Fin Whale (*Balaenoptera physalus*)

Biological parameters and assessment.

The generation time for a non-depleted Fin Whale population is estimated to be 25.9 years (Taylor *et al.* 2007). The time period of three generations is 1929-2007.

Estimates of age at sexual maturity for female Fin Whales, based on observed proportions mature by age, are 6-7 years in the Southern Hemisphere from British catches in the 1960s (Lockyer 1972) and Japanese catches in the 1960s and early 1970s (Mizroch 1981), but these values are likely negatively biased due to selection against smaller animals. For the North Atlantic, Gunnlaugsson and Víkingsson (2006) estimated an average of 8.9 years from catches off Iceland during 1967-89, but with some indication of an increase over time from 7.5 years during 1967-78 to 9.25 years during 1979-89. Aguilar *et al.* (1988) estimated 7.9 years using the same method from catches off Spain during 1979-84. Slightly different values are obtained using alternative methods. There do not seem to be any precise values for the North Pacific, but Kimura *et al.* (1958) estimated 8-12 years. For the purpose of this assessment, an age at maturity of eight years is assumed, corresponding to an age at first reproduction of nine years. The values of other biological parameters (age at first capture, net recruitment rate, and natural mortality rate) were taken from the previous Scientific Committee assessments (Allen 1977).

Because the available published assessments for this species are not up to date, an updated population assessment is conducted here to enable assessment of the population reduction over the period 1929-2007 relative to the A criterion. While the available data do not permit a scientifically rigorous estimation of the extent of population reduction, it is reasonable to use conventional population assessment methods to provide a crude indication of the extent of possible reduction relative to the criteria. A conventional deterministic age-structured model with an age at first capture ("recruitment") (a_r) and an age at first reproduction (a_m), and linear density-dependence was applied to the North Pacific, North Atlantic and Southern Hemisphere regions separately. The parameter values are listed in Table 1. The starting year was 1874 in the North Atlantic and 1900 in the North Pacific and Southern Hemisphere. The sex ratio of the population and catches is assumed to be 50:50.

Denoting the population of animals aged a in year t as $P_{a,t}$, the equations for the pre-recruit (unexploited) age classes are:

$$P_{a+1,t+1} = S P_{a,t} \qquad (a < a_r)$$

where $S = \exp(-M)$ is the annual survival rate. The exploitation rate (the annual fraction of the population that is taken) in year t is given by:

$$E_t = C_t \Big/ \sum_{a=a_r}^{a_m} P_{a,t}$$

where C_t is the historical catch in year t. Age classes from the age at first reproduction onwards are grouped together. The equations for the recruited age classes are:

$$P_{a+1,t+1} = S\,P_{a,t}\left(1 - E_t\right) \quad (a_r \le a < a_m - 1)$$
$$P_{a_m,t+1} = S\left(P_{a_m-1,t} + P_{a_m,t}\right)\left(1 - E_t\right)$$

The mature population size in the starting year ($t = 0$) is set to K, the nominal carrying capacity:

$$P_{a_m,0} = K$$

The values of K in each region were chosen so as to hit the population targets listed in Table 1. The births in year t are given by:

$$P_{0,t} = R_t P_{a_m,t}$$

where R_t is the reproductive rate in year t. The density-dependent assumption is that R_t is linearly related to the mature population level:

$$R_t = R_K\left(P_{a_m,t}/K\right) + R_0\left(1 - P_{a_m,t}/K\right)$$

The minimum (R_K) and maximum (R_0) values of the reproductive rate are given by:

$$R_K = (1-S)S^{-a_m}$$
$$R_0 = \left(1 - \frac{S}{1+r}\right) S^{-a_m}\left(1+r\right)^{a_m - a_r}$$

The formula for R_K ensures that the net population growth rate is zero when the population is at carrying capacity, while the formula for R_0 ensures that the annual net recruitment rate is r when the population is held stable at a low level.

The resulting population trajectories are shown in Figure 1. The world population is estimated to have declined over the period 1929-2007 by about 75%, from nearly 400,000 to under 100,000, although the model predicts that the populations have been recovering since the late 1970s.

Table 1: Parameters of logistic population model.

Region	North Atlantic	North Pacific	Southern Hemisphere
Age at 1st reproduction	8	8	8
Age at 1st capture	5	5	5
Natural mortality rate	0.04	0.04	0.04
Max. net recruitment rate	0.105	0.061	0.055
Population estimate	52,000	17,000	15,178
Population component	total	exploitable	total
Year of estimate	2001	1975	1983

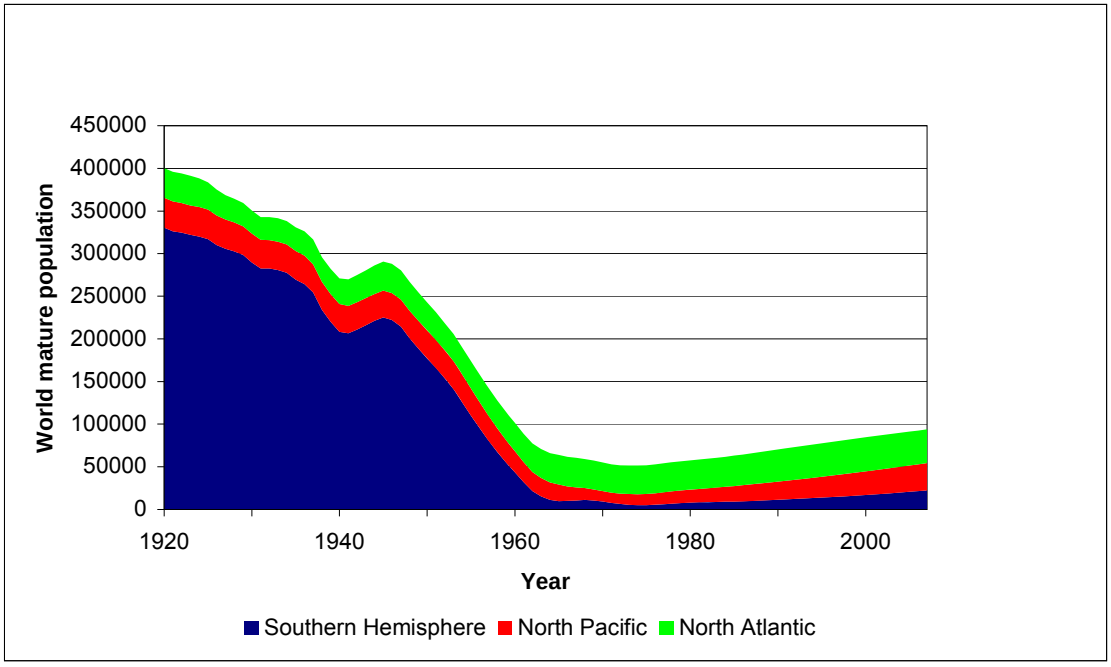

Figure 1: Estimated population trajectory 1920-2007.

It should be emphasized that this assessment is subject to many sources of uncertainty, and does not take account of many possible factors that may have influenced Fin Whale population trends over the last 80 years. The values used for the maximum net recruitment rates are based on poor data and may be over-optimistic, especially in the North Atlantic. In the Southern Hemisphere, a multi-species model of the Antarctic (Mori and Butterworth 2006) suggests that the initial abundance of Fin Whales may have been substantially lower (about 200,000) because much of the catch is interpreted as resulting from external dynamics (increased prey level) rather than from internal dynamics (births and deaths assuming constant food levels). The authors considered this productivity to be a response to the krill surplus arising from earlier depletion of the Blue Whale population, but recognized that the quantitative estimates from the analyses should be regarded as tentative. The simple model above

also does not account for potential loss of stocks that will result in slow recovery (if any) in parts of the ocean where local extirpations occurred.

References:

For details of the references used, see the species account on the Red List web site.