REVIEW DRAFT

IMPROVING PRODUCTIVITY OF WASHINGTON'S WATER RESOURCES THROUGH AQUACULTURE

INVESTIGATORS

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INTRODUCTION

Abundant food supplies can be provided only by improving the natural productivity of our resources. Technological development and innovation has resulted in vast improvements in the food producing capabilities of our agricultural resources. The rapid progress and enormous expansion achieved in agriculture will be duplicated for coastal water resources only by developing effective cultural methods. Serious limitations restrict progress in achieving this objective. Three types of restrictions need to be distinguished for the purpose of surveying the potential for improving the productivity of Washington's water resources through aquaculture. Development must be guided by market demand. Technology must be adequate to supply products at competitive prices. Finally, institutional restraints preventing sound development must be removed. This latter problem may prove to be the most difficult.

The types of products that may be economically produced must be guided fundamentally by market demand. Interest in aquaculture based on world population growth and food shortages, for example, may result in too much attention focused on products with relatively low value due to interest in high productivity at low cost. Only through consumer purchases are food needs translated into market demand and, subsequently, justification for investment in expanded production. While interest should continue in a broad range of possible sea farming products, it is important to appraise and periodically review the outlook for market demand as the fundamental base for guiding development programs. The current outlook for market demand for products that may be important in the development of Washington's water resources is presented in the next section.

Sea farming of products that rank low on the consumer preference scale is likely to be successful only with enormous production efficiency. Technology to develop efficient output of products with higher consumer preferences, even though more costly production methods are involved, may prove to be far more successful. This demonstrates the close relationship between market prices and available technology in encouraging investment in development of aquaculture activities. Technology must be developed to provide the means to produce what consumers want at a price they are willing to pay. The current status of aquaculture technology and research programs is reviewed in the third section of this report.

Even with satisfactory market demand and efficient production technology, a third major type of restriction may limit full utilization of sea farming productivity. Unlike land resources, institutional constraints associated with resource ownership can limit investment interest in aquaculture. For common property resources, such as coastal waters, essential characteristics that encourage development and investment are often lacking. Resource ownership provides right to the economic benefits generated by the resources, permits use of capital investment to improve economic benefits over a period of time, and enables the owner to vary production methods to achieve maximum efficiency.

For aquaculture enterprises, public involvement must include not only cooperative effort with private industry in development programs, but, equally important, the need to provide institutional arrangements that will permit full utilization of water resources through aquaculture. Equally important, the methods used to provide private access to coastal waters may largely determine how the benefits of these resources will be shared by society. The importance of removing institutional barriers to developing aquaculture will follow the sections on market demand and technology review.

The final section of this report will provide preliminary estimates on the potential impact of aquaculture activities on the State's economy if demand and technology are realized through removal of institutional restrictions.

The following discussion of each of these topics is based on only limited information and research and should be viewed as a preliminary appraisal of this topic. The discussion and projections presented in this report are only tentative estimates due to the limited time and resources available to develop this information.

General trend in consumption and demand projections for some potential aquaculture products

The Report of the Commission on Marine Sciences, Engineering, and Resources suggests that aquatic culture of certain species can contribute substantially to food supplies and to the economy of the nation on the reason that, unlike other fisheries which operate on natural (wild) populations and whose harvestable surplus is limited, the harvest of cultured species of fish, shellfish, and aquatic plants are limited only by the acreage to be farmed and the ability to compete economically with other marine stocks.[1] The Commission, however, also recognizes the complexities and problems of aquaculture in the United States:

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1. Our Nation and Sea, Report of the Commission on Marine Sciences, Engineering and Resources. 91st Congress, 1st Session, House Document No. 91-42 at 12 (1969).

> "Although research is rapidly demonstrating the feasibility of aquaculture, full-scale commercial application is limited by legal, organizational, political, and technical constraints. As these constraints are removed, aquaculture should become a powerful new global resource." 2

The Washington Department of Fisheries also indicate the potentials, through aquaculture of increased harvest of salmon and some species of shellfish by the commercial and recreational sectors of the state.[3]

There is general agreement that world demand for marine food products will continue to increase and that aquaculture can play an important role in supply. For many species such as shrimp, salmon, oyster, clam, and lobster which are now or may be capable of being cultured, increasing world demand and competition means higher prices to be paid by United State consumers if natural supplies are limited or are not augmented by supplies from aquaculture.

The general trend in world and United States consumption and projected demand for salmon, oyster, shrimp and clam are given in figures 1, 2, 3, and 4 respectively.[4] Included in each figure is the Washington landing of that species to provide a general perspective as to its contribution (supply) to world and United States consumption in the past. The projected world demand for salmon (figure 1) show hardly any increase and United States demand some increase but at levels lower than those of the early 1950's as they are based on the assumption that maximum sustainable yield (MSY) will be reached by 1975. The general outlook then, is higher prices

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2. Id. at 12.
3. Plan for Washington State Food Fisheries, Wash. Dept. Fish. at 70, 85, 89 and 99. (June, 1970).

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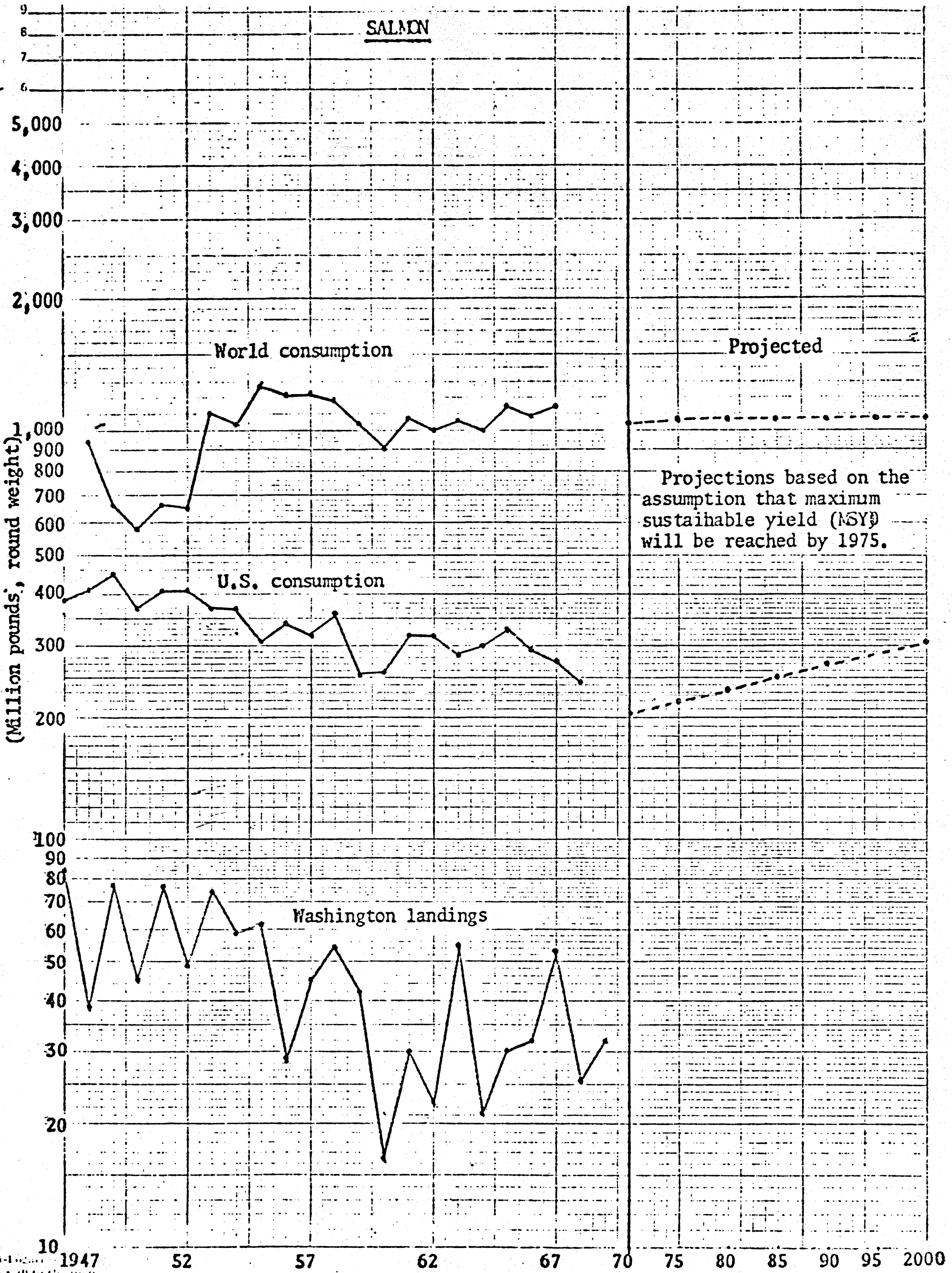
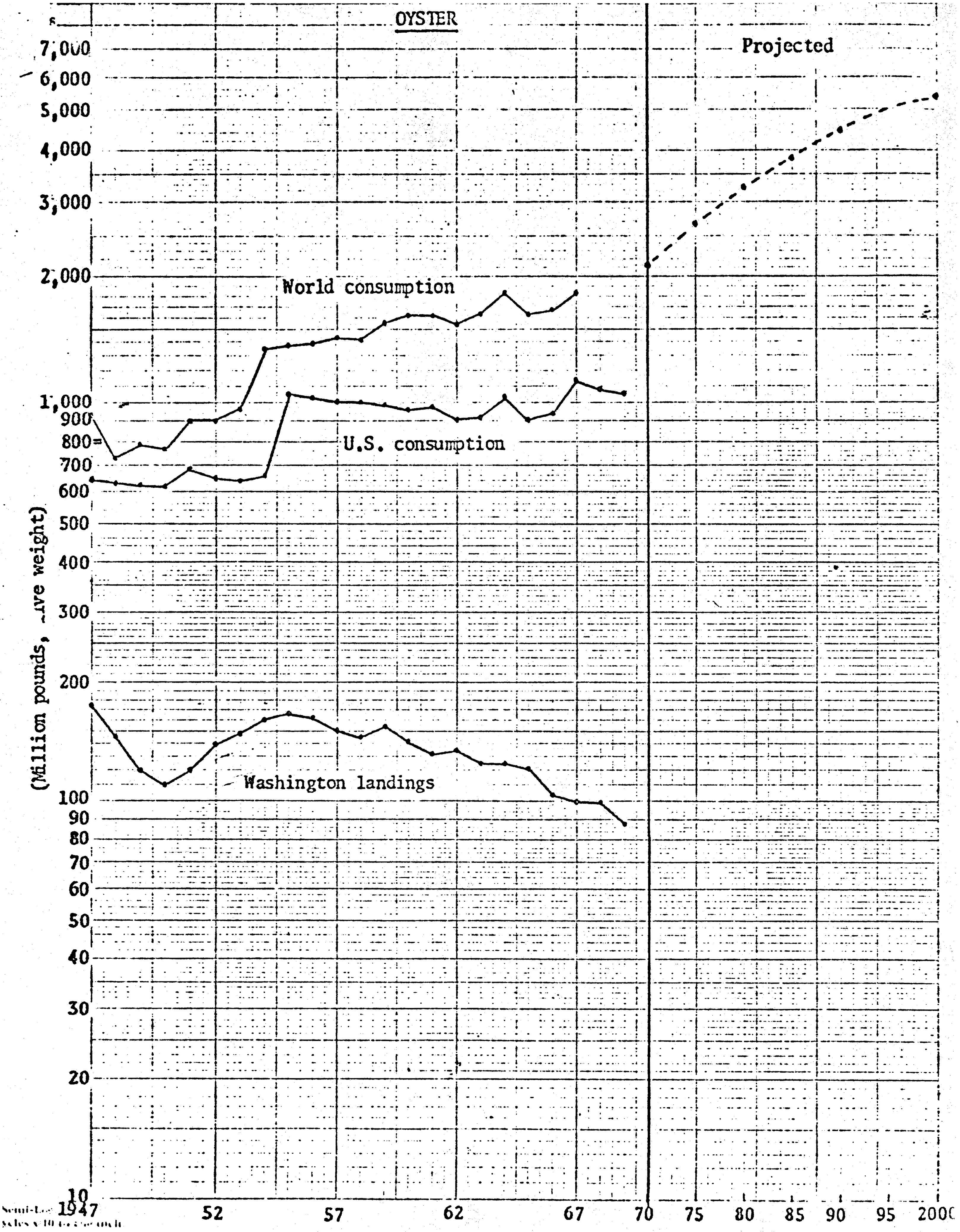
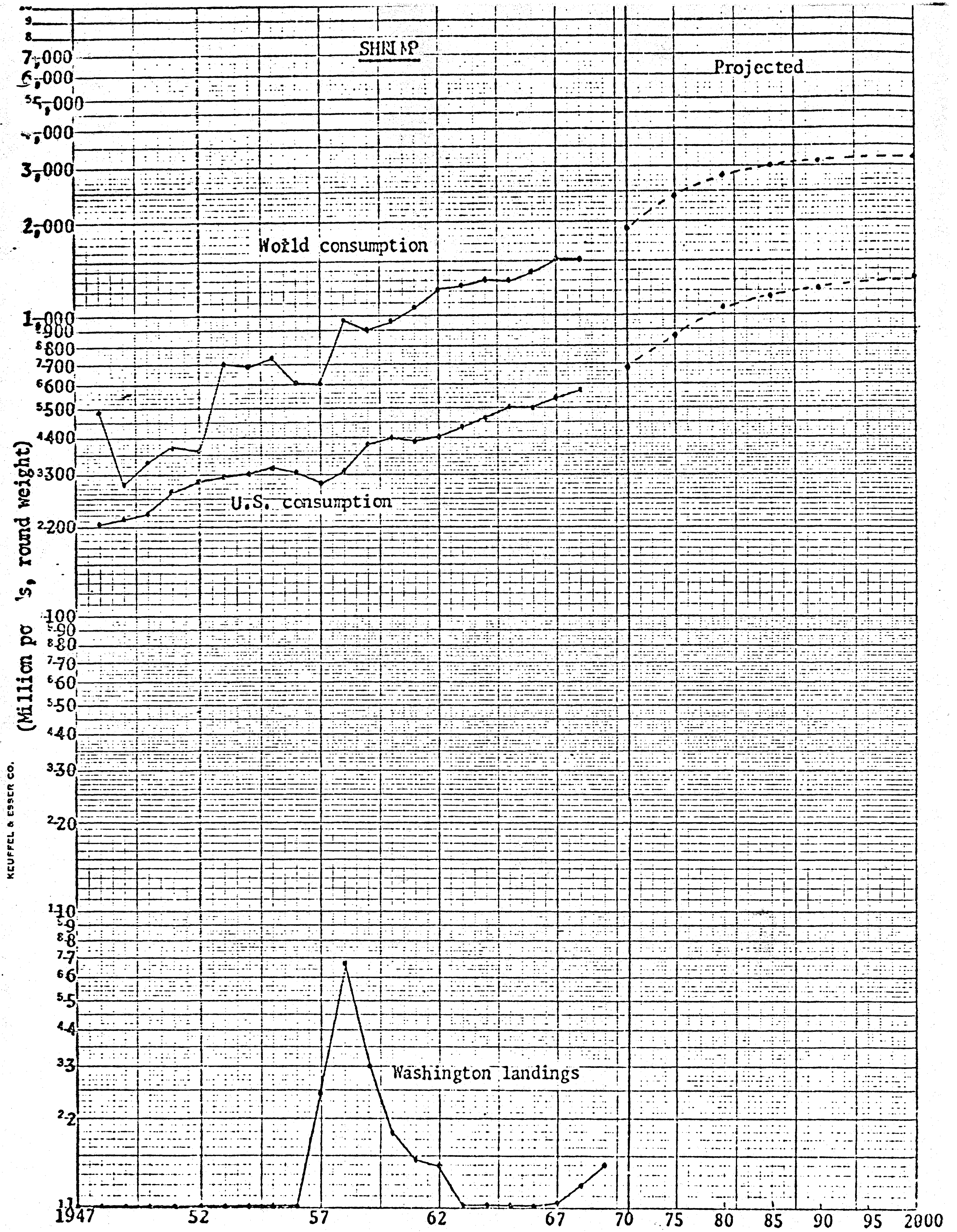
4. Data source: Fisheries Statistics of the United States (1947-69) and the following publications of the Division of Economic Research, National Marine Fisheries Service:
   Basic Economic Indicators--Salmon, Master Plan Fishery 50 10 48, Working Paper No. 62; Basic Economic Indicators--Oyster, Master Plan Fishery 50 10 21



SALMON
(Million pounds, round weight)
5,000
4,000
3,000
2,000
1,000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
World consumption
Projected
Projections based on the assumption that maximum sustainable yield (MSY) will be reached by 1975.
U.S. consumption
Washington landings
1947
52
57
62
67
70
75
80
85
90
95
2000



OYSTER
Projected
World consumption
U.S. consumption
Washington landings
(Million pounds, live weight)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
1947
52
57
62
67
70
75
80
85
90
95
2000


SHRIMP
Projected
World consumption
U.S. consumption
Washington landings
(Million po 's, round weight)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
1947
52
57
62
67
70
75
80
85
90
95
2000
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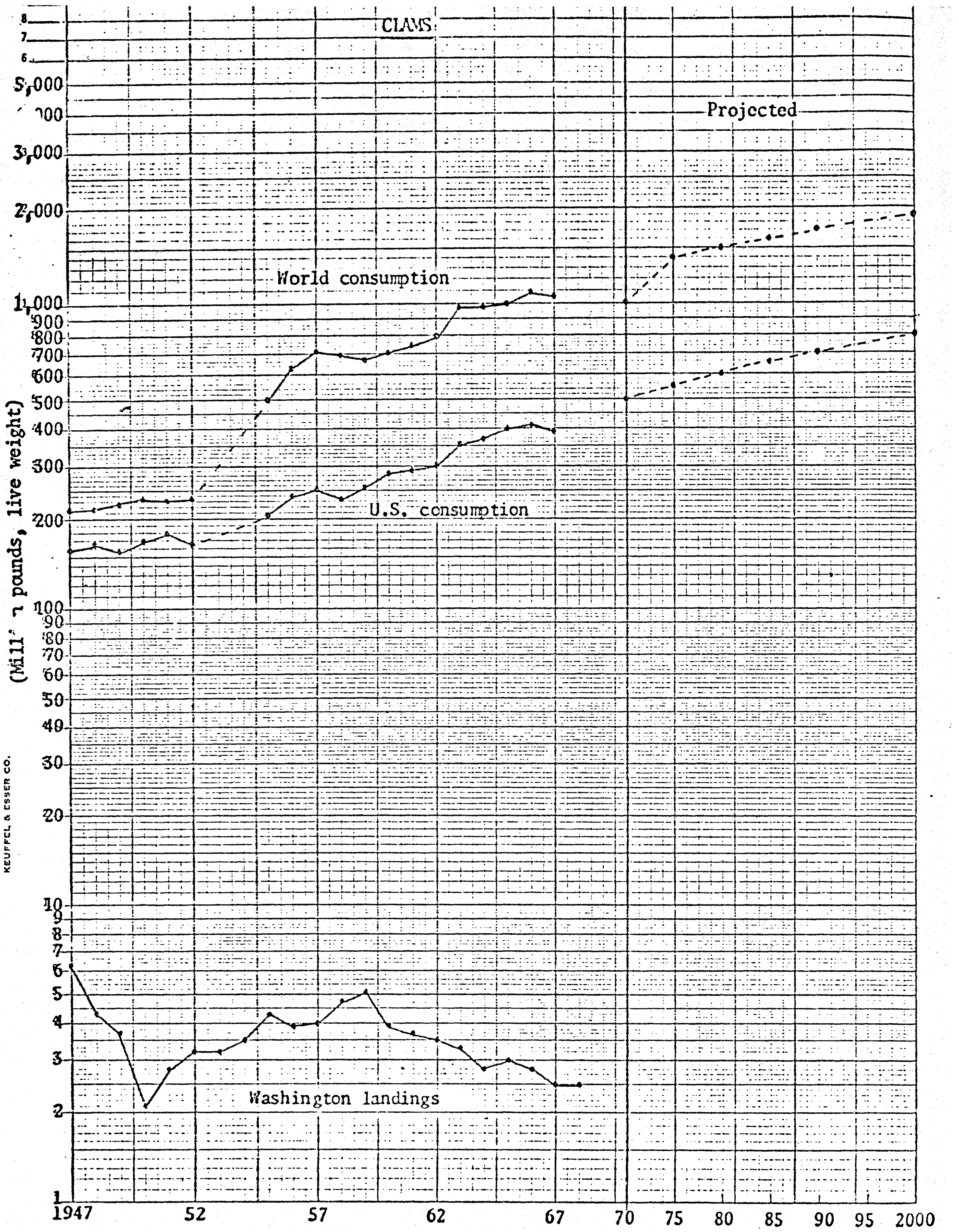

CLAMS
Projected
World consumption
U.S. consumption
Washington landings
(Millions pounds, live weight)
5,000
3,000
2,000
1,000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
1947
52
57
62
67
70
75
80
85
90
95
2000
KEUFFEL & ESSER CO.

to consumers if other sources of supply cannot be developed. The projected world demanand for oysters by year 2000 (figure 2) is more than twice that of current consumption. Demand projections for the United States are in the process of reevaluation and are not available at this time. World and United States demand for shrimp and prawn (figure 3) by year 2000 are estimated as approaching twice that of current consumption, as are demand projections for clam products (figure 4).

Table 1 summarizes the consumption and supply aspects of the above four species for the past decade (1960 through 1968 or 1969). Of the average annual world consumption of 1.1 billion pounds (round weight) of salmon, approximately 27.7 percent were consumed in the United States. Of annual world supplies the United States produced approximately 28.5 percent. Of the United States supply, Washington State in turn contributed an average of 10.6 percent, or 31.9 million pounds annually. For salmon, the United States experienced an average annual net export of 18.9 million pounds during the past decade in contrast to the net imports experienced during the 1950s'.

For oysters, United States consumption has exceeded her domestic supply--an average annual consumption (live weight) of 976 million pounds (58.4 percent of world consumption) on an average annual supply of 846.8 million pounds (50.6 percent of world supply). Washington's harvest of oysters was an average 116 million pounds, or 13, 7 percent of the United States harvest. An average annual net import of 10 million pounds (meat weight) was experienced by the United States during the past decade.

United States consumption of shrimp and prawn has also exceeded her domestic supplies. Consumption averaged 467.6 million pounds (round weight) annually, or 36.5 percent of the world, while harvest was an average 246.6 million pounds, or 19.2 percent of world supplies. Washington landings averaged only 1.1 million pounds annually, or less than 1 percent of United States landings. During the past decade the United States had average net imports of 147.8 million pounds (heads-off weight) of shrimp and prawn annually, that is, more than 50 percent of the annual consumption of shrimp and prawn was made up of imports.

Consumption of clam products in the United States has slightly exceeded her domestic supplies. The United States consumed an average 353.4 million pounds (live weight), or 38.5 percent of world consumption, while supplies averaged 340 million pounds, or 37 percent of world supplies. The average annual landing of 3.5 million pounds in Washington represents only 1 percent of United States supply. The United States has averaged an annual net import of 1.7 million pounds (meat weight) of clam products.

In general, the outlook is for increased demand for some of the species currently under culture in the World or the United States, or with the potentials for culture. Aquaculture in Washington offers a potential, through orderly growth, in meeting part of the world and United States demand for marine food products. This potential, of course, depends on demonstration of technical feasibility through research, the reordering of legal, organizational, social, and political constraint and support, and most important, the development of aquaculture in Washington to levels there it can compete economically with other sources of supply.

Table 1.--Summary of consumption and supply aspects of salmon, oyster, shrimp and prawn, and clam, 1960-69 (in millions of pounds). 1/

Fishery	Average annual consumption			Average annual supply					Average annual United States trade 2/			
	World	U.S.	Percent U.S.	World	U.S.	Percent U.S.	Wash. landing	Percent Wash. of U.S.	Net export (pounds)	Net export (percent)	Net import (pounds)	Net import (percent)
Salmon	1,055.6	292.4	27.7	1,055.6	301.2	28.5	31.9	10.6	18.9	6.3	--	--
Oyster	1,672.5	976.0	58.4	1,672.5	846.8	50.6	116.0	13.7	--	--	(10.0)	15.5
Shrimp, Prawn	1,281.8	467.6	36.5	1,281.8	246.6	19.2	1.1	1.0	--	--	(147.8)	50.1
Clam	918.8	353.4	38.5	918.8	340.0	37.0	3.5	1.0	--	--	(1.7)	3.0

1/ Meat or heads-off weight are reported in parenthesis. All others are in live or round weight.

2/ Percentages are expressed in terms of apparent annual United States consumption.

The Potential for Sea Farming in Washington State

The sheltered bays, sounds and estuaries of the coastal zone have much potential for increasing the production of quality sea foods. By development of appropriate systems of aquaculture, such waters can be used for the production of sea food in the same way that that the flood plains of river basins have been used for agricultural production.

Aquacultural products can be expected to stimulate expanding markets as production, processing and distribution become more efficient. Perhaps even more importantly, by providing an economically attractive incentive for clean water, the orderly growth of aquaculture can help prevent coastal waters from becoming further despoiled by uncontrolled urban and industrial growth.

Puget Sound is an inland sea with over 2,300 miles of shoreline, much of it protected by high bluffs from strong winds. Its deep waters are well-flushed by strong tidal action and enriched in nutrients by abundant runoff from the land. In the main channels, the temperature is remarkably uniform throughout the year (7 - 13°C.), whereas in the shallow, less saline waters at the heads of inlets it may range from 4 - 18°C. Salmon, oysters, clams and crabs were once plentiful and provided abundant food for Indian populations before the coming of the Europeans. These resources, ever since, have steadily declined under increasing population pressure and the land-use practices of white men. The native oysters, for example, have been virtually wiped out.

To recover the capacity of the Sound to produce high, sustained yields of valuable sea products, it will be essential to prevent further deterioration of its waters and to restore their pristine quality. Recognizing this need, an Oceanographic Atlas of Puget Sound is being planned by the Washington State Department of Natural Resources, the University of Washington and the National Marine Fisheries Service. It is intended for use as a guide for the planning of water-use zoning for the Sound. Zoning schemes should recognize that mariculture can play a major role in restoring and expanding the yield of living resources from this unique inland sea. Provided that funds are made available, charts will be prepared for the atlas to show conditions of temperature, salinity and current speed for each month of the year as well as bottom characteristics, direction of prevailing storm winds, and the location of protected shorelines. Information regarding shoreline development, population, shipping, the location of key industries, and the discharge sites for municipal, industrial and agricultural wastes will also be added.

The basic properties of water areas that must be considered in planning for aquaculture are essentially the same as for any life-support systems: space, temperature, availability of oxygen and suitable food, and the means for disposing of, or recycling, wastes. For any given system, requirements for these properties will vary according to the organisms to be cultivated and to the extent that the system is open or closed. Consider the following examples:

1. Feed lots. In this type of system, the cultured organisms are held in flow-through enclosures, such as cages or pens, in which they are given prepared feeds while being grown to marketable size. Such a system requires

a high volume of flow of clean water to carry in fresh oxygen and to carry away unwanted wastes and bacteria. The temperature of the water should be sufficiently high to sustain an economically satisfactory rate of growth relative to the amount of feed supplied, yet sufficiently low to discourage the proliferation of disease. The water should be of high clarity to keep to a minimum the amount of surface capable of carrying deleterious micro-organisms.

2. Grazing. These are usually open systems with some form of spatial restriction of the cultured organisms, in which natural feed is a component of the water supply. Suspended culture systems for molluscs fit into this category, as do partially open systems such as those in which small fish and shrimp might be held in tidal rearing ponds to feed on natural food. In such systems, in addition to oxygen, the new water must carry to the cultured stocks either sufficient food organisms or the nutrients for their production at a satisfactory rate. Flushing must be adequate to dilute or to remove wastes to tolerable levels.

One variant of grazing is open-range culture in which spatial restraints are unnecessary. In aquaculture, an open range is possible with anadromous species such as salmon which undertake predictable homing migrations. Young, hatchery-reared fingerlings, imprinted by the fresh water in which they have been reared, return to the rearing site after several years of growing and fattening in the sea. Fishery scientists, armed now with new insights into the effects of juvenile rearing conditions on the behavior and survival of adults at sea, believe that it may be feasible, by carefully controlling rearing conditions for juvenile salmon, not only to increase significantly the numbers ultimately returning to homing sites, but also, to a limited extent, to influence the distribution of adults at sea. For example, recent evidence indicates that coho salmon from Puget Sound hatcheries, held and fed beyond their normal release date in April until the first of July, do not migrate to the ocean as do their earlier-released siblings, but rather stay in Puget Sound to grow to adulthood, thereby enhancing their accessibility to local sport and commercial fishermen.

3. Hatcheries. For hatchery production of eggs, larvae and small organisms requiring neither large amounts of space nor large volumes of water, systems have proven to be useful in which most of the water is recycled after treatment to remove wastes, inactivate deleterious micro-organisms, and to replace oxygen. A very great advantage to be gained from recycling is the relative ease and economy of controlling the water temperature, affording control over the rate of development of eggs and larvae, making it possible to stagger the planting of juveniles to extend the period for harvesting.

Salmon culture. Recent experiments in Puget Sound by the National Marine Fisheries Service have shown that in salt water of the proper temperature and sufficient flow, and with appropriate feeds, it is possible to rear coho salmon from fingerlings weighing 5 to 10 grams to marketable fish weighing 300 grams in 6 months with negligible losses. Conversion of feed is efficient--better than one unit weight of growth for each two of feed.

Clear, fresh water is required for the incubation of salmon eggs and for the rearing of young until they have started feeding. Ideally, the temperature of the water should be between 9 and 12°C. Partially recycled water systems can be effective at this stage. The fry can be reared to about 10 grams most efficiently in slightly brackish water. In the spring, before the onset of high summer temperatures, and the fish are still quite small so that high volumes of flow are not yet necessary, brackish lagoons could prove most useful. Feeding would most likely be necessary, but substantial dietary supplementation could come from natural food in such lagoons. For the final stages--rearing from 10-gram fingerlings to a marketable size of 300 grams, or for breeding for which they would be reared to several thousands of grams or more--floating pens made of netting, moored in saltwater bays, sounds and tidal estuaries, are suitable. For saltwater rearing, acceptable temperature limits are 5 and 15°C, the optimum being about 12°C.

Heat from the discharges of electric power stations could provide opportunities for improving conditions for salmon culture where cold water in the winter would preclude optimum growth rates. At the other end of the temperature scale, cool, subsurface waters might be economically air-lifted to the surface where temperatures in the summer are too warm.

At the NMFS Experiment Station at Manchester, ways are being developed to utilize the energy and foods naturally available from the waters of Puget Sound. Fresh water for our hatchery and nursery systems is drawn from a creek and piped for about 800 meters beneath a small bay to a delivery site at the end of a pier. Since the annual range of temperature of the salt water at the bottom of the bay is considerably less than that of the creek water, the piped creek water is cooled in the summer and warmed in the winter. To take advantage of tidal currents, saltwater rearing pens are placed where current velocities fall between 0.05 and 0.5 knots, sufficient to give a good exchange of water in the pens without exerting excessive lateral pressure on the nets or stress on the mooring system. During those periods of the growing season when there is in the bay an abundance of plankton suitable for food for salmon, underwater lamps are used to attract the plankton either directly into the pens or to the intake of a plankton pump.

On the basis of information from our current experiments, it would appear that the western shore of the central part of the Sound, including Admiralty Inlet, would have the best potential for the rearing of salmon in salt water. Excellent protection from the southwesterly storms which prevail in the winter is afforded by the high bluffs along the western shore. Also, there are relatively few large communities and industrial developments on the western side.

Oyster Culture. For oysters, the situation is more complex. To replace the native oyster stocks which were virtually eliminated by pollution earlier in this century, Puget Sound oystermen now mostly grow Japanese oysters. Growing conditions for these oysters are generally excellent in Puget Sound south of Tacoma Narrows, in Liberty Bay, Burley Lagoon and in Port Susan, but appropriate spawning conditions cannot be relied upon, and seed imported from Japan and Korea is necessary to maintain the stocks. In Puget Sound, the physiological processes associated with growth seem to be out-of-phase with those associated with reproduction in these oysters, which are tuned to different sets of conditions prevailing in Asiatic waters. In maturing Japanese oysters planted on beds at the heads of inlets in southern Puget Sound, physiological stresses appear to accumulate during the second summer, resulting in high mortalities. Otherwise, the waters of these inlets is well suited for Japanese oysters. Evaluation of recent studies shows that better preparation of oyster beds to reduce turbidity close to the bottom, moving oysters before their second summer from beds at the heads of the inlets to cooler waters near the entrances, and the introduction of suspended culture techniques to take advantage of deeper water for oyster growing, will significantly reduce summer mortalities and promote production of higher-quality oysters.

The current construction by the Lummi Indians of a shellfish hatchery on their tribally-owned tidelands near Bellingham, Washington, is very encouraging. If successful, it should help reduce the dependence of local oystermen on imported seed and further improve the prospects for expanded production and a greater variety of oysters and other molluscs from Puget Sound shellfish farms. The basic techniques for producing oyster seed are applicable also to other molluscs such as clams, scallops, abalone and mussels. Commercial shellfish hatcheries have recently been established in Long Island Sound and in California. Their development in Washington State should lead to better husbandry practices by the shellfish industry with resultant improvements in the quality and diversity of its products.

Prawns. Prospects for the culture of the spot prawn, a delectable crustacean native to Puget Sound, have been enhanced by recent advances at the University of Washington. Artificial culture of this species to post-larval stages was successfully accomplished in a recirculating saltwater system. Further development of the technique, designed to extend the culture through to market size, is planned by University researchers with the cooperation of the NMFS which will provide running salt water facilities at Manchester. The spot prawn, a scavenger of detrital materials, shows much promise as a component of multiple-culture systems. Wastes from the rearing of fish and molluscs might be effectively utilizated by the prawns.

Seaweeds. Washington State does not have a well-established seaweed industry despite the fact that its miles of coasts and inland waterways support one of the most diverse marine floras found anywhere in the world.

The Lummi Indians are experimenting with the harvesting of naturally-occurring stands of the red seaweed, *Iridea cordata*, in the San Juan Islands. If successful, this experiment may point the way to a valuable new industry for the state.

The State Department of Natural Resources, which seeks to encourage the introduction of seaweed harvesting to supplement shellfish and salmon aquaculture, has estimated that the standing crop of naturally-occurring seaweeds in state waters is worth approximately $500,000 annually. Algologists at the University of Washington have suggested that this figure could, at least, be doubled by the development of appropriate culture methods.

Inland waters other than Puget Sound. Although the emphasis in this discussion has been on Puget Sound, other estuarine areas of the state will also have a greatly increased potential for aquaculture if protection through pollution abatement and control, and a rational system of water-use zoning is properly developed. Grays Harbor, Willapa Bay and the Columbia Estuary could be considered as having possibilities for the development of sea farming.

Open-range salmon ranching would seem an excellent prospect for the Columbia Estuary, and the shallow flats and the channels of Baker Bay should be investigated for the possibility of other types of brackish-water sea farming.

Willapa Bay already supports an extensive oyster farming industry. However, the water quality so vital to the industry is being threatened by the seepage of groundwater contaminated by the rapid increase in the number of septic tanks associated with new residential developments. A hard look at the adequacy of existing zoning regulations and authority is sorely needed.

The present condition of Grays Harbor resulting from extensive industrial development would prevent serious consideration of this area for aquaculture. However, if pollution abatement is eventually successful in restoring the quality of its waters, consideration could be given to the establishment of sea farming in areas not given over to port and industrial facilities.

Potential impact of sea farming on Washington's economy

The report prepared by Crutchfield and MacFarlane[5] for the Department of Fisheries, State of Washington, on an economic valuation of the 1965-1966 salt-water fisheries of Washington was used as a guide in estimating the potential impact of aquaculture on Washington's economy. For commercial undertakings, the above report shows that a substantial net addition to State incomes result from the activities of Washington's fishing industry:

> "Its products are largely shipped out of the State, and since only minor amounts of goods and services must be imported from other areas to support the industry, it provides a very substantial net inflow of money payments to Washington residents."[6]

Their estimated net addition to State incomes of $43.8 and $48.6 million for years 1965 and 1966 respectively, represent an average 94 percent of the total wholesale value of Washington's fishery products for those years.

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5. James A. Crutchfield and Dougald MacFarlane, Economic valuation of the 1965-1966 Salt-water Fisheries of Washington, Res. Bull. No. 8, State of Wash., Dept. Fish., at 55 (Dec. 1968).

6. Id.

Even by discounting the processing values added to imported fish, we arrive at an average of approximately 90 percent of the total wholesale value of Washington's fishery products as respresenting net addition to State incomes. For sea food production from mariculture in Washington, this implies (assuming that it is an economical operation) that for every wholesale dollar of aquaculture products, about 90 cents would be net inflow of money payments to Washington residents.

Pen-reared salmon

Studies in progress by the National Marine Fisheries Service (NMFS) show the feasibility of rearing coho salmon to "plate" size in salt-water pens located in Puget Sound, Washington. Currently, private ownership of living salmon is illegal. Although markets are not as yet developed, as this is a new concept and product, marketing personnel of NMFS indicate its possibilities whether as a new market or in competition with the fresh-water trout market. For the latter, United States production of trout is currently estimated at 10 million pounds annually,[7] of which 6.6 million pounds goes for human consumption. United States import of trout during the past decade (1960-69) has been around 3.9 million pounds annually.[8] Wholesale prices of domestic trout (dressed form) range from $.75 to $1.30 per pound depending on locale and whether it is priced at the production plant or distribution point. The wholesale price of imported trout (dressed form) was reported as ranging from $.43 to $.57 per pound to large retail, and chain stores and up to $1.05 per pound in Los Angeles.[9]

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7. Personal communication, NMFS, Branch of Marketing, Seattle, Wash.
8. See supra note 4.
9. See supra note 7.

Demand is a complex interaction of price, income, quality of the product, available substitutes, and the like. However, let us assume a consumer appeal associated with the new product, salmon-trout, and an a priori potential for its marketing. What is the outlook and its potential impact on Washington's economy? As an example, preliminary studies by NMFS indicate that there are approximately 20 miles of suitable culture areas for salmon-trout in middle Puget Sound alone. Also, studies show production possibilities of 1 pound of salmon-trout per cubic feet of water with flows of .05 to .50 knots.

Assume, hypothetically, that a 1/4 mile long (1,320 feet), by 500 feet wide, by 20 feet deep area in middle Puget Sound is zoned and developed for salmon-trout culture. This alone represents 13.2 million cubic feet of water, or a general potential of 13.2 million pounds of salmon-trout in little over a year. Assuming a 75 percent recovery of edible parts from a whole fish, and at a heads-on, dressed wholesale price of $0.75 per pound for salmon-trout, this is a potential of $7.4 million in total wholesale value of which approximately $6.7 million (7.4 million x .90) would be net inflows of money payments to Washington residents in the year sold from this enterprise. In addition to additional income generated by this enterprise, direct labor requirements for 13.2 million pound production is expected to be around 212 positions not including administrative requirements.

Raft oyster-culture

Oyster production in the State of Washington is primarily from natural bed oyster cultures at this time. The raft culture method (as practiced extensively in Japan, for example) is not employed to any degree in the State although preliminary indications are that per area production is superior with the raft method. The report by Westley indicates a potential raft oyster-culture acreage in Greater Puget Sound along of 187,408 acres. Analysis by NMFS personnel of a 5.5 acre, raft oyster-culture enterprize currently operating in Puget Sound show a per acre, per year production of 3,960 bushels (or 34,650 pounds of meat).[11] The raft-culture enterprise investigated showed very high returns on investments.

The impact of any expanded raft oyster-culture on the traditional (natural bed) oyster fisherman of the State is not known at this time. How their welfare may be affected will be an important consideration. For simplicity, and for this report, however, we are assuming no conflict between the traditional and potential (raft) methods.

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10. Ronald E. Westley, The Oyster Producing Potential of Puget Sound, Wash. St. Dept. Fish., Res. Div., August, 1967. 13 p.

11. Generally, one bushel of oyster = one gallon of meat = 8.7 pounds of meat. Per acre estimates are: 3,960 bushels = 3,960 gallons = 34,650 pounds of oyster meat.

For the raft method, at a price of $3.00 per bushel, an acre has a annual potential of $11,880 gross value to the grower. Add to this the processing value of approximately 240 percent of the value to the grower, as estimated from the data of Crutchfield and MacFarland, then gives an average expected wholesale value of $40,392. Assuming everything being equal and constant, and that the raft method is an economical operation, what is the potential impact on Washington's economy if 1 percent of the potential acreage reported (187,408) was put into production? The 1,874 acres could yield 7.4 million bushels per year (or 64.9 million pounds of meat) and of an average price, say, of $3.00 per bushel would mean $22.2 million to growers and $75.5 million at the wholesale level. The net addition to State incomes from this represents a potential $68.0 million. The direct labor requirement for 1874 acres would be around 1,500 full time positions and about 750 additional positions would be added through seasonal employment.

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12. See supra note 5 at 20.

Mussel culture

Mussels are not harvested nor consumed to any degree in the United States. They are, however, cultured extensively in Europe and consumed there. Preliminary studies by NMFS personnel indicate the potential of cultured mussel as an alternative and more stable supply for the developing marine or fish protein concentrate (FPC) market.

Based on Spanish production method (raft culture) and estimates, the indications are that mussel production from 116 acres in Puget Sound, for example, can supply 76,900 tons of whole mussels to a 5,000 ton mussel protein concentrate (MPC) capacity plant in a year. Assuming that the operation is economical, the 5,000 tons of MPC at a wholesale price of $500 per ton means a total wholesale value of $2.5 million of which $2.2 million would be net inflow of money payments to Washington residents. The direct labor requirements for 76,900 tons or 116 acres would employ around 768 people.

Other products

With further research and technological developments, in context of proper social, economic, and political climates, many other species of fish, shellfish, and aquatic plants may present opportunities for sea farming (e.g., trouts, scallop, clams, shrimp, laver , etc.). If new aquaculture activities result in products which are consumed primarily out of the State of Washington, then each enterprise would be contributing substantial net inflows of money to the State.

In the area of recreational harvest, the development of "nurseries" to provide seed stock for sale to the public may be a potential worthy of consideration.

Potential Economic Impact

The potential economic impact has been considered for development of only three possible sea farming products. Even for these three examples, production from only a small part of available water resources was considered in order to indicate potential employment and income opportunities. The total potential obviously is much larger if full development is justified by market demand.

In addition to the direct employment and income generated by sea farming, this would also result in further expansion of probably more than double this amount through induced income and employment that results indirectly through business purchases of production inputs and consumer spending of additional income. Pen-reared salmon, for example, would add significantly to the demand for feed and thus employment and income in this industry. This in turn could increase the demand for other fish products used in producing feed for pen-reared salmon and consequently--add to income for fishermen.

The greatest initial impact on the State's economy may be in new income with a smaller initial impact on employment. To the extent that any slack exists in present facilities, expanded production will increase the use of existing labor and capital resources committed to these industries which would add to income more than employment. Processing of pen-reared salmon, for example, may take place in existing facilities using currently employed labor or perhaps expand seasonal employment. To the extent that this occurs, the direct influence will be expanded income more than numbers employed. Indirectly, however, this would add to both employment and incomes through business and consumer purchases.

The preliminary estimates that have been pointed out are intended only to indicate the tremendous potential for improved income and employment opportunities that may be possible. Full realization of this potential depends on the sound growth of sea farming activities which in turn depends on adequate investment and development interest.

Institutional Restrictions Limiting Aquaculture

Continued development of aquaculture can be limited by institutional arrangements even though market demand and production technology are adequate to stimulate investment interest. Existing technology and preliminary research encourage continued interest in supplying an increasing share of the market demand through continued development of sea farming. This can provide substantial benefits for Washington's economy. In order to fully realize existing potential and increase interest in development of coastal waters, however, it is essential to eliminate institutional obstacles that may jeopardize further progress.

The issues involved in this problem can be viewed in two phases. First, the range of alternatives available. This involves determining the changes needed to encourage development of aquaculture and alternative methods of accomplishing these changes. Then, given these possible choices, what system will prove most satisfactory.

The range of possible choices is determined by the need to provide the characteristics of property rights in some form to encourage sound development of what are now common property resources. This is possible through various forms of tenure arrangements. The attributes of ownership are essential for development within our basic free enterprise economic system. They are also essential as the basis for public ownership and development, but this involves a different range of alternatives and may be more important for international resources.

Resource ownership operates through our market price system that provides the fundamental guide for our economy. Ownership can provide the incentive to develop water resources and encourage the investment needed to maintain and improve their value generating capabilities. Ownership also assures that the appropriate combination of productive inputs are used and stimulates adjustment to economic changes such as the development of new technology.

Exclusive resource control provides the incentive for development through assurance that the rewards of this effort will accrue to the developer. With this assurance, the value generating potential of the resource will be protected and improved. Control over the resource and exclusive rights to its use will be possible for many types of aquaculture (e.g., pen-raised salmon) through lease or other common tenure systems. For other types of sea farming, exclusive right will not be possible (e.g., "open-range" salmon aquaculture). Benefits from resource development may accrue to other sectors of society in this case. These benefits may provide abundant justification for development; and, at the same time, fail to provide adequate incentive for private enterprise to pay for development cooperation such as subsidies or tax incentives since benefits from development will accrue to society as well as to the private firm.

Effective resource improvement programs also require that benefits from the development effort accrue for sufficient duration to justify necessary investment. Existing technology indicates that large capital outlays will be necessary for private development and tenure arrangements will be required that will permit equity or debt capital to be provided for these investment programs.

In addition to assuring that benefits accrue to the owner, and do so for an adequate time to justify investment in their improvement, resource control arrangements must also stimulate response to economic changes such as development of new technology. This requires flexibility in managing the resource and a tenure arrangement that encourages adjustments in production methods and inputs in response to new economic developments. Some land tenure arrangements such as share cropping, for example, failed to provide adequate incentive for capital investment by either tenant or landlord since the reward did not accrue in proportion to the required investment. Tenure arrangements for sea farming need to assure that optimum production efficiency will not be restricted through inability to use the correct combination of production inputs and the appropriate production method.

For products where exclusive control can be provided, the major concern should be focused on providing tenure arrangements that are sufficiently long to support needed investment, flexible enough to assure efficient production, and are consistent with multiple use objectives of publicly-owned water resources. If exclusive control over the product is not possible, then some type of public-private cooperation will be necessary to encourage development.

Alternative methods will usually be available for accomplishing, as far as possible, the combined objectives of the tenure arrangement. Leases can limit the amount and quality of resources controlled, and can be provided for varying periods of time. Subsidies can be used to encourage desired development and taxes to restrict unwanted development. The following examples indicate how the choice among possible alternatives may affect future development.

1. The economic structure of the industry (e.g., numerous small firms or a few large units).
2. Efficiency of production (i.e., full utilization of new technology may require large amounts of capital that would be available only with relative long-term claims to production sites).
3. Who will receive the benefits from these water resources (i.e., consumers, producers, processors, general public through improved food supplies, higher income, or employment, etc.).
4. How coastal waters are managed (e.g., through taxes, subsides, leases).
5. Relationship with other water uses (e.g., pollution control, recreational use).

The methods used to encourage private development of coastal water resources will affect the division of benefits that are generated by these resources. These benefits may be solely to the developers, partially to society in general (e.g., taxes or lease income), or benefit particular sectors (e.g., the fishing industry or improved recreational opportunities). The tenure arrangement must encourage sound development and efficient production if this is to be eliminated as an obstacle to full use of water resources. At the same time, tenure arrangements must be consistent with multiple use objectives and provide the desired division of benefits from development of coastal water resources.

Summary and Conclusions

Market demand should be the basic guide for production through sea farming. Market demand appears to be adequate to justify immediate interest in production of some high value products and to support continued interest in a broad range of other possible products.

Existing technology and current research also encourages continued interest in supplying an increasing share of the market from Washington's coastal waters. Market demand and production technology are closely related since new technology can reduce production costs and with adequate competition market price. This in turn will increase the quantity that consumers will purchase.

Continued development of Washington's coastal waters through aquaculture can have an important impact on the State's economy through additional income generated and expanded employment opportunities. A large direct impact initially may be recorded in increased income, but employment opportunities may also be substantially increased.

Institutional restraints may be the most important barrier limiting full development of these coastal water resources. Control over the resource is needed to stimulate development. This must be sufficiently permanent to justify necessary investment. Tenure arrangements must also provide adequate flexibility to assure the use of efficient production methods. Where resource control can not be exclusive, some form of public-private cooperation may be essential. These are the characteristics that need to be considered for development by private enterprise. The methods used to accomplish these objectives will influence who receives the benefits from developing coastal water resources, the extent of development that takes place, and how sea farming is associated with other uses of coastal water resources.