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MSY ESTIMATE OF PELAGIC SHARKS IN THE WESTERN NORTH ATLANTIC

by

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INTRODUCTION

Pelagic sharks (defined here as all sharks except dogfish) are distributed throughout the world's oceans. In many areas, sharks have been harvested either by directed fisheries or more commonly as inadvertent by-catch in fisheries directed towards other species. Such has been the case in waters that now are within the United States (US) Fishery Conservation Zone (FCZ) in the Atlantic Ocean (including the Gulf of Mexico and the Caribbean Sea).

According to the Fishery Conservation and Management Act of 1976 (FCMA), a management plan for any fishery in the FCZ must specify an optimum yield which includes consideration of the maximum sustainable yield (MSY) from that fishery. Determination of the MSY for pelagic sharks in the US FCZ in the Atlantic is confounded by a variety of factors. Many species of sharks are included in the overall harvest, but statistics for individual species are not available. Sharks are generally wide-ranging in distribution, discrete stocks are not confined to waters of the FCZ, and information is lacking on which to base any delimitation of shark stocks. Reported catches of sharks represent only a portion of the total harvest, although Anderson (1980) presented estimates of various sources of unreported by-catch of sharks in the FCZ in the Atlantic and Gulf. Reliable fishing effort or catch-per-unit-effort (CPUE) data for sharks are lacking.

Mathematical models used to estimate MSY for most teleost (bony) fishes, such as the Schaefer-type surplus-yield model, which employ catch and effort data, are not as applicable to elasmobranch species. These models assume, among other things, (1) an immediate increase in population size (through recruitment) following a population decrease, and (2) the rate of population

increase is independent of the population's age composition. Neither of these assumptions is valid for sharks, as described by Holden (1974, 1977). Sharks have a very low reproductive potential compared to teleost fishes, a delayed and slower recovery response from exploitation, and exhibit a close relationship between stock and recruitment (i.e. reproductive potential is probably greatest at a level nearer virgin biomass than at half the virgin biomass as assumed in Schaefer-type models and decreases as the population decreases).

In spite of the many deficiences in the data and the lack of an appropriate model, an attempt was made by Otto et al. (1977) to estimate the MSY for sharks in the Western North Atlantic (FAO Areas 21 and 31) (Figure 1). MSY was determined to be about 41,000 metric tons (tons) utilizing international commercial shark catches reported to FAO, estimates of US recreational catch, and CPUE derived from Japanese longline data for 1965-74. This MSY estimate was used in the Preliminary Fishery Management Plan (PMP) for Atlantic Billfishes and Sharks.

The recent analysis of shark catches by Anderson (1980) indicates that the catch data used by Otto et al. (1977) to estimate MSY was grossly in error. Dogfish catches were inadvertently incuded in FAO Area 21 statistics as a result of misreporting by the USSR. Estimates of US recreational catch for 1971-74 extrapolated from 1965 and 1970 estimates were considerably in excess of later estimates by Anderson (1980).

The purpose of this paper is to recalculate MSY for sharks in the Western North Atlantic utilizing the most recent analysis of catch data for that area (Anderson 1980) and Japanese CPUE data for 1965-77. It must be recognized that the approach used and the data employed are generally inadequate, and the results must be evaluated with appropriate caution.

METHODS AND MATERIALS

For the purposes of estimating MSY for sharks in the Western North Atlantic, FAO Areas 21 and 31 were arbitrarily defined as a stock area. Catch data for sharks in this area were taken from Anderson (1980) (Table 1).

Effort data (number of hooks fished) reported by 5° Marsden squares for the Japanese longline fishery in FAO Area 31 were obtained for 1965-77 from the "Annual Report of Effort and Catch Statistics by Area on Japanese Tuna Longline Fisheries" by the Fisheries Agency of Japan (Zuboy and Witzell[1]). Reported Japanese catches of sharks in Area 31 for 1965-77 were obtained from FAO Yearbooks of Fishery Statistics. Annual CPUE values were calculated as the ratio between Japanese catch and number of hooks fished in Area 31 and expressed as tons per 100,000 hooks fished. CPUE for each year was divided into the total estimated catch for the entire area (Areas 21 and 31) to obtain an equivalent total fishing effort measure (Table 2).

The generalized stock production model (Pella and Tomlinson 1969) was fitted to CPUE and weighted average fishing effort data using the method (PRODFIT program) developed by Fox (1975). At equilibrium, the model is expressed as

$$U_i = (a + b\bar{f}_i)^{\frac{1}{m-1}} \qquad (1)$$

where U_i is the CPUE in year i, $\bar{f}_i$ is the weighted average fishing effort in year i, and a, b, and m are parameters estimated by the program.

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[1]James R. Zuboy and Wayne N. Witzell, National Marine Fisheries Service, Southeast Fisheries Center, Miami, FL, personal communication.

Equilibrium conditions were approximated by averaging fishing effort over the number of years that a year class contributes significantly to the fishery. Gulland (1961) defined this number as the mean life expectancy of a fish in the exploited stock or 1/Z, where Z is the instantaneous total mortality. Gulland (1969) also suggested that this number be equivalent to half the age span of the species in the exploited phase of the fishery. Estimates of Z for 17 different species of sharks have been derived (Gulf of Mexico Fishery Management Council 1980) based on a methodology developed by Holden (1974). Average Z for these species was 0.46; the reciprocal of 0.46 is 2.17, which rounded up implies a mean life expectancy in the fishery of 3 years. This corresponds to an age span of about 6 years in the fishery. Age data are available for only a few shark species including porbeagle (*Lamna nasus*) (Aasen 1963), sandbar sharks (*Carcharhinus milberti*) (Lawler 1976, Casey[2]), and blue sharks (*Prionace glauca*) (Stevens 1975, Casey, in press), which suggest life spans ranging from 15 to 30 years. However, the age span during which sharks are subject to significant levels of exploitation is uncertain. Lacking definitive information, an averaging period of 3 years was chosen to approximate equilibrium conditions. Other averaging periods up to 6 years were employed for comparison.

RESULTS

Reported and estimated shark catches from FAO Areas 21 and 31 for 1965-78 are presented in Table 1. Total international catches ranged from an estimated 17,400 tons in 1967 to 30,700 tons in 1978 and averaged about 23,600 tons per year for the period.

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[2]John G. Casey, National Marine Fisheries Service, Northeast Fisheries Center, Narragansett Laboratory, Narragansett, RI, personal communication.

Estimated international shark catches from the US FCZ in the Atlantic and Gulf varied between 12,000 tons in 1967 and 20,100 tons in 1978 (Table 1) and averaged about 15,100 tons per year during 1965-78. These results indicate that about 65% of the reported and estimated shark catches from the Western North Atlantic during 1965-78 were taken in the US FCZ.

The generalized stock production model was allowed to iterate through successive values of m, beginning at m = 1, until convergence at a minimum residual sum of squares was achieved at m = 1.63. The results indicate a model more closely resembling the logistic model (Schaefer 1954, 1957) (m = 2) than the Gompertz exponential model (Fox 1970) ($m \rightarrow 1$). Estimated equilibrium relationships between CPUE and fishing effort and between catch and fishing effort are plotted in Figures 2 and 3, respectively. The estimate of MSY derived from the model was about 25,700 tons.

The use of averaging periods such as 4, 5, or 6 years resulted in curves deviating considerably from that for 3 years with poorer fits of the data and higher estimates of MSY. The use of no averaging period and a fixed value of m = 2 (Schaefer-type logistic model) resulted in an MSY estimate of 29,700 tons. Given that the averaging period of 3 years provided the best fit of the data to the model and also corresponded with available estimates of Z, the estimate of 25,700 tons was considered best of those determined.

DISCUSSION

A suitable data base and appropriate model are lacking to properly determine MSY for sharks in the Western North Atlantic and more particularly in the US FCZ within this overall region. An attempt has been made, however, to estimate total catches in this area during 1965-78 (Anderson 1980). It is likely that some components of the total shark harvest in the Western North Atlantic have been overlooked, and the accuracy of the estimated catch is unknown. Nonetheless, the reported and estimated catches utilized in this paper represent the best available data at the present time.

The CPUE values based on reported Japanese catch and effort data may not be an accurate reflection of shark abundance. Anderson (1980) felt that the reported Japanese shark catches in FAO Area 31 were underestimates of the actual harvest of sharks in the tuna longline fishery, based on observed catch rates in 1978.

As mentioned previously in this paper, the application of conventional surplus-yield models developed for teleost species to elasmobranch species such as sharks represents a further source of error, in addition to uncertain catch and effort statistics. The estimate of 25,700 tons must be considered a rough approximation of MSY. However, because of an improvement in the catch data base, this estimate must be considered more valid than the previous estimate of 41,000 tons by Otto et al. (1977).

The average annual estimated catch of sharks in the Western North Atlantic of 23,600 tons during 1965-78 must also be considered as a rough approximation of MSY. The relatively small difference between this estimate (23,600 tons) and that generated from the stock production model (25,700 tons) suggests that an MSY value of approximately 25,000 tons may be appropriate. Present data indicate that estimated catches during 1975-78 have been excess of this amount.

The management plans being developed for pelagic sharks within the US FCZ utilize a determination of MSY. One method of estimating the shark MSY for waters within the FCZ would be to assume that the resource is distributed throughout the Western North Atlantic in equal proportion to catch. Using this approach, 65% of the MSY estimate could be attributed to the FCZ. To further divide the MSY within the FCZ into Atlantic (and Caribbean) and Gulf of Mexico components based on the average proportion of the estimated catch in each area would result in 56% assigned to the former and 44% to the latter area.

LITERATURE CITED

Aasen, O. 1963. Length and growth of the porbeagle (Lamna nasus, Bonnaterre) in the North West Atlantic. Repts. Norwegian Fish. Mar. Invest. 13(6): 20-37.

Anderson, E.D. 1980. Analysis of various sources of pelagic shark catches in the Northwest and Western Central Atlantic Ocean and Gulf of Mexico. NMFS, NEFC, Woods Hole Lab. Ref. No. 79-56, 37 p.

Casey, J.G. in press. Blue shark Prionace glauca. In Fish Distribution. M.D. Grosslein and T.R. Azarovitz, ed. U.S. Dept. Comm., NOAA, N.Y. Bight Atlas, Monog. Ser. 15.

Fox, W.W., Jr. 1970. An exponential surplus-yield model for optimizing exploited fish populations. Trans. Amer. Fish. Soc. 99:80-88.

_____. 1975. Fitting the generalized stock production model by least-squares and equilibrium approximation. U.S. Fish. Bull. 73:23-37.

Gulf of Mexico Fishery Management Council. 1980. Draft fishery management plan for the shark and other elasmobranch fishery of the Gulf of Mexico. 160 p.

Gulland, J.A. 1961. Fishing and the stocks of fish at Iceland. Fish. Invest. Minist. Agric. Fish. Food (G.B.), Ser. 2, 23(4), 52 p.

_____. 1969. Manual of methods for fish stock assessment. Part 1. Fish population analysis. Food Agric. Organ. U.N., Man. Fish. Sci. 4, 154 p.

Holden, M.J. 1974. Problems in the rational exploitation of elasmobranch populations and some suggested solutions. p. 117-138. In Sea Fisheries Research. F.R. Harden-Jones, ed. Elek Science, London, 510 p.

_____. 1977. Elasmobranchs. p. 187-215. In Fish Population Dynamics. J.A. Gulland, ed. John Wiley & Sons, London, 372 p.

Lawler, E.F., Jr. 1976. The biology of the sandbar shark Carcharhinus plumbeus (Nardo, 1827) in the lower Chesapeake Bay and adjacent waters. MS Thesis, College of William and Mary, 49 pp.

Otto, R.S., J.R. Zuboy, and G.T. Sakagawa. 1977. Status of Northwest Atlantic billfish and shark stocks. Report of the LaJolla Working Group, March 28-April 8, 1977. (in final draft).

Pella, J.J., and P.K. Tomlinson. 1969. A generalized stock production model. Inter-Amer. Trop. Tuna Comm., Bull. 13:419-496.

Schaefer, M.B. 1954. Some aspects of the dynamics of populations important to the management of commercial marine fisheries. Inter-Amer. Trop. Tuna Comm., Bull. 1:25-56.

Schaefer, M.B. 1957. A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Inter-Amer. Trop. Tuna Comm., Bull. 2:245-285.

Stevens, J.D. 1975. Vertebral rings as a means of age determination in the blue shark (*Prionace glauca* L.). J. Mar. Biol. Assoc. U.K. 55:657-665.

Table 1. Total international reported and estimated pelagic shark catch (tons) in the Western North Atlantic (FAO Areas 21 and 31) during 1965-78, including the amount taken from within the US FCZ (Anderson 1980).

	Reported commercial		Estimated						
Year	FAO Area 21	FAO Area 31	US rec.	Swordfish by-catch	Squid by-catch	Tuna by-catch	Other[1]	Total	US FCZ
1965	5,534	4,800	2,623	4,061	1	1,740	2,383	21,142	13,967
1966	2,473	5,400	4,068	2,825	2	1,472	2,383	18,623	12,258
1967	831	5,200	5,516	3,147	4	270	2,383	17,351	12,008
1968	1,117	5,400	6,962	3,593	24	189	2,383	19,668	13,557
1969	1,428	5,700	8,409	3,471	41	147	2,383	21,579	14,729
1970	934	6,000	9,854	3,049	90	948	2,383	23,258	17,054
1971	770	6,700	9,294	4	101	4,028	2,383	23,280	16,053
1972	451	7,900	8,732	76	228	1,892	2,383	21,662	13,847
1973	307	10,500	8,170	506	265	2,266	2,383	24,397	14,240
1974	163	10,900	7,608	1,523	255	1,216	2,383	24,048	13,808
1975	231	11,400	7,972	3,174	240	1,075	2,383	26,475	15,977
1976	389	10,600	8,552	3,807	223	2,180	2,383	28,134	18,377
1977	454	13,700	9,133	2,543	194	1,140	2,383	29,547	15,643
1978	522	10,600	9,714	4,851	128	2,492	2,383	30,690	20,095

[1]By-catch in shrimp trawl, groundfish, snapper-grouper, and other miscellaneous fisheries in the Gulf of Mexico.

Table 2. Japanese reported shark catch (tons), reported longline effort (all pelagics), and calculated shark catch per unit effort for FAO Area 31, and international catch and effort (international catch divided by Japanese CPUE for Area 31) for the Western North Atlantic (FAO Areas 21 and 31), 1965-77.

	FAO Area 31			FAO Areas 21 and 31	
Year	Japanese catch	Japanese effort[1]	Japanese CPUE[2]	International catch	International effort[3]
1965	800	20,879,615	3.83	21,142	5,520
1966	700	11,503,228	6.09	18,623	3,058
1967	200	5,804,609	3.45	17,351	5,029
1968	100	5,004,961	2.00	19,668	9,834
1969	200	5,157,624	3.88	21,579	5,562
1970	200	8,540,876	2.34	23,258	9,939
1971	200	11,889,891	1.68	23,280	13,857
1972	100	3,297,972	3.03	21,662	7,149
1973	100	2,070,674	4.83	24,397	5,051
1974	74	2,674,822	2.77	24,048	8,682
1975	147	5,464,756	2.79	26,475	9,842
1976	76	5,706,423	1.33	28,134	21,153
1977	24	4,990,038	4.81	29,547	6,143

[1]Number of longline hooks fished.

[2]Catch per 100,000 hooks.

[3]Expressed as Japanese hook equivalents (10^5).

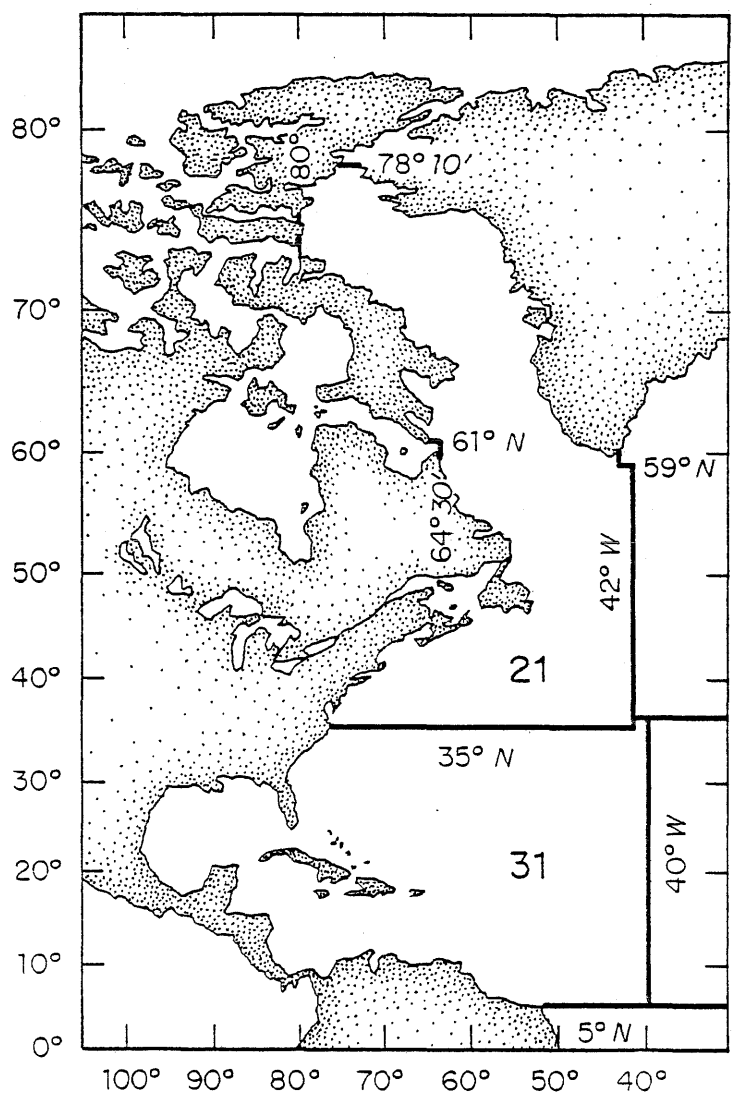

Figure 1. Map showing FAO Areas 21 and 31 in the Western North Atlantic.

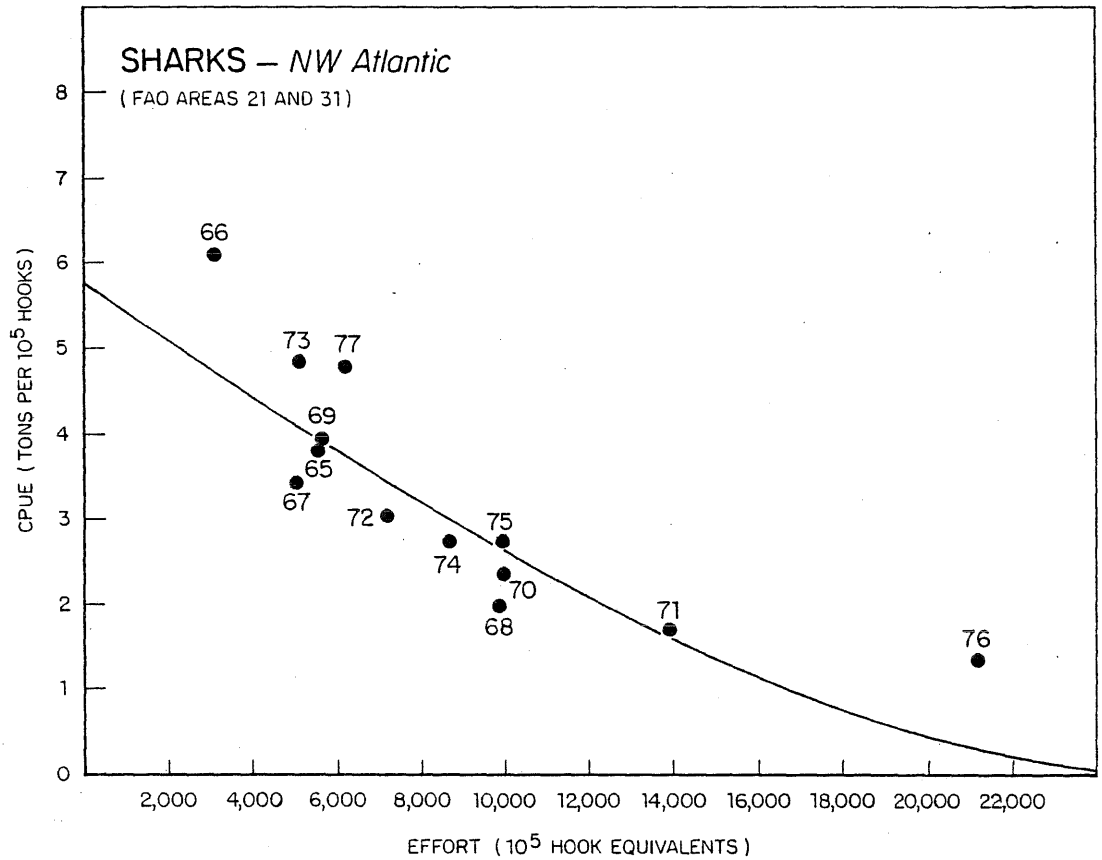

Figure 2. Equilibrium relationship between CPUE and fishing effort for pelagic sharks in the Western North Atlantic using a 3-year weighted averaging period for effort. Actual data points are plotted.

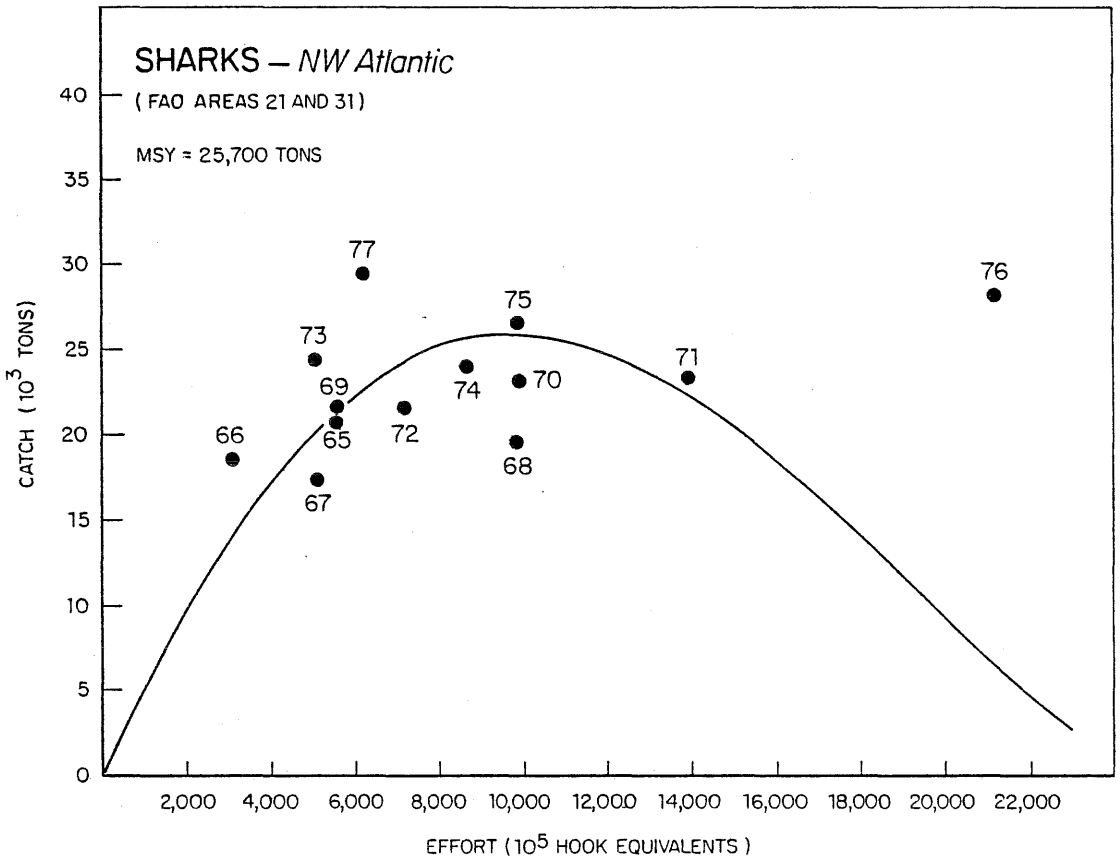

Figure 3. Equilibrium relationship between catch and fishing effort for pelagic sharks in the Western North Atlantic using a 3-year weighted averaging period for effort. Actual data points are plotted.