ECONOMIC FEASIBILITY OF DOMESTIC GROUNDFISH HARVEST FROM WESTERN ALASKA WATERS: A COMPARISON OF VESSEL TYPES, FISHING STRATEGIES, AND PROCESSOR LOCATIONS

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ABSTRACT

An economic model relating fishing costs to vessel characteristics and operating conditions was used to estimate the costs and benefits to U.S. fishermen of harvesting groundfish under a variety of conditions. Comparisons were made between 1) two vessel types, 2) two modes of operation: delivering to a floating processor and delivering to a shore-based processor, and 3) three fishing strategies in Alaskan waters.

Fishing costs were about 50% less and fuel efficiency was 28% higher for the smaller of the two vessels. Costs for either vessel decreased by 30% and fuel efficiencies increased by 35% when delivering the catch to a floating processor rather than delivering to port. Cost estimates for both sea delivery and port delivery were sensitive to changes in fuel price. A $0.026/l ($0.10/gallon) increase in fuel price increased the break-even ex-vessel prices by $6/t for sea delivery and $8/t for port delivery in one example.

Given the ex-vessel prices currently offered by two joint venture firms and a fuel price of $0.277/l ($1.05/gallon), break-even catch rates were calculated for each vessel type and targeting strategy, assuming sea delivery. All of the catch rates were considered highly feasible when compared with the average catch rates of foreign trawlers and experimental U.S. fisheries in the area. Assuming similar prices were offered by shore-based processors, the break-even catch rates, although higher than under the sea delivery mode, were still considered feasible. However, the margin for profit is narrower and could be negative with increases in fuel price.

Since the implementation of the U.S. 200 mi economic zone (public law 94-265, 13 April 1976), a great deal of interest has been generated by the large stocks of groundfish off the western Alaska coast. The combined annual optimum yield of walleye pollock, *Theragra chalcogramma*; Pacific cod, *Gadus macrocephalus*; sablefish, *Anoplopoma fimbria*; flatfish, and rockfish from the eastern Bering Sea, Aleutians, and western Gulf of Alaska (Kodiak Island westward; Figure 1) has been estimated to be over 1.6 million t (North Pacific Fisheries Management Council 1978a, b). In perspective, this potential is equivalent to 58% of the total 1978 U.S. commercial landings of all species from all areas (U.S. Department of Commerce 1979). Although the Fisheries Conservation and Management Act of 1976 grants preference to U.S. harvesters over foreign fishing fleets, a domestic trawl fishery for groundfish has been slow to develop, and the precise set of conditions necessary to stimulate growth has been a topic of considerable concern (Sullivan and Heggelund 1979; Gorham[2]; Little[3]; Alaska Fisheries Development Foundation[4]; Combs[5]).

In this paper I demonstrate the utility of an economic model which estimates fishing costs based on vessel characteristics and operating conditions. The model is used to predict the fishing costs and the catch rates required to cover costs under conditions that are likely to occur during future domestic groundfish harvests from western Alaska. These catch rates are then compared with actual catch rates observed in foreign and experimental domestic fisheries in the area. In this way I seek to contribute to the development of an appropriate methodology for evaluating the economic feasibility of domestic groundfishery expansion in Alaska.

[1]Center for Quantitative Science in Forestry, Fisheries, and Wildlife, University of Washington, Seattle, WA 98195.

[2]Gorham, A. H. 1978. Interim report on an investigation of joint U.S./foreign ventures in the developing commercial fishery off Alaska, 12 p. Submitted to the North Pacific Fishery Management Council.

[3]Little, A. D. 1978. The development of a bottomfish industry: Strategies for the State of Alaska, vol. 1, 33 p.

[4]Alaska Fisheries Development Foundation. 1978. Development proposal for bottomfish off Alaska, 37 p.

[5]Combs, E. R. 1979. Prospectus for development of the United States fisheries. Alaska groundfish, p. 25-112, 327-362. Prepared for Fisheries Development Task Force, NMFS, NOAA.

Manuscript accepted November 1980.
FISHERY BULLETIN: VOL. 79, No. 2, 1981.

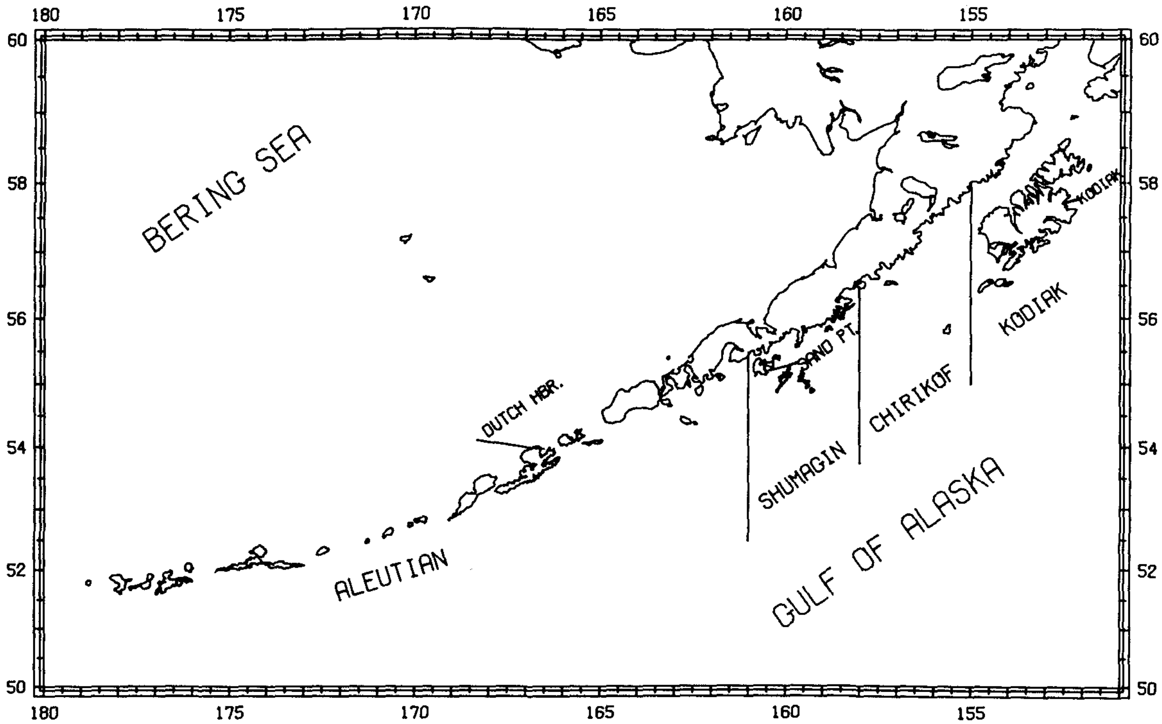

FIGURE 1.—Western Gulf of Alaska and eastern Bering Sea and selected International North Pacific Fisheries Commission areas.

In addition, an economic model such as the one described in this paper may be helpful to fishermen considering future diversification. The model could be easily adapted for use with a programmable calculator or onboard microcomputer. After tailoring the parameters to his vessel, the vessel owner need only key in a few pertinent variables such as expected ex-vessel price, distance to the fishing ground, and fuel price and receive an immediate estimate of the average catch rate required to cover his expenses.

One advantage of the modeling approach is that it allows one to examine the effects of individual factors of interest by allowing these factors to vary while holding all others constant. This paper examines the effects upon fishing costs and fuel efficiency (fish harvested per fuel consumed) of the following factors: vessel type, processor location, fishing strategy, and fuel price. Costs and benefits are estimated only within the harvesting sector. A consideration of economic feasibility within the processing and marketing sectors of the industry is beyond the scope of this paper.

THE ECONOMIC MODEL

Given a set of operating conditions, such as distance to the fishing grounds and number of crew required, a set of vessel characteristics, such as cruising speed and hold capacity, as well as a schedule of capital expenses, such as the vessel's initial value and finance rate, the model projects the costs of a single fishing trip and computes a set of catch rates and corresponding ex-vessel prices required to balance fishing costs with net revenue.

Assuming the crew (including skipper) receives shares of the revenue as remuneration, the benefit (B_{ij}) to the vessel owner of a single fishing trip is simply:

$$B_{ij} = (1 - S_{ij}) \cdot U \cdot P$$

where S_{ij} = total crew shares (expressed as decimal fraction) for the ith vessel type and jth mode of operation, U = total catch, and P = ex-vessel price.

Fishing costs are commonly categorized as fixed or variable. Fixed annual costs are invariate with respect to the amount of vessel use per year. Using the subscripts i and j as before, the fixed annual costs can be prorated over the length of the fishing trip, allowing for yearly down time due to bad weather, maintenance, and vacations, according to the formula:

$$F_{ij} = [T_{ij}/(365 - D_i)]A_i$$

where F_{ij} = fixed costs per trip, T_{ij} = length of trip in days, D_i = total inoperative days per year, and A_i = annual fixed costs.

Assuming the crew pays a share of certain variable costs, the total fishing costs (C_{ij}) incurred by the vessel owner per trip can be expressed as:

$$C_{ij} = F_{ij} + V_{ij} + (1 - S_{ij})W_{ij}$$

where V_{ij} = variable costs incurred only by vessel owner and W_{ij} = variable costs incurred by owner and crew.

Setting benefits equal to costs and solving for ex-vessel price gives:

$$P = \left[\frac{F_{ij} + V_{ij}}{1 - S_{ij}} + W_{ij}\right] \frac{1}{U}. \qquad (1)$$

This equation defines the ex-vessel price, P, required to break even for a fishing trip with catch rate U. Conversely, Equation (1) can be used to compute the catch rate required to break even for a fishing trip when the ex-vessel price is P. A computer program (TRAWL)[6] was written to calculate solutions for P over a range of catch rates for a given vessel type and mode of operation.

A tacit assumption has been made that the criterion for economic feasibility of a fishery is met if a fisherman can receive enough revenue to balance the variable and fixed costs of fishing. In fact, if the vessel and gear already exist and no other more profitable fisheries are available, it will be economically advantageous for the fisherman to enter the fishery in question if it provides enough revenue to cover variable costs alone, since the fixed costs will be incurred whether fishing or not. However, the objective of this paper is to examine the conditions under which the fisherman can cover both fixed and variable costs.

The model relies on a number of assumptions which relate fishing costs to the vessel type and the mode of operation. Table 1 lists these assumptions according to a cost accounting format similar to that suggested by Smith (1975). A description of the cost derivations and the sources of their estimates can be found in Appendix I. Note that, unlike Smith's cost accounting procedures, the average annual cost of financing is included here as a fixed cost. Variable costs IIB-D (Table 1), represented in total by symbol W_{ij} in the above development, are commonly deducted from the gross revenue before the crew shares are taken. Fixed costs IA-F and variable costs IIA are in turn represented by symbols A_i and V_{ij} above. Crew

[6]Written in Fortran IV. A program listing and user's guide are available from the author on request.

TABLE 1.—Fixed and variable fishing costs as a function of vessel characteristics and operating conditions.

Cost category	Parameter values and variables
I. Fixed annual costs:	
A. Routine boat and engine maintenance	\$0.07 × vessel's initial value (VIV)
B. Insurance:	
1. Hull	0.021 × VIV
2. P & I	2,100.0 × no. in crew
C. Depreciation	0.0533 × VIV
D. Association dues	2,500.0
E. Contingencies/miscellaneous	0.05 × (above total)
F. Average annual finance cost n = no. of payment periods i = interest rate per period	$1.0 \times \text{VIV} \times \left[\frac{\text{\% financed}}{\text{yr financed}}\right] \times \left[\frac{ni(1+i)^n}{(1+i)^n - 1} - 1\right]$
II. Variable costs:	
A. Fishing gear repair and replacement (see Append. I)	\$1.0 × gear costs/h × towing h
B. Fuel:	
1. Cruising	0.2105 × horsepower × travel h × fuel price/l
2. Towing	0.1579 × horsepower × towing h × fuel price/l
3. Stove and auxiliaries	30.283 × trip h × fuel price/l
4. Lube oil	0.235 × trip h × price/l
C. Food	13.50 × trip d × no. in crew
D. Ice	$25.00 \times \frac{\text{capacity for groundfish (wt)}}{1 + (\text{fish:ice wt ratio})}$

shares, composing S_{ij}, are assumed to be 12% for the skipper and 7% for each additional crew member.

FACTORS OF INTEREST

Vessel Types

Two representative vessel types were considered: a 33 m (108 ft) combination crabber/trawler and a 25-28 m (80-92 ft) bottom trawler or combination shrimp and groundfish trawler. These vessel types are thought to be representative of many of the U.S. vessels likely to participate in future western Alaska groundfish harvests.

The vessel characteristics and capital expenses for the two vessel types are listed in Table 2. The vessel characteristics are based on statistical analyses of vessels registered with the State of Alaska as performed by Katz et al.[7] The characteristics of vessel type 1 are average values for a group of combination crabber/trawler vessels fishing for king and tanner crab in Alaska (class 8.5 of Katz et al. (footnote 7)). Similarly, the characteristics of vessel type 2 are representative of a group of Alaska shrimp trawlers and smaller crabber/trawlers (class 8.3 of Katz et al.). Type 2 vessel characteristics are also believed to be representative of the larger groundfish trawlers of California, Oregon, and Washington. The capital expenses incurred by owners of these vessel types were estimated with the help of industry personnel (Pigott[8]; Jaeger[9]).

TABLE 2.—Vessel characteristics and capital expenses for two representative vessel types (see text).

Item	Vessel type 1	Vessel type 2
Vessel characteristics:		
Age, yr	1-2	5
Keel length, m (ft)	33 (108)	25-28 (80-92)
Engine type	Diesel	Diesel
Horsepower	1,000	650
Cruising speed, kn/h	11.5	10.0
Hold volume, m³ (ft³)	225 (8,000)	140 (5,000)
Capacity for groundfish, t	150	115
Capital expenses:		
Vessel's initial value, $	1,500,000	500,000
Amount financed, %	80	80
Annual finance rate, %	10	8.5
Amortization, yr	20	15
Payment period	Monthly	Monthly
Interest per period (i), %	0.7174	0.6821
No. of payment periods (n)	240	180

Processor Location and Mode of Operation

Two modes of operation were compared: delivering the catch at sea to a floating processor and delivering the catch to a land-based processor. The method of sea delivery is currently being employed by U.S. fishermen participating in two international joint fishing ventures for groundfish off the western Alaska coast. Under the arrangements of these joint ventures, the U.S. trawlers transfer their catch at sea via detachable cod ends to large floating processors provided by the foreign partner. The fish are then processed aboard the factoryships and the resulting product is taken to foreign ports and sold on the foreign market.

During the sea delivery mode of operation, it is assumed that: 1) the floating processor is on or near the fishing grounds, 2) fishing vessels have at least two cod ends so replacement after each haul is not delayed, 3) full cod ends are towed to the processor and empty cod ends are returned to the fishing vessel periodically by a motor launch, and 4) the processing rate of the factory vessel is not limiting.

Table 3 lists the estimated operating conditions for the sea delivery and land delivery modes of operation. Differences between the two modes are as follows:

TABLE 3.—Operating conditions for vessels harvesting groundfish from western Alaska. Delivering the catch at sea versus delivering to a land-based processor.

Item	Mode of operation: Sea delivery	Mode of operation: Land delivery
No. of crew required (including captain)	4	5
Maximum trip length:		
Vessel type 1	28	7
Vessel type 2	26	7
Fish:ice weight ratio (if applicable)	N.A.	2:1
Search time per trip, h	6	6
Towing time per day on grounds, h	9	9
Time spent in port replenishing supplies, refueling, and unloading	24	24
Distance to fishing grounds:		
Gulf of Alaska	75	75
Bering Sea:		
Walleye pollock or Pacific cod	65	65
Sole species	220	220
Gear costs per hour of towing:		
Vessel type 1	20.57	20.57
Vessel type 2	16.90	16.90

[7]Katz, P. L., K. C. Lee, L. J. Bledsoe, and J. Buss. 1976. The classification, enumeration, characteristics and economic performance of Alaska shellfish vessels. Part 1-Classification, enumeration and vessel characteristics. Norfish Tech. Rep. 61, 59 p.

[8]George M. Pigott, University of Washington, Department of Food Science, Seattle, WA 98195, pers. commun. December 1979.

[9]Sig Jaeger, President, North Pacific Vessel Owners Association, Fishermen's Terminal, Seattle, WA 98119, pers. commun. January 1980.

1) The maximum trip length when delivering at sea is limited only by the storage capacities for fuel, water, and supplies, while the maximum trip length when delivering onshore is limited by the iced storage life of the catch. In the first case, the maximum trip length has been estimated as 28 d for vessel type 1 and 26 d for vessel type 2. In the latter case, a 5-d storage life for fresh walleye pollock (Sea Fisheries Institute and National Marine Fisheries Service[10]) limits the trip to a maximum of 7 d (including time traveling to the grounds and time in port). At higher catch rates the actual trip length may be further limited by the hold capacity for groundfish and ice.

2) No ice is required when delivering at sea.

3) Fewer crew members are needed when delivering the catch at sea since no sorting or stowage of the catch is required. Jaeger[11] predicted that two fewer crew members would be required if delivering at sea. This proved true for at least one vessel owner participating in the joint venture for Pacific whiting (formerly known as Pacific hake) off the coast of Oregon during 1978 and 1979 (Fisher[12]). However, in this analysis, a conservative estimate of one fewer crew member has been adopted.

The search time, towing time, and the time in port have all been assumed to be the same for both modes of operation. The search time, or time spent prospecting for fish, and the time spent in port replenishing supplies, refueling, and unloading (if applicable) have been estimated to be 6 and 24 h, respectively. The towing time per day on the grounds has been taken to be 9 h after Jaeger (footnote 11). Again, these assumptions are conservative. If vessels delivering their catch at sea are fishing for a joint venture operation, the information sharing that is likely to occur may reduce the search time per trip. It has also been argued that the cod end transfer system employed in the sea delivery mode requires less rerigging time and therefore allows more towing time per day on the grounds (Fisher footnote 12).

[10]Sea Fisheries Institute, Gdynia, Poland, and National Marine Fisheries Service, Seattle, Wash. 1977. Preliminary report Gulf of Alaska research cruise. First leg, July 1977, 21 p.

[11]Jaeger, S. 1977. Presentation to the North Pacific Fishery Management Council on the subject of foreign joint ventures. August 5, 1977. Seattle, Wash.

[12]Barry Fisher, Vessel Owner/Operator, Newport, OR 97065, pers. commun. with R. Major, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, Seattle, WA 98112, November 1979.

Fishing Strategy

Three different fishing strategies were examined based on the following stocks as targets: Pacific cod and walleye pollock in the western Gulf of Alaska, walleye pollock in the Aleutian area, and sole, especially yellowfin sole, *Limanda aspera*, in the eastern Bering Sea. The distances to the fishing grounds are based on the locations of the nearest of the most productive foreign fishing locations during 1977 and 1978 (Smith and Hadley[13]). Table 4 lists these locations and their approximate distances to the nearest port.

Fuel Price

For most of the following comparisons the fuel price was taken to be \$0.277/l, which was the current price for no. 2 diesel fuel at Dutch Harbor as of the time of this writing (1980). A subsequent section details the sensitivity of cost estimates to increases in fuel price.

RESULTS

Delivering at Sea Versus Delivering to Port

At any given catch rate for vessel type 1, the break-even ex-vessel price when delivering to a floating processor is at least 31% lower than when delivering to port. For example, at a catch rate of 10 t/d on the fishing grounds, vessel type 1 would require an ex-vessel price of \$421/t to cover costs if unloading in port while requiring only \$290/t if transferring the catch at sea. A plot of the relationship between break-even price and catch rate [described by Equation (1)] for vessel type 1 operating in the Gulf of Alaska delivering to a floating processor (solid) and delivering to a land-based processor (dashed) is shown in Figure 2.

Similar results were obtained from the analysis of vessel type 2 operating in the Gulf of Alaska (Figure 3). Under the sea delivery mode of operation break-even ex-vessel prices are at least 33% lower than under the port delivery mode. At a catch rate of 10 t/d the required break-even prices are \$146/t and \$217/t for sea delivery and port delivery, respectively. These results are in general agreement with Jaeger's (footnote 11) analysis in

[13]Smith, G. B., and R. S. Hadley. 1979. A summary of productive foreign fishing locations in the Alaska region during 1977-78: trawl fisheries. Alaska Sea Grant Rep. 79-7, 287 p.

TABLE 4.—Foreign catches from western Alaska waters during 1977 and 1978. Source: Smith and Hadley (text footnote 13).

Nation	Predominant species	Location lat.	Location long.	Nearest port	Distance (nmi)
R.O.K.	Walleye pollock and Pacific cod	54°18′ N,	160°23′ W	Sand Point	75
U.S.S.R.	Walleye pollock and Pacific cod	56°30′ N,	152°30′ W	Kodiak City	75
Japan	Walleye pollock and Pacific cod	56°30′ N,	152°30′ W	Kodiak City	75
U.S.S.R.	Sole species	57°31′ N,	166°55′ W	Dutch Harbor	220
R.O.K.	Walleye pollock	53°25′ N,	166°15′ W	Dutch Harbor	65

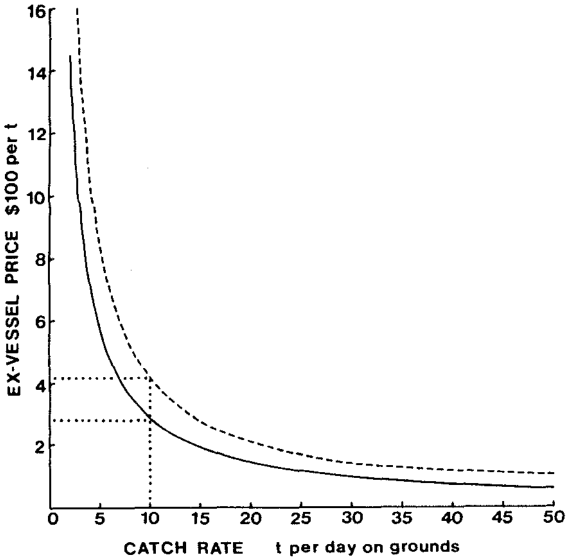

FIGURE 2.—Break-even price versus catch rate for vessel type 1, delivering to a floating processor (solid) and delivering to a shore-based processor 75 nmi from the fishing grounds (dashed). Dotted lines indicate required ex-vessel prices for a catch rate of 10 t/d.

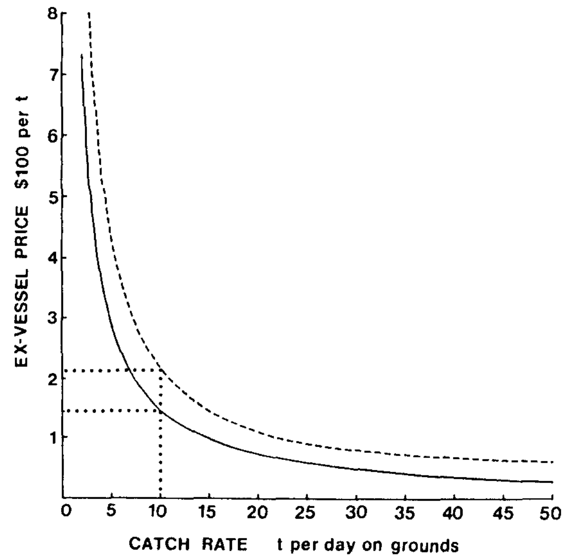

FIGURE 3.—Break-even price versus catch rate for vessel type 2, delivering to a floating processor (solid) and delivering to a shore-based processor 75 nmi from the fishing grounds (dashed). Dotted lines indicate required ex-vessel prices for a catch rate of 10 t/d.

which it was found that ex-vessel prices under the sea delivery mode could be 50% less than under the port delivery mode and still yield the same profit to the fisherman.

Another criterion for comparing harvest methods is the weight of whole fish harvested per volume of diesel fuel consumed, hereafter referred to as the fuel efficiency. At a catch rate of 10 t/d the fuel efficiency for vessel type 1 is 3.2 kg/l if delivering to port and 4.3 kg/l if delivering at sea. For vessel type 2 fuel efficiencies at 10 t/d are 4.0 kg/l and 5.5 kg/l for port and sea delivery modes, respectively. Thus, the fuel efficiencies increase by 34% (vessel 1) and 36% (vessel 2) under the sea delivery mode.

If the expected average catch rate is high (> 29 t/d for vessel 1 or >22 t/d for vessel 2), then the relative advantages of sea delivery increase since the hold capacity becomes limiting under the port delivery mode.

Comparison of Vessel Types

Based on the above results, it can be seen that the break-even price required by vessel type 2 is about 49% less than that required by vessel type 1, given the same catch rate. Alternatively, for any given ex-vessel price, the catch rate required by vessel type 1 to cover costs is about twice as high as that for vessel type 2. Furthermore, fuel efficiencies for the second vessel type are about 28% higher than those of vessel type 1.

Sensitivity to Changes in Fuel Price

The effect of changes in the price of fuel upon the relationship between the break-even price and catch rate will now be examined. For a given set of vessel characteristics and operating conditions, the fixed and variable costs are constant over a range of catch rates (assuming hold size is not limiting) and Equation (1) can be reduced to:

$$P = \frac{C_1}{U} + \frac{C_2 D}{U} \qquad (2)$$

where C_1 and C_2 are constants (C_2 = volume of fuel consumed), D = fuel price, P = break-even ex-vessel price, and U = total catch. Thus, the effect of the price of fuel upon the break-even ex-vessel price depends upon the catch rate and, of course, the vessel type and mode of operation. Once again using 10 t/d as a point of reference, Equation (2) predicts that for each \$0.026/l (\$0.10/gal) increase in the price of fuel, a \$6/t increase in the break-even ex-vessel price results (vessel type 1, delivering at sea, distance = 75 nmi). The same increase in fuel price for vessel type 1 unloading in port results in an \$8/t change in the break-even ex-vessel price. An equivalent increase in fuel price for vessel type 2 results in \$5/t and \$7/t increases in the break-even ex-vessel price for the sea delivery and land delivery modes, respectively. Thus, any estimates of economic feasibility will be moderately sensitive to changes in fuel price.

Comparison of Fishing Strategies

In the above comparisons, the distance from fishing grounds to the nearest port was fixed at 75 nmi, which is the expected distance if targeting on Pacific cod and walleye pollock in the western Gulf of Alaska. For the two alternative strategies, targeting on walleye pollock in the Aleutians area and targeting on yellowfin sole in the eastern Bering Sea, the expected distances are 65 and 220 nmi, respectively (Table 4). Accordingly, the model was run and Equation (1) was solved for a range of catch rates using these latter distances.

Figure 4 shows the ex-vessel prices required by vessel 1 under both modes of operation when the distance is 65 nmi and when the distance is 220

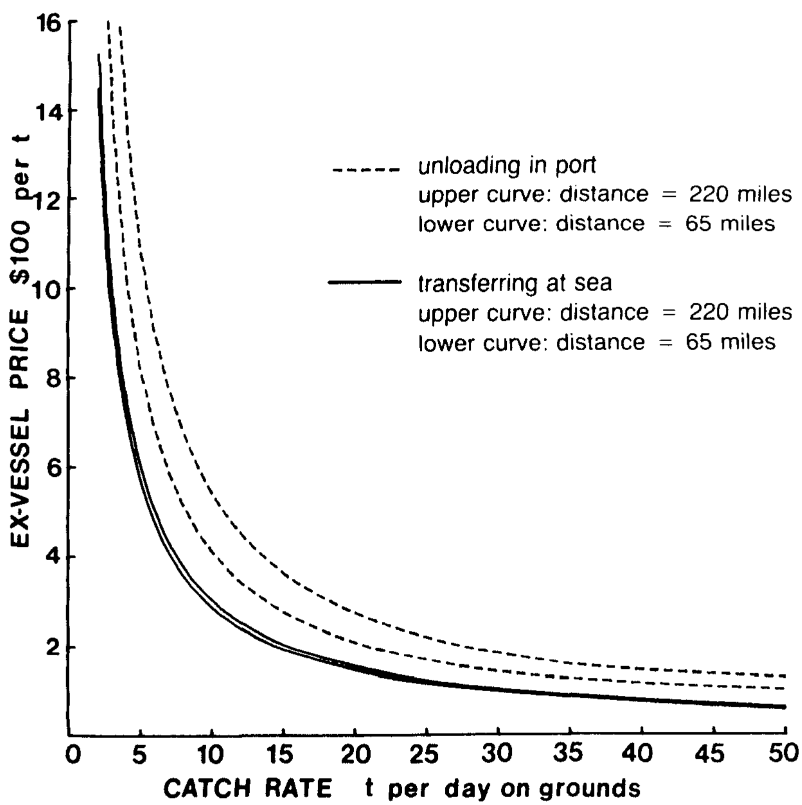

FIGURE 4.—Break-even price versus catch rate for vessel type 1, sea delivery and shore delivery, for distances of 65 and 220 nmi to the nearest port.

nmi. Similar curves result for vessel 2. It can be easily seen that under the port delivery mode a large increase in break-even price results from increasing the distance from 65 to 220 nmi (at 10 t/d these prices are \$414/t and \$545/t, a 32% increase). Under the sea delivery mode, however, the increased distance results in only a 6% increase in price (\$289/t to \$305/t at 10 t/d). Thus, any estimates of feasibility for the sea delivery mode are liable to be insensitive to changes in the distance to the fishing ground.

Feasibility of Groundfish Harvest

Table 5 lists the average species composition of the catches of three U.S. vessels fishing for two joint venture corporations in the Gulf of Alaska during 1979 and presumably targeting on Pacific cod and walleye pollock. In addition, the species composition obtained by Soviet factory trawlers targeting on sole in the Bering Sea and Korean factory trawlers targeting on walleye pollock in the Aleutians during 1978 is given (National Marine Fisheries Service[14]). Also listed in Table 5 are the ex-vessel prices offered by one of the joint venture firms as of the end of 1979. If U.S. trawlers catch the same species mix and receive the same prices, the expected average ex-vessel price per metric ton will be \$169 if targeting on Pacific cod and walleye pollock, \$217 if targeting on sole, and \$121 if targeting on walleye pollock. Table 6 presents the average catch rates, as predicted by the model, which would allow owners of vessel types 1 and 2 to break even, given the expected ex-vessel price and operating conditions for each of the three targeting strategies. I would now like to determine if these catch rates are feasible. Unfortunately, since the trawl fishery for groundfish in western Alaska is new to U.S. vessels, there is a paucity of U.S. commercial catch rate data.

Although the average catch rate for the three U.S. vessels fishing for joint ventures in 1979 was not available, a single U.S. vessel (25 m in length) fishing experimentally for one of the joint venture companies in the Shumagin area during 1978 averaged 11.8 t/d on the grounds. This vessel fished for only a short period, but the catch rate steadily increased from 4.8 to 22.3 t/d as the weather improved and experience was gained (Ely[15]). In light of these results, the catch rates of 17 and 9 t/d required by vessel types 1 and 2, if targeting on Pacific cod and walleye pollock and delivering to a floating processor, are considered feasible. Even the catch rates of 25 and 13 t/d required by the same vessels if landing their catch in port may be feasible; however, the vessel owner's margin for profit (if any) is substantially reduced. Again, these catch rates are fairly sensitive to the price of fuel (considered here to be \$0.277/l). An increase in the price of fuel to, say, \$0.528/l (\$2.00/gal) without a subsequent increase in groundfish prices, would lead to required catch rates of 21 and

[14]National Marine Fisheries Service, Foreign Observer Department. 1980. Unpubl. manuscr., n.p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, Seattle, WA 98112.

[15]R. C. Ely, American Fisheries Corporation, Anchorage, AK 99503. Report on progress of the KMIDC/Davenny pollock joint venture in the Gulf of Alaska. Report given to the North Pacific Fishery Management Council in public hearings. November 30, 1978.

TABLE 5.—Recent ex-vessel prices offered by a joint venture corporation and average species composition and average catch rates of groundfish taken by: 1) U.S. vessels fishing for joint ventures in the Gulf of Alaska during 1979, 2) Soviet factory trawlers fishing in the eastern Bering Sea during 1978, and 3) Korean factory trawlers fishing in the Aleutians area during 1978. Source: National Marine Fisheries Service (text footnote 14).

Species	Ex-vessel price	Percentage composition		
		U.S.	U.S.S.R.	R.O.K.
Walleye pollock	\$132	38.5	4.1	84.2
Pacific cod	187	47.0	2.1	5.1
Sole[1]	242	5.0	85.9	0
Rockfish	308	6.0	0	.1
Others	—	3.5	7.9	10.6
Catch rate, t/d		11.8	43.2	61.0

[1]Yellowfin sole and Alaska plaice.

TABLE 6.—Expected ex-vessel prices and required break-even catch rates by target strategy, vessel type, and mode of operation.

Target species	Area	Price/t	Vessel type	Required break-even catch rate (t/d on grounds)	
				Sea delivery	Land delivery
Pacific cod and walleye pollock	Gulf of Alaska	169	1	17	25
			2	9	13
Sole species	Bering Sea	217	1	14	25
			2	7	14
Walleye pollock	Aleutian Islands	121	1	24	37
			2	12	17

12 t/d for the two vessel types if delivering at sea and 30 and 17 t/d if delivering to port.

The catch rates that can be expected by U.S. groundfish trawlers operating in the Bering Sea and Aleutians are even more nebulous. The Soviet trawlers targeting on sole in the Bering Sea during 1978 were much larger (76-89 m, 2,000 hp) than the U.S. trawlers under consideration (Pruter[16]). However, much of the factory trawler's size is devoted to supporting crews of 87-96 for periods up to 90 d at sea. In addition, these vessels must have space for large processing and storage facilities. The U.S. vessels, on the other hand, with crews of four or five and no processing facilities, are more efficient for their size as catchers. Therefore, the break-even catch rates of 14 and 7 t/d for vessel types 1 and 2 targeting on sole and delivering to sea seem quite feasible when compared with the Soviet's average of over 43 t/d. Even though the catch rates required if delivering to port (25 t/d for vessel type 1, 14 t/d for vessel type 2) are nearly twice as high as required when delivering at sea, they still may be considered feasible when compared with the average Soviet catch rate.

If instead, U.S. trawlers similar to types 1 and 2 target primarily on walleye pollock in the Aleutians as did large Korean factory trawlers (89-111 m, 3,500-6,000 hp, Pruter footnote 16) the U.S. vessels would require catch rates of approximately 24 and 12 t/d if delivering at sea. The corresponding catch rates if delivering to port are 37 and 17 t/d. Although these catch rates are higher than under the previous strategies, they may be feasible considering the high availability of walleye pollock in the area. In fact, none of the above catch rates can be considered unfeasible since the average Korean catch rate in the Aleutian area exceeded 61 t/d.

DISCUSSION

Recently a number of events have occurred which have made fishing for groundfish in western Alaska relatively more attractive.

1) A market for potentially large quantities of groundfish has developed with the initiation of the two international joint ventures in western Alaska.

2) Groundfish markets in California, Oregon, and Washington have been erratic and prices have been generally low (Sorensen[17]).

3) Vessel profits from the western Alaska shellfisheries have decreased due to:

   a) declining abundance of pandalid shrimp (Jackson et al.[18]) and snow crab stocks (Somerton[19]),
   b) a drop in the ex-vessel price for king crab from $2,460/t ($1.23/lb) in 1978 to $1,720/t ($0.86/lb) in 1979 (Browning[20]), and
   c) expansion of the king crab fleet (from 60 boats in 1977 to 226 in 1979) leading to shortened seasons and reduced average vessel shares of the relatively constant quota.

The results of this analysis indicate that given a market with ex-vessel prices similar to those being offered by the joint venture firms, U.S. fishermen may currently find it economically attractive to participate in a trawl fishery for groundfish in western Alaska. In fact, some 23 vessels are committed to fish for the joint venture operations in western Alaska during 1980 (Blackburn[21]). It would seem, from this analysis, that operators of vessels similar to vessel types 1 or 2 can currently cover both fixed and variable costs given the above ex-vessel prices whether delivering at sea or delivering to port. However, the profits if delivering to port would be less. To equal the vessel profits under the sea delivery mode, land-based processors would have to offer ex-vessl prices at least 45% higher than those offered at floating processors would have to offer ex-vessel prices at least delivering at sea should increase with increased fuel costs. As fuel prices increase, owners of larger vessels with high horsepower, such as vessel type 1, will have a harder time making a profit in a western Alaska groundfish trawl fishery than owners of smaller vessels such as type 2.

This paper has not examined the economic feasibility of domestic processors. However, since

[16]Pruter, A. T. 1980. Preliminary analysis of data obtained by foreign fishery observers in 1978. Processed Rep. 80-7, 58 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, Seattle, WA 98112.

[17]Sorensen, S. 1979. Statement to the International Trade Commission. Reprinted in Alaska Fisherman's J. 2(12):20-21.

[18]Jackson, P. B., P. Holmes, A. Spalinger, and J. Nickels. 1979. Shrimp research. *In* Westward Region Shellfish Report to the Alaska Board of Fisheries, April, 1979, p. 216-242. Alaska Dep. Fish Game, Kodiak.

[19]Somerton, D. 1979. A reappraisal of the declining trend of recruitment to the Bering Sea stock of tanner crab (*Chionoecetes bairdi*). Norfish Tech. Rep. 92, 16 p.

[20]Browning, R. 1979. Crab season cut short as Bering boats fill quota. Natl. Fisherman 60(8):11.

[21]Blackburn, C. 1979. Plans progress for KMIDC fish purchases. Kodiak Daily Mirror 39(185):1-3.

U.S. fishermen are restricted by law to using only U.S. built vessels for fishing related activities, any domestic floating processors are likely to be either new vessels or extensive conversions, both of which may be cost prohibitive. On the other hand, distant water fishing nations, faced with increasing area and quota restrictions, may have factory vessels which are receiving less than optimal use (Kaczynski and LeVieil[22]). For this reason, international joint fishing ventures may be the only viable option for potential domestic groundfish trawlers in western Alaska in the near future. Although it has been argued that international joint fishing ventures may hinder the development of domestic land-based processors (Sullivan and Heggelund 1979), and the long-term net benefits to the domestic industry as a whole may be negative (Gorham footnote 2), the immediate benefits to the U.S. fishermen involved are positive.

CONCLUSIONS

On the basis of the economic model and assumptions applied in this study it was shown that:

1) Delivering the catch at sea via detachable cod ends is more economically efficient for U.S. fishermen than landing the catch in port. This is particularly true of fisheries for species with high spoilage rates, such as walleye pollock. The cost savings in this analysis amounted to over 30% and derive primarily from the following factors:

a) Fewer crew members are required when delivering the catch at sea.
b) A much higher percentage of the season can be devoted to trawling time when delivering to a sea-based processor.
c) Less fuel per season is spent running back to port, thus the fuel efficiency is greater when delivering the catch at sea.

These cost savings apply whether fishing for an international joint fishing venture or delivering the catch to a domestic floating processor.

2) Increasing the distance to the fishing grounds, while largely affecting the economic efficiency if delivering to port, had little effect if delivering at sea.

3) The relationship between catch rate and break-even ex-vessel price is sensitive to increases in fuel price for both the sea delivery and land delivery mode of operation. However, it is slightly less critical for the sea delivery mode. Each increase of $0.026/l ($0.10/gal) should lead to an increase of $6/t in the break-even ex-vessel price for a vessel similar to type 1 delivering at sea (distance to grounds = 75 nmi) and averaging 10 t/d. For the same vessel delivering to port, such an increase in fuel price should lead to an increase in $8/t in the required ex-vessel price.

4) Fuel efficiencies (weight of fish caught per volume of fuel consumed) were 28% higher for vessel type 2 (25-28 m) than for vessel type 1 (33 m), and were about 35% higher for both vessels for sea delivery than for port delivery.

5) U.S. fishermen operating vessel types similar to the 33 m crabber/trawler and the 25 m trawler considered in this analysis may find it economically attractive to participate in joint fishing ventures for groundfish in the western Gulf of Alaska and the eastern Bering Sea given the ex-vessel prices currently being offered by the joint venture companies and the large volumes of fish in which these companies are interested.

It was considered feasible for these U.S. vessels to attain average catch rates sufficiently high to cover the fixed and variable costs of fishing under each of three fishing targeting strategies in which the target stocks are: 1) Pacific cod and walleye pollock in the western Gulf of Alaska, 2) sole in the eastern Bering Sea, and 3) walleye pollock in the Aleutians area.

ACKNOWLEDGMENTS

I would like to thank S. Jaeger, V. Kaczynski, and G. M. Pigott for contributing helpful information and suggestions during the development of this paper. Thanks are also due to D. Somerton and L. J. Bledsoe for their helpful critiques.

The research for this paper was supported by the University of Washington Sea Grant Program (Grant No. NA-79-AA-00054) through subgrants extended to the Institute for Marine Studies (Grant No. R/MS-6) and the Norfish Research Group (Grant No. R/F-9).

LITERATURE CITED

NORTH PACIFIC FISHERY MANAGEMENT COUNCIL.
1978a. Fishery management plan for the Gulf of Alaska groundfish fishery during 1978. North Pacific Fishery

[22]Kaczynski, W., and D. LeVieil. 1980. International joint ventures in world fisheries. Their distribution and development. Wash. Sea Grant Rep. 80-2, 33 p.

Management Council, P.O. Box 3136 DT, Anchorage, AK 99510, 220 p.
1978b. Fishery management plan and draft environmental impact statement for the groundfish fishery in the Bering Sea/Aleutian Island area. North Pacific Fishery Management Council, P.O. Box 3136 DT, Anchorage, AK 99510, 279 p.

SMITH, F. J.
1975. The fisherman's business guide. International Marine Publ. Co., Camden, Maine, 172 p.

SULLIVAN, J. J., AND P. O. HEGGELUND.
1979. Foreign investment in the U.S. fishing industry. Lexington Books, Lexington, Mass., 185 p.

U.S. BUREAU OF THE CENSUS.
1978. Statistical abstract of the United States: 1978. 99th ed. Wash., D.C., 1057 p.

U.S. DEPARTMENT OF COMMERCE.
1979. Fisheries of the United States, 1978. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Curr. Fish. Stat. 7800, 120 p.

APPENDIX I.—COST DERIVATIONS AND SOURCES OF ESTIMATES

I. A. Boat and engine routine maintenance. 7% of the vessel's initial value (VIV) is based on Marine Economics Data Sheets[23-27] for bottom draggers which indicate boat and engine repairs ranging from 5.1 to 11.4% (average 7.0%) of the vessel's market value. Katz and Lee[28] used a "rough estimate" of 6% for crab vessels.

B. Insurance. 2.1% of VIV for hull is a midpoint estimate based on a range of 1.7 to 2.5% (Jaeger footnote 11; Katz and Lee footnote 28).

C. Depreciation. Based on the following assumptions for vessel type 1 (Jaeger footnote 9):

	Cost	*Useful life (yr)*
Electronics	$ 100,000	6
Engine	$ 250,000	10
Hull	$1,150,000	30

Over a 30-yr period, assuming constant replacement costs, costs due to depreciation will be 5 × $100,000 + 3 × $250,000 + $1,150,000 = $2,400,000. The yearly cost is then $80,000 which equals 0.0533 VIV. Assuming equal cost proportions for vessel type 2 (electricity 6.7%, engine 16.7%, and hull 76.6% of VIV) also yields 0.0533 VIV.

D. Association dues. From Katz and Lee (footnote 28) updated to current values based on insurance cost index (U.S. Bureau of the Census 1978).

E. Contingencies/Miscellaneous. From Smith.[29]

F. Average annual cost of financing. Assumes 80% VIV financed and amortization through equal monthly payments. Financing for vessel type 1 is for 20 yr at 10% annual interest. Financing for vessel type 2 is for 15 yr at 8.5% interest. Differences in interest rates are due to different times of purchase.

[23]Marine Economics Data Sheets. 1971a. Seattle drag fishing business. Oregon State University Extension Service SR500-9.
[24]Marine Economics Data Sheets. 1971b. Seattle drag fishing business. Oregon State University Extension Service SR500-10.
[25]Marine Economics Data Sheets. 1971c. Seattle drag fishing business. Oregon State University Extension Service SR500-11.
[26]Marine Economics Data Sheets. 1971d. Seattle drag fishing business. Oregon State University Extension Service SR500-12.
[27]Marine Economics Data Sheets. 1977. Charleston drag fishing business. Oregon State University Extension Service SR500-19.
[28]Katz, P. L., and C. L. Lee. 1976. Computing annual return to vessel investment in a fisheries economic projection model—demonstration of method, based on a vessel in the Bering Sea king crab fishery. Norfish Tech. Rep. 63, 10 p.
[29]Smith, F. J. 1978. Understanding and using marine economics data sheets. Oreg. State Univ. Sea Grant Spec. Rep. 500, 4 p.

II. A. Gear repair and replacement. It is generally agreed that fishing gear maintenance and repair is roughly proportional to the amount of fishing time, but very little data are available which describe this relationship. The estimate of \$20.57/h for vessel type 1 is based on the following estimates of Jaeger (footnote 11):

Total gear maintenance costs per year	\$20,000
Total towing hours per year	972

The hourly costs for vessel type 1 are taken to be the same (\$20,000/972) as for the vessel described by Jaeger. Since the trawl used by vessel type 2 would be smaller and hence less expensive than that of vessel type 1, its hourly costs were reduced by a factor based on the values of one net (including roller gear and floats) as estimated by Hurd.[30]

	Value of net
Vessel type 1	\$7,000
Vessel type 2	\$5,500-\$6,000

B. Fuel costs. Gal/h:hp ratios as estimated by Jaeger (footnote 9). Fuel price of \$0.277/l (\$1.05/gal) based on current price at Dutch Harbor, Alaska.

C. Food costs. Based on Katz and Lee (footnote 28) and Jaeger (footnote 11) and updated by cost index (U.S. Bureau of the Census 1978).

D. Ice. Based on Bledsoe and Mesmer[31] and updated by cost index (U.S. Bureau of the Census 1978).

E. Crew and captain's shares. Katz and Lee (footnote 28), Jaeger (footnote 11).

[30]Rod Hurd, Seattle Marine and Fishing Supply Co., Seattle, Wash., pers. commun. December 1979.

[31]Bledsoe, L. J., and K. Mesmer. 1978. Summary of regional fishery system simulator configuration for N.E. Pacific shellfishery studies (NEPAC model and simulator). Norfish Pap. NM46, 19 p.