GENERAL CONSIDERATIONS AND RECOMMENDATIONS

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FOOD CHAIN

The Salton Sea is a large "marine-like" body of water rich in basic food consisting of microscopic plants. In the interest of a sportfishery, as much as possible of this basic food should be converted into catchable gamefishes. Those normally considered as gamefishes are carnivores which do not feed directly upon the phytoplankton. Intermediate organisms are necessary to assimilate the phytoplankton, and then, in turn, serve as "bite-sized" particles for fish or for other intermediates in the food chain.

There are several food chains operating in the Salton Sea. The most important to the sportfishery is the chain: phytoplankton→ zooplankton→ detritus→ detritus-eating worm (*Neanthes*)→ worm-eating fish (bairdiella and sargo)→ fish-eating fish (corvina). Of seasonal importance is the phytoplankton→ zooplankton→ threadfin shad→ corvina chain. In the Salton Sea only the phytoplankton, which is found throughout, and the blue-green algae, which are restricted to the bottom in shallow, quiet areas, are actually capable of producing food. They do this by utilizing energy from the sun to combine the mineral elements of the Sea into complex food products. These foods can be eaten by animals which use them for growth or oxidize them to provide energy. The food substances oxidized for energy are broken down into their original, simple components which are no longer available as energy sources, but are available for re-use by plants. Each animal in a food chain passes on to its successor only a part of the food it has consumed; that is, there is a loss at each link in a food chain. Therefore, the shorter a food chain, the more efficient it generally is. The plankton-shad-corvina chain is the shortest and therefore, at least theoretically, the most efficient one present.

Most prominent is the plankton-detritus-*Neanthes*-bairdiella and sargo-corvina chain. The plankton organisms, upon death, sink to the bottom and form a layer of organic debris (detritus) which is rich in food materials. This detritus is eventually broken down into its simple components by bacteria and other organisms; however, this process is relatively slow and the detritus therefore represents a temporary reservoir of basic food materials. The detritus is eaten by the worm, *Neanthes*, which in turn is eaten by bairdiella and other small fish which provide food for the orangemouth corvina. The existing food chains are working quite successfully.

All organisms studied in nature seem to have good and bad years in terms of abundance. Therefore, the greater the number of parallel links in a food chain the smaller will be the influence if any one link is lost. In the present primary food chain, the phytoplankton is composed of a number of species and the loss of any one would not have much effect upon the total production.

Barnacle nauplii and *Neanthes* larvae are fairly abundant in spring; copepods and rotifers are abundant in summer, but in the winter zooplankton is sparse and this link (which may be by-passed) in the food chain is therefore weak during this season. The next link, the detritus, is fairly strong as long as the rest of the chain functions properly. In fact, the detritus acts as a buffer during minor disturbances because it functions as a reservoir of food materials. The weakest link in the major chain is that provided by the worm, *Neanthes,* because it has no parallel. To date the shad has not occurred in sufficient numbers to be of major importance, and could not support the corvina if the bairdiella and sargo populations were to decline suddenly due to failure of *Neanthes.* There is one species, the orangemouth corvina, at the end of the chain.

A factor that should be considered is the efficiency of utilization of each organism in the chain; in other words, how much of the available food does each "eat," and what percentage is passed on to the next link in the chain. The Salton Sea is a very productive body of water; per unit volume it produces more phytoplankton than fertile coastal ocean water.

It is not possible, with the data on hand, to illustrate the efficiency of transfer of nutriment at each link in the food chain in the Salton Sea. The general order of magnitude can be indicated, however, by inference from other studies of productivity. Harvey (1950) discussed production of living matter in food chains in the ocean. Considering such factors as annual mortality, rate of growth, and loss by respiration he estimated that 30 percent of phytoplankton production is used by the plants for their growth and respiration. The next link in the usual food chain in the ocean is a filter-feeding zooplankter, such as a copepod, which converts 70 percent of the plant production into animal tissue. This high efficiency of transfer holds only for rapidly-growing, short-lived filter-feeders. Longer-lived bivalves and worms are far less efficient; they convert only about 11 percent of the plant production into animal tissue.

Carnivorous fish convert 6 to 10 percent of their food into tissue. Thus, for 100 grams of plant tissue assimilated, Harvey estimated that:

70 grams become herbivorous, short-lived zooplankton.
11 grams become herbivorous, long-lived bivalves and worms.
4-7 grams (6-10 percent of 70 grams) become fish, feeding on zooplankton.
1 gram (6-10 percent of 11 grams) becomes fish, feeding on bivalves and worms.
0.1-0.4 gram (6-10 percent of 1-7 grams) becomes fish, feeding on fish.

Obviously the most efficient fishery would involve a plankton-feeding fish and the least efficient would be a sportfishery based on a carnivorous fish that eats other fish.

In the Salton Sea, because it grows to maturity within three to six months, *Neanthes* probably has an efficiency intermediate between a rapidly-growing copepod and a slow-growing bivalve. However, it feeds on detritus, which means that the plant material is first subject to bacterial degradation; because of their high rate of respiration, bacteria use much of the organic matter of the detritus, converting it to carbon dioxide and dissolved organic matter no longer available as food for *Neanthes.* So, although there may be fairly efficient utilization of the detritus by *Neanthes,* much of it is "wasted" by bacteria. *Neanthes* makes up for this inherent wastefulness because it is fast-growing, ha a high reproductive potential, and is itself an excellent food. It has n hard exoskeleton, as do molluscs and crustaceans, and in addition, ac cording to Zenkevich (1951), *Neanthes* has a higher proportion of pro teins and fats, and less carbohydrates than molluscs or crustacean

Reproductive potential is another factor of importance to the foo chain. Organisms with high reproductive potentials tend to make th most complete use of the available food by varying their populatio size to match the food supply. Organisms of lower reproductive poter tial cannot adjust their population size as rapidly to food fluctuation and tend to stabilize near the low point of their food supply. The detr tus may seem to be a stabilizing factor, making food continuously avai able to *Neanthes*. However, during the summer when half the botto area is anoxic, the *Neanthes* population is reduced. The bairdiella an sargo, with longer life cycles, would tend to be limited to the low poir of the supply of food.

The present food chain in the Sea is reasonably efficient, even thoug there are weak links and inefficient steps in the conversion of plant pr duction into gamefish. Gamefish production in the Salton Sea might l increased and stabilized by introducing other organisms of certai specific types, but extreme care must be used not to upset and destro the present food cycle.

THE CHANGING ENVIRONMENT

The environmental conditions in the Salton Sea are undergoing rather rapid transition. The most important and drastic change, in r gard to the fauna of the Sea, is the increase in salinity. Although mar controlling variables are involved which afford many chances for va ation in the rate of increase, it seems probable that the salinity w increase about 0.4 parts per thousand per year. This would bring t salinity level to about 40 parts per thousand by 1975 and to about : parts per thousand by the year 2000. Although predictions as to wh this will do to the biota are based on scattered, diverse, and not ve direct information, it seems probable that the food chain in the Salt Sea will be seriously affected, and possibly destroyed by about 1980 1990. This time estimate is subject to considerable variation; there is sure way of knowing when the biota will be affected.

Since it was realized from the start of the project that salinity fluct ation would be a problem, tolerance to this condition was considered prime requisite when recommending animals for introduction. The pr ent fauna consists largely of species which are tolerant to salini changes, and so it is probable that it can exist about as long as a combination which might be considered. There seems little likeliho that introducing different animals could prolong the life of a sp fishery for more than a few years.

The only thing which could have a profound effect on the life of t fishery would be environmental control. To be effective, this would ne to reduce drastically the rate of salinity increase. Since there is conceivable method by which the addition of salts to the Sea might stopped (the agriculture of the area is dependent upon this practi it would seem that the only possibility of control would be to rem salts.

Removal of salts from the Sea is possible, and the low relief of much of the shoreline would aid such an undertaking. Whether or not this kind of project is justified becomes a matter of economics. Certainly not only the fishery, but also the value of the area for other recreation and for real-estate development, will be affected by the Sea's increasing salinity. Eventually it will become a brine lake, similar to the Great Salt Lake of Utah, if the salinity buildup goes unchecked.

The project was unable to investigate possibilities for salinity control. We can only point out the inevitable consequences of lack of control.

THE RATIONALE FOR MANAGEMENT RECOMMENDATIONS

There is little background information on which to base recommendations for managing the Salton Sea. It is an unusual biological situation. No definite information on the results of managing any area even closely approximating Salton Sea conditions has been available to us.

Our bases for management proposals, therefore, stem from our own limited findings, and certain hypotheses based on ideas from other areas. Of necessity, we have had to rely largely on information derived from studies of habitats quite different from those in the Sea. None of the conclusions drawn is unequivocal, and if viewed critically, they are at best only guesses. These conclusions are based on what we consider was the heaviest weight of the general evidence.

Faunal Composition

The primary consideration in determining a desirable fauna for the Salton Sea was the desire of the managing agency, the California Department of Fish and Game, to establish a sport fishery. This was mediated to some extent by the limited fauna already present in the Sea, and by other more general considerations. The various points are discussed below.

Gamefish

Opinions vary considerably as to what fishes qualify as gamefishes. Those most eagerly sought by American anglers have certain characteristics in common, however. They must be catchable on rod and line, and they should take artificial lures. When hooked they put up a good fight. The most popular marine types reach a reasonably large size (at least 10 to 30 pounds), but are still desirable at smaller sizes. Of perhaps lesser importance, but yet a very significant factor, they should be desirable for food.

We felt that the fish at the top of the food chain should have these attributes in addition to biological characteristics which would enable it to live, reproduce, and maintain a sizable population in the peculiar environment of the Salton Sea. The species chosen as the best probable choices were the corvinas. It was soon evident that one of them, the orangemouth corvina (*Cynoscion xanthulus*), had already become established in the Sea as a result of the general plantings by the California Department of Fish and Game.

There are other species, often referred to as panfishes, which are considered gamefishes by most sportsmen. They also may be caught on rod and line, usually will take artificial lures, and are good to eat, but they do not reach as large a size as the primary gamefishes. Usually their

MANAGEMENT RECOMMENDATIONS

Salinity Control

The feasibility of attempting to control the salinity of the Sea is dependent on economic factors. Not only the sportfishery, but other recreational values of the Sea, the surrounding real estate, and perhaps nearby agricultural developments, could be affected by the increasing salinity. It is recommended that possibilities for control be studied and considered in future development plans. Perhaps the cost of such control could be partially paid through commercial development.

Introduction of Submerged Aquatic Plants

There is no indication that introducing submerged aquatic plants would have any great effect on the sportfishery. The plants would undoubtedly be restricted to waters shallower than three feet because of the high turbidity. They might serve as hiding places for young fishes, but there is no indication such areas are lacking at present. Their value as a means to increase the lower links of the food chain is extremely doubtful, but they could be important as a new habitat for invertebrates. Perhaps the greatest danger from plant introductions is from the diverse and unknown invertebrate types which almost certainly are introduced at the same time. These unknowing introductions could be disastrous to fishery development. At the same time, they might provide an important new source of food. Our consideration of the total problem leads us to believe that introducing submerged aquatic plants is not justified from the standpoint of the sportfishery.

A good stand of submerged aquatic plants which serve as food for waterfowl would be of great value to the area surrounding Salton Sea, however. Because of this factor, we agree that experiments with such plants should be made, on the grounds that chances for benefits probably outweigh the chances for damage.

Submerged aquatics can be navigational nuisances. Boating is a well-established recreational use of the Sea and the boat launching channels are shallow. They could easily be choked by aquatic plants.

The increasing salinity of the Sea will limit the length of time that plants as well as animals can exist there.

Introduction of Additional Kinds of Animals

We recommend a conservative attitude towards introducing new animal forms. There is now a growing sportfishery, and there is the possibility that additional forms will do more harm than good. If the fishery is considered inadequate or if a decline in catch occurs; however, we recommend the following introductions and feel that any forms chosen should be tolerant of wide temperature and salinity fluctuations:

Zooplankters

We have been unable to secure any information on specific forms to introduce at the zooplankton level. Zooplankton is rich seasonally, and there seems no reason to introduce new forms unless they would reduce the seasonal fluctuations. We are not able to offer specific suggestions. In addition, we cannot suggest a reasonable method of securing pure cultures of any such organisms.

General Management Methods

A continuing program of limited biological sampling and creel census will be necessary to insure intelligent management of the Sea. Sampling bairdiella, sargo, and corvina populations to secure information on growth and catch rates should provide an index for the relative success of these species. If the growth rates are judged too low, compared to indications of the population size, this may be considered as evidence that the food chain is weak. If the bairdiella shows the greatest reduction, the *Neanthes* link probably is weak; and if the corvina shows an unusual drop this would indicate weakness at the panfish level. Absolute population estimates were impractical during the original research, and are probably impossible for routine management. It is therefore necessary to base continued management on fairly simple checks, such as relative growth studies and catch rates.

Attempts should also be made to ascertain what changes, if any, are taking place in the fauna. These determinations can only be qualitative, in all probability, but it will be valuable to know if new forms have become established. In addition to limited plankton and bottom sampling, diet studies on the fishes would be of particular value in discovering changes in the food chain. Systematic checking through the season would be desirable, but probably will not be possible. Sampling no oftener than once a year could be exceedingly valuable.

Rate of Harvest of Fishes

The biological conditions in the Sea are such that the fishes near the end of the food chain should be harvested at a high rate. The game fishes grow rapidly at least in early years, and their reproductive potentials are high. Moreover, the life of the fishery is limited by the Sea's rapid increase of salinity. Bairdiella have already shown themselves capable of producing an overpopulation, and there are signs that the sargo may be on the way to doing the same thing. Based on biological information alone, we see no reason to limit the take of bairdiella and sargo by sportfishermen. There is probably little danger of over-fishing the corvina, but a generous limit might be wise during the early years of the fishery. We can see no reason for a closed season on any of the fishes.