Catch to natural predation ratios for sardine and anchovy

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One approach to place the size of annual fishery catches of sardine and anchovy into perspective is to contrast them with annual losses to natural mortality, which correspond to the amounts consumed by natural predators. This is pursued here using results from the most recent assessments of these two resources (de Moor and Butterworth 2009a,b). The methodology for computing consumption of anchovy is set out in the Appendix; that for sardine is very similar.

Results and Discussion

Results for the two resources, each as a whole, are given in Table 1, with the time series of the ratio of catch to consumption by predators plotted in Figure 1. Ratios were initially high, but since the late 1990s the ratio for anchovy has seldom exceeded 10%. For sardine it was in the high teens over much of this period, but since 2007 has risen to exceed 30%. This last result might be positively biased as the assessments assume a time-invariant natural mortality rate, but this might increase with a fall in abundance, as recently in the case of sardine as predators endeavour to maintain their consumption levels in absolute terms.

Apportioning the natural mortality losses spatially is problematic, as there is generally insufficient information to structure the assessment analyses spatially (though some initiatives in this regard are currently being pursued for sardine). The best that could immediately be done is simply to assume that predation losses are in proportion to the abundance distribution indicated by the November surveys (unlike the May surveys, the November surveys attempt coverage of nearly the full distributional range). Under this assumption the ratios of catches to consumption by predators in the area to the north of Cape Point (see Table 2) are as shown in Figure 2. Clearly the assumption made here is poor: one really wants an estimate of the distribution on average over the full year, but the November surveys occur when virtually all the recruits of the year have already passed through the region north of Cape Point onto the Agulhas Bank. Nevertheless the information shown does suggest that catches in the west may reflect a larger proportion of overall abundance than the corresponding proportion of an appropriate measure of resource abundance distribution over the year.

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Table 1. The annual estimated anchovy/sardine loss to predation (in ‘000t) compared to the annual anchovy/sardine catch (in ‘000t) (Sources: de Moor and Butterworth 2009c/b).

	Anchovy			Sardine		
Year	Loss to *M*	Catch	Catch: Loss to *M*	Loss to *M*	Catch	Catch: Loss to *M*
1984	1466.7	268.9	0.18	97.1	29.5	0.30
1985	1164.2	277.0	0.24	63.2	29.6	0.47
1986	1593.3	303.8	0.19	81.5	35.4	0.43
1987	1643.5	600.4	0.37	83.4	33.5	0.40
1988	1378.4	572.7	0.42	163.1	36.3	0.22
1989	824.6	294.4	0.36	125.6	34.7	0.28
1990	658.9	151.6	0.23	161.2	57.4	0.36
1991	1262.9	151.0	0.12	236.0	53.0	0.22
1992	1456.3	349.0	0.24	205.4	55.1	0.27
1993	1006.9	235.9	0.23	251.8	51.1	0.20
1994	641.3	155.9	0.24	344.8	94.9	0.28
1995	493.8	178.4	0.36	375.5	121.2	0.32
1996	432.6	40.9	0.09	657.8	107.9	0.16
1997	729.6	60.4	0.08	639.4	119.4	0.19
1998	1014.7	107.9	0.11	1079.7	133.3	0.12
1999	1448.2	179.9	0.12	1076.1	131.9	0.12
2000	2851.4	267.3	0.09	983.3	135.2	0.14
2001	3852.2	287.5	0.07	898.3	191.5	0.21
2002	3688.2	213.4	0.06	1522.7	260.9	0.17
2003	3048.2	258.9	0.08	1902.1	290.0	0.15
2004	2316.6	190.1	0.08	2706.6	373.8	0.14
2005	2122.4	282.7	0.13	1513.7	246.7	0.16
2006	1781.9	134.2	0.08	715.4	217.3	0.30
2007	1922.2	253.1	0.13	398.1	139.5	0.35
2008	2602.1	265.8	0.10	254.7	90.9	0.36
2009	3265.7	174.3	0.05	266.5	94.3	0.35

Table 2. The annual proportion of the anchovy/sardine biomass observed north of Cape Point in the November survey and the annual proportion of catch taken north of Cape Point.

	Anchovy		Sardine	
Year	November survey biomass	Catch	November survey biomass	Catch
1987	0.38	0.93	0.69	0.80
1988	0.16	0.92	0.22	0.77
1989	0.11	0.83	0.09	0.75
1990	0.00	0.93	0.02	0.80
1991	0.15	0.93	0.11	0.44
1992	0.05	0.91	0.02	0.46
1993	0.00	0.99	0.17	0.69
1994	0.10	0.74	0.22	0.63
1995	0.00	0.97	0.05	0.72
1996	0.06	0.94	0.05	0.78
1997	0.02	0.90	0.15	0.78
1998	0.00	0.96	0.35	0.74
1999	0.07	0.95	0.07	0.69
2000	0.02	0.92	0.25	0.48
2001	0.14	0.94	0.91	0.39
2002	0.13	0.98	0.00	0.44
2003	0.01	0.97	0.00	0.34
2004	0.00	0.88	0.00	0.11
2005	0.00	0.87	0.00	0.03
2006	0.00	0.77	0.09	0.07
2007	0.00	0.92	0.03	0.20
2008	0.04	0.76	0.00	0.25
2009	0.13	0.75	0.23	0.09

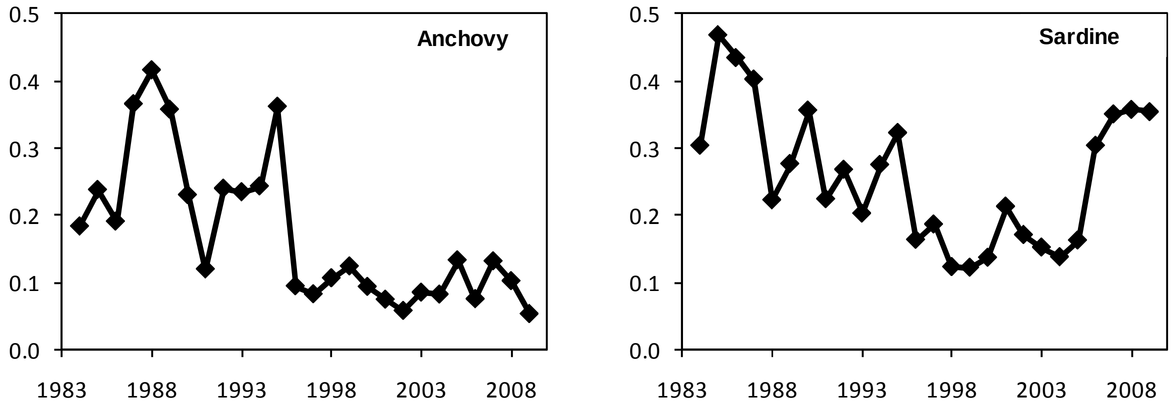

Figure 1. The annual ratio of anchovy and sardine biomass lost to commercial catch compared to predation (natural mortality).

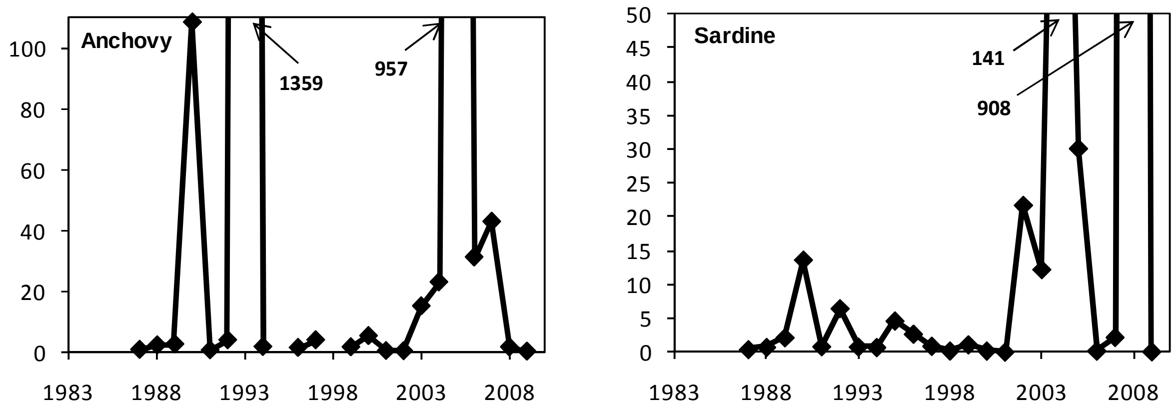

Figure 2. The annual ratio of anchovy and sardine biomass lost to commercial catch compared to predation (natural mortality) for the region north of Cape Point only. The ratios for anchovy in 1995 and 1998 are not plotted as the survey estimates of the proportion of biomass north of Cape Point in those years were zero.

Appendix: Calculation of Loss to Predation for Anchovy

The assessment model assumes catch is taken in a pulse mid-way through the year. The loss in numbers of age a in year y is calculated by:

$$P^N_{y,a} = N^A_{y-1,a-1}\left(1-e^{-M^A_{a-1}/2}\right)+\left(N^A_{y-1,a-1}e^{-M^A_{a-1}/2}-\hat{C}^A_{y,a-1}\right)\left(1-e^{-M^A_{a-1}/2}\right), \qquad a=1,2$$

$$= N^A_{y-1,a-1}\left(1-e^{-M^A_{a-1}}\right)-\hat{C}^A_{y,a-1}\left(1-e^{-M^A_{a-1}/2}\right)$$

$$P^N_{y,3} = N^A_{y-1,2}\left(1-e^{-M^A_2}\right)$$

$$P^N_{y,4} = N^A_{y-1,3}\left(1-e^{-M^A_3}\right)+N^A_{y-1,4}\left(1-e^{-M^A_4}\right)$$

The loss in biomass of fish of age *a* to predation in year *y* is therefore given by:

$$P_{y,a} = \left(N^A_{y-1,a-1}\left(1-e^{-M^A_{a-1}/2}\right)+\left(N^A_{y-1,a-1}e^{-M^A_{a-1}/2}-\hat{C}^A_{y,a-1}\right)\left(1-e^{-M^A_{a-1}/2}\right)\right)\frac{1}{2}\left(w_{y-1,a-1}+w_{y,a}\right), \qquad a=1,2$$

$$= \left(N^A_{y-1,a-1}\left(1-e^{-M^A_{a-1}}\right)-\hat{C}^A_{y,a-1}\left(1-e^{-M^A_{a-1}/2}\right)\right)\frac{1}{2}\left(w_{y-1,a-1}+w_{y,a}\right)$$

$$P_{y,3} = N^A_{y-1,2}\left(1-e^{-M^A_2}\right)\frac{1}{2}\left(w_{y-1,2}+w_{y,3}\right)$$

$$P_{y,4} = N^A_{y-1,3}\left(1-e^{-M^A_3}\right)\frac{1}{2}\left(w_{y-1,3}+w_{y,4}\right)+N^A_{y-1,4}\left(1-e^{-M^A_4}\right)\frac{1}{2}\left(w_{y-1,4}+w_{y,4}\right)$$

The assumption is made that $w_{1983,a} = w_{1984,a}$, $a = 1,\ldots,4+$.

The total loss in anchovy biomass to predation in year *y* is then given by:

$$P_y = \sum_{a=1}^{4+} P_{y,a} \; .$$