North American Journal of Fisheries Management 13:27–34, 1993

Opportunity Costs and the Decision to Fish for Northern Anchovy

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Abstract.—Since 1982, declines in the U.S. reduction fishery for northern anchovy *Engraulis mordax* were due to ex-vessel prices too low to meet opportunity costs of traditional crew members in the southern California wetfish fleet, rather than to inability to meet variable (short-run) costs for items such as fuel. The decline of the fishery appeared to be driven largely by opportunity costs, which, in turn, depended on the ethnic background of crew members. Our analysis indicated that opportunity costs and sociological factors, which are often ignored by fishery managers who traditionally focus on biological analyses, can affect a fishery and its performance. Estimates of opportunity and variable costs from our study should be useful in the development of management plans for the wetfish fishery.

The central population of northern anchovy *Engraulis mordax* ranges from about San Francisco, California, south to Punta Baja, Baja California, Mexico. Northern anchovy have been harvested by U.S. and Mexican fleets for reduction to fish meal and oil primarily, although modest amounts have also been taken for live bait, dead bait, and human consumption. Annual U.S. reduction landings averaged 62,000 tonnes during 1966–1982, but annual landings dropped abruptly in 1983 and averaged only 920 tonnes during 1983–1989 (Figure 1).

Our data and industry sources indicate that the U.S. northern anchovy reduction fishery declined after 1982 because of low ex-vessel prices (prices paid to fishermen by reduction processors), not because of biological or regulatory factors. Ex-vessel prices for northern anchovy landed for reduction in the USA (Table 1) were $\$53–103 \cdot tonne^{-1}$ during 1974–1982 but only $\$29–48 \cdot tonne^{-1}$ during 1983–1989. (All monetary values in this article are given in 1989 U.S. dollars). In contrast, northern anchovy biomass levels during 1983–1988 were not low (Methot 1989; Jacobson and Lo 1990) and U.S. reduction landings were less than annual harvest quotas (Thomson et al. 1990).

The purpose of our analysis was to determine the effect of ex-vessel prices on participation in the northern anchovy reduction fishery. We begin by describing the fishing fleet and our data sources. Next, we define variable and fixed costs and explain why our analysis focused on variable costs and short-run business decisions in the fishery. Then, we define opportunity costs, describe two groups of crew members in the wetfish fishery, and estimate opportunity costs for one group. A simple bioeconomic model for earnings by crew members is developed and used to estimate opportunity costs for the second group of crew members.

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Definitions and Background

The Fishery

In terms of total landings, the most important segment of the U.S. reduction fishery for northern anchovy has been the southern California "wetfish fleet" that is based in Los Angeles Harbor and has small segments in the Ventura and Monterey Bay areas (Huppert 1981). In addition to northern anchovy, the fleet harvests chub mackerel *Scomber japonicus*, jack mackerel *Trachurus symmetricus*, Pacific bonito *Sarda chiliensis*, California market squid *Loligo opalescens*, Pacific sardine *Sardinops sagax*, bluefin tuna *Thunnus thynnus*, and other tunas *Thunnus* spp., depending on availability. Fishing for northern anchovy is regulated by the Pacific Fishery Management Council (1983, 1990), whereas fishing for chub mackerel and Pacific sardine is regulated by the state of California (California Department of Fish and Game 1990).

During 1989, the fleet consisted of 38 active purse-seiners averaging 20 m in length (Thomson et al. 1990). Approximately one-third of the fleet was boats with steel hulls built during the last 20 years. The others were boats with wooden hulls built during 1930–1949, the heyday of the Pacific sardine fishery in California (Murphy 1966). The crew on a boat in the wetfish fleet consists of a skipper, who usually owns the boat, an engineer, and other crew members.

During 1983–1989, while ex-vessel prices paid

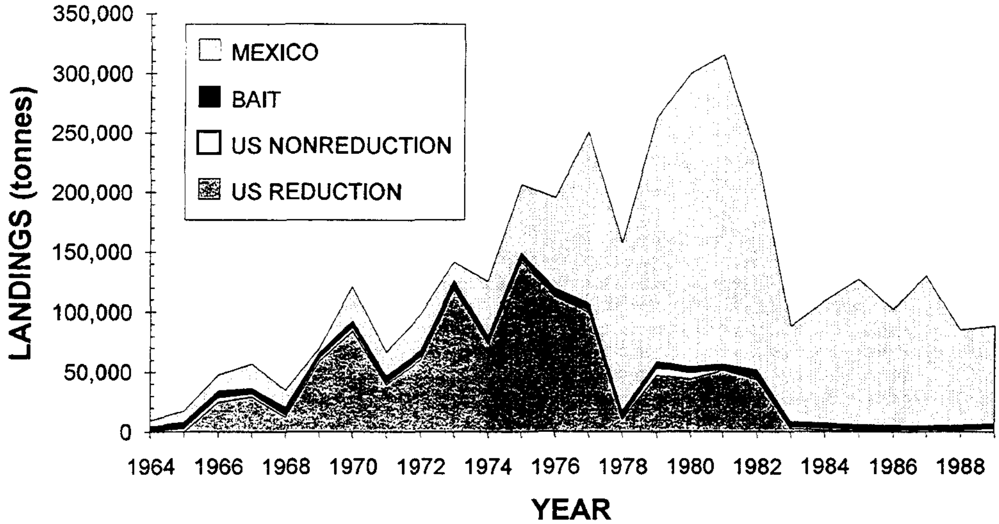

FIGURE 1.—Northern anchovy landings during 1964–1989 by the Mexican reduction fishery, U.S. reduction fishery, U.S. nonreduction commercial fishery, and U.S. live-bait fishery. The U.S. reduction fishery began in 1965.

by reduction processors for northern anchovy were low (\$29–48·tonne^{-1}; Table 1), ex-vessel prices (per tonne) were \$150–200 for mackerels and Pacific sardine, \$175–275 for California market squid, \$200–450 for Pacific bonito, and \$1,000–5,000 for tunas. Because fishing for other species is more lucrative, the wetfish fleet tends to take northern anchovy for reduction as a sideline when other species are not available (Thomson et al. 1990).

TABLE 1.—Landings and ex-vessel prices for northern anchovy in the U.S. reduction fishery, 1974–1989. \$ = 1989 U.S. dollars.

Year	Landing (tonnes)	Price (\$·tonne^{-1})
1974	73,400	103
1975	141,586	71
1976	112,270	79
1977	99,674	96
1978	10,339	91
1979	47,408	80
1980	43,699	82
1981	51,290	82
1982	43,742	53
1983	2,854	48
1984	1,722	39
1985	825	34
1986	546	30
1987	149	29
1988	234	33
1989	109	36

Mackerels, California market squid, tunas, and Pacific bonito are the mainstay of the fleet during most years. Fishing for Pacific sardine has been allowed since 1986, but until 1990, annual quotas for directed fishing were limited to 2,000 tonnes so that Pacific sardine contributed little to overall landings and revenues (the products of ex-vessel prices and landings) for the wetfish fleet. Mackerels are usually available to the fleet year-round. Pacific bonito, California market squid, and tunas are available to the fishery on a seasonal basis.

Data Sources

Our analysis used financial, socioeconomic, and fishery logbook data for a segment of the wetfish fleet based at the port of San Pedro in the Los Angeles Harbor. Data sources were interviews with boat owners, business records for 1990 provided by the Fishermen's Cooperative Association and by the Fisherman and Allied Workers Union in San Pedro, and logbook data provided by the California Department of Fish and Game. The Fishermen's Cooperative Association and the Fisherman and Allied Workers Union included a substantial fraction (about 25%) of boat owners and fishermen in the wetfish fleet.

Logbook data used in this analysis were for seven of the most modern vessels in the San Pedro wetfish fleet during 1966–1979, which was a period when the U.S. fleet made substantial northern anchovy reduction harvests (Figure 1). More recent logbook data for the wetfish fleet were not available. Information about catch rates and duration of fishing trips for northern anchovy from logbook data for 1966–1979 was probably still valid, because most of the vessels for which logbook data were available were still in operation and boats and equipment used by the fleet had changed little since 1979. We used sensitivity analysis to determine if our results would have been substantially affected by modest changes in the efficiency (catch rates) of boats after 1979.

Variable Costs and the Short-Run Decision to Fish

In economics, business expenses that do not change during a period of interest are deemed "fixed," whereas costs that can change are called "variable." Fuel is the major variable cost in the wetfish fishery. In addition, a certain period is considered "the short run" if some costs are fixed and "the long run" if all costs are variable (Henderson and Quandt 1971). In the long run, according to economic theory, all costs are variable because, for example, boat owners can sell their boats, quit fishing, and avoid mortgage expenses altogether. Theory indicates that, in the short run, boat owners' decisions about how, when, and where to fish will tend to depend on variable costs, such as fuel expenses, but not fixed costs, such as mortgage expenses. The significance of these concepts in our analysis is that boat owners and crew members in the wetfish fleet will tend to fish for northern anchovy as a sideline in the short run only if variable costs and their opportunity costs (described below) can be met. As long as fishing for northern anchovy is a sideline activity, boat owners will meet their fixed costs primarily by fishing for other species. Our analysis focused on variable costs and short-run decisions, because we were concerned primarily with decisions about whether to participate in the northern anchovy reduction fishery as a sideline activity rather than with decisions about whether to quit the wetfish fishery altogether.

A share system, described below, is used in the wetfish fishery to divide certain variable costs and revenues between boat owners and the crew; fixed costs, however, are paid by boat owners from their share of revenues. Fixed costs for the wetfish fleet tend to be modest because most boats are owned outright (mortgages are paid off) and boat owners consider hull insurance for boats with wooden hulls too expensive to purchase.

Opportunity Costs

Most of the costs entailed in fishing or any business activity are tangible and readily quantified because they involve an exchange of money for goods and services. In contrast, opportunity costs are not an out-of-pocket expenditure but a measure of opportunities forgone in the course of making employment, business, and consumer decisions. The concept of opportunity cost reflects the reality that limited time and resources allow people to pursue economic opportunities only at the "cost" of forgoing alternatives (Ferris and Plourde 1982; Charles 1988). For boat owners, the opportunity cost of fishing is the income that they could expect to earn in an alternative business activity. For crew members, opportunity cost is the income that they could expect to earn in an alternative occupation.

The important point in connection with crew shares and opportunity costs is that crew members will tend to cease fishing and find other employment when crew shares fall below opportunity costs. Opportunity costs vary among fishermen, depending on the market value of their skills and how flexible they are about where they will work and what they will do for a living. Crew members who cherish fishing as a lifestyle may continue to participate when their apparent opportunity cost exceeds their earnings because they enjoy a "satisfaction bonus" from fishing that is sufficient compensation for forgone income (Smith 1981).

Types of Crew Members in the Wetfish Fleet

"Traditional" wetfish fishermen come from the Italian-American and Yugoslav-American fishing community in San Pedro. The ethnic composition of crew members has changed in recent years: individuals from other (mainly Hispanic) ethnic backgrounds have been replacing traditional ethnic groups. Data for seven boats whose crew members belonged to the Fisherman and Allied Workers Union in San Pedro indicated that Hispanics ("nontraditional" wetfish fishermen) increased from 5% of total crew members in 1980 to 20% in 1990. Industry sources indicated that the Hispanic representation was even higher during 1990 on nonunion boats. According to boat owners and union personnel, many Hispanics employed in the fishery are recent immigrants to the USA who tend to have employment opportunities limited to low-paying jobs. For this reason, we consider the legal minimum wage ($\$4.25 \cdot h^{-1}$ in California during 1991) to be a reasonable estimate of the opportunity cost for nontraditional crew members.

TABLE 2.—Mathematical symbols used in the analysis. \$ = U.S. dollars.

Symbol	Description and units
b	Spawning biomass (1,000 tonnes)
f	Catch rate (1,000 tonnes$\cdot$h^{-1})
p	Ex-vessel price (\$$\cdot$tonne^{-1})
R	Total revenue (\$$\cdot$h^{-1})
α	Parameter used to relate biomass and catch rates
β	Parameter used to relate biomass and catch rates
C_t	Costs that depend on time spent fishing (\$$\cdot$h^{-1})
C_f	Costs that depend on catch rate (\$$\cdot$h^{-1})
C_g	Costs that depend on gross revenue (\$$\cdot$h^{-1})
Φ	Price of fuel (\$$\cdot$L^{-1})
π	Landings tax for northern anchovy (\$$\cdot$tonne^{-1})
R	Gross revenue (\$$\cdot$h^{-1})
R_a	Adjusted revenue (\$$\cdot$h^{-1}), $R - C_f - C_g - C_t$
R_c	Crew member's share of adjusted revenue (\$$\cdot$person$^{-1}\cdot$h^{-1})
EIV	Error-in-variables regression estimate for parameters

Boat owners indicated during interviews that, whereas nontraditional crew members would likely be willing to fish for northern anchovy at a price of \$50$\cdot$tonne^{-1}, traditional crew members would not. Moreover, boat owners, who were almost all from traditional backgrounds, indicated that they were reluctant to fish with an exclusively nontraditional crew because, in their opinion, nontraditional crew members tend to be less experienced, communicating with them is more difficult, and they have a higher turnover rate than traditional fishermen. This reluctance was probably reinforced by cultural differences between traditional and other fishermen, and by familial ties that often exist between boat owners and traditional crew members.

Industry sources indicated that \$50$\cdot$tonne^{-1} was the minimum price that would induce traditional crew members to participate in the reduction fishery. This assertion was supported by historical records indicating that reduction fishing virtually ceased when the ex-vessel price fell below \$50$\cdot$tonne^{-1} (Table 1). We used the model described below to calculate hourly wages for crew members at ex-vessel prices of \$50$\cdot$tonne^{-1} and, because interviews and our data indicated that \$50$\cdot$tonne^{-1} was the critical price, we assumed that the result was an estimate of opportunity costs for traditional crew members in the wetfish fishery.

Model

Our model, which was similar to that used by Perrin and Noetzel (1970), related crew shares to ex-vessel price, biomass, and catch rates for northern anchovy, and fuel price, landings tax, and miscellaneous costs. Vessels, fishing practices, and cost-sharing arrangements in the wetfish fishery have changed little during the last few years, so the model should remain useful until major changes occur in the fishery. With minor modifications, the model should be useful for species other than northern anchovy that are also harvested by the wetfish fleet (e.g., Pacific sardine). Mathematical symbols used in the model are summarized in Table 2.

Revenues

Revenues (expressed on a per-hour basis) depend on catch rates and ex-vessel prices:

$$R = fp. \qquad (1)$$

The relationship between catch rates and total biomass was assumed to be nonlinear:

$$f = \alpha b^{\beta}. \qquad (2)$$

Substituting equation (2) into equation (1) gives revenues per hour as a function of ex-vessel prices and northern anchovy biomass:

$$R = \alpha b^{\beta} p. \qquad (3)$$

We used an error-in-variables (EIV) regression analysis to obtain estimates of $\alpha = 0.38$ and $\beta = 0.39$ (Jacobson and Thomson 1992). An approximate 95% confidence interval for the EIV estimates was bounded by $\alpha = 3.95$ and $\beta = 0.03$, and by $\alpha = 0.05$ and $\beta = 0.71$.

The relationship between biomass and catch rates was assumed to be nonlinear because abundance is not the only factor that affects northern anchovy catch rates (Bannerot and Austin 1983, and references therein; Pacific Fishery Management Council 1983). The southern California reduction fishery operates in an area smaller than the range of the stock; thus, catch rates probably reflect abundance of northern anchovy in the area where the fleet operates but not total abundance over the range of the stock. Aerial fish spotters (pilots employed by commercial fishermen to locate schools of fish; see Squire 1972) are usually used to search for schools and direct the setting of nets; this approach reduces time spent searching by boats and increases catch rates. Trip limits on northern anchovy landings are often imposed by processors who are constrained by market orders and processing capacity. Finally, it is well known that, for schooling species such as northern anchovy, catch rates decline more slowly than abundance (Bannerot and Austin 1983). The effects of these problems on our analysis were minimized by using a nonlinear model (equation 2) for the relationship between catch rates and biomass and by not extrapolating beyond the range of data used to fit the model.

Costs

The following operating costs affect crew shares in the northern anchovy fishery: (1) costs that depend on time spent at sea (C_t), (2) costs that depend on the catch rate (C_f), and (3) costs that depend on gross revenue (C_g). For convenience, these costs were expressed in units of dollars per hour at sea ($\$ \cdot h^{-1}$).

Costs that vary with time at sea include fuel and ship-to-shore telephone expenses:

$$C_t = 143\Phi + 6.8; \quad (4)$$

143 $L \cdot h^{-1}$ was the average fuel consumption rate reported by fishermen during interviews. Mean ship-to-shore telephone expenses ($\$6.8 \cdot h^{-1}$) were computed from mean cost per trip ($\$81 \cdot trip^{-1}$, estimated from business records) and mean trip duration (12 h, estimated from logbook data).

Costs that depend on catch rate include a landings tax levied by the state of California and two special assessments (patrol fund and wetfish assessment) levied by the industry itself. The patrol fund supports an employee who observes unloading of fish to ensure that boat owners and crew are paid for all fish actually landed. The wetfish assessment is used to support legislative and management programs. According to business records, the costs were $\$1.82 \cdot tonne^{-1}$ for the patrol fund and $\$0.23 \cdot tonne^{-1}$ for the wetfish assessment.

In the model, costs that depend on catch rate were

$$C_f = (\pi + 2.05)f; \quad (5)$$

$\$2.05 \cdot tonne^{-1}$ was the sum of the special assessments. To correspond to state laws, π varied with p (ex-vessel price):

$$\pi = \$1.32 \cdot tonne^{-1} \text{ when } p < \$45.40 \cdot tonne^{-1}; \quad (6)$$

$$\pi = \$2.89 \cdot tonne^{-1} \text{ when } p \geq \$45.40 \cdot tonne^{-1}.$$

Costs that depend on gross revenues include payments to fish spotters and pension benefits for the crew, which according to business records were 5 and 2% of gross revenues, respectively. Thus, these costs were

$$C_g = 0.07\,fp. \quad (7)$$

Hourly Wages for Crew Members

The share system used in the wetfish fishery splits total adjusted revenues (total revenues minus costs described above) between boat owners and crew. Total adjusted revenues (R_a) were calculated:

$$R_a = R - C_t - C_f - C_g. \quad (8)$$

Business records and interviews indicated that, on average during 1990, vessel owners received 48% of total adjusted revenues and crew members received 52%; there was some minor variability from boat to boat. According to industry sources, these proportions have changed little over time. According to data obtained from the California Department of Fish and Game, average crew size in the wetfish fleet (including the skipper) was 8.9 crew members per boat. The hourly wage (gross wage before deductions for groceries, taxes, and union dues) per crew member ($\$ \cdot person^{-1} \cdot h^{-1}$) was

$$R_c = 0.52\,R_a/8.9. \quad (9)$$

The following equation results when equations (2)–(8) are substituted for terms in equation (9):

$$R_c = 0.058\alpha b^{\beta}(0.930p - 2.050 - \pi) - 8.355\Phi - 0.397. \quad (10)$$

Hence, the hourly wage per crew member (R_c) was a function of northern anchovy biomass, ex-vessel price, landings tax rate, diesel fuel price, and parameters α and β.

We used equation (10) to compute average hourly wages for crew members at northern anchovy biomass levels of 300,000–1,700,000 tonnes, ex-vessel prices of $30–100·tonne, and diesel fuel prices of $0.125, $0.25, and $0.375 per liter (Table 3). The ex-vessel prices and northern anchovy biomass levels used in our calculations covered the range of historical data. Biomass estimates for northern anchovy during 1964–1990 ranged from 306,000 to 1,800,000 tonnes; the first quartile was at 401,000 tonnes, the median was at 529,000 tonnes, and third quartile was at 852,000 tonnes (Jacobson and Lo 1990). The lower limit of the range used for biomass levels corresponded to management regulations, because reduction fishing is not permitted at spawning biomass levels lower than 300,000 tonnes. The range of fuel prices ($0.25 ± 50%) was centered around the average spot price for diesel fuel sold to wetfish fishermen by a distributor in San Pedro during 1990 (D. Squires, Southwest Fisheries Science Center, personal communication).

TABLE 3.—Hourly wages for crew members ($·h^{-1}) estimated under various assumptions about ex-vessel price, northern anchovy biomass, and the price of fuel. $ = U.S. dollars.

Biomass (1,000 tonnes)	Ex-vessel price (per tonne landed):							
	$30	$40	$50	$60	$70	$80	$90	$100
			Fuel price = $0.125·L^{-1}					
300	3.60	5.52	7.11	9.02	10.93	12.85	14.76	16.67
500	4.72	7.05	8.99	11.33	13.66	16.00	18.33	20.66
700	5.58	8.24	10.46	13.12	15.78	18.44	21.10	23.76
900	6.30	9.24	11.68	14.62	17.55	20.49	23.42	26.36
1,100	6.93	10.11	12.75	15.92	19.10	22.27	25.45	28.62
1,300	7.50	10.89	13.70	17.09	20.48	23.87	27.26	30.65
1,500	8.01	11.59	14.57	18.16	21.74	25.32	28.91	32.49
1,700	8.48	12.25	15.37	19.14	22.90	26.66	30.42	34.19
			Fuel price = $0.25·L^{-1}					
300	2.56	4.47	6.06	7.98	9.89	11.80	13.71	15.63
500	3.67	6.01	7.95	10.28	12.62	14.95	17.29	19.62
700	4.54	7.20	9.41	12.07	14.73	17.40	20.06	22.72
900	5.26	8.19	10.64	13.57	16.51	19.44	22.38	25.32
1,100	5.89	9.06	11.70	14.88	18.05	21.23	24.40	27.58
1,300	6.45	9.84	12.66	16.05	19.44	22.83	26.21	29.60
1,500	6.97	10.55	13.53	17.11	20.70	24.28	27.86	31.44
1,700	7.44	11.20	14.33	18.09	21.85	25.62	29.38	33.14
			Fuel price = $0.375·L^{-1}					
300	1.52	3.43	5.02	6.93	8.84	10.76	12.67	14.58
500	2.63	4.96	6.90	9.24	11.57	13.91	16.24	18.58
700	3.49	6.15	8.37	11.03	13.69	16.35	19.01	21.68
900	4.21	7.15	9.59	12.53	15.46	18.40	21.34	24.27
1,100	4.84	8.02	10.66	13.83	17.01	20.18	23.36	26.53
1,300	5.41	8.80	11.62	15.00	18.39	21.78	25.17	28.56
1,500	5.92	9.50	12.48	16.07	19.65	23.23	26.82	30.40
1,700	6.39	10.16	13.29	17.05	20.81	24.57	28.34	32.10

Results

Hourly wages for crew members (Table 3) increased over the range of ex-vessel prices ($30–100·tonne^{-1}) by about 400% on average (400% is the mean increase at each fuel price and biomass level in Table 3). Hourly wages increased over the range of biomass levels (300,000–1,700,000 tonnes) by about 140% on average. Hourly wages decreased over the range of fuel prices ($0.125–0.375·L^{-1}) by about 22% on average. The proportional effect of ex-vessel prices was greatest at high fuel prices and low northern anchovy biomass levels. The proportional effect of northern anchovy biomass was greatest at high fuel prices and low ex-vessel prices. The proportional effect of fuel prices was greatest at low ex-vessel prices and low northern anchovy biomass levels.

Hourly wages for crew members were positive even at the lowest biomass levels, lowest ex-vessel prices, and highest fuel prices (Table 3), indicating that ex-vessel revenues were sufficient to cover variable costs shared by boat owner and crew in reduction fishing under a wide variety of fishery conditions. The important conclusion from these results was that inability to cover variable costs was apparently not a factor in the decline of the northern anchovy reduction fishery.

As discussed earlier, crew members' hourly wages associated with the prevailing fuel price ($0.25·L^{-1}) and minimum acceptable ex-vessel price for northern anchovy fishing ($50·tonne^{-1}) were reasonable estimates of opportunity costs for traditional fishermen. Results from the model (Table 3) indicated that opportunity costs for traditional fishermen were in the range of $6.06–14.33·h^{-1}. These estimates for traditional fishermen were considerably higher than our estimate of opportunity cost for nontraditional fishermen ($4.25·h^{-1}).

Hourly earnings in excess of opportunity cost for nontraditional fishermen ($4.25·h^{-1}) can be expected at a wide range of biomass levels and fuel costs, even when ex-vessel prices are as low as $30·tonne^{-1} (Table 3). Thus, the results from our model are consistent with information from boat owners indicating that nontraditional fishermen would be willing to fish for northern anchovy in

TABLE 4.—Hourly wages for crew members ($\$ \cdot h^{-1}$) estimated under the assumption of ex-vessel prices of $30, $40, and $50 per tonne landed, a fuel price of $\$0.25 \cdot L^{-1}$, the historical range of northern anchovy biomass, and an approximate 95% confidence interval for estimates of α and β. The middle estimates ($\alpha = 0.38$, $\beta = 0.39$) are "best estimates" from an EIV regression. The other two sets of estimates ($\alpha = 3.95$, $\beta = 0.03$; and $\alpha = 0.05$, $\beta = 0.71$) bound the confidence interval. $ = U.S. dollars.

Biomass (1,000 tonnes)	$\alpha = 3.95$, $\beta = 0.03$, and ex-vessel price is:			$\alpha = 0.38$, $\beta = 0.39$, and ex-vessel price is:			$\alpha = 0.05$, $\beta = 0.71$, and ex-vessel price is:		
	$30	$40	$50	$30	$40	$50	$30	$40	$50
300	4.24	6.79	8.92	2.56	4.47	6.06	1.63	3.19	4.49
500	4.35	6.94	9.09	3.67	6.01	7.95	3.43	5.68	7.54
700	4.42	7.03	9.21	4.54	7.20	9.41	5.03	7.88	10.25
900	4.47	7.11	9.30	5.26	8.19	10.64	6.50	9.91	12.74
1,100	4.51	7.16	9.37	5.89	9.06	11.70	7.88	11.80	15.07
1,300	4.55	7.21	9.43	6.45	9.84	12.66	9.18	13.60	17.28
1,500	4.58	7.25	9.48	6.97	10.55	13.53	10.43	15.32	19.39
1,700	4.60	7.29	9.52	7.44	11.20	14.33	11.63	16.98	21.43

the reduction fishery at prices less than $\$50 \cdot tonne^{-1}$ but traditional fishermen would not.

To evaluate the potential effects of uncertainty about the relationship between biomass and catch rates in equation (2), we calculated crew members' hourly wages for values of α and β corresponding to the 95% confidence interval around our estimates from the EIV regression, for ex-vessel prices of $30, $40, and $50 per tonne, for the range of northern anchovy biomass levels, and for a fuel price of $\$0.25 \cdot L^{-1}$ (Table 4).

Results obtained with different parameter values were essentially the same as those obtained with EIV estimates (Table 4). The opportunity cost of traditional fishermen at the approximate median biomass level of northern anchovy (500,000 tonnes), for example, was estimated to be $\$8 \cdot h^{-1}$ with EIV parameter estimates and about $\$7.50$–$9.00 \cdot h^{-1}$ over the range of alternative parameter values considered. Hourly wages for crew members exceeded the opportunity cost of nontraditional fishermen ($\$4.25 \cdot h^{-1}$) over a wide range of biomass levels and at ex-vessel prices as low as $\$30 \cdot tonne^{-1}$ (Table 4).

Discussion

The results of our analysis reflect current biological, economic, and sociological conditions in the wetfish fishery. Relationships involving opportunity costs will probably change as conditions in the fishery change. In the long run, for example, a significant decline in abundance or ex-vessel prices for wetfish species other than northern anchovy could result in a sizeable increase in the minimum acceptable price for northern anchovy, because revenues from fishing for other species could not be used to meet fixed costs. A northern anchovy reduction fishery might be reestablished, even at low ex-vessel prices and low northern anchovy biomass levels, if boat owners are willing to work with an exclusively nontraditional crew who would accept earnings at the minimum wage level or if boats are purchased by people who are comfortable working with nontraditional crew members. Thus, changes in ethnic backgrounds of boat owners and crews may have important effects on the wetfish fishery.

Management Applications

The northern anchovy fishery is managed on the basis of a formula that links the catch quota for reduction fishing to the level of spawning biomass (Pacific Fishery Management Council 1983, 1990). The best, but most expensive, estimates of spawning biomass for northern anchovy are obtained with the egg production method described in Lasker (1985). As an alternative, less-accurate and less-expensive approaches are used (Methot 1989; Jacobson and Lo 1990). The egg production method has not been used to collect data in recent years because of inactivity in the U.S. northern anchovy reduction fishery and the expense involved with the method. Our analysis sheds light on reasons for inactivity in the fishery and should help managers to anticipate increased harvest levels, due to increased ex-vessel prices or changes in the ethnic composition of crew members and boat owners, and the need to obtain more precise biomass estimates by the egg production method.

The Pacific Fishery Management Council is developing a federal fishery management plan for coastal pelagic fisheries on the west coast of the USA. The new plan will address management of fisheries for chub mackerel, jack mackerel, Pacific sardine, and northern anchovy. In development of the plan, the council is responsible for considering socioeconomic, as well as biological, information (Magnuson Fishery Conservation and Management Act, Public Law 94-265). Our study provides useful information about opportunity costs and variable costs that are important, but usually neglected, elements in socioeconomic analyses used for fishery management.

Acknowledgments

We acknowledge the work and ideas of Dan Huppert (University of Washington), Alec MacCall (National Marine Fisheries Service, Tiburon, California), and Rick Methot and Gary Stauffer (National Marine Fisheries Service, Seattle, Washington). Tom Crehan and boat owners affiliated with the Fishermen's Cooperative Association in San Pedro provided data and information about operating costs. John Royal and Dinka Amalfitano (Fisherman and Allied Workers Union, San Pedro) provided socioeconomic and cost data. Doyle Hanan and Rick Klingbeil (California Department of Fish and Game) provided unpublished logbook data, information about state taxes, and other data. Dale Squires (National Marine Fisheries Service, La Jolla, California) provided fuel price data. Izadore Barrett and John Hunter (National Marine Fisheries Service, La Jolla) and two anonymous referees provided suggestions about presentation and content. Thanh-Huyen Vu typed, prepared tables, and provided other assistance.

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