are believed to spawn several times within the November to July spawning season. Eggs are non-buoyant and highly adhesive, and are spawned on floating materials including natural flotsam and the fish aggregation devices and gillnets used to catch adult flyingfish. Since the average life span is around one year, mortality rates are high (instantaneous annual rates have been estimated to be greater than 1 and as high as 4.4). Flyingfish are patchily distributed across the eastern Caribbean with tagging data demonstrating that

individuals move freely between the islands of the eastern Caribbean. Also, survey data from 1988 suggest that flyingfish are likely to be available in commercially viable quantities beyond range of most local fishing fleets. Given this background, Medley et al. implemented a stock assessment model commonly used with flyingfish (Mahon 1989) with a Bayesian estimation implementation. Note, Bayesian estimation uses prior probability distributions for important parameters based on expert opinion which are statistically adjusted using the data (catch rates and catches) to achieve a “best” final estimate of the parameters. Further discussion of the models are given in the Technical Appendix.

Since the completion of the Medley et al. analysis, the database has deteriorated significantly: directed catches that were reasonably well-reported have declined and catches being used for bait have increased. These bait catches were not monitored. An updated assessment was conducted (CRFM 2019). That analysis assumed that landed (reported) catches post-2008 composed all of the catch and that the catch rates were proportional to the catches, using the prior to 2008 data to obtain the proportionality. That assumption is unlikely to have been true. Instead, we stipulate that the Medley database remains the best available since it included the catches for bait and used considerable expertise in its compilation. The estimated biological parameters of the dynamics prior to 2008 are still useful for interpreting the likely dynamics and status of the stock at this time. Additional analyses were conducted herein (Technical Appendix) to reflect further model testing.

1. The evolution of research since 2008 of appropriate ratios of biomass at maximum sustainable yield to biomass when there was no fishing (i.e. B_{MSY}/B_0) for stocks of specific life histories
2. The interpretation of the Medley results for B_0 based upon the ensuing events in this fishery (sargassum/changes in distribution).

The essential results of the analyses both here and in Medley was that the catch rate data during the period prior to 2008 does not contain much information about trend. However, these rate data are important in estimating the intrinsic productivity rate (how quickly the stock grows and declines within a year after the recruitment of eggs to juveniles). A summary of the Medley results medians: Biomass 2007/ B_{MSY} =2.71, MSY =7897mt, B_0 =26351 mt, 2007 fishing mortality rate relative to the rate at MSY =0.17, intrinsic rate of annual increase=3.40. Also, these results indicate that B_{MSY}/B_0 is 0.35. Recent stock assessment research indicates that even slow-growing multi-cohort stocks have B_{MSY}/B_0 ratios of less than 0.35. So, it seems unlikely that 0.35 is appropriate for a single cohort stock. An alternative model that is more flexible was fit where B_{MSY}/B_0 was fixed at 0.2. This resulted in higher MSY levels (Technical Appendix). Nevertheless, the Medley conclusions were aware of this possibility when they made their recommendations which are summarized below.

An improved stock assessment may lead to further international fishing controls. The most significant uncertainty in the current assessment stems from the poor data available on catches and effort. Improved data collection and monitoring is required to ensure sustainable use of this and other fishery resources.

The catch rates (during the time prior to 2008 used in the Medley analysis) were stable overall in the time series as catches increased. Given the potential stock area, and estimates of a relatively large stock size from tagging and survey estimates, it is likely that the potential yield exceeds total catches taken throughout the history of the fishery.

A catch trigger point of 5 000 mt should be established when action may be taken to ensure the stock does not become overfished. The trigger point defines when further management action should be undertaken. The maximum recorded catch has been 4 700 mt. The assessment indicates that any fisheries development exceeding 5 000 mt would have unpredictable consequences. Among the actions that should be taken if catches rise to, or above, the trigger point, are a freeze on further fishery development until a full scientific reassessment of the stock has been completed.

Note that this latter point was a key recommendation of the subsequent draft management plan: “Implementation of a precautionary sub-regional freeze on expansion of flyingfish fishing effort and/or fishing capacity applied to all authorised vessel types, should the agreed catch trigger point be realized, to be followed by reassessment of resource status and adaptive management” (CRFM 2014).

While the flyingfish catch database has deteriorated, the above analysis of bait usage indicates that it is unlikely that recent catches have reached the 5000 mt trigger. Additionally, given the high productivity of flying fish (intrinsic rate 3.40) and the broad geographical distribution it is unlikely that a stock would not recover quickly given reductions in catches. Thus, we concur with the Medley et al. (2008) recommendations.

1.4.2 BIGEYE SCAD

Given the paucity of data on both catches and catch rates, there is no basis for conducting analytic assessments of bigeye scad at this time. However, it is likely that this species is quite productive and has a broad geographical distribution (Sieben and Gascoigne 2021). But the stock tends to be more coastal than flyingfish, being caught by beach seines. At one time a fishery targeting bigeye scad for consumption in Grenada supported annual catches of 200 mt or higher (Figure 1) but have declined. Declines were originally thought to be related to the increasing longline activities and their demands for bait. However, an alternative explanation is that environmental conditions may have changed and could be impacting these resources either their availability close to shore or their actual abundance. Given the analysis of bait usage above, it is entirely possible that current bigeye scad catches are greater than 200 mt. It is recommended that bait usage of bigeye scad be quantified (beyond the cursory analyses of usage above) and that a trigger be established for annual catches with appropriate variation based on those results.

1.4.3 THREADFIN HERRING

It is likely that the stock is quite productive and has a broad geographical distribution extending to temperate Atlantic waters in both the northern and southern hemispheres (Sieben and Gascoigne 2021).

Also, it has been indicated that threadfin herring baits are typically imported to Grenada from outside the region. Thus, it is likely that attempts of local management would be fruitless. Nevertheless, it is recommended that the use of this species by the longline fishery be quantified and that these values be compared to the potential catches both within and without the Caribbean region.

1.5 ON HARVEST CONTROL RULES AND MANAGEMENT STRATEGY EVALUATIONS FOR BAIT SPECIES

Harvest control rules (HCRs) are prespecified directions to limit fishing mortality rates or catches in response to the status of the stock. For example, Medley et al. suggested the control rule that fishing mortality rates should not exceed $2/3$ of the fishing mortality rate at MSY for flying fish. Other examples include reducing the fishing mortality rate below that at MSY proportionally to the ratio of current biomass relative to B_{msy} . The CRFM (2014) draft management plan recommendation "...should the agreed catch trigger point be realized, to be followed by reassessment of resource status and adaptive management" is an example of the first step of a control rule.

However, there are characteristics of the longline bait species and the monitoring systems available that should be considered when constructing an HCR. First, the bait species are highly productive, thus both the abundance and the annual catches are expected to be quite variable. If catches exceeded a trigger point in one year due to a large recruitment event, then it would not be unreasonable that the following year would have lower recruitment and lower catches independent of any HCR that might be imposed. In this example by the time a management action to reduce catches could be implemented, the stock had already adjusted. Therefore, there always needs to be a meshing of the timing of the dynamics, the ability to monitor and detect changes in status and the ability to implement management actions.

Ideally, HCRs should be based on biomass indices (such as catch rates). However, with these baitfish species indices are not available. Thus, catch triggers (as in Medley et al. 2008) are what is available. Additionally, the proportional mixture of species in the longline catches might be considered.

Since the bait species are highly dynamic, typically these call for controls on effort (e.g. limiting seasons or trips or access) versus controls on catch such as catch quotas or TACs. These are also referred to as input controls and output controls, respectively.

Given these characteristics, we can foresee a candidate rule in which a catch trigger for each of the species is established. If it is exceeded for “x” consecutive years then the fishing effort be reduced “y” percent. In the case of bigeye scad, that effort might relate to beach seine effort. Additionally, when the bait usage distribution among the species deviates “substantially” from “the norm”, then this might indicate other ecosystem issues and might trigger a reevaluation of the system.

The definition of “x”, “y”, “substantially” and “the norm” should be examined through management strategy evaluations where the robustness of the rules and their definitions are tested through computer simulations of suites of models reflecting various hypotheses about the dynamics of the baitfish stocks. This activity is well beyond the scope of this consultancy.

Additionally, an HCR and its implementation should consider the ecosystem effects and competing interests of users of Grenadian resources. Still the key issue in successfully implementing an HCR is the ability to monitor catches. It is imperative that baitfish usage be monitored such that appropriate rules can be defined and that eventually stock assessments can be conducted.

1.6 CHAPTER REFERENCES

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1.7 TECHNICAL APPENDIX

The Mahon (1989) population dynamics model used to assess flyingfish Is

$$B_{t+1} = \frac{B_0 r B_t}{B_0 + (r-1)B_t} - C_t \quad \frac{B_{msy}}{B_0} = \frac{\sqrt{r}-1}{(r-1)} \quad MSY = \sqrt{r} \frac{(\sqrt{r}-1)}{(r-1)} \quad \text{equilibrium } \frac{dB}{dt} = \frac{B_0 r B}{B_0 + (r-1)B} - B$$

where B_t is the biomass at the beginning of year t, B_0 is the equilibrium biomass when there is no fishing, r is the intrinsic rate of increase and C_t the catch (wt) in year t. The data observations in Medley et al. (2008) were time series of catches and standardized catch per effort of Caribbean flyingfish where the catch per effort X_t was modeled as $X_t = qB_t$ where q is a catchability coefficient. The catch per effort data was obtained primarily from the Barbados targeted fishery for flyingfish while the catches were from Caribbean nations' catches plus estimates of Grenada's bait usage at the time. Medley et al. (2008) fit the model to these data using Bayesian methods with prior probabilities on B_0 , r and q. The prior on B_0 was based upon a tagging study, the prior on r was based upon life history parameters of growth, mortality and reproduction estimated for flyingfish and the prior distribution of q was assumed to be log-uniform. Additionally, process error was fixed at a relatively high level consistent with a population that exhibits large variability in recruitment. The Medley et al. 2008 results were:

	Prior Median	Posterior Median
r	4.047	3.40
B0 tonnes	~ 220,000	26,351
MSY tonnes		7,897
Bmsy/B0		0.35
B 2007 tonnes		25919
C 2007 tonnes		2512
B/Bmsy		2.71
F/Fmsy		0.17

There are several issues with these results that might be explored based upon the history of flyingfish catches subsequent to this assessment in 2008 and also evolving best practices since 2008 when specifying productivity parameters. The first issue is that the prior on B_0 was very uninformative: the posterior estimate was an order of magnitude smaller than the prior. These results tell us that the basic catch per effort data are informing us about r, but little else. Additionally, the shifting of the location of catches since the early 2000's and their decline argues that B_0 may be much larger. Medley was well aware of this and noted it.

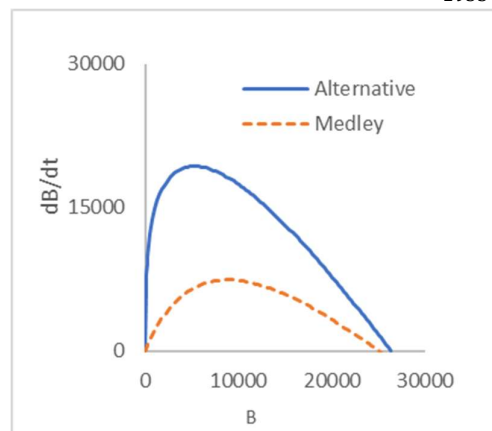
The second issue is the estimate of $B_{msy}/B_0 = 35\%$. This is contrary to current practices, where B_{msy}/B_0 of even low productivity age-structured stocks have $B_{msy}/B_0 = 25\%$. It would be expected that B_{msy}/B_0 for a highly dynamic flyingfish species would be lower than 25%. But, this characteristic is a feature of the Mahon model =where

B_{msy}/B_0 is a function of r alone.

As a simple sensitivity test, an alternative model was fit:

$$\frac{dB_t}{dt} = a B_t^p - m B_t - C_t \quad B_{msy}/B_0 = \left(\frac{1}{p}\right)^{\frac{1}{p-1}} \quad a = m B_0^{1-p}$$

Note that with a judicious choice of p and m, this model can be made to be identical to the Medley results. However, in this test B_{msy}/B_0 was fixed at 20% and B_0 was fixed at the posterior estimate from Medley, i.e. 26,351 t. This test was designed to explore the effects of an alternative p. The model fit the catch per effort series at the beginning and end of each year compared to the biomass at the beginning and end of the year. Parameters estimated were m, q and B_{1955} the biomass at the beginning of the time series and the differential



equation was solved numerically. The results are summarized in the following equilibrium dB/dt graph. The MSY (the maximum on each graph increases) and B_{msy}/B_0 decreases. Medley alluded

to this in acknowledging the limitations of that assessment.

Based on Medley and the sensitivity test explored here, we remain in support of the draft control rule and the draft management plan that was discussed in the body of this report.