Southern Indian Ocean
Deepsea Fishers Association

YIELD PER RECRUIT ANALYSIS OF ALFONSINO AND IMPLICATIONS FOR THEIR MANAGEMENT IN THE SOUTHERN INDIAN OCEAN

R. Shotton
Executive Secretary
Southern Indian Ocean Deepsea Fishers Association
<r_shotton@hotmail.com>

1.   INTRODUCTION

As alfonsino grow, as for all fish, they increase in size and thus weight. At the same time, the numbers of alfonsino in any particular age class of a stock or population decline because of mortality, either from natural causes, such as predation, or capture by a fishery. When alfonsino are young their individual weights are low. Even though there may be many fish in the young age classes the product of fish numbers and weight still results in low age-class biomass. As the alfonsino grow a year-class biomass will increase as long as the gain in year-class biomass from growth exceeds loss of biomass weight due to decline in numbers from mortality. Above a certain age, an age class's total biomass will start to decline as increase in biomass from growth becomes less than loss of biomass from decline in numbers of fish in the age class because of mortality. Further, growth itself declines with age/size as energy intake is progressively used for somatic maintenance and reproductive products rather than somatic growth.

With knowledge of the growth rates and natural mortality, even if the numbers of recruits in an age class is unknown, the relative yield-per-recruit can be determined for different levels of fishing mortality and age of entry into the fishery. In this way maximum relative yield in terms of biomass can be determined and the corresponding parameter values. There is no knowledge of year class numbers not indeed is much definitely known about their stock structure for alfonsino in the Southern Indian Ocean. In such cases analyses usually must focus on the index of the expected yield per recruit (Y/R). In this way the size of fish (or equivalently, their age) can be determined at which the maximum Y/R would be obtained.

This paper examines the Y/R of alfonsino as a function of fishing mortality (F) and age of recruitment into the fishery using the well-accepted Y/R function of Beverton & Holt (1957). Various parameter values may be used in the Y/R function for alfonsino, depending on the results of a different researchers that one may chooses and the region where in which they obtained their alfonsino samples. With the exception of a brief note by Ivanin & Rybek (2012) no parameter values have been specifically determined for alfonsino stocks in the Southern Indian Ocean. While determining such values for Southern Indian Ocean stocks is, of course, desirable, indeed essential, it is not believed that appreciable errors will result from using values that have been determined for alfonsino in other oceans. Where there does appear to be large differences in alternative estimates of parameters values, it is appropriate to examine ranges in the parameter estimates.

2. NATURAL MORTALITY

2.1 Introduction

The causes of natural mortality in fish are numerous – starvation, disease, and ultimately senescence as a result of increasing age but mostly predation by other species. It is common fisheries theory that rates of natural mortality decline as the size of a fish (or indeed any animal) increases. With larger size they become prey for fewer animals so at least natural mortality from predation should be lower.

How natural mortality of alfonsino (as for most fishes) changes with age is unknown and conventionally, at least for analyses, natural mortality is assumed to be constant during a fish's life. There is no factual basis to hypothesize some other relation that better describes the change of natural mortality with age, though one might reasonably assume that during the middle years of life, i.e. before the effects of senescence become important, but after fish recruit to aggregations of adults, natural mortality is relatively low. Should this be the case, the relative M (the fraction of an age class dying each year) would have a U-shape as a function of age.

Most natural mortality is believed to occur as eggs and larvae and small fish of the 0-year class. At this time they are of a size when they are vulnerable to many predators. If there is an abundance of food, the alfonsino larvae will grow rapidly and more quickly pass through the size ranges of heavy predation. Small differences in the percentage of eggs surviving hatching and the larval stage (e.g. from 0.01% to 0.02%) can cause enormous changes in recruit success resulting in large year classes. Conversely, high larval mortality can result in recruitment failure.

If there has been no fishery on a stock, then the only cause of death is that of natural mortality. If there has been no fishery on a specific stock, an estimate of M can be obtained by taking a sample of the population and determining the numbers of fish as a function of age – assuming this is possible. However, when there has been a fishery on the stock it becomes difficult to separate the two sources of mortality: fishing mortality (F) and natural mortality. Dynamic pool models, which are a common and useful class of management models, require the use of a value for M: in this case either an assumption is made about the value of M, or one of a number of estimators may be used.

2.2 Estimates of Natural Mortality of Alfonsino

Rikhter & Efanov (1976), Alagaraja (1984), Alverson & Carney (1975), Roff (1988) and Taylor (1958) provide estimates of the natural mortality of alfonsino in Chile that are summarized in Table 1.

Table 1
Estimates of natural mortality (year^{-1}) for alfonsino in Chile. The 95% confidence intervals are shown within parentheses. (Gili *et al*. 2002)

Method	Rikhter & Evanof (1976)	Alagaraja (1984)	Alverson & Carney (1975)	Roff (1988)	Taylor (1958)
Males	0.148	0.178	0.323	0.199	0.116
	(0.136,0.160)	(0.158,0.198)	(0.286,0.359)	(0.212,0.187)	(0.103,0.129)
Females	0.136	0.158	0.287	0.211	0.103
	(0.129,0.143)	(0.147,0.170)	(0.265,0.307)	(0.203,0.218)	(0.096,0.111)
Both sexes	0.134	0.155	0.281	0.213	0.101
	(0.128,0.141)	(0.145,0.165)	(0.263,0.299)	(0.207,0.220)	(0.095,0.108)
Model $M =$	$\dfrac{1.521}{t_m^{1.521}} - 0.155$	$\dfrac{-\log 0.01}{t_\infty}$	$\dfrac{3}{e^{t_\infty\,0.025k} - 1}$	$\dfrac{3ke^{-kt_p}}{1 - e^{-kt_p}}$	$\dfrac{k\,2.966}{2.966 + kt_0}$

Horn & Sutton (2009) note that to date, no reliable estimates of M are available for any population of alfonsino in New Zealand or [in their view] elsewhere. They estimated M using the method of Hoenig (1983)

$$M = -(\log_e 0.01)/A \qquad\qquad (1)$$

where:
0.01 = proportion of the population that reaches age *A* or older.

Using *A* = 18 in (1) gave Horn & Sutton an estimate of *M* = 0.26 and using *A* = 20 a value of 0.23. These authors note that the true age of alfonsino is slightly greater than 20 years and thus they assume *M* is in the range 0.20 to 0.26. Ageing studies of alfonsino from various locations in the North and South Pacific Ocean have indicated that the maximum age for this species probably is about 20 years (e.g., Lehodey & Grandperrin 1996). The oldest alfonsino aged from New Zealand waters was 18 years (Massey & Horn 1990, NIWA unpublished data).

Table 2 shows that that estimates of M have generally increased with time though providing the reasons for these is not attempted here.

Table 2
Estimates of M over the period 1958 – 2009

Date of Estimate	Citation	Value of M (both sexes combined)
1958	Taylor	0.101
1975	Alverson & Carney	0.281
1976	Rikhter & Evanof	0.134
1984	Alagaraja	0.155
1988	Roff	0.213
2009	Horn & Sutton	(mid-value) 0.23
Average		0.185

Horn & Sutton's mid-value is not within the confidence interval of any of the estimates given in Table 1. A careful review of the methods and assumptions used by the different workers remains to be done. In this analysis I have chosen the mean of the three high estimates as an upper range,

(0.281 + 0.213 + 0.23) / 3 = 0.241

For this note I arbitrarily reject the estimate of Taylor as an outlier and calculate for a lower range estimate,

(0.134 + 0.155) / 2 = 0.144.

This results in a considerable range! The higher the actual M is the higher will be the fishing mortality that maximizes yield per recruit: conversely, the lower the actual M then the more likely high rates of fishing mortality are to cause growth overfishing. The mean of these two estimates of M is 0.192. I stress that these calculations should not be taken as 'high' fisheries science, but rather as a way to progress given the considerable uncertainty that exists. To avoid implying a level of precision greater than is certain to exist, values of 0.24, 0.19 and 0.14 are subsequently used here.

3. ESTIMATES OF GROWTH PARAMETERS

3.1 Model Parameters

I have elected to use the von Bertalanffy growth relation: this is not to say that it is the best growth model for alfonsino and further studies may identify a better growth model. However, it is a widely used and there should be no particular opprobrium in using this model without examination of alternatives.

The von Bertalanffy growth model is parameterized with three coefficients: the von Bertalanffy growth coefficient (K with dimensions of yr^{-1}), the asymptotic weight (W_∞) and the age at which an alfonsino is estimated to have zero length (a model fitting mechanism), t_0. Many workers have determined that these parameters are different for the two sexes. Where one value is given I presume that the fish were not sexed, rather than a mean was taken of values estimated for males and females. Estimates of these parameters are given in Table 3. Table 4 lists estimates and 95% confidence intervals of von Bertalanffy parameters for alfonsino from the Palliser Bank, Tuaheni High and Paoanui Ridge determined by Massey & Horn (1990) in New Zealand.

Massey & Horn (1990) found male and female length-at-age relationships to be significantly different in all comparisons of lengths at five, eight and eleven years from all grounds. The differences became more significant with increasing age; females on the Palliser Bank were about 0.7, 1.0 and 2.5 cm larger than males at 5, 10 and 15 years, respectively. Maximum sizes recorded from all grounds were 49 cm for males and 57 cm for females.

Table 3
Growth-related parameter values for alfonsino

Area	Author(s)	L_∞ (cm)		W_∞ (g)	K (yr^{-1})		t_0	
		M	F		M	F	M	F
Canary	Rico et al. 2001[1]	44.51			0.15		3.41	
Madeira		58.71			0.06		5.71	
Azores		43.10			0.17		2.80	
New Caledonia: Norfolk-Loyalty Ridges	Lehodey & Grandperrin (1996)	45.2	50.8		0.146	0.134	2.34	2.00
	Males & Females	51.3			0.119		0.005	
Southern Indian Ocean	Ivanin & Rebyk (2012)[2] – Males & Females	66.8		10 570	0.0823		-2.60	
Azores	Anabil *et al.* (1998)	45.3	53.7		0.133	0.085	-2.74	-4.02
	Anabil *et al.* (1998): Males & Females	46.1			0.120		-3.18	
	Fishbase	>50						
North Pacific Ocean	Yanagimoto & Nishimura 2007	46.48	58.17		0.1725	0.1193	-2.046	-2.230
New Zealand	Massey & Horn							

---

[1] Tempnote: fishbase in error here – delete me later
[2] The relation of Ivanin & Rebyk given here is for Standard Length where SL = 0.91 FL.

Location	Reference	L_∞ Males	L_∞ Females		K Males	K Females	t_0 Males	t_0 Females
	1990							
Palliser Bay		51.1	57.5		0.11	0.088	-3.56	-4.1
Tuaheni		54.9	76.3		0.093	0.042	-4.3	-8.25
Paoanui		49.1	-		0.144	-	1.81	-
Japan								
Sagami Bay	Ikenouye 1969	37.8			0.439			
Sagami Bight	Masuzawa *et al.* 1975	45.8			0.323		-0.2228	
Zunan Sea		54.4			0.1813		-0.0757	
Atlantic								
Corner Rise	de Leon & Malkov 1979	48.5			0.181		-2.63	
New England Rise		44.8			0.209		-0.89	
Chile								
Juan Fernández Islands	Gili *et al.* 2002	58.5	63.6		0.095			
		63.4			0.093		-2.567	
Chile	Niklitschek & Toledo (2011)	49.3			0.12		-2.0	

Table 4
Estimates and 95% confidence intervals of von Bertalanffy parameters for alfonsino from the Palliser Bank, Tuaheni High, and Paoanui Ridge, (New Zealand. (Massey & Horn 1990)

	von Bertalanffy Parameters					
	L_∞ (cm)		K		t_0 (years)	
Sample	Males	Females	Males	Females	Males	Females
Palliser						
Observed	51.1 ± 2.1	57.5 ± 2.5	0.110 ± 0.016	0.088 ± 0.012	-3.56 ± 0.79	-4.10 ± 0.72
Back-calculated	49.6 ± 2.6	57.9 ± 2.6	0.116 ± 0.023	0.087 ± 0.012	-3.67 ± 0.96	-4.7 ± 0.65
Tuaheni						
	54.9 ± 11.9	76.3 ± 22.5	0.093 ± 0.069	0.042 ± 0.026	-4.30 ± 4.02	-8.25 ± 3.34
Paoanui						
Male	49.1 ± 3.0		0.144 ± 0.038		-1.81 ± 1.25	

The most notable feature of Massy and Horn's (1990) analysis of all age-length curves was that the growth data show no evidence of an asymptote. They concluded that unless large fish were not being sampled by the trawl gear, alfonsino grow through their entire life and continue to do so until they die of old age. Such results are unexpected and have not been reported by any others. Ikenouye (1969), Masuzawa *et al.* (1975), and de Leon & Malkov (1979) also report L_∞ values which are larger than maximum observed alfonsino sizes.

Niklitschek & Toledo (2011) investigated three growth models, that of Gompertz, von Bertalanffy and Schnute. According to the Schnute model, length at age one would be 17.9 cm and at age 14, 42.3 cm. Females had a tendency to grow faster than males, e.g. at age one, length was estimated at 17.7 cm and 43.1 cm at age 14, while for males, the corresponding values were 17.6 and 40.0 cm. The growth parameters that were obtained are listed in Table 5.

Table 5
Growth Parameters reported by Niklitschek & Toledo (2011)

Model	Parameters	
Von Bertalanffy	L_∞	49.3
	K	0.12
	t_0	-2
Gompertz	L_∞	54.0
	G_t	0.13
	t_0	1.97
Schnute	A	0.36
	B	-2.94
	L_1	17.9
	L_2	42.3

Deep-water species in the ICES area ranked according to longevity and growth rate, summarised from Anon. (2001c) are given in Table 5.7

Table 5.7
ICES Estimates (ICES 2001)

	Longevity (yr)	Growth Rate (k) yr^{-1}
Beryx splendens	11 (5)	0.13 – 0.14

3.2   Summary of Parameters
3.2.1   Length Estimates

Area	Author(s)	L_∞ (cm)	
		M	F
Canary	Rico *et al*. 2001	44.51	
Madeira		58.71	
Azores		43.10	
New Caledonia: Norfolk-Loyalty Ridges	Lehodey & Grandperrin (1996)	45.2	50.8
	Males & Females	51.3	
Southern Indian Ocean	Ivanin & Rebyk (2012)[3] – Males & Females	66.8	
Azores	Anabil *et al*. (1998)	45.3	53.7
	Anabil *et al*. (1998): Males & Females	46.1	
	Fishbase	>50	

---

[3] This relation is for Standard length where SL = 0.91 FL.

North Pacific Ocean	Yanagimoto & Nishimura 2007	46.48	58.17
New Zealand	Massey & Horn 1990		
Palliser Bay			
Observed		51.1 ± 2.1	57.5 ± 2.5
Back-calculated		49.6 ± 2.6	57.9 ± 2.6
Tuaheni		54.9 ± 11.9	76.3 ± 22.5
Paoanui – male		49.1 ± 3.0	
Japan			
Sagami Bay	Ikenouye 1969	37.8	
Sagami Bight	Masuzawa *et al*. 1975	45.8	
Zunan Sea		54.4	
Atlantic			
Corner Rise	de Leon & Malkov 1979	48.5	
New England Rise		44.8	
Chile			
Juan Fernández Islands	Gili *et al*. 2002	58.5	63.6
		63.4	
Chile	Niklitschek & Toledo (2011)	49.3	

Not surprisingly, given the estimates are derived from samples that have been taken on a global basis, there is a considerable range in the values of L_∞ that have been obtained. The only estimate for alfonsino sampled from the Southern Indian Ocean (Ivanin & Rebyk 2012) is also one of the largest – 73.4 cm - and is sufficiently large that I believe it would be prudent to treat it as an outlier. The mean of the estimates for male fish is 48.5 and for females, 60.0, though this includes the large estimate of Massy & Horn (1990) that has a confidence interval of 22.5 cm. It would seem prudent to also treat this value as an outlier, in which case the mean for the female estimates becomes 56.8 cm. The mean of the two sexes combined is 52.9 cm. This appears consistent with the estimates for the two sexes separated – 52.5 cm. Thus for the calculations here, I use

$$L_\infty = 52.9 \text{ cm.}$$

An argument could be made that the values of Rico *et al.* (2001) should be treated as a single estimate, i.e. (48.51 + 58.71 + 43.10)/3 = 50.1. This would have resulted in an average estimate of 52.04 for L_∞, which is slightly lower (1.7%) than what has been chosen.

3.2 Selection of Model Parameters*
3.2.1 Asymptotic weight

An estimate of W_∞ is possible from length-weight relations. Table 5.8 lists parameters for the weight-length relation $W = aL^b$ with weight in grams, length in centimeters. Figure 5.5 shows the length-weight relation for alfonsino samples from Southwest Indian Ridge banks taken during 1980-1988 (Ivanin & Rebyk 2012). de Leon & Malkov (1979) calculated length-weight equations for alfonsino from the Corner Rise (c. 35° N, 50° W) and New Year Rise (c. 15° N, 54° W) in the west-central Atlantic. The relation of Ivanin & Rebyk (2012) was derived from much smaller fish (17-36 cm) than those of Massey & Horn (1990) and de Leon & Malkov (1979).

Table 5.8

Weight-length relation ($W = aL^b$): weight in grams, length in centimeters. The estimate for W_∞ is for a length estimate of 52.9cm.

Author	Length	a	b	$W_\infty = a L_\infty^{\ b}$
Ivanin & Rebyk 2012	Standard	0.0384	2.98	
Massey & Horn (1990) New Zealand	10L	1.877×10^{-5}	3.061	Male, October-May
		1.966×10^{-5}	3.061	Male, June and September
		1.857×10^{-5}	3.061	Female, October-May
		1.913×10^{-5}	3.061	Female, June, and September
Stocker & Blackwell (1991) New Zealand		0.0225	3.018	
de Leon & Malkov (1979)				
Corner Rise		1.01×10^{-5}	3.0245	
New England		1.21×10^{-5}	3.1538	
Azores		0.0178	3.0755	
Ikenouye (1969)		2.42×10^{-5}	2.979	
Niklitschek & Toledo (2011) – Males		0.0156	3.107	
Females		0.0147	3.122	

To avoid excessive cross-confounding of parameter estimates I have chosen to work with the parameter estimates of Ivanin & Rebyk (2012), Lehodey & Grandperrin (1996) and Massey & Horn (1990) for Palliser Bay. This choice is somewhat arbitrary but stands for analysis of alfonsino from the Southern Indian Ocean and two locations in the South-west Pacific – Noumea and New Zealand. Clearly, examination of the consequences of using parameter estimates for different areas would provide additional insight.

The estimates of W_∞ used here have been obtained as follows.

Ivanin & Rebyk (2012)

$$W_\infty = 0.0384 \, SL^{2.98}$$

Where   SL = standard length, the maximum is assumed here to be 55.0 cm.[4]

Thus   **W_∞ = 5897 g (5900 g)**

Lehodey & Grandperrin (1996)
Note, these authors give separate lengths for males and females. The males were far smaller than the females and I use the maximum female length here, which will confound comparisons for

---

[4] Ivanin & Rebyk (2012) note "On SWIR length of fish in catches hesitated from 12 to 55 cm (age from 2 to 18 years), making 27,2 cm on the average, mass was 70 - 6260 gramme (average - 437 gramme). Basis of catches of alfonsino was made by fish by modal group 24-32 cm."

estimates that use both sexes combined. These authors do not determine a length-weight relationship. Therefore I have chosen to use that of Ivanin & Rebyk (2012) and Massey & Horn (1990) and take the average (high science!). Thus using Ivanin & Rebyk's (1996) estimates:

$$W_\infty = 0.0384\ SL_\infty^{2.98}$$

Where

$$SL_\infty = 51.3/0.91$$

Thus,

W_∞ = 3617 g. (3620 g)

Using Massey & Horn's (1990) parameter estimates:

$$W_\infty = 0.001930\ L^{3.061}$$

W_∞ = 3313 g (3310 g)

The average is thus 3465 g.

Massey & Horn (1990) provide four estimates of the first coefficient – by sex and for two seasons. I use the average of the four here.

Massey & Horn (1990)
I take the average of the two observations where values are given for males and females, i.e.,

$$L_\infty = (51.1 + 57.5 + 54.9 + 76.3)/4 = 59.9\ cm$$

It would be prudent to consider the last value an outlier, but as it has apparently been observed I have included it in the average here. This may not be wise. Thus

$$W_\infty = 0.001930\ 59.9^{3.061}$$

Or,

W_∞ = 5324 g.

In summary,

'Source'	W_∞ (g)
Ivanin & Rebyk (2012)	5897
Lehodey & Grandperrin (1996)	3465
Massey & Horn (1990)	5324

These results indicate that the estimate based on Lehodey & Grandperrin (1996) may be an outlier or underestimate. I arbitrarily continue to use the average of Ivanin & Rebyk (2012) and Massy & Horn (1990) as a 'best estimate' (5897 + 5324)/2 = 5610 g.

3.2.2   Von Bertalanffy Gowth Coefficient*
Table 3 shows estimates for the von Bertalanffy growth coefficient and t_0, the theoretical time when the extrapolated length of newborn fish would be zero. Table 7 below shows the values given by three of these workers.

Massey& Horn only give coefficient values disaggregated by sex: I have taken the values for the two

sexes and averaged them, almost certainly introducing incalculable biases as the K and t0 values have a relation with each other. Further averaging these values for the two errors will compound such outrageous statistical liberties. But, it is done – see the last row of Table 6. The appropriate

Table 6
Growth-related parameter values for alfonsino

Source		K	t_0
Ivanin & Rebyk (2012)		0.0823	-2.60
Lehodey & Grandperrin (1996)		0.119	0.005
Massey & Horn (1990)			
	Palliser	0.099	-3.83
	Tauheni	0.0675	-6.275
	Average	0.0832	-5.052
Grand average		0.0948	-2.667

procedure would be do a single fitting of the parameters to all of the available data – in this case it would be better to use real data from the Southern Indian Ocean, but ageing analyses of alfonsino remains to be done. [5]

4.   YIELD PER RECRUIT
4.1   Yield per Recruit Model
Various approximations exist for estimating the yield per recruit but the original model of Beverton & Holt (1957) is used here:

$$\frac{Y_w}{R} = FW_\infty \sum_{n=0}^{n=3} \frac{\Omega_n e^{-nK(t_{\rho'}-t_0)}}{Z+nK} + \left[1 - e^{-(Z+nK)\lambda}\right] \tag{2}$$

Where:
$\frac{Y_w}{R}$ = Yield per recruit
F = fishing mortality
W_∞ = asymptotic weight of alfonsino
Ω_n = summation operator for n = 1,-3, 3 and-1
K = von Bertalanffy growth constant, i.e. the rate at which length reaches its asymptote
$t_{\rho'}$ = age of recruitment to the fishery
t_o = age at which fish length was theoretically zero and
λ = fishable life span in years between recruitment and death.

Analyses are undertaken to examine how the expected yield from a single alfonsino varies as the fishing mortality and age of recruitment to the fishery changes. If these variables can be altered then so the yield per recruit can be changed – increased or decreased. Note, the last term in braces tends to zero, or at least becomes insignificant, as λ, fishable life span in years between recruitment and death becomes relatively large.

4.2   Fishing Mortality in the Fishery
The two fisheries for alfonsino in the Southern Indian Ocean target separate populations: aimed trawling targets large mature fish while extensive trawling targets young and usually immature fish.

---

[5] SIODFA (2013, 2014) have identified this as a priority research need.

Thus, at present no estimates of what is the actual F in the fishery exist. For the sake of comparisons a range of values from F = 0.0 to F = 1.0 in increments of 0.2 have been used.

4.3   Age at Time of Recruitment to the Fishery

The analysis is done for two ages at recruitment to the fishery, when mean fish length was 22 cm and when mean fish length was 35 cm. It is assumed here that recruitment to the fishery is 'knife edge'. That is, no fish are caught smaller than 22 cm (or 35 cm). This, of course, is a simplification of what actually happens in the fishery.

These lengths are converted to age by rearranging the standard relation,

$$L_t = L_\infty (1 - e^{K(t-t0)})$$

Thus,

$$t = \frac{-\ln (1 - \frac{L_t}{L_\infty})}{K} + t_0$$

Thus calculated age at L_t = 22 cm is 2.8 yr and at L_t = 35 cm is 8.4 yr. These values are thus taken as the two possible ages of recruitment to the fishery.

4.4   Parameter Values for Yield per Recruit Analysis

These are taken as follows.

Variable	Value
W_∞	5610 g
K	0.098
t_0	-2.67
t_ρ	2.8, 8.4
M	0.19, 0.24, 0.14

4.5   Results

Y/R estimates have been plotted against the three choices for natural mortality, M. The results are shown in Figure 1 assuming an age of recruitment of 2.8 years, i.e. fish of length 22 cm. As expected yield per recruit decreases, by almost three fold from an M of 0.24 (high estimate) to an M of 0.14 (low estimate). However, fishing mortality that results in maximum yield per recruit is reasonably stable. Thus, any management decision on desirable levels of fishing effort is not likely to be greatly affected by changes in the assumptions about M.

Figure 1
Yield per Recruit: Change in M
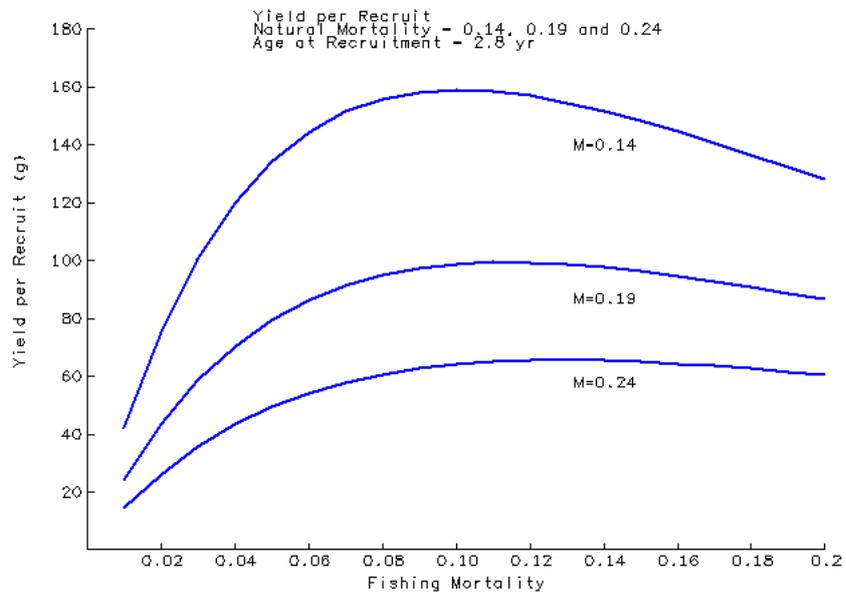
When the age of recruitment to the fishery is increased to 8.4 years (i.e. length of 35 cm) the most striking result is the increase in yield per recruit.

Figure 2
Yield per Recruit: Change in M
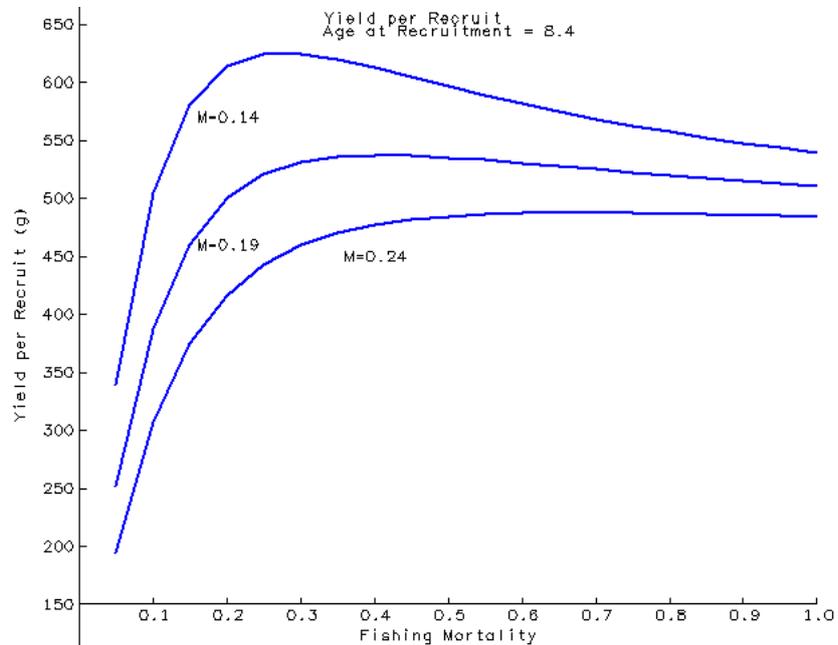
The differences arising from different assumptions about the natural mortality follow the pattern seen in Figure 1. However, all three plots show a major increase in the potential yield per recruit that is possible.

Figure 3 shows the results of comparing the two options for age at recruitment, corresponding to first size of capture of 22 cm and 35 cm. These results show the considerable benefits from delaying recruitment to the fishery to an older age.

Figure 3
Comparison of Yield per Recruit from age 2.8 years (22 cm) to 8.4 years (35 cm) and at 4, 5, 6 and 7 years
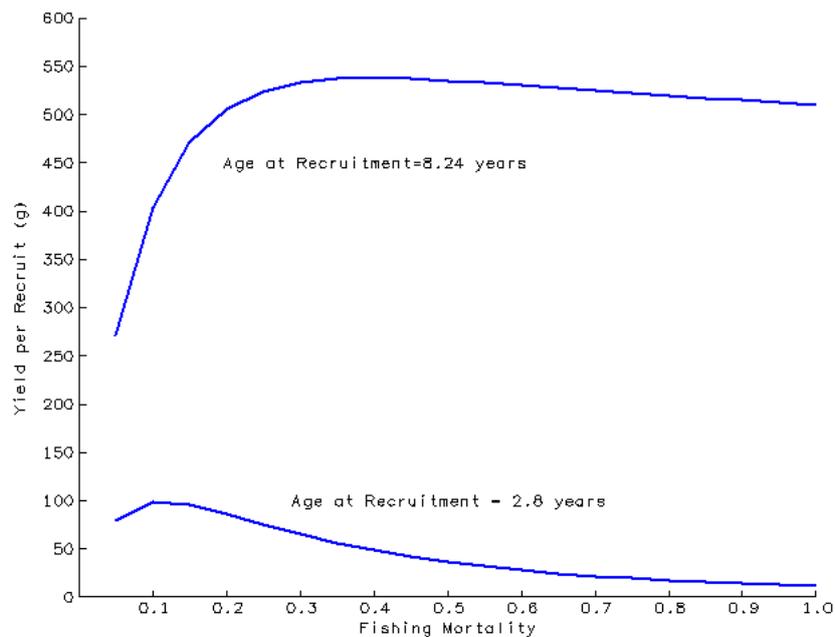
5. DISCUSSION
These results should be considered preliminary and require careful checking by myself for errors and, ideally, independent confirmation by another analyst. At least as they stand, these results deserve careful consideration and reflection. Superficially they indicate a potential increase in catches of an order of magnitude (x 10) by fishing with a target age at recruitment of 8.4 or 35 cm. But, re-checking of my numbers is a top priority.

6. LITERATURE CITED
LITERATURE CITED
Alagaraja, K. 1984. Simple method for estimation of parameter for assessing exploited fish stocks. Indian J. Fish. 31: 177-208.
Alverson, D. & M. Carney 1975. A graphic review of growth and decay of population cohort. J. Cons. Int. Explor. Mer. 36: 133-143.
Anabil, J., E. Esteves, H. Krug & H. Marques da Silva 1998. Age and growth in the Alfonsino, Beryx splendens, (Berycidae) from the Azores (central eastern Atlantic). Ital. J. Zool. 65, Suppl.: 215 – 218.
Anon. 1980. Instructions and recommendations. PINRO, Murmansk, 246 p. (in Russian).
Anon. 1980b. Fisheries Atlas of the South East Pacific Ocean for 1979. Zaprybpromrazvedka, Kalinungrad (In Russian). 50pp.
Anon. 1983. Fishery description of the Walvis Ridge. AtlantNIRO. 63 p. (in Russian)..
Anon. 1984. Fisheries description of the North Atlantic Ridge seamounts. Sankt-Peterburg, 53 pp. (in Russian).

Anon. 1985. Fisheries Description of the South-eastern Pacific Ocean. AtlantNIRO. Central directorate of navigation and oceanography, St. Petersburg, 154 p. (in Russian).

Anon. 1988. Description of seamounts and rises in the fishing grounds of the World Ocean (the open part). In: Valchuk S.V. (ed): The Atlantic and Indian Oceans. Volume 1. 485 p. (in Russian).

Anon. 1993. Fisheries description of the North Azores complex of seamounts and Corner Rise. PINRO, St.Petersburg, 170 p. (in Russian).

Anon. 2001. Fleet flops on seamounts: mountains of debt from Indian Ocean. Fishing News International, 40(1), 1.

Beverton, J.H. & S.J. Holt 1957. On the Dynamics of Exploited Fish Populations. HMSO. 533pp.

de Leon, E. & A. Malkov 1979. Preliminary study of the age and growth of the *Beryx splendens,* Lowe, of the west-central Atlantic. *Revista Cubana de investiganciones pesqueras 4(4):* 67-73. (In Spanish. English translation held at Fisheries Research Centre Library, MAF, P. O. Box 297, Wellington.)

Gili, R.L., H. Cid, H. Pool & Z. Young 2002. Estudio de Edad, crecumento y mortalidade natural de los recursos orne roughy y alfonsino. FIP 2000 – 2012. 129pp.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin 82*: 898–902.

Horn, P.L. & C.P. Sutton 2009. Commercial catch sampling for length and age of gemfish, alfonsino and rubyfish in QMA 2 in the 2006–07 and 2007–08 fishing years. New Zealand Fisheries Assessment Report 2009/19. 38 pp.

Ikenouye, H. 1969. Age determination by otolith of a Japanese alfonsino *Beryx splendens,* with special reference to growth. J. Toko Univ. Fish 55: 91-98.

Ivanin, N. & S. Rebyk 2012. Age, growth parameters and some aspects of reproduction of alfonsino *Beryx splendens* Lowe on the Southwest Indian Ridge. YugNIRO, Ukraine. Working Paper. Workshop on Assessment and Management of *Alfonsino* Fisheries. FAO, Rome, Italy, 10 – 12 January 2012. 4pp.

Lehodey, P. & R. Grandperrin 1996a. Age and growth of the alfonsino *Beryx splendens* over the seamounts off New Caledonia. Mar. Biol . 125: 249 – 258.

Massey, B.R. & P.L. Horn 1990. Growth and age structure of alfonsino (*Beryx splendens*) from the lower east coast, North Island, New Zealand. N.Z. J. mar and Freshwat. Res. 24:121-136.

Masuzawa, T., Y. Kurata & K. Onishi 1975. Results of group study on demersal fishes in water from Sagami Bay to southern Izu Islands: Population biology of Japanese alfonsino and other demersal fishes. Pap. Fisehry Res. 28. 105pp. Japan Aquatic Resources Conservation Association, Tokyo. English transl. Fisehries Research Centre Library, Wellington, Ministry of Agriculture and Fisheries, P.O. Box 297, Wellington, New Zealand.

Niklitschek, E.J. & P. Toledo (Eds) 2011. Informe Final, Evaluación Hidroacústica de Alfonsino, Año 2009. Proyecto FIP 2009-14. Universidad de Los Lagos, Centro i~mar. 190pp.

Rikhter, V. A. and V.N. Efanov 1976. On one of the approaches to estimation of natural mortality of fish populations. ICNAF. Res.Doc. 76/VI/8: 12pp.

Rico V., J.M. Lorenzo, J.A. González, H.M. Krug, A. Mendonça, M.E. Gouveia & M.A. Dias 2001. Age and growth of the alfonsino *Beryx splendens* (Lowe, 1834) from the Macaronesian archipelagos. *Fisheries Research* 49 (3): 233-240.

Roff, D.A. 1988. The evolution of migration and some life history parameters in marine fish. Env. Biol. Fishes 22: 33-146

SIODFA 2013. SIODFA Members' Perceptions of Fisheries Policy, Management and Research Issues to be Addressed and their Priorities. Working Document 2013/XIII-05. 11pp.

SIODFA 2014. Report of the XVth General Meeting of the Southern Indian Ocean Deepsea Fishers Association. Port Louis, Mauritius. 33pp.

Taylor, C. 1958. Temperature, growth and mortality - The Pacifc Cockle. J. Cons. CIEM, 26: 117-124.

Yanagimoto, T. & A. Nishimura 2007. Review of the Japanese Fisheries in the Emperor

Seamount Area. First Meeting of the ESM Scientific WG (Jan 2007). SG1/J1.