Appendix A7. History and basis of natural mortality estimates for surfclams.

Natural mortality is an important uncertainty for surfclams. This appendix contains an excerpt from the surfclam stock assessment in 2000 (NEFSC 2000) that reviews the information available at that time concerning natural mortality of surfclams. In particular, it documents the basis for the current estimate of M=0.15 y^{-1}. This information is provided solely for the convenience of Reviewers.

The excerpt is from: *NEFSC. 2000. Surfclams, p. 311-477. In: Report of the 30th Northeast Regional Stock Assessment Workshop (31th SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. Northeast Fish. Sci. Cent. Ref. Doc. 00-03.* It can be downloaded from the web site: http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0004.pdf.

STOCK SIZE MODELS AND BIOLOGICAL REFERENCE POINTS (BRPs)

This section contains results from models that estimate stock biomass, natural mortality, fishing mortality and exploitation rates, and biological reference points. As a first step, it is important to identify plausible values for the instantaneous rate of natural mortality (M, defined in terms of numbers of surfclams per year), a key parameter in most stock assessment calculations. According to the Stock Assessment Review Committee responsible for the last surfclam assessment (NEFSC 1998, p. 72, *italics added*):

"The current *[1997]* assessment assumes a nominal natural mortality rate (M) = 0.05. By inference, this rate implies that, if not fished, 5% of the animals should survive to age 60. This conflicts with aging information which has documented few animals older than age 30, even in areas not subject to massive dieoffs in 1976. Given the sensitivity of net productivity, DeLury population estimates and YPR calculations to M, additional studies to refine the assumed M are considered a high priority."

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Revised estimates (see summary table below and details following) were based on recent age and growth studies (Weinberg and Helser 1996) and a variety of methods. Considering problems with certain estimates (see detailed descriptions below), results suggest a plausible range of M=0.10-0.20 y^{-1} in surfclam. Based on these results, M=0.15 y^{-1} was used in most analyses and values in the range 0.05-0.20 y^{-1} were used for sensitivity analyses.

Source	Range
Weinberg (1999)	0.16-0.22 y^{-1}
Hoenig (1983)	0.10-0.17 y^{-1}
Jensen (1996)	0.18-0.33 y^{-1}
5% rule	0.08-0.10 y^{-1}
Literature survey	0.09-0.20 y^{-1}
All	0.08-0.22 y^{-1}

Weinberg (1999) used age length keys, survey length composition, survey catch rates and catch curves to estimate Z (where Z is total mortality, F+M) for surfclam in the NNJ (survey stratum 88) and DMV (survey stratum 9) assessment areas. Estimates were for the 1976-1979 yearclasses in the 1980 to 1997 surveys starting at age 4 (length > 75 mm). Weinberg's (1999) data were collected following a hypoxic event off New Jersey and low surfclam biomass in both areas during 1976, followed by strong recruitment during 1976 (NNJ) and 1977 (DMV). Fishing mortality rates were likely less than 0.05 y^{-1} in both areas and certainly less than 0.1 y^{-1}. Results (see below) suggest that M for surfclams is in the range 0.16-0.22 y^{-1}.

Yearclass	**Z for NNJ Stratum 88 (y^{-1})**	**Z for DMV Stratum 9 (y^{-1})**
1976	0.26	0.33
1977	0.26	0.28
1978	0.3	0.22
1979	--	0.22
1980	--	0.26
Mean	0.27	0.26
Mean Z - F (F=0.05 y^{-1})	0.22	0.21
Mean Z-F (F=0.1 y^{-1})	0.17	0.16

Hoenig (1983) gives linear regressions for predicting Z based on maximum observed age [$\ln(Z)=\alpha+\beta\ln(A)$, where A is maximum observed age] in mollusks (β=-0.832, α= 1.23) and all types of marine organisms (β=-0.982, α= 1.44). If age data were collected from an unfished or lightly fished stock, then Hoenig's method estimates M. If age data were collected from a fully exploited stock, then it estimates an upper bound for M. Predictions are imprecise but Hoenig's method is widely used in stock assessment work to identify plausible values for M. Estimates are affected by the number of animals aged (Hoenig 1983). The oldest surfclam aged by NMFS (all surveys and all areas, including areas not affected by the 1976 and areas with no fishing) was 36 years old but maximum ages of 40 years are plausible.

Maximum Age	**Z (y^{-1}) for Mollusks**	**Z (y^{-1}) for All Organisms**
36	0.17	0.13
37	0.17	0.12
38	0.17	0.12
39	0.16	0.12
40	0.16	0.11
41	0.16	0.11
42	0.15	0.11
43	0.15	0.11
44	0.15	0.10
45	0.14	0.10

Jensen's (1996) simple theoretical result suggests that M=1.5 K , where K is a parameter in the Von Bertalanffy model for weight at age. Results (see below) based on estimates for K in each stock area suggest M for surfclams is in the range 0.18-0.33 y^{-1} (average 0.26 y^{-1}).

Assessment Area/Years	K (y^{-1})	M (y^{-1})
Average	0.176	0.26
NNJ 1989&1992	0.145	0.22
DMV 1980	0.175	0.26
DMV 1989&1992	0.117	0.18
LI (all years)	0.189	0.28
SNE (all years)	0.220	0.33
GBK (all years)	0.168	0.25
		0.26

As described above, the value M=0.05 y^{-1} used in previous assessments was chosen to give a predicted 5% of animals in a theoretical population at age 60 (a measure of typical lifespan). Assuming typical lifespans of 30, 35 and 40 years, the predicted "5% rule" gives M values of 0.10, 0.088 and 0.077. Thus, the 5% rule gives lower predicted M values than other methods.

Studies on marine bivalves with life histories similar to surfclam are summarized in Weinberg (1999, and see below). The estimate (M=0.2 y^{-1}) for an unexploited population of *S. solidissima* (Atlantic surfclam) in New Brunswick (Caddy and Billard 1976) is particularly relevant. A leukemia-like disease may explain some of the low S values reported for *Mya arenaria*. The average of estimates from literature sources is M=0.17

Species	$S=e^{-M}$ (Midrange)	M (y^{-1})	Source
Spisula solidissima (New Brunswick, unexploited population)	0.82	0.20	Caddy and Billard (1976)
Panope abrupta	0.95	0.05	Sloan and Robinson (1984)
Mya arenaria	0.73	0.32	Brousseau and Baglivo (1988); Weinberg et al. (1997)
Mercenaria mercenaria	0.91	0.09	Malinowski and Whitlatch (1988)
Yoldia notabilis	0.84	0.18	Nakaoka (1993)
Average	0.85	0.17	