PROS AND CONS OF PINNIPED MANAGEMENT ALONG THE NORTH AMERICAN COAST TO ABET FISH STOCKS

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Abstract. In this paper, we discuss the merit (or lack, thereof) of controlling pinniped populations for the purpose of enhancing fish stocks. Inherent in this approach is the assumption that predation by pinnipeds limits net production of at least some fish populations and, that any net surplus in production, caused by a culling program, can be effectively utilized in commercial harvests. Four generally accepted ecological relationships work against the success of culling pinniped herds to enhance fishery production. First, prey species almost always have more than one predator. Second, pinniped species rarely are dependent on only one species of prey. Third, the recruitment rate of most fish stocks is highly variable, and this is one of the most likely factors determining stock abundance. And fourth, fish, as a predatory group, consume more fish than do other predators (e.g., seabirds, cetaceans, and pinnipeds). Two examples of control programs and their effects on local fisheries are discussed. The following information is necessary to evaluate the biological merits of a pinniped control program (excluding ethical considerations and public sentiment): (1) kind, size, and amount of target species taken by pinniped species (by age, sex, and area), by other predators, by commercial fisheries, and by recreational fisheries and how knowledge of these takes will be effected by the management program; (2) standing stock, trends in stock size, and the relationship between net production and standing stock of the target species; (3) population size, trends in abundance, status, and net production of pinniped species; (4) expected increase in yield (and confidence levels) resulting from cull, and value of this increase in net production to the fishery and the general public; (5) cost of the control program; (6) proposed number (by age and sex classes) of pinnipeds to be culled each year, and the duration of the cull in years; and, (7) long-term effect of the cull on the pinniped population. It is unlikely that information on points (1), (3), and (4) will ever be known with reasonable confidence. Statistically designed removal experiments may be the only method of determining the merit of a control program. Unfortunately, it will be difficult to generalize results from one such experiment to other areas, species, or fisheries.

INTRODUCTION

Multispecies or ecosystem management requires managers to decide: (1) the optimal species composition in a given community and, (2) the degree to which the existing species community can be manipulated (May et al. 1979). Inherent in controlling pinniped populations for the purpose of enhancing fish stocks is the assumption that predation by pinnipeds limits the net production of a least some fish populations, and that any net surplus in production caused by a culling program can be effectively utilized in the commercial harvests. To date, specific cases where this assumption has been met have only been reported for a fresh water system (Power and Gregoire 1978). In this paper we provide an additional case.

In 1981 a workshop was held in La Jolla, California to review the relations between marine mammal populations and their prey, some of which are of commercial and recreational value to fishermen (see Beddington et al. 1985). The workshop participants concluded that there were no unambiguous examples in which marine mammal predation has affected the abundance of a commercial fish stock (Beverton 1985). This conclusion, as applied to west coast and Alaskan pinnipeds, was based on reports by Lowry and Frost (1985), Swartzman and Haar (1985), and DeMaster et al. (1985). It was further reported at this workshop that pinniped-fishery interactions can be significant, and have been well documented. These include cases where pinnipeds damage gear or fish caught in fishing gear, or frighten fish away from traditional fishing grounds (DeMaster et al. 1982, Beach et al. 1982). In 1983, another workshop was held in Anchorage, Alaska to evaluate the interactions between marine mammals and fisheries in the southeastern Bering sea (Melteff and Rosenberg 1984). The participants of this workshop concluded that the available information on the number and diet of marine mammals was insufficient to evaluate the extent to which marine mammal predation on fish may affect a fishery.

In the absence of data needed to make predictions about the effects of seal predation on a fishery, one would hope the scientific literature might provide experimental evidence. However, there are very few publications or references describing seal control programs that were coupled with adequate monitoring programs to determine whether both the pinniped and fish populations responded as predicted. One such example is given by Harwood and Greenwood (1985), where in 1963 a Consultative Committee on Grey Seals and Fisheries recommended that grey seal (*Halichoerus grypus*) populations in the Orkney and Farne Islands be reduced to three-quarters of their current size by killing pups during the breeding season. While several culls did take place, the populations continued to increase. In 1976, a new management scheme was introduced to reduce the grey seal population of the Outer Hebrides and Orkney from 50 000 to 35 000 animals over a five-year period. This second control program involved the taking of cows and pups. However, after one year, the cull was discontinued because of public protest. Fur seal control programs are described also by Shaughnessy (1985) and Swartzman and Haar (1985). Again, the effect of the cull on fish stocks could not be determined in either case. Unfortunately, pinniped control programs are historically associated with periods of extremely variable, usually increasing, fishing effort, which confounds an analysis of the effect of the seal cull on the fish stock.

Therefore, progress in evaluating the efficacy of pinniped control programs to enhance fish stocks has remained elusive over the last ten years. This failure stems in part from a lack of support from the general public for continuing seal control programs long enough (if at all) to adequately test their effects, inadequate control of fishing effort immediately following the initiation of culling, and the inherent variability in fish recruitment. The underlying premise in this paper is that pinniped management programs specifically directed at benefiting a commercial fishery should be considered only if they meet the following criteria: (1) it must be possible to estimate with confidence intervals, how much larger the yield would be from the fishery in question if the pinniped population were reduced by a specified amount, other things being equal, (2) the number of pinnipeds by age and sex class that have to be removed from the population each year to maintain the post-treatment population level must be specified, and (3) the cost of pinniped management must be significantly less than the minimum estimated value of the increase in fishery production.

Throughout this paper we have avoided the issue of whether it is ethical to manipulate marine ecosystems. That is, we have assumed that managers will initiate only seal control programs that meet the above criteria and that final decisions concerning implementation will be "negotiated" among all of the user groups. Proposals to manipulate seal populations where there is no economic gain presumably will be dismissed. Attempts to garner public acceptance of seal control programs should only proceed for those situations where economic gains are expected based on sound scientific analyses. A final decision to proceed should incorporate the expected response of the public, because such programs will likely require a minimum of five years to show any affect on fish abundance or fishery yields.

The remainder of this paper will be directed at a general evaluation of each of these criterion and the application of these criteria to west coast pinniped-fishery interactions.

Determination of how much larger the yield would be from the fishery if the pinniped population were reduced

To date, none of the pinniped control programs have been preceded by what would currently be considered adequate statistical analysis. The intriguing similarities between traditional experimental design, with its assurance of specified confidence intervals, and the recent advances in using credibility intervals (see Press 1989), based on Bayesian theory, indicate that there is more than one approach that can be used to evaluate the merits of a pinniped control program. In any event, information needed to estimate the expected increase in yields and, the posterior distribution of yields must be available. Clearly, there are few marine mammal-fishery interactions presently available where data on the posterior distribution of yields would be informative.

We have identified four generally accepted ecological relationships between predators and prey that confound precise estimation of increases in yield resulting from pinniped control programs. First, prey species almost always have more than one predator. Expected gains in yield by reducing one predator population can be offset by functional or numerical responses (Holling 1970) in other predator populations. Second, predator species rarely are dependent on one species of prey. Therefore, predicting the predation rate on a particular species will undoubtedly be area and time-specific. Third, the recruitment rate of most fish stocks is highly variable, and it is one of the most likely factors controlling stock abundance. Because stock-recruitment relationships for most commercially valuable fish are obscure (Houde 1989, Sissenwine et al. 1984), it is unlikely that we will be able to predict, with adequate precision, the effect of removing pinnipeds on the recruitment rate. Furthermore, at least some populations of pinniped prey species are greatly affected by storms that disrupt the distribution of forage (Lasker 1975). This interaction is mediated through the larval stage (at least for anchovies, *Engraulis mordax*) and is, therefore, relatively independent of pinniped predation on older age classes. And fourth, fish, as a predatory group, consume more of gross fish production than do other predators (e.g., seabirds, cetaceans, and pinnipeds). For example, Sissenwine et al. (1984) estimated that Georges Bank fish consume over 70% of their own production. Smith (1976) estimated that pinnipeds consumed approximately 15% of anchovy production in the California current (Mammals of the sea 1979: appendix IV). In ecosystems where pinniped predation is only a minor component of total predation, pinniped culls on the order of 25-50% of the estimated equilibrium population (which is the maximum cull that would ever likely be authorized under the existing U.S. Marine Mammal Protection Act) would produce only marginal increases in production. Such marginal increases would be very difficult to detect with statistical confidence.

We believe that adequate information to predict changes in annual yields of fisheries caused by a pinniped management programs will be unobtainable for many pinniped species and, for other pinniped species, control programs will not result in increased yields to fisheries. Nevertheless, there may be specific cases where yield predictions are possible and ecological relationships are such that control programs could conceivably increase fishery yields.

The following information is necessary to predict changes in annual yields: (1) kind, size, and amount of target species taken by the pinniped species (by age, sex and area), by other predators, by commercial fishing, and by recreational fishing, and how variable these predation rates are over time, (2) Standing stock size of target species, trends in stock size, and the relationship between net production and stock size, and (3) Relationship among predation rates on the target species by the pinniped species and other predators, distribution and abundance of target species, distribution and abundance of pinniped species, and distribution and abundance of other predators.

Given the above information, it should be possible to estimate the increase in annual yields over a specified time period that is due to the pinniped control program. It is critical to ascertain item (1) because there are many different types of ecological interactions possible between pinniped and fish species. We have identified six basic types of interactions (Fig. 1), following on work by Beverton (1985). Additional interactions are certainly possible. In three of the six interactions, the net result on the target species of a pinniped control program is equivocal. In two of the six interactions, seal culls are predicted to abet fish stocks, whereas in one interaction, seal culls will actually disadvantage a fish stock. Obviously, it is necessary to understand the primary predator-prey relationships in an ecosystem before it is possible to predict the outcome of reducing the density of one of the predators.

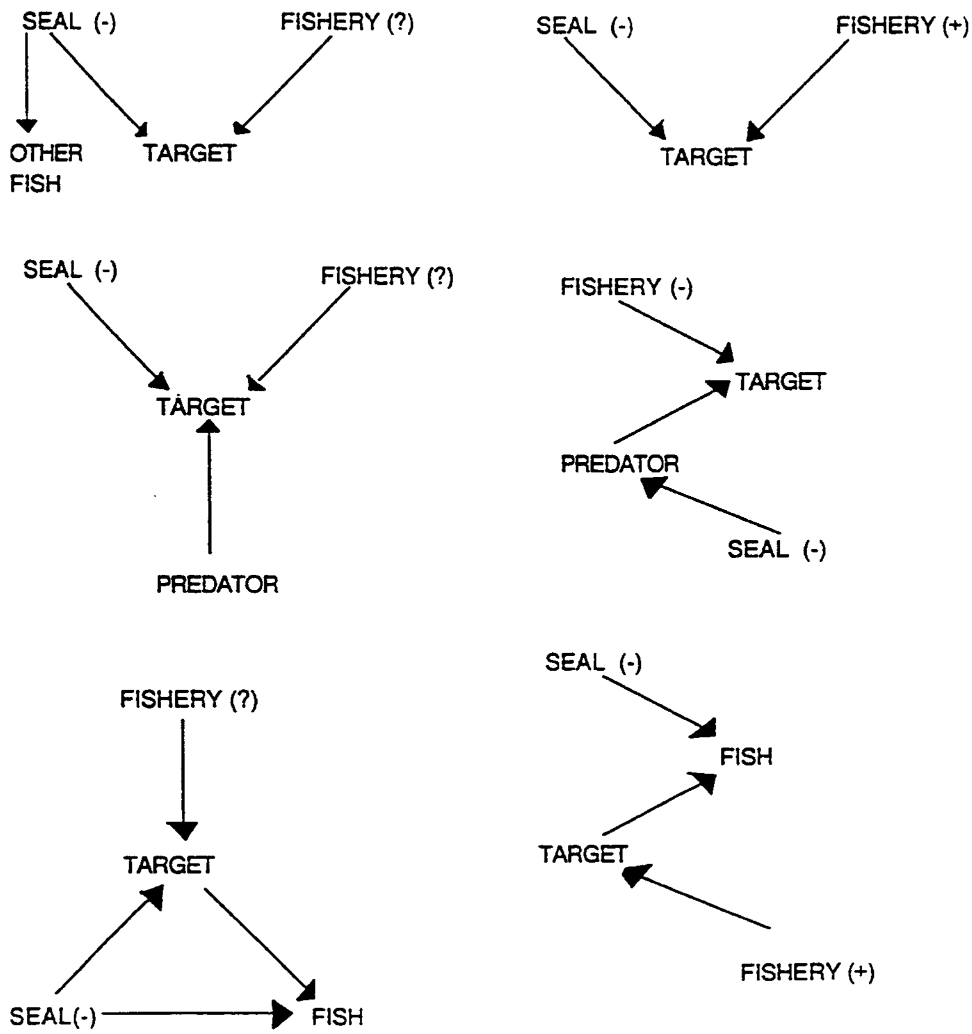

FIG. 1. Six possible ecological interactions among target species, pinniped species, other predator species and fisheries. Minus sign implies reduction in seal populations and fishery yield, plus implies fishery yields will likely increase, and question marks imply fishery yields are equivocal.

Items (2) and (3) will be very difficult obtain in any marine ecosystem. It is relatively straight forward to develop estimates of total consumption by a pinniped species with information on population size, average weight, and an estimate of daily food requirements (Boulva, 1975, Gallivan and Ronald 1979, Geraci 1977, Harwood and Greenwood 1985, Lavigne et al. 1985, and Prime and Harwood 1987), whereas, predicting the amount of individual prey species consumed in a given time period is very difficult. For example, California sea lions (*Zalophus californianus*) are known to feed on a wide variety of prey items (Antonelis and Fiscus 1980, Bailey and Ainley 1981, Antonelis et al. 1983, and Lowry et al. 1991*a*). However, other than the report by Bailey and Ainley (1981), there is virtually no information relating patterns of prey composition in the diet to relative abundance of prey.

Specification of the number of pinnipeds to be removed each year and the duration of the removal program

The following information is needed to address this criterion: (1) population size of pinniped species, trends in abundance, status, and the relationship between net production and stock size, and (2) proposed post-cull population size of pinniped population.

Given the above information, it should be possible to specify the number (by age and sex classes) of pinnipeds to be culled each year, and the duration of the cull in years to achieve the proposed post-cull population size. It should be recognized that control programs directed at young-of-the-year will necessarily require a longer time to equilibrate than control programs that involve the taking of all age and sex classes. Directing a control program at young-of-the-year will also require removal of significantly more animals than a program directed at mature females. Control programs directed at subadult and adult males will have very little influence on the total population size, but may affect local numbers significantly.

It should also be recognized that control programs directed at reducing pinniped populations, or even maintaining current population levels, will involve large numbers of animals. For example, the California sea lion population in California has been increasing at almost 12% per year between 1983 and 1990, and in 1990 was thought to number in excess of 100 000 animals (M. Lowry, *personal communication*, Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, California). That means the population is growing by over 10 000 animals per year. Using the survivorship schedule from Boveng (1988*c*), and a current population estimate of 120 000 animals, the mature female segment of this population (i.e., five years or older) includes over 28 000 animals. Control programs directed specifically at mature females would have to take on the order of 2000 animals per year to maintain the population at its current level. The male population that typically migrates north of Point Conception outside the breeding season is similarly estimated to include over 29 000 animals. With the available information, it is not possible to estimate how the distribution of males would change if the male population were reduced in size. It is likely that local changes in abundance could be produced by removal programs, although this effect may be more the result of "harassment from an area" than the absolute number of animals removed from an area.

Populations of northern elephant seals (*Mirounga angustirostris*) and harbor seals (*Phoca vitulina*) along the west coast (i.e., north of U.S.-Mexico border and south of U.S.-Canadian border) are also large (50 000 animals for each species, Boveng 1988*a* and *1989b*). Control programs directed at either of these populations would involve culling of hundreds, if not thousands, of animals per year.

Determination of the net value of the pinniped control program

The following information is needed to address this criterion: (1) expected cost of pinniped control per year over the first five years of the program, and (2) value of minimum expected increase in annual yields of the fishery per year over the first five years of the program.

Given the above information, the "worst case" net economic value of the pinniped program can be estimated. The "worst case" scenario may seem extreme to the fishing industry, but it is consistent with Congressional intent to err on the side of the marine mammal population in the Marine Mammal Protection Act. The need to project costs and economic gains over a five year period (or longer) is necessary for two reasons. First, depending on the age and sex classes of pinnipeds targeted for removal, a lag between initiation of the program and achieving the post-treatment population size should be expected. Second, the annual variability in fishery yields is such that an average over time is needed to characterize the effects of the treatment. As reported by Beverton (1985), "Because the `improvement´ (in fishery yields) is relative rather than absolute does not necessarily diminish its real value, even though its perceived value in terms of stock enhancement may be questioned." That is, the value of the expected increase in annual fishery yield has to be relative to the value of yield in the absence of a predator control program, and not relative to the average or annual yield of a fishery over some fixed period of time.

Case study: California sea lion and fishery interactions along the west coast

As stated earlier in this paper, California sea lions are recovering from over-exploitation in the late 19th and early 20th centuries (Cass 1985, Helling 1984). The number of California sea lions in California at the time the Marine Mammals Protection Act passed was approximately 50 000 animals, based on total pup production and using the same multiplier as Boveng (1988*c*). The current population size is at least twice that number and is currently increasing. Total consumption of fish by this species at various population levels have been estimated to be 100 000-300 000 tons (DeMaster 1983), 270 000 tons (Smith 1976), and 290 000 tons (Green 1978). Only Green (1978) has attempted to apportion total consumption among the known list of prey species.

California sea lions are unlikely to limit the biomass of any of their prey species. This conclusion is admittedly speculative, but it is based on the following arguments. First, California sea lion prey are generally between 50mm and 250mm in length (Hawes 1983). If the current theories about recruitment of California sea lion prey species are correct, regulation of these species is mitigated through variability in the annual recruitment of larval (and perhaps juvenile) age classes. Therefore, California sea lion predation is affecting age classes that have already made it through the "recruitment bottleneck." Second, California sea lions are likely constituting a relative small fraction of the total predation on any of their species of prey. Third, fishery landings in California have traditionally exceeded the total estimated consumption by California sea lions. The maximum tonnage per year of landings in California over the last 60 years was over 800 000 tons (O'Bannon 1990), while the maximum consumption by California sea lion in the last 50 years is likely to have been between 100 000 and 300 000 tons. Total landings in California in 1988 and 1989 were 248 000 tons and 209 000 tons, respectively.

California sea lions undoubtedly are causing financial losses to fishermen along the west coast. These losses are caused by California sea lions directly damaging gear and catch, and by their frightening fish away from traditional fishing grounds. However, pinniped control programs targeted at reducing the general population of California sea lions will do little to mitigate these interactions. Only changes in the local abundance of California sea lions or the development of methods to frighten them away from fishing grounds will address this problem.

In general, the only California sea lion control programs that could possibly satisfy the three criteria proposed in this report are those that are directed at local populations. In particular, an evaluation of a control program directed at California sea lion that utilize an endangered run of steelhead (*Oncorhynchus mykiss*) in Puget Sound, Washington seems warranted. A detailed analysis is therefore recommended. Our preliminary analysis suggests that without some type of pinniped control, this population of steelhead will be lost or that recovery will be severely retarded. Because of this, the expected increase of yield following pinniped controls will likely have a low probability of producing negative results. The maximum number of animals to be removed would be on the order of a few hundred individuals (DeLong, *personal communication*, National Marine Mammals Laboratory, Seattle, Washington). The cost of this removal would depend on whether animals were live-captured and translocated or killed. The cost of the former approach likely would be prohibitive. The duration of the control program is difficult to predict at this time but, conceivably, animals would stop utilizing this area as a haul-out and feeding area once culling was initiated. The net value of such a program also is difficult to measure because it involves evaluating the "worth" of recovering an endangered population as well as estimating the value of increasing the yield of this stock from zero to some substantially larger number. Obviously, we are not recommending that such a control program be initiated only that the merits of such a program be evaluated carefully. If the previously mentioned criteria are met, the problems of negotiating this strategy with the general public and surmounting the legal problems, as required under the Marine Mammals Protection Act, will remain significant.

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