cause of its large size and overall abundance within the area and the latter because of its schooling behavior. Schools of *R. bonasus* often destroy large areas of eelgrass and other habitats in search of clams, their primary food (Orth 1975, 1977). Burton (footnote 3) used hog wire fencing to keep schools of cownose rays from his beds of inventoried and replanted market size *Mercenaria*. Because of the suddenness of the disappearance (<2 wk) and the presence of crushed clam shell in this and other plantings, we believe the most likely predator was a school of *R. bonasus*.

Our data indicate that losses, due to such predation, would be unpredictable, but it would be financially devastating to the clam grower. The use of a fence or some other device to protect the clams is essential for successful field culture in areas where large predators occur. These fences can be removed during the winter to prevent ice damage, but along the Virginia coast they should be kept in place and maintained at all times from late March to early November.

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A DIRECT METHOD FOR ESTIMATING NORTHERN ANCHOVY, *ENGRAULIS MORDAX*, SPAWNING BIOMASS

Two methods exist for estimating spawning biomass, the total weight of mature fish, from abundance of spawning products. The first, or direct, method (Saville 1963) consists of dividing an estimate of egg production by the product of batch fecundity and the proportion of females in the mature stock. Saville safely assumed spawning frequency to be unity. The second method is indirect (Murphy 1966; Smith 1972) and utilizes information from two different species. Smith illustrated the second method, using information on the Pacific sardine, *Sardinops caerulea*, and northern anchovy, *Engraulis mordax*. Sardine spawner biomass is estimated from landings data and cohort analysis; anchovy spawner biomass is estimated by multiplying the estimated sardine spawner biomass by the product of the anchovy-to-sardine ratio of larval abundance and the sardine-to-anchovy ratios of fecundity, and spawning frequency. Computation was facilitated by assuming the unknown spawning frequencies to be equal, making the ratio of spawning frequencies unity. Up to the present only the second method has been used for the northern anchovy. This paper presents estimates derived from the first.

Computation of spawning biomass is simplified for the direct method when spawning occurs but once and for the indirect method when both species spawn with equal frequency. Difficulties arise when spawning is continuous and when it cannot be safely assumed that all mature fish spawn with the same frequency. This is the case with the northern anchovy. Spawning products are present all year, with a maximum abundance occurring in the late winter and early spring and a minimum during late summer and early fall. Abundance of and seasonal pattern of spawning products give no clue as to the number of spawnings by size and age, or even to the average number of spawnings.

Under the following conditions spawning frequency can be estimated from examining the spawning condition of females: 1) females can be examined for a characteristic that indicates when spawning takes place; 2) the length of time such a characteristic remains detectable can be estimated; 3) the spawning rate remains relatively constant over the sampling interval.

The spawning fraction, or frequency, is the

fraction of females displaying the characteristic divided by the length of the time interval the characteristic remains detectable. Say, from a sample of 10 females, 2 display a characteristic which lasts for 1 day and which indicates that spawning will take place in approximately 1 wk. The daily spawning fraction 1 wk hence will be 1/5.

Given this method for estimating spawning fraction the following relationship holds:

$$P = S(abc) \qquad (1)$$

where P = production in eggs,
a = batch fecundity in (eggs)/(unit weight),
b = fraction spawning (weight of spawning females)/(weight of all mature females),
c = (weight of females)/(weight of spawning stock),
S = spawning biomass.

Spawning biomass can be estimated directly:

$$S = P(abc)^{-1}. \qquad (2)$$

Hunter and Goldberg (1979) examined female northern anchovies for characteristics that would indicate a recent spawning. They found that following spawning follicles of the northern anchovy go through a sequence of identifiable degenerative stages. The first two stages, which Hunter and Goldberg referred to as day 0 and day 1, have durations of 1 day. Stage identification is subject to error. Day-0 follicles can be misidentified as day 1; day-1 follicles can be misidentified as day 2 and beyond. The most easily identified stage is day 1. If the spawning fraction, b, is based on day-1 follicles an adjustment factor, say d, is required in Equation (2):

$$S = P(ab'c)^{-1}d \qquad (3)$$

where b', replacing b, is the observed fraction.

The adjustment factor is computed by using information on the fraction of day-0 follicles misclassified as day 1, say d_0, and the fraction of day-1 follicles correctly classified, say d_1.

$$d = (d_0 + d_1)$$
$$\text{Var}(d) = \text{Var}(d_0) + \text{Var}(d_1).$$

Estimates based on Hunter and Goldberg's (1979,

table 1) blind classification study for d_0 and d_1 are 5/21 and 16/19 respectively; hence

$$d = 1.080$$
$$\text{Var}(d) = 0.016.$$

From examination of 195 females taken by midwater trawl during the time interval 15-27 February 1978, Hunter and Goldberg estimated the observed daily spawning fraction and its variance:

$$b' = 0.159$$
$$\text{Var}(b') = 4.561 \times 10^{-4}.$$

Based on the total female weight of nonspawners the estimated batch fecundity and variance are from Hunter and Goldberg (1979, table 6)

$$a = 396 \text{ eggs/g (or } 3.96 \times 10^8 \text{ eggs/t)}$$
$$\text{Var}(a) = 886.$$

For the time period 18 February-17 March 1978, Zweifel[1] estimated daily egg production. From 177 plankton samples, northern anchovy eggs and larvae were staged from time of spawning. Estimated total numbers at stage were regressed on time. The ordinate intercept, number at time zero, is the estimated egg production:

$$P = 2.321 \times 10^{13} \text{ eggs/d}$$
$$\text{Var}(P) = 1.825 \times 10^{26}.$$

If the female to male sex ratio in numbers were 1:1 and if the two sexes had equal growth rates in terms of weight then c could be assumed to be 0.5. However, because of conflicting and insufficient evidence neither of these two hypotheses can be supported. Klingbeil (1978) demonstrated that the distribution of northern anchovy sexes is heterogeneous over space and time and that estimates of sex ratio are dependent on the sampling gear. From the purse seine fishery Klingbeil estimated that the ratio of numbers of females to males varies between 1.14:1 and 2.02:1 for 1969-76. From 9 yr of midwater trawl data Klingbeil estimated that the sex ratio is 1.03:1. Since midwater trawl surveys cover a wider geographic area and size range of anchovies, they probably provide an estimate closer to that of the true population sex ratio. However, since neither midwater trawl surveys

[1]James Zweifel, Southwest Fisheries Center La Jolla Laboratory, NMFS, NOAA, P.O. Box 271, La Jolla, CA 92038, pers. commun.

nor purse seines are designed to estimate sex ratio it can only be stated that the anchovy sex ratio has not been adequately estimated.

Collins (1969) showed that females are greater in length and weight at age than males. However, since Collins' estimates are based on combined data from three fishing seasons and, since female weights are known to fluctuate within season due to spawning activity, the precision with which the data can be used for estimation purposes is open to speculation.

For the present purpose of estimating c the sex ratio of the number of females to males plus females as estimated from the February 1978 midwater trawl survey (Hunter and Goldberg 1979) will be used. Reexamining original data used by Hunter and Goldberg (1979, table 5) the ratio estimate is

$$c = 0.550$$
$$\mathrm{Var}(c) = 0.001.$$

This assumes, of course, an equal weight at age.

In the future, the best estimate of c is likely to be the ratio of the actual sampled weights of males and females; these were not available for the

February 1978 survey. This would, of course, require the assumption that the sex ratio can differ from 1:1, that the weight distribution of the two sexes can change with time, and that a sample estimate is a better estimate than any hypothesized or long-term average value.

Using the following estimates

$$P = 2.321 \times 10^{13} \text{ eggs/d} \qquad c = 0.550$$
$$a = 3.96 \ \times 10^{8} \ \text{ eggs/t} \qquad d = 1.080$$
$$b' = 0.159$$

the estimated S is approximately 0.72 million t. This is reasonably close to the estimate by the Smith procedure (Stauffer and Parker[2]) of 1.17 t.

At this time caution should be exercised in interpreting the general range described by these two estimates. The parameters of Smith's procedure have not been formally estimated. The parameter estimates of this new method are only first ap-

proximations. P may not be constant for as long a time interval as assumed here. Observed b' was found to be consistent for time of day, weight of fish, and geographic location. This may not prove to be the case under more intensive sampling. Another problem in estimating the spawning fraction is in determining female sexual maturity. This problem may be particularly acute for recently spawned young females where microscopic analysis is necessary to separate the recently spawned from the sexually immature. Misclassifying recently spawned as immature would tend to inflate the estimated b.

By the delta method (Seber 1973), the variance of S is

$$\mathrm{Var}(S) = (ab'c)^{-2} \left[d^2 \mathrm{Var}(P) + P^2 \mathrm{Var}(d) \right.$$
$$\left. + (Pd)^2 \left[\frac{\mathrm{Var}(a)}{a^2} + \frac{\mathrm{Var}(b')}{b'^2} + \frac{\mathrm{Var}(c)}{C^2} \right] \right]. \tag{4}$$

Dividing Equation (4) by the square of Equation (3) and then taking the square root we have the coefficient of variation (CV) of spawning biomass

$$\mathrm{CV}(S) = \sqrt{[\mathrm{CV}(P)]^2 + [\mathrm{CV}(a)]^2 + [\mathrm{CV}(b)]^2 + [\mathrm{CV}(c)]^2 + [\mathrm{CV}(d)]^2}, \tag{5}$$

which is the component vector of the coefficients of variation of the estimated parameters, right side of Equation (3). Since possible covariance terms are neglected, Equation (5) may be somewhat oversimplified. However, Equation (5) allows a first approximation to delegating the relative impact of the precision of the individual parameter estimates. The squared coefficients of variation are as follows:

$$[\mathrm{CV}(P)]^2 = 0.339 \qquad [\mathrm{CV}(c)]^2 = 0.003$$
$$[\mathrm{CV}(a)]^2 = 0.005 \qquad [\mathrm{CV}(d)]^2 = 0.013.$$
$$[\mathrm{CV}(b)]^2 = 0.018$$

Thus $\mathrm{CV}(S) = 0.614$. P contributes approximately 8 times more to the coefficient of variation of the spawner biomass estimate than all other parameters combined. In the future, additional effort will be allocated to estimating production.

The utility of the direct method, Equation (2), lies in the fact that all the parameters can be estimated. The same samples used for estimating b' can be used to estimate a and c. This can be done with 2 wk of midwater trawling. It is hoped

[2]Stauffer, G. S., and K. R. Parker. 1978. Estimate of the spawning biomass of the northern anchovy central subpopulation for the 1978-79 fishing season. U.S. Dep. Commer., NOAA, NMFS/SWFC Adm. Rep. LJ-78-9, 10 p.

that precise estimation of production can be done within 30 d by sampling for eggs; this goal seems attainable for the northern anchovy. Utilization of the method for other species seems feasible.

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FOOD OF THE HARBOR SEAL, *PHOCA VITULINA RICHARDSI*, IN THE GULF OF ALASKA

The harbor seal, *Phoca vitulina richardsi* (Shaughnessy and Fay 1977), is the most abundant and widespread coastal pinniped in the Gulf of Alaska. Harbor seals occupy virtually all nearshore habitats, and individuals occasionally occur as far as 100 km offshore (Spalding 1964; Wahl 1977; Fiscus et al.[1]). Despite their abundance and ecological importance, little information is available on their diet in Alaskan waters. In the most extensive food study published to date, Imler and Sarber (1947) examined stomachs of 99 seals from southeastern Alaska and 67 from the Copper River Delta. Wilke (1957) presented information on the food of seven harbor seals collected from Amchitka Island in the western Aleutian Islands. Kenyon (1965) reported on the stomach contents of 11 harbor seals taken in the same location. Bishop (1967) commented on stomach contents of two seals from Aialik Bay and two from Tugidak Island. Virtually no information has been available on the food of harbor seals from the Gulf of Alaska.

The study area (Figure 1) included coastal Gulf of Alaska from Yakutat Bay to Sanak Island. The portion of Cook Inlet north of Kachemak and Kamishak Bays was not included. The study area was divided into seven subareas for data analysis: northeastern Gulf of Alaska, Copper River Delta, Prince William Sound, Kenai coast, Lower Cook Inlet, Kodiak, and Alaska Peninsula.

Selection of Valdez as terminus of the trans-Alaskan oil pipeline and planned outer continental shelf oil and gas lease sales were the principal motivating factors for conducting this research. Production and transport of crude oil appeared to have the potential for significant alteration of the marine biota (Evans and Rice 1974) thus influencing the abundance and composition of harbor seal prey species. Established commercial fisheries for salmon, *Oncorhynchus* spp.; Pacific herring, *Clupea h. harengus*; halibut, *Hippoglossus stenolepis*; king crab, *Paralithodes camtschatica*; snow crab, *Chionoecetes bairdi*; Dungeness crab, *Cancer magister*; and shrimp, *Pandalus* spp., occur over the area, and pinnipeds are sometimes considered to be significant competitors with these fisheries. Data are needed to establish the possible impact of harbor seals on these commercially exploited species. Plans for developing fisheries are required by Federal laws (Public Law 94-265, Fishery Conservation and Management Act of 1976, and Public Law 92-522, Marine Mammal Protection Act of 1972) to utilize an integrated ecosystem approach to management

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[1] Fiscus, C. H., H. W. Braham, R. W. Mercer, R. D. Everitt, B. D. Krogman, P. D. McGuire, C. E. Peterson, R. M. Sonntag, and D. E. Withrow. 1976. Seasonal distribution and relative abundance of marine mammals in the Gulf of Alaska. *In* Environmental assessment of the Alaskan Continental Shelf. Vol. 1. Principal investigators reports for October-December 1976, p. 19-264. Environmental Research Laboratories, NOAA, Boulder, Colo.