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Note

Feasibility of a new fishery in Baja California, Mexico based on the red crab *Pleuroncodes planipes*: preliminary economic evaluation and risk assessment

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Abstract – A preliminary economic evaluation of the feasibility of establishing a fishery to process red crab meal (*Pleuroncodes planipes*) was conducted. Risk assessment indicated that a fishery of nine boats could operate with an average 1.53 benefit-cost ratio ($B\,C^{-1}$) and annual net revenues (NR) of US$427 840, and that there is certainty of obtaining economic profit in every season, with a $B\,C^{-1} > 1$ and $NR > 0$. Total catch and average catch per trip could be reduced from a total baseline catch of 10 328 tons (1735 t meal) to 6061 (1844 t meal), and from a baseline catch per trip of 11.4 t (4.78 t meal) to 6.73 tons (4.85 t meal) without economic losses. There was no possibility for profit when total catch and average catch per trip were, respectively, lower than 5365 t (1648 t meal) and 5.96 t (4.71 t meal). For a single-fishing trip operation, average $B\,C^{-1}$ was 1.5 and NR was US$480. We determined that there was a confidence level of 84% to generate profits. To guarantee profits, a catch of 13.5 t per trip (1.35 t meal) should be obtained. Single trips catching less than 3.3 t (0.94 t meal) cannot make a profit. Sensitivity analysis indicated that plant processing efficiency for converting fresh red crab to meal, catch per trip, and sales price of red crab meal were most important in determining $B\,C^{-1}$ and NR values. Plant efficiency constitutes the main element that needs to be optimized, particularly management practices to preserve fresh catch quality. A low sensitivity to costs for processing suggests the possibility of negotiating a higher price and the opportunity for processing plants to venture into processing of red crab meal.

Key words: Red crab / *Pleuroncodes planipes* / Galatheidae / Fishery / Economic evaluation / Mexico

1 Introduction

The red crab *Pleuroncodes planipes* (Stimpson) is an abundant pelagic crustacean (Galatheidae) along the Pacific coast of the Baja California Peninsula of Mexico. Annual abundance of this crustacean has been estimated at 205 000 tons (Ehrarhdt and Ramírez 1982) and 460 217 t (Aurioles-Gamboa 1995). Sustainable annual catch has been estimated at 73 600 t (Balart 1996).

The red crab has seasonal inshore-offshore movements during its benthic phase (Aurioles-Gamboa 1992), inshore-offshore larval drift (Gómez-Gutiérrez and Sánchez-Ortiz 1997), and daily vertical movements (Boyd 1967; Robinson and Gómez-Gutiérrez 1998; Robinson et al. 2004). From field observations, active upwelling sites play an important role in shaping the distribution of the red crab in the southern part of the California Current (Aurioles-Gamboa 1992; Aurioles-Gamboa and Pérez-Flores 1997; Robinson et al. 2004).

The possibility of establishing a fishery for this species had been evaluated (Kato 1974; López et al. 1982; Carrillo-Domínguez et al. 1995). In other studies, catches ranging from 19 to 70 t of red crab were used to produce red crab meal as a dietary ingredient for salmonids and shrimp, with encouraging results (Spinelli and Mahnken 1978; Ellis 1979; Villarreal 1995; Civera et al. 2000). However, a systematic evaluation of feasibility to capture and process red crab meal (RCM), as an ingredient in diets for aquaculture purposes, is lacking. Absence of an evaluation has been one of the main factors impeding initiation of a new red crab fishery.

A pilot project was carried out to comprehensively assess feasibility and provide criteria for starting a new fishery. We present results of the pilot project and economic evaluation for a future fishery, where the red crab catch is used to produce meal. The analysis assumes that a fleet of shrimp boats could operate when the local shrimp fishery is closed. The evaluation is preliminary, since no potential investors are identified for starting a new fishery. A more complete evaluation should be tailored to meet the specific situation of future entrepreneurs.

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Table 1. Characteristics of the two shrimp fishing vessels used in the pilot project.

	"*Calisureño IV*"	"*BIP II*"
Gross tonnage	97.0	140.0
Net tonnage	48.0	67.0
Length (m)	20.8	20.9
Beam (m)	6.6	6.8
Engine	Cummins 370 HP	Caterpillar 480 HP
Hydraulics	Winch, 2 drums	Winch, 2 drums
Hold	Refrigerated	Refrigerated

2 Materials and methods

Two shrimp trawlers were used to capture red crab in August-September and November-December on 23 fishing trips in the vicinity of the Bahía Magdalena-Bahía Almejas Lagoon Complex (Fig. 1). Running from 3 pm to 6 am, trips lasted 6 to 7 h per day. There were an average 8.6 hauls per trip with a range of trawling time from 24 to 43 min per haul. The characteristics of the two trawlers are presented in Table 1.

Catches of red crab were brought to Puerto San Carlos in Bahía Magdalena and processed in an industrial plant to produce meal. The plant handled 25 batches, which varied from 3 to 9 h for processing in batches ranging from 1.9 to 15.8 t. The efficiency of processing was measured for every run as the ratio of meal/fresh red crab used to produce the meal.

A preliminary economic evaluation was conducted to determine the feasibility of operating a fishery for red crab. Red crab in this area (22 063 km^2) was estimated at 319 883 t by Aurioles-Gamboa (1995). Fishing operations in the project were limited to an area of 699 km^2 where reaches 80−200 m (Fig. 1). The assumptions and parameter estimates used in the economic evaluation are shown in Table 2.

The following criteria were used for the evaluation (annual basis):

a) Benefit-cost ratio (B C^{-1}), where benefit (B) is the product of the total RCM produced and RCM sale price (SP), and costs (C) are the total costs of fishing (FC), offloading (OC), and processing (PC).
b) Net revenue (NR): NR = B – C.
c) Breakeven production of RCM (BP): BP = FC × [SP – ((OC+PC) TRCM^{-1}))]$^{-1}$, where TRCM is the total RCM produced.
d) Breakeven catch (BC): BC = BP × APE^{-1}, where APE is the average efficiency of processing (as a percentage).

The general flowchart of the algorithm to carry out this evaluation is presented in Fig. 2. Stochastic elements were included in the calculations to account for random one-season variability in the catch per trip and random variability in processing efficiency of the plant. Calculations were performed with an Excel 2000 spreadsheet; Crystal Ball® software (Version 7, Decisioneering, Inc., Denver, CO) was used to assess risk on a single-fishing trip basis and on an annual basis for the proposed fishery. Stochastic variations in catch per trip and in processing efficiency were based on frequency distributions of catches and efficiencies observed in the pilot project (Fig. 3). Customized frequency distributions were constructed using the facilities available in Crystal Ball® after none of the theoretical probability distribution functions available in the software gave satisfactory fits to catch and efficiency data.

Table 2. Assumptions and parameter estimates used for economic evaluation of a red crab fishery. For a single-fishing trip evaluation, the number of boats and trips were set at 1.

Red crab abundance (tons km^{-2})	14.49[1]
Fishing area (km^2)	700
Trawling depth (m)	80–200
Total catch (tons year^{-1})	10 129
Average catch (tons trip^{-1})	11.4
Length of the fishing season (days)	100
Number of boats	9
Number of trips	900
Fishing cost (US$ trip^{-1})	565.8
Offloading cost (US$ ton^{-1})	12.5
Average plant efficiency (RCM[2]/ fresh red crab)	0.16
Processing cost (US$ ton^{-1})	86.25
RCM sale price (US$ ton^{-1})	700

[1] Estimated after Aurioles-Gamboa (1995).
[2] RCM = red crab meal.

Sampling with the Monte Carlo method was conducted, as follows. For a single-trip operation, one random variation in plant efficiency was allowed to occur for each random variation in the catch. For the whole fishery, we estimated that two runs of the plant would suffice to process the daily catch obtained from the nine vessels. Consequently, for every fishing season, sampling was balanced to account for 200 random variations in plant efficiency for the total of 900 trips. Catch per trip and plant efficiency values were then averaged on an annual basis, and used to calculate produced meal and corresponding income.

Complementarily, the sensitivity of net revenue values to stochastic variables and parameters was determined using the programs in Crystal Ball®. Sensitivity to stochastic variables was calculated by computing rank correlation coefficients between NR and catch per trip and processing efficiency. Sensitivity was obtained as percentage of the contribution to the variance of NR, where the contribution is calculated by squaring the rank correlation coefficients and normalizing them to 100%. Sensitivity to parameters was determined by calculating NR corresponding to changes amounting to ±20% in baseline parametric values.

For this evaluation, the only costs were those required for operation of the fleet and manufacturing RCM, since no investment costs would be required for starting the fishery. The costs were based on the results of the pilot project; sale price for RCM was assumed to be the same as the price received for red squat lobster meal ("langostino rojo") *Pleuroncodes monodon* harvested in Chile (Roa and Bahamonde 1993; Roa et al. 1995).

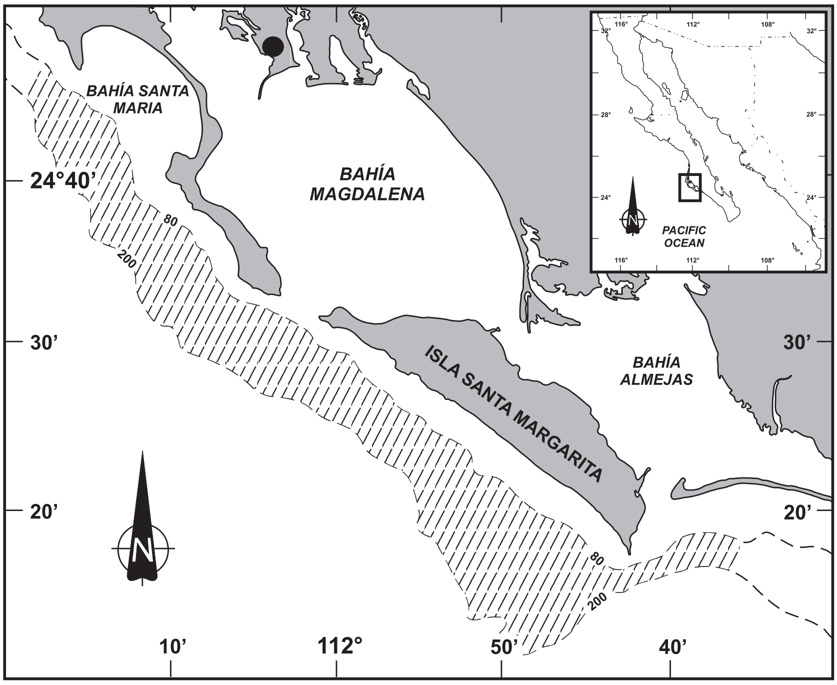

Fig. 1. Proposed area for the red crab fishery along the Pacific coast of Baja California Sur, Mexico.

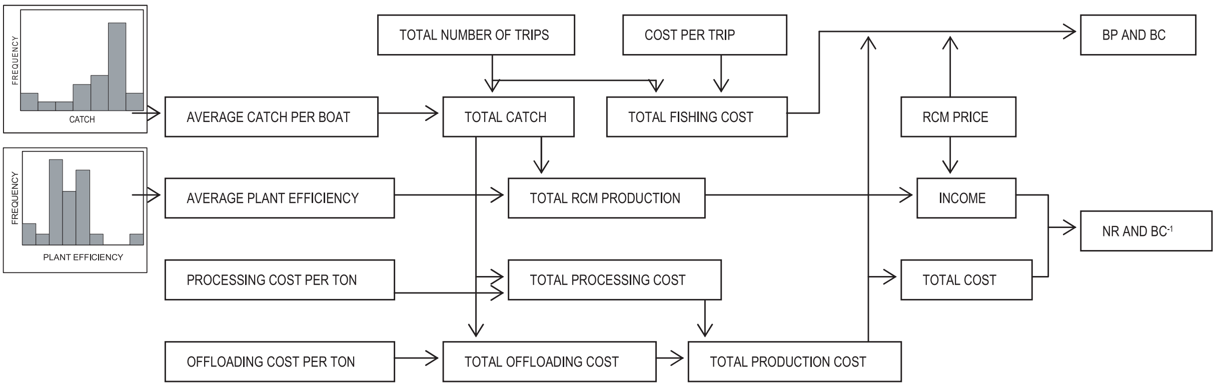

Fig. 2. General flowchart of the algorithm used to carry out evaluation. Red crab meal (RCM); breakeven production (BP); breakeven catch (BC); net revenue (NR) and benefit-cost ratio (B C^{-1}).

3 Results and discussion

The calculations for the frequency distributions resulting from Monte Carlo simulations for a single-trip operation and a hypothetical nine-vessel fishery are presented in Tables 3 and 4, respectively. The frequency distributions for benefit-cost ratio, net revenue, and breakeven catch are shown for a single-trip operation (Fig. 4). Average benefit-cost ratio and net revenue were 1.5 and US$480, respectively. This resulted in a confidence level of 84% for yielding profits when the benefit-cost ratio is >1 and net revenue is >0. To guarantee profits, a catch of 13.5 t per trip (or 1.35 t RCM) should be obtained (rather than a mean catch of 11.4 t and mean 1.91 t meal). Fishing operations catching less than 3.3 t (or 0.94 t meal) cannot earn a profit.

Analyses for a regional fishery indicated that mean values of benefit-cost ratio and net revenue were, respectively, 1.53 and US$427 840 (Table 4; Fig. 5). In contrast to results obtained from the evaluation on a single-trip basis, the regional fishery could operate every season with a certainty of economic profit. Total catch and average catch per trip could respectively be reduced from 10 328 t (1739 t RCM) to 6061 (1844 t RCM), and from 11.4 t (4.8 t RCM) to 6.7 t (4.9 t RCM) without economic losses (Fig. 5). There is no possibility for the fishery to earn a profit when total catch and average catch per trip are lower than 5365 t (1648 t RCM) and 5.96 t (4.7 t RCM), respectively.

Sensitivity analysis for a single-trip indicated that the variance in net revenue is attributable to catch variability per trip and plant efficiency, which were similar (i.e., 51.7% and 48.7%, respectively). On the other hand, net revenue was more sensitive to changes in values of these parameters and sale price of red crab meal, while costs were less important (Fig. 6). Fishing costs per trip represented the main

Table 3. Statistical results from risk assessment of a single-trip operation.

	B C^{-1}	NR ($US)	Catch per trip (t)	Breakeven catch (t)	Processing efficiency	RCM (t)	Breakeven RCM (t)
Mean	1.50	480	11.4	6.76	0.17	1.91	1.08
Standard deviation	0.50	434	3.6	1.93	0.03	0.73	0.07
Coefficient of Variability	0.33	0.89	0.32	0.29	0.002	0.38	0.06
Range minimum	0.24	−475	2.0	3.3	0.1	0.20	0.94
Range maximum	2.88	1807	14.0	13.5	0.27	3.91	1.35

Table 4. Statistical results from risk assessment for the fishery.

Statistic	B C^{-1}	NR (US$)	Catch (t)	BC (t) (t)	BCT (t)	ACT (t)	APE	RCM (t)	BRCM (tons)	BRCMR (tons)
Mean	1.53	427 840	10 328	5679	6.3	11.4	0.168	1735	956	4.78
Standard deviation	0.02	19 518	109	102	0.1	0.12	0.002	30	4.1	0.02
Coefficient of Variability	0.02	0.05	0.01	0.02	0.02	0.01	0.01	0.02	0.004	0.004
Range minimum	1.46	366 845	9961	5365	5.96	11.0	0.160	1648	943	4.71
Range maximum	1.62	496 521	10 723	6061	6.73	11.9	0.175	1844	971	4.85

BC = Breakeven catch, B C^{-1} = benefit-cost ratio, BCT = Breakeven catch per trip, ACT = Average catch per trip, APE = Average plant efficiency, BRCM = Breakeven RCM, BRCMR = Breakeven RCM per run, NR = net revenues, RCM = red crab meal.

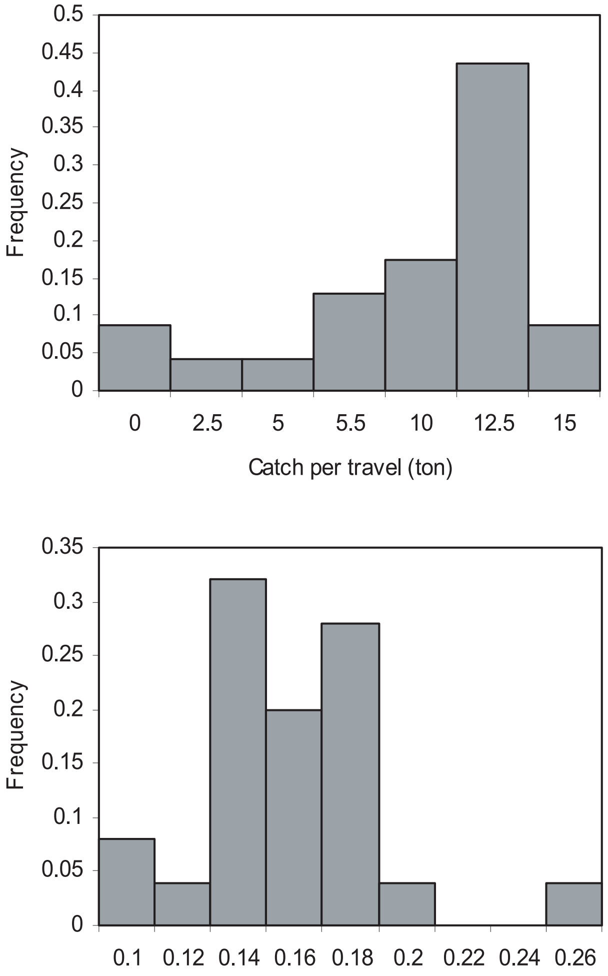

Fig. 3. Frequency distributions of catch per trip and plant efficiency per run in the pilot project.

expenditure (Table 2) and the net revenues values showed higher sensitivity to changes in the corresponding parameter.

When compared with results obtained for a single-trip, sensitivity analysis for the regional red crab fishery indicated that the variance in net revenue attributable to plant efficiency (73.1%) increased in relation to the variance explained by catch variability (26.9%). The importance of catch diminished as a consequence of the adjustment of sample sizes used to conduct the simulation runs (i.e., 900 random variations in catch versus 200 variations in plant efficiency). Reduction in variance of average catch per trip was larger than the reduction in variance of average plant efficiency because a larger sample size was used for the former variable. Further studies considering inter-annual variability of catch could demonstrate greater importance for this variable. The variability in plant efficiency, on the other hand, is scarcely dependent on exogenous factors and most probably would remain similar to the conditions observed during our one-year study.

Lower coefficients of variability for the fishery indicate risk reduction when compared with single-trip operations (Tables 3 and 4). Economic and production variables for the fishery are computed as averages from single trip operations, resulting in lower coefficients of variability and normal-shaped distributions. This situation is expected to occur according to the central limit theorem of statistics (Vose 2001).

Sensitivity analysis indicated that the relative importance of the parameters in determining net revenue for the regional fishery was the same as for a single-trip operation. For the percentage of variation in the base line values that were tested, increasing the number of fishing boats or the length of the fishing season were of intermediate importance. Significant improvements in economic performance could be expected from optimizing other parameters, such as plant efficiency. In particular, catch management appears to constitute a major factor in improving efficiency. For example, Okonski and Martini (1978) reported that 26 t of fresh red crabs were

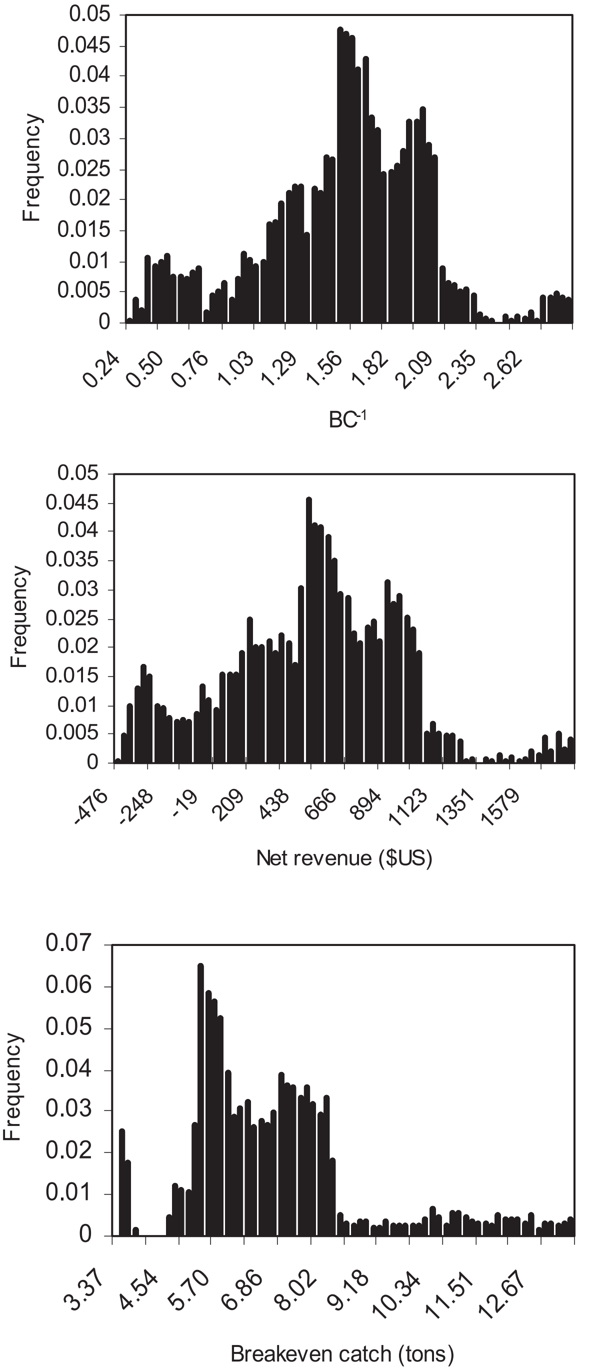

Fig. 4. Benefit-cost ratio (B C^{-1}), net revenue (NR), and breakeven catch for a single-trip operations.

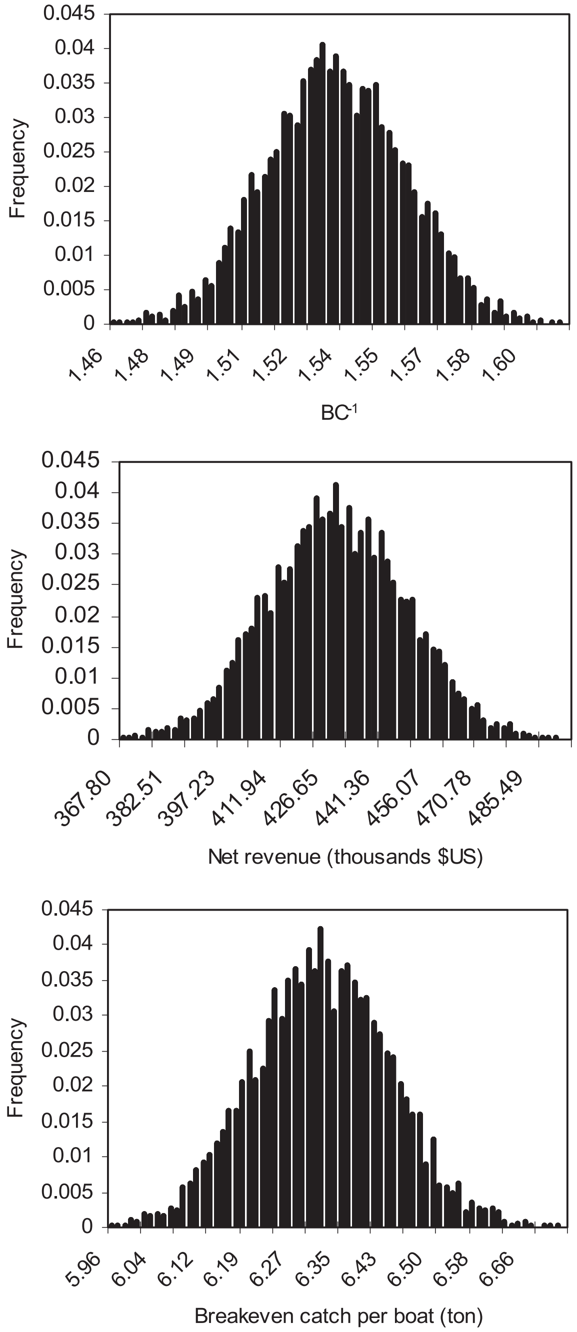

Fig. 5. Benefit-cost ratio (B C^{-1}), net revenue (NR) and breakeven catch for the fishery.

needed to produce two tons of meal (i.e., 7.7% efficiency). In their study, the catch was collected 28−96 h prior to processing and was landed by pumping. However, the authors report a 10% improved efficiency (26 t fresh red crab converted to 2.6 t meal) after the catch collection period decreased to 18−72 h and a conveyor belt was used for landing the catch. In our study, attention was paid to impede or reduce decomposition before processing. The holding time prior to processing was reduced to less than 10 h and the catch was kept at 6.0 ± 3.0 °C in the vessel holds, using plastic trays containing 40 kg of red crabs or bags containing 20−30 kg. Our catch was landed manually and rapidly moved by truck to the processing plant. These procedures resulted in plant efficiency significantly higher than that reported by Okonski and Martini (1978).

A low sensitivity of net revenues to processing cost was observed. An increase of 20% in the processing costs of red crab meal would scarcely reduce net revenues for the fishery, from US$427 840 to 395 181 (Fig. 6), and leads to a slight reduction in benefit-cost ratio from 1.53 to 1.48 for the fishery. A price

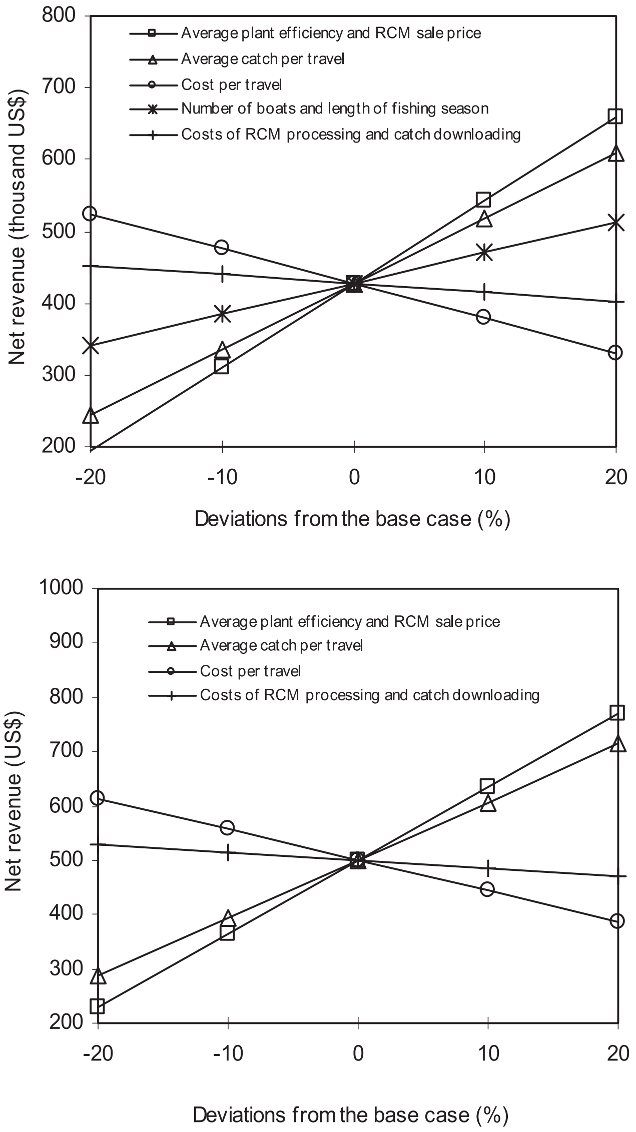

Fig. 6. Sensitivity of net revenue to changes of ±20% in baseline parameter values considered for evaluation of (a) Single-trip operation and (b) Fishery. Parameters where a common line is indicated gave identical results or scarcely discernible differences. Average plant efficiency and red crab meal sale price (■ squares), average catch per trip (▲ triangles), cost per trip (○ circles), costs of red crab meal processing and catch (+ crosses), and number of boats and length of fishing season (* asterisks).

higher than US$86.25 per ton could be negotiated. This would stimulate the venture into processing red crab into meal. This situation is reinforced by the high sensitivity of net revenues and benefit-cost ratio to increased plant efficiency. Any improvement in efficiency would facilitate price negotiation for both the fishery and the processing plant.

The recommended annual catch for the red squat lobster *Pleuroncodes monodon* in Chile does not represent more than 10% of the yearly estimated standing stock. This catch was established since the reopening of the fishery in 1992, after it had collapsed many years earlier (Roa and Bahamonde 1993). Estimated annual catch for the proposed regional fishery does not exceed 10% of estimated abundance of the red crab (Aurioles-Gamboa 1995; Aurioles-Gamboa et al. 1995). This cautionary approach should be stressed during the first years of the fishery to assess the impact on population dynamics of red crab.

This study is based on parameters of an inexperienced fleet and an unexploited population of the red crab to provide criteria for starting a new fishery. It is acknowledged that abundance of the red crab will decline after the fishery has been established, and that the catch per trip could be lower than the ones used here. However, it is also expected that this reduction in catch per trip could be compensated by increases in overall efficiency, as a consequence of more experienced management. Other possible improvements could be derived from: 1) minor modifications to holds of shrimp fishing boats for better storage; 2) mechanizing catch management during onboard storage and land transfer; and 3) modifying the stern-towing gear to make fishing possible in deeper waters. In every case, a rigorous monitoring of the fishery is strongly recommendable and future estimates of some parameters will likely be needed for re-evaluations of fishery performance. This should indicate the most convenient avenue for sustainable management of the fishery.

4 Conclusion

A preliminary economic evaluation of developing a red crab fishery to obtain red crab meal indicates that profits are feasible. A more complete evaluation would require, among other issues, additional economic criteria and defining more specific conditions for a fishery to operate.

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