Environment Canada Environnement Canada
Fisheries Pêches

Loss of commercial snow crabs to cod gillnets in Newfoundland

by R. J. Miller and J. R. Hoyles

FISHERIES RESEARCH BOARD OF CANADA
TECHNICAL REPORT NO. 429

1973

FRB

FISHERIES RESEARCH BOARD OF CANADA

Technical Reports

FRB Technical Reports are research documents that are of sufficient importance to be preserved, but which for some reason are not appropriate for primary scientific publication. No restriction is placed on subject matter and the series should reflect the broad research interests of FRB.

These Reports can be cited in publications, but care should be taken to indicate their manuscript status. Some of the material in these Reports will eventually appear in the primary scientific literature.

Inquiries concerning any particular Report should be directed to the issuing FRB establishment which is indicated on the title page.

FISHERIES RESEARCH BOARD OF CANADA

TECHNICAL REPORT NO. 429

LOSS OF COMMERCIAL SNOW CRABS TO COD GILLNETS IN NEWFOUNDLAND

by

R. J. Miller and J. R. Hoyles

This is the thirty-fourth FRB Technical Report from the

Biological Station, St. John's, Nfld.

Fisheries and Marine Service

Department of the Environment

December 1973

ABSTRACT

The weight of crabs caught in cod gillnets and the weight of crabs killed were estimated for 11 areas on the south and east coasts of Newfoundland. Crab mortality was due to injuries suffered in untangling them from gillnets rather than to air exposure. 4.2 million pounds of crabs were caught in gillnets, 52% of commercial size, and 1.9 million pounds were killed, 59% of commercial size. There was a significantly greater mortality among commercial than sub-commercial crabs (47% vs. 38%). The catch of female crabs was negligible, presumably because of their small size. The weight of legs lost from survivors of all sizes was insignificant at 40,000 pounds. Western Notre Dame Bay was the area with greatest crab mortality, the loss being 0.9 million pounds. The total mortality in areas with potential to support a crab fishery was a maximum of 1.5 million pounds. At 1973 prices this would have a gross value to fishermen of $240,000 and a gross value to processors of $840,000. Of five possible solutions for preventing this loss, the introduction of gillnets modified so they do not catch crabs holds the greatest promise.

INTRODUCTION

The popularity of the cod gillnet has greatly increased over the last 12 years, and with this increase have come several associated problems. The number of gillnets in use increased from 4000 in 1961 to 76,000 in 1971 (Anon. 1972) following the switch from cotton to nylon gillnets in 1961-63 (Fleming et al. 1964). Gillnet fishing largely replaced longline fishing because of higher catches of cod, the market acceptability of flatfishes (a group caught effectively with gillnets), and the incompatibility of the two fishing methods (A. M. Fleming, personal communication). Gillnets selectively catch larger cod on the average than longlines and remove this high priced component from the longline catches. Also, gillnets are commonly set perpendicular to depth contours and remain on the grounds throughout the season. This excludes longlines from these grounds as they are usually set parallel to the depth contours and are usually set and hauled the same day, thus not permanently occupying the grounds. Other problems with gillnets are that they are sometimes hauled as infrequently as once per week resulting in poor quality fish, and some lost gillnets are suspected of "ghost fishing", i.e. continue catching fish even though they are never tended. Gillnets compete with trawlers for fishing grounds beyond the 12 mile limit, and gillnets incidentally catch and kill large quantities of snow crab, a resource that has only recently been exploited.

Snow crabs have been a nuisance to gillnet fishermen in Newfoundland since about 1965 when a fishery for flatfish developed in depths greater than 80 fathoms. Up to one man-hour per net may be required to clean crabs from gillnets. It was the crab catches in gillnets in Trinity Bay that prompted the establishment of an experimental crab processing plant there in 1967 (Simpson and Simpson 1968). A productive crab fishery is now established in Newfoundland with landings of 3.3 million pounds in 1972. Landings will likely continue to increase for the next few years since much of the known resource is not yet exploited.

Crabs killed when they are removed from gillnets are a loss of the crab resource when this occurs in an area where crabs are abundant enough to be fished commercially. This loss is defined as waste since (1) the Newfoundland crab resource is limited and (2) the market for crab meat is, for the foreseeable future, insatiable[1]. Therefore, the more of the resource that can be sold as finished product the larger the economic return from the fishery.

The purpose of this study was to indicate the general magnitude of the annual loss of snow crabs to the gillnet fishery and to identify the geographic areas where the problem is greatest. We hope the information will stimulate discussion within the fishing industry and among resource managers of possible remedial action. We do not intend to cast gillnet fishermen as villains. Clearly, most would be pleased never to have to untangle another crab from their nets.

The area studied was from White Bay south to Cape Race, and from Cape Race west to Placentia Bay (Fig. 1). The remainder of the Newfoundland coast was not included since it has not yielded commercial concentrations of crabs. Labrador was not included since its crab potential is not known and the gillnet fishery is small. The field work was conducted from July through November 1972, and May through July 1973.

The results include, for each of 11 areas, the pounds of commercial sized (greater than 4 inches shell width) and sub-commercial sized (less than 4 inches shell width) crabs caught, the pounds of commercial and sub-commercial crabs killed, and the pounds of legs removed from commercial and sub-commercial crabs that lived.

Data used in calculating these results were obtained as follows. A few trips with gillnet fishermen revealed the most common injuries to crabs caused by removing them from gillnets. These injuries were duplicated in the laboratory and the percentage dying from each type of injury was observed. A total of 143 fishing skippers were interviewed in 11 areas

---

[1]Although demand for crab meat is increasing, the supplies of King Crab and Blue Crab have dropped precipitously in the last 5 years, and catches of Dungeness Crab have apparently peaked.

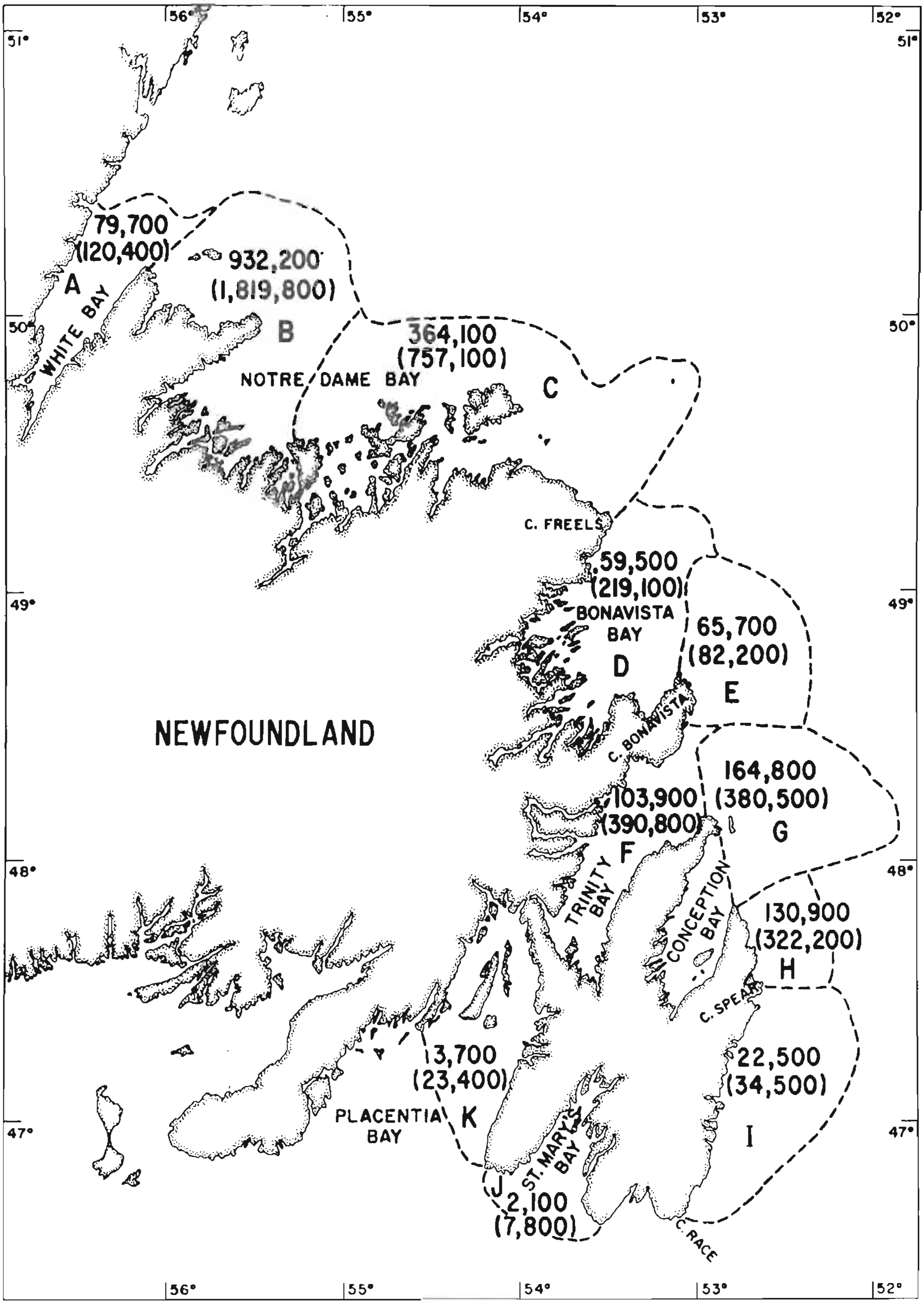

Fig. 1. Pounds of snow crabs killed and pounds caught (in parentheses) per year in gillnets for each of 11 areas.

to determine (1) the number of boats fishing gillnets and catching a significant quantity of crabs (more than 10 pounds per day), (2) the number of nets hauled per trip, and (3) the areas fished. Twenty-four one-day trips were made with fishermen to record the number and sizes of crabs caught, and the numbers and types of injuries. The number and sizes of these samples for each area are given in Table 1. The great variability inherent in the data from these samples prevents precise interpretation of results. The average number of times per year fishermen hauled their nets in each of the 11 areas was obtained from sales slips collected by the Economics Branch of the Fisheries and Marine Service.

The non-scientist may want to skip the sections of this report labelled Methods and Appendix. They contain the details of data collection and calculations.

Table 1. Details of samples taken on trips with fishermen.

Area code	Area	Date	No. fishermen	No. samples	No. nets	No. crabs
A	White Bay	July 20, 1973	1	1	30	385
B	Notre Dame Bay Horse Is. to New Bay	July 17, 1973	1	1	16	446
C	Notre Dame Bay New Bay to Cape Freels	July 5, 1973	1	1	36	331
D	Bonavista Bay	Sept. 6 and 8, 1972	2	2	70	369
E	Cape Bonavista Offshore	June 21, 1973	1	1	25	73
F	Trinity Bay	Aug. 3, 1972; May 31, 1973	2	2	112	838
G	Offshore Trinity and Conception Bay	July 20, 1972; June 4, 1973	2	2	115	450
H	Cape St. Francis to Cape Spear	Sept. 15, 21, 23, 1971; June 5, 1972	2	4	106	687
I	Cape Spear to Cape Race	July 6 and 24, 1972	3	3	72	0
J	St. Mary's Bay	July 13, 1972	1	1	12	59
K	Placentia Bay	Nov. 14, 15, 16, 1972	2	5	41	54
	TOTALS:		19	24	635	3695

METHODS

Laboratory studies of crab injuries and exposure: Crabs were purchased from crab fishermen and held in a tank in the laboratory or in a crab trap in the sea for at least 1 day before they were used in experiments. They were 3.5 to 4.1 inches carapace width, had at least 8 of their 10 legs (many crabs in natural populations are missing one or more legs), and were in healthy condition as determined by quick reaction to mechanical stimulus.

Experimental animals were held in pairs in compartments 12 by 12 by 10 inches deep. Experiments were conducted during May and June 1972 in a 10 by 3 foot tank supplied with a continuous flow of ambient sea water varying from 33 to 40°F. Crabs were placed in compartments and treatments were assigned to the compartments using a random numbers table. The suitability of the tank was tested by holding crabs for 8 days at 33 to 36°F. No crabs died or became weak and there was no cannibalism.

Air exposure was accomplished by holding crabs in plastic trays in a constant temperature room. Crabs were exposed to warm water in a 20 gallon plastic tank.

Crab injuries were inflicted as we had observed fishermen inflicting them. Legs were removed with a fast twisting motion at right angles to the plane of the carapace. Carapaces were cracked by squeezing the sides of the carapace between the heels of the hands until the legs from both sides met under the crab.

At various time intervals following exposure or injury crabs were placed on their backs in water at the ambient sea water temperature and the time required for them to right themselves was recorded. Each crab was given a maximum of 2 minutes to turn over, and time was recorded to the nearest second. The righting times of experimental animals and controls (no exposure or injury) were compared using a one-tailed "t" test. Only crabs which survived until the end of experiments were included in these comparisons.

Interviews with fishermen: In each community visited we attempted to interview most fishermen fishing gillnets in water depths normally yielding crabs, 60 to 200 fathoms. Each fisherman was asked where he was fishing, the average number of nets he hauled per day, his average crab catch per day, and whether he picked his nets at sea or at the dock. A fisherman's estimate of his crab catch was only used in calculations to eliminate fishermen catching no crabs.

Samples of crab catches: We made 24 one-day trips with fishermen to record the total number of crabs caught, the size of these crabs, the number and types of crab injuries, and the number of nets hauled. Injuries caused by removing crabs from nets were easily distinguished from old injuries by the absence of scar tissue. Since we were dependent on the cooperation of fishermen, weather, and fish (fishermen may stop fishing or switch to other types of fishing in times of groundfish scarcity) for these samples some areas were not as well represented as we would have liked. As an indication of the variability involved, the average catch per net for two samples from Trinity Bay were 8.3 and 3.0 pounds/net, and the two samples from offshore of Trinity and Conception Bay were 4.5 and 2.0 pounds/net. Net soak time, fish catch, and season were sources of variability not investigated.

Number of landings per boat per year: This statistic, equivalent to the number of times per year fishermen hauled their nets, was estimated from the number of sales slips per fisherman for 1971. This year was chosen since it was the last complete annual record when the study began in 1972, and 1971 was a "normal year" in that the inshore fishery was of average duration and did not fail on any major section of the coast studied (Fishery Statistics of Canada, 1965-72).

Calculations: The details of calculating the statistics on the crab catch and an example for White Bay are given in the Appendix with only a summary presented here. Fishing effort per area, defined as the number of nets hauled per year times the crab catch per net, gave the annual crab catch for an area. Of the crabs picked from nets at sea, the overwhelming majority, the fraction that died was determined from the frequency of injuries observed on trips with fishermen and the probability of death from those injuries. Of the crabs that lived, some had lost legs. The weight of lost legs was estimated from the number of each type of leg (cheliped, 1st, 2nd, 3rd, 4th walking leg) lost and the weight of each type of leg. Crabs picked from nets at the dock were assumed dead, or at least permanently lost from the fishing grounds. All results on the crab catch were calculated for both commercial and sub-commercial sized crabs.

RESULTS

Laboratory studies of crab injuries and exposure: Although many crabs removed from gillnets are uninjured, the question arises as to whether they survive the trip from bottom to surface and back again. Experiments with cold air exposure simulated winter exposure on deck. Combination warm air-warm water exposure simulated summer deck exposure plus exposure to surface water temperatures. Normally, air exposure would not exceed a few minutes before crabs were removed from nets and returned to the water. Time to recovery is the time after injury or exposure before the righting time of experimental animals becomes as fast as that of control animals.

This is assumed to indicate the period that crabs might be more vulnerable than usual to predation after they have returned to the bottom.

The most important result of these observations was the near absence of mortality due to exposure (Table 2). Air exposure of 3 days at 30°F and up to 3 hours at 65°F resulted in only one death among 40 crabs; however, over one hour was required for complete recovery in all cases. Although there is no measure of the relation between recovery time and crab survival, it is a reasonable assumption that if crabs are returned to the fishing grounds unharmed they will have a high rate of survival.

Further evidence of high crab survival after deck exposure was provided from tagging studies and from stocking crabs in traps. In July 1969, 2400 crabs caught in crab traps were tagged on the decks of fishing vessels and released in Trinity Bay. Over the next 2 years 40% of these were recaptured (E. J. Sandeman, personal communication), a high percentage considering the low crab fishing effort in that bay and considering that crabs lose the tag when they molt (shed their shell in growth). In similar tagging studies in the western Gulf of St. Lawrence, 50 to 60% of tagged crabs released in heavily fished areas were recaptured (Watson 1970, Watson and Wells 1972). Also in the western Gulf, crab traps were stocked with several hundred crabs and hauled 1 to 2 days later in a study to measure escapement from traps. There was no crab mortality (J. Watson, personal communication).

We assume that crabs removed from nets at the dock do not get back to the fishing grounds since they will have been on deck from several hours to a few days. If they are still alive when released, they are in an

Table 2. Crab deaths and recovery times of survivors after cold air exposure, and combination warm air-warm water exposure.

Exposure			No. crabs experi-mental	No. crabs control	Days after exposure	No. crabs died	Recovery of survivors	
Medium	Time	Temp (°F)					Elapsed time	Yes or no
air	3 days	30	10	6	1	0	4 hr 1 day	no yes
water air water	1 min 5 min 2 min	61 64 61	10	6	1	0	1 hr 3 hr	no yes
water air water	1 min 30 min 2 min	61 64 61	10	6	1	0	1 hr 3 hr	no yes
water air water	1 min 3 hr 2 min	61 64 61	10	6	1	1	1 hr 3 hr	no yes

alien environment of stronger light and, for much of the year, warmer water temperatures than they are accustomed to. The usual water temperature in the crab habitat is between 30 and 34°F.

Considerable mortality resulted from injuries but those surviving recovered quickly (Table 3). Death from injuries varied from 20% for removal of one walking leg to 100% for a cracked carapace. As would be expected, mortality increased with the number of legs removed. Recovery of survivors, as determined by righting time, occurred in less than one hour.

Table 3. Crab mortality and recovery times of survivors after injuries. Water temperature 31 to 40°F.

Injury	Number of crabs		Days after injury	Fraction dead	Recovery of Survivors	
	Experi-mental	Control			Elapsed time	Yes or no
1 cheliped removed	20	16	2	0.25	1 hr 1 day	yes yes
1 cheliped and 1 walking leg removed	20	16	2	0.65	1 hr 1 day	yes yes
1 walking leg removed	20	12	2	0.20	1 hr 1 day	yes yes
2 walking legs removed	20	12	2	0.40	1 hr 1 day	yes yes
3 walking legs removed	20	12	2	0.70	-	-
carapace cracked	10	6	1	1.00	-	-

Crab catch in gillnets: The total annual catch was estimated at 4.2 million pounds (Table 4). 1.9 million pounds of these were killed and a further 40,000 pounds of legs were removed from the survivors. These results and the subsequent breakdown of catches and fishing effort by area include only fishing grounds where the crab catch was at least 10 pounds per boat per day.

The catch estimates for Placentia Bay and Cape Spear to Cape Race need to be qualified. In Placentia Bay about two-thirds of the nets hauled per year are fished in depths less than 60 fathoms and the remainder from 60 to 150 fathoms. As we were unable to obtain a sample from nets fished in the deeper range, we applied the sample catches from shallow water to the entire fishing effort for the bay. This probably resulted in an underestimate in total crab catch in the bay and may have underestimated the proportion of commercial sized crabs since crabs are generally larger and more abundant in deeper water. Although there were no crabs in our 3 samples taken between Cape Spear and Cape Race, we heard many reports of large catches during 1 month in the spring of 1972. Therefore, estimates of total catch and the number of nets picked at the dock were estimated from interviews with fishermen. The percent mortality, percent leg loss, and size distribution were estimated from samples from adjacent areas.

The mortality was generally higher for commercial than for sub-commercial crabs, 47% vs. 38% ($P < 0.05$, $t = 2.18$, 1 tailed test), as was the leg loss from survivors, 2.0 vs. 1.6% ($P < 0.1$, $t = 1.58$, 1 tailed test). These comparisons are on a weight basis and exclude areas E, I, J, and K since those samples included less than 100 crabs (Table 1). The lower mortality and leg loss for sub-commercial animals is attributed to the fact that smaller animals are not as badly entangled in the gillnets and the injuries caused by removing them from nets are not as great.

Injuries to female crabs are minimal, also probably because of their small size. Females stop growing when they reach sexual maturity and seldom exceed 2.5 inches shell width in Newfoundland waters (personal observation). The catch of females is far less than the catch of males. In only one area, offshore Trinity and Conception Bay, did females exceed 1% of the number of crabs in the samples. In this area the catch was 15% females (37 of 250 crabs). An estimated 22% of these died from injuries compared with 43% for males.

Leg loss from survivors is as absolute a loss to the fishery as crab mortality; however, the weight of legs lost is insignificant compared with loss through mortality. Considering the total catch (Table 4), the weight of legs lost is only 2.1% of the weight of crabs killed. If the higher meat yield and higher price for leg meat are considered, this makes the legs 1.3 times as valuable per pound as the whole crab. However, this brings the value of leg loss to only 2.7% of the value of loss through crab mortality. Regeneration of legs would reduce the leg loss slightly, but regeneration is very slow. Ninety percent regeneration of a leg on a commercial sized crab would require approximately 7 years (Niwa and Kurta 1964, Watson 1969).

The potential conflict of the crab and gillnet fisheries is considered below for each of the 11 areas. In most areas commercial potential for a crab fishery was assessed from gillnet catches by fishermen and a federal-provincial program of exploratory crab fishing. These results are subjective since there is no factor available to convert gillnet catch to crab trap catch, since the exploratory fishing does not provide information on seasonal variation in the catch, and since the traps used for most of the exploratory fishing were of a different design from those now used in the crab fishery. The history of success of a crab fishery is the most reliable indicator of commercial potential and was used where available.

Table 4. Calculated estimates of gillnet fishing effort and crab catch in gillnets for each of 11 areas.

Area code	Area	Nets hauled per year	Crab size	Catch per net (pounds)	Annual crab catch in pounds: Total catch	Mortality	Leg loss of survivors	Mortality plus leg loss
A	White Bay	9,070	Commercial	9.61	87,200	61,300	500	61,800
			Sub-commercial	3.66	33,200	18,400	200	18,600
			Total	13.27	120,400	79,700	700	80,400
B	Notre Dame Bay Horse Is. to New Bay	78,100	Commercial	11.8	921,600	554,400	9,600	564,000
			Sub-commercial	11.5	898,200	377,800	5,700	383,500
			Total	23.3	1,819,800	932,200	15,300	947,500
C	Notre Dame Bay New Bay to Cape Freels	108,010	Commercial	2.80	302,400	168,000	2,300	170,300
			Sub-commercial	4.21	454,700	196,100	5,000	201,100
			Total	7.01	757,100	364,100	7,300	371,400
D	Bonavista Bay	39,630	Commercial	4.56	180,700	46,100	3,300	49,400
			Sub-commercial	0.97	38,400	13,400	500	13,900
			Total	5.53	219,100	59,500	3,800	63,300
E	Cape Bonavista Offshore	27,300	Commercial	2.08	56,800	47,300	400	47,700
			Sub-commercial	0.93	25,400	18,400	400	18,800
			Total	3.01	82,200	65,700	800	66,500
F	Trinity Bay	69,400	Commercial	2.00	138,700	33,300	1,900	35,200
			Sub-commercial	3.63	252,100	70,600	3,100	73,700
			Total	5.63	390,800	103,900	5,000	108,900

Cont'd.

Table 4. Cont'd.

Area code	Area	Nets hauled per year	Crab size	Catch per net (pounds)	Annual crab catch in pounds: Total catch	Mortality	Leg loss of survivors	Mortality plus leg loss
G	Offshore Trinity and Conception Bay	114,630	Commercial	1.93	221,200	112,400	2,300	114,700
			Sub-commercial	1.39	159,300	52,400	1,800	54,200
			Total	3.32	380,500	164,800	4,100	168,900
H	Cape St. Francis to Cape Spear	48,600	Commercial	4.77	231,800	101,700	1,600	103,300
			Sub-commercial	1.86	90,400	29,200	900	30,100
			Total	6.63	322,200	130,900	2,500	133,400
I	Cape Spear to Cape Race	2,300	Commercial	10.0	23,000	15,000	100	15,100
			Sub-commercial	5.0	11,500	7,500	100	7,600
			Total	15.0	34,500	22,500	200	22,700
J	St. Mary's Bay	960	Commercial	6.25	6,000	1,400	0	1,400
			Sub-commercial	1.85	1,800	700	0	700
			Total	8.09	7,800	2,100	0	2,100
K	Placentia Bay	25,890	Commercial	0.11	3,900	500	200	700
			Sub-commercial	0.57	19,500	3,200	200	3,400
			Total	0.68	23,400	3,700	400	4,100
	TOTALS:	523,890	Commercial		2,173,300	1,141,400	22,200	1,163,600
			Sub-commercial		1,984,500	787,700	17,900	805,600
			Total		4,157,800	1,929,100	40,100	1,971,000

White Bay: The crab resource potential and potential conflict of crab and groundfish fisheries are great. The crab catch in gillnets was low only because of low fishing effort. The gillnet fishing effort is provided by only 4 resident longliners (I use this term to refer to boat design rather than gear employed) and occasional visitors from St. Anthony and Notre Dame Bay. The catch per net (13 pounds), crab size (72% commercial), and percentage killed (66%) were all high. Catch per net is higher in the deeper parts of the bay but gillnetters fish only the slopes for most of the year because of the crab problem. There has been no crab fishery in White Bay because there is no processing facility, but exploratory fishing and the experience of gillnetters indicate that much of the bay deeper than 100 fathoms has commercial potential.

Notre Dame Bay - Horse Islands to New Bay: One-half the total crab kill in gillnets is in this area. The fishing effort and catch per net (23 pounds) were high; the percent commercial (51%) and percent mortality (51%) were about average. Twenty-one resident longliners provide most of the fishing effort. A good crab resource (as determined from exploratory fishing and gillnet catches) and large gillnet fishing effort signify potential conflict of the two fisheries east of Horse Islands and east of the Baie Verte Peninsula, beyond the 100 fathom contour in both cases. A small crab fishery (less than 100,000 pounds per year) supplies a multipurpose cannery at Little Bay Islands.

Notre Dame Bay - New Bay to Cape Freels: This very large area includes a wide range of potential for crab fishing and for conflict between the crab and gillnet fisheries. Thirty-seven longliners fish areas yielding some crabs and are responsible for a large annual fishing effort. The most likely areas for crab catches of commercial size are between the 100 and 150 fathom contours. Within this depth range gillnet fishermen reported their highest crab catches from northwest of Moreton's Harbour on New World Island, northwest to northeast of Twillingate Island, and north of Shoal Bay on Fogo Island. Exploratory fishing confirmed the crab potential at the first of the three areas but not the other two. There has been intermittent crab fishing from Twillingate and Lewisporte selling to plants at Valleyfield and Bonavista.

Bonavista Bay: The conflict between the gillnet and crab fisheries is not large. The historic record of the crab fishery as well as exploratory fishing confirms that Bonavista Bay has only a small potential for crab fishing. Both plants on the bay have been forced to seek supplies from other areas. The best yields have come from holes east of Indian Bay in the north (landings at the Valleyfield plant) and reaches and holes in the southwest (landings at the Bonavista plant). Little conflict between the gillnet and crab fisheries exists in the Valleyfield area since the 10 longliners that fish within the bay concentrate their effort east of Cabot Island. There is greater conflict from the 10 longliners fishing the southwest part of the bay however. The Bonavista Bay gillnetters caught large crabs (82% commercial size) but were responsible for a low mortality (27%).

Cape Bonavista - Offshore: There is no evidence of commercial concentrations of crabs in this area from either gillnet catches or exploratory fishing; consequently there is no potential conflict between the two fisheries. Thirteen longliners put most of their fishing effort in this area.

Trinity Bay: A moderately large crab catch in gillnets comes from many parts of Trinity Bay, however, the commercial potential for crab fishing is only marginal in the best areas. Twenty-two longliners spend about 75% of their fishing effort in the bay, fishing most of the bay area deeper than 60 fathoms. Although several boats have tried fishing crabs in Trinity Bay since 1968, they have in general found groundfish fishing more profitable. Catches from both crab traps and gillnets have been sold to the Hant's Harbour plant. The crabs caught in gillnets were small (36% commercial) and suffered a low mortality (27%).

Offshore Trinity and Conception Bay: Neither gillnet catches nor a limited amount of exploratory fishing have indicated commercial crab concentrations in this area. The sizable crab catch in gillnets (380,500 pounds) reflects a large fishing effort provided by 37 longliners rather than a high crab density.

Cape St. Francis to Cape Spear: A minor conflict between crab and gillnet fisheries exists between 5 and 12 miles east of Cape St. Francis and within 5 miles of shore to the south between Black Head and St. John's Harbour. One million pounds of crabs were landed from these areas in 1972 and the 1973 landings will probably be greater. The gear conflict is minor at present since most gillnet fishing, provided by 12 longliners, is south and east of the good crab areas. The crabs caught in gillnets were large (72% commercial) and crab mortality was about average (41%).

Cape Spear to Cape Race: Currently only a small conflict between gillnet and crab fishermen exists. There is, however, potential for a much larger problem. In 1973 crab fishermen began fishing an area of about 80 square miles located 15 miles east to southeast of Fermeuse. At least one million pounds will be taken from there in 1973. In addition, limited crab fishing from Bay Bulls in 1973 indicated commercial potential and gillnetters encountered troublesome concentrations of crabs near Cape Broyle in 1972. There is only a small gillnet fishing effort from the 6 resident longliners in these areas but, when fishing is good, they are joined by parts of the larger fleets from St. John's and Conception Bay.

St. Mary's Bay: There is little conflict here as the gillnet fishing effort is very small in the area of crab abundance. The 5 resident longliners and numerous smaller boats fish predominately in depths too shallow for crabs. The only area with a high crab density, as determined by exploratory fishing, is a hole west of Great Colinet Island. Our sample, taken on the edge of this hole, included large crabs (77% commercial) and a low percent kill (27%).

Placentia Bay: Only one-third of the gillnet fishing effort in Placentia Bay (about 9000 net hauls per year) is in depths with significant numbers of crabs. Although, as discussed earlier in this section, we were unable to obtain a reliable estimate of the crab catch per net for the deeper water, interviews with fishermen indicated it was not unusually large. This indication plus a small fishing effort in deep water suggests a small crab catch in gillnets. Exploratory fishing showed some commercial potential but a single attempt at commercial fishing by one longliner in 1972 produced only sub-commercial catches.

The crabs killed in gillnets that might be caught by crab fishermen have a gross value to fishermen of $240,000 and a gross value to processors of $840,000. Calculations of these estimates are based on three assumptions. (1) Current prices for live crabs and crab meat will remain constant. Prices will, of course, fluctuate; the trend over the last three years has been a marked increase. (2) The total weight of sub-commercial crabs killed in gillnets would have the same total weight if allowed to grow to commercial size (i.e. although sub-commercial crabs both grow and suffer natural mortality before reaching commercial size, we assume these factors cancel each other out). Available information on growth and mortality of snow crabs indicates that this is a reasonable assumption. (3) Our information on the location of commercial concentrations of crabs is sufficient to correctly estimate how much of the loss of crabs to gillnets might be caught by crab fishermen if the entire commercial resource was fished. This assumption has the largest potential for error. The gillnet catches for the areas of Cape Bonavista offshore and offshore Trinity and Conception Bay have been excluded since there is no evidence to date of commercial crab concentrations. Portions of the gillnet catch of 3 other areas have been excluded for the same reason: Bonavista Bay - one-half, Trinity Bay - one-half, Cape St. Francis to Cape Spear - three-quarters, and Placentia Bay - two-thirds. The weight of catch killed plus leg loss for the remaining areas is 1,545,000 pounds. For these areas gillnet fishing is thought to be on or near commercial concentrations of crabs; however, our data are not sufficiently refined to distinguish between these two categories. Therefore, we have made no adjustment to account for the gillnet catches that are only near commercial crab concentrations and the above values for loss to the gillnet fishery should be considered maximum estimates.

DISCUSSION

The crab catch in gillnets represents a significant waste of the crab resource. Crab mortality and leg loss of nearly 2 million pounds per year is significant compared to 1972 landings of 3.3 million pounds and an estimated maximum sustainable yield of 9 million pounds per year (Miller, unpublished).

Five possible methods of treating the problem are considered below.

(1) A partial solution is for crab processors to buy crabs from gillnet fishermen. However, many crabs are so badly tangled in nets that it is not practical to remove them alive. Also, the gillnet fishery is widely dispersed, and the size of the crab catch landed in a single community would often not justify the cost of transportation to a crab plant. Crabs caught in gillnets should be processed soon after they are landed because, on the average, they have experienced more exposure and leg loss than trap caught crabs and do not live as long out of water (R. Tuck, personal communication). Less than 5% of the annual crab catch in gillnets is now processed.

(2) Gillnet fishermen could be asked to remove crabs from gillnets with a minimum of injury. A regulation to this effect would be difficult to enforce, however, since violations would occur on the fishing grounds. Also, such a request would be unpopular with fishermen since, in areas where crabs are a problem, taking time to carefully remove crabs would reduce the number of nets that could be fished daily.

(3) Exclusive crab fishing zones might be practical for a few small areas with a particularly high crab potential, but over large areas the value of fish caught probably exceeds the value of crabs lost. A comparison for the two areas with the highest crab catch per net is given below.

	Gross value of groundfish catch in crab depths[1]		Gross value of crabs killed in gillnets[2]	
	to fisherman	to processor	to fisherman	to processor
White Bay	$ 65,000	$187,000	$ 13,000	$ 43,000
Horse Is. to New Bay	$186,000	$531,000	$152,000	$503,000

[1]1971 catches and 1973 prices

[2]1973 catches and 1973 prices

(4) Different seasons for gillnet and crab fisheries would not provide a remedy since, as far as we know, there is no marked change in crab vulnerability to gillnets throughout the fishing season.

(5) Some Japanese fishermen use gillnets modified so that the bottom meshes fish one foot off the sea bottom. This greatly reduces the catch of snow crabs (K. Ishida, personal communication). If this works in Newfoundland (we will try the modified nets in 1974), it holds the greatest promise for alleviating the conflict between the crab and gillnet fisheries.

A conceptual (but untested) model has been constructed to illustrate some of the likely interactions of the crab trap and groundfish gillnet fisheries (Fig. 2). Gillnets catch crabs down to a slightly smaller size than do crab fishermen, but both fisheries apparently catch crabs up to the maximum size in the population. Crab fishermen, of course, fish crabs up to the maximum density they can find but generally consider catches below 15 pounds per trap unprofitable (the absolute density - pounds of crabs per unit area of fishing ground - at any given catch level is not known). A gillnet fisherman on the other hand fishes in areas of zero crab density but will not tolerate densities near the maximum. His tolerance of crabs, based on opinions solicited in interviews, increases with increasing fish catch. His maximum tolerance is approximately 30 pounds of crabs per net averaged over a fleet. Above this he will have to restrict the number of nets he can handle per day on the fishing grounds or bring his nets to the dock to remove the crabs. In either case

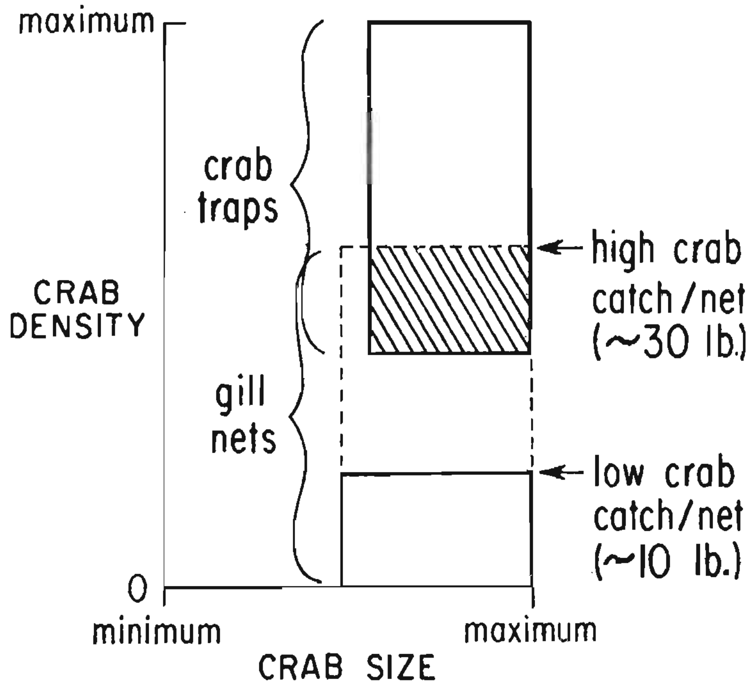

Fig. 2. Interactions between the crab trap fishery and groundfish gillnet fishery. Shading indicates the ranges of crab density and size included in both fisheries.

he will probably move his nets to another location in hope of finding continued high fish catches but fewer crabs. At intermediate to low fish catches, crab catches of 10-30 pounds per net will still enter in his decision of where to fish. A crab catch below 10 pounds per net is probably not enough nuisance to affect his decision.

The density producing the highest crab catches tolerated by gillnetters probably overlaps the minimum crab density that will attract crab fishermen (gillnetters fish areas with commercial concentrations of crabs, e.g. White Bay and east of Cape St. Francis). This overlap may make good crab fishing grounds more vulnerable to gillnetting and less suitable for crab fishing. That is, if crab fishermen fish an area down to the minimum catch per trap acceptable to them, it may place crab density well within the range acceptable to gillnetters. If gillnet fishermen then engage in a sustained fishing effort on these grounds, they might destroy the annual production as it occurs and prevent the crab stock from regaining a commercial density.

ACKNOWLEDGMENTS

We are indebted to the many gillnet fishermen who generously provided us with information on their fishing activities and allowed us to accompany them on fishing trips. We thank Messrs. E. J. Sandeman and M. C. Mercer for reading the manuscript, Dr. W. R. Black for suggestions on presentation of results, and the Marine Sciences Research Laboratory, Memorial University of Newfoundland, for laboratory facilities to work with live animals (MSRL Contribution No. 159).

The Commercial Invertebrates Group suffered a grievous loss when Mr. Maxwell H. Manuel lost his life in an automobile accident while collecting information for this report. Mr. Manuel will be missed for his service to the laboratory and for his amiable disposition.

REFERENCES

Anon. 1962. Men, boats and gear. Economics Branch (Newfoundland), Fish. and Mar. Serv., Dept. of the Environment.

Fleming, A. M., A. T. Pinhorn and R. Wells. 1964. The inshore cod fishery with synthetic gillnets. In W. Templeman, Fish. Res. Bd. Canada, Biol. Sta. Ann. Rep. 1963-64, 88 p., mimeo.

Niwa, K. and H. Kurata. 1964. Limb loss and regeneration in the adult king crab *Paralithodes camtschatica*. Fish. Res. Bd. Translation Ser. No. 1190, St. Andrews, N.B., 8 p.

Simpson, S. L. and J. Simpson. 1968. Interim report, Atlantic queen crab, Newfoundland, 1967. Proj. Rep. No. 19, Ind. Dev. Branch, Fish. and Mar. Serv., Ottawa, 14 p., mimeo.

Watson, J. 1969. Biological investigations on the spider crab *Chionoecetes opilio*. *In* Proceedings Meeting on Atlantic Crab Fishery Development. Can. Fish. Rep. 13: 19-47.

1970. Tag recaptures and movements of adult male snow crabs *Chionoecetes opilio* (O. Fabricius) in the Gaspé region of the Gulf of St. Lawrence. Fish. Res. Bd. Canada Tech. Rep. No. 204, St. Andrews, N.B., 16 p.

Watson, J. and P. Wells. 1972. Recaptures and movements of tagged snow crabs (*Chionoecetes opilio*) in 1970 from the Gulf of St. Lawrence. Fish. Res. Bd. Canada Tech. Rep. No. 349, St. Andrews, N.B., 12 p.

APPENDIX

Sample calculation of annual crab catch for White Bay.

(1) Fishing effort

$$E = f \times \bar{a} \times \bar{b}$$

E = nets hauled/year

f = number of boats

$\bar{a}$ = mean number of nets hauled/boat/fishing day

$\bar{b}$ = mean number of fishing days/boat/year

$E = 9072$, $f = 4$, $\bar{a} = 42$, $\bar{b} = 54$

Subsequent calculations are carried out for both commercial and sub-commercial sized crabs.

(2) Crab catch per net in sample(s).

$$\bar{p} = \frac{\sum_{i=1}^{n} N_i Y_i}{H}$$

$\bar{p}$ = mean crab catch/net in sample (lb)

n = number of size classes

N_i = frequency in size class i

Y_i = weight/crab in size class i (lb)

$= .00000155 X_i^{2.879}$

X_i = carapace width of crabs in size class i in mm

H = number of nets fished to catch sample(s)

Sample size frequency distribution

Commercial			Sub-commercial		
X_i		N_i	X_i		N_i
104	(102-106)	64	59	(57-61)	3
109	(107-111)	51	64	(62-66)	2
114	(112-116)	43	69	(67-71)	5
119	(117-121)	39	74	(72-76)	3
124	(122-126)	22	79	(77-81)	5
129	(127-131)	5	84	(82-86)	13
134	(132-136)	4	89	(87-91)	24
			94	(92-96)	54
			99	(97-101)	48

H = 30 nets

Commercial: $n = 7$; $\bar{p} = 9.61$ lb/net

Sub-commercial: $n = 9$; $\bar{p} = 3.66$ lb/net

(3) Crab catch/year (P)

$P = \bar{p}\, E$

Commercial: P = 87,182 lb/year

Sub-commercial: P = 33,203 lb/year

(4) Weight of crabs that die (D)

$D = KP\,(1 - B) + PB$

K = fraction of crab catch that die/year

$$K = \frac{\sum_{j=1}^{m} M_j I_j}{\sum_{j=1}^{m} I_j}$$

m = number of injury types (including no injury)

M_j = fraction of crabs with injury j which die

I_j = frequency of crabs in sample with injury j

B = fraction of annual catch picked from nets at the dock

Injury type	M_j	I_j Commercial	I_j Sub-commercial
1 (1 cheliped)	0.25	8	7
2 (1 cheliped + 1 walking leg)	0.65	5	5
3 (1 walking leg)	0.20	5	5
4 (2 walking legs)	0.40	6	3
5 (3 walking legs)	0.70	3	4
6 (cracked carapace)	1.00	151	74
7 (no injury)	0	53	56

Commercial: D = 61,288 lb/yr; K = 0.70; B = 0.01; M = 7
Sub-commercial: D = 18,411 lb/yr; K = 0.55; B = 0.01; M = 7

(5) Weight of crabs that lived (L)

$L = P - D$

Commercial: L = 25,894 lb/yr
Sub-commercial: L = 14,792 lb/yr

(6) Weight of legs lost from crabs that lived (Q)

$$Q = \frac{\sum_{j=1}^{m} (1 - M_j)\, I_j W_j}{\sum_{j=1}^{m} (1 - M_j)\, I_j} \times L$$

$1 - M_j$ = fraction of crabs with injury j that lived

W_j = fraction of leg(s) weight of total crab weight for injury j

Injury type	$1 - M_j$	I_j		W_j	
		Comm.	Sub-comm.	Comm.	Sub-comm.
1	0.75	8	7	0.085	0.068
2	0.35	5	5	0.137	0.120
3	0.80	5	5	0.052	0.052
4	0.60	6	3	0.103	0.103
5	0.30	3	4	0.155	0.155
6	0	151	74	-	-
7	1.00	53	56	0	0

Commercial: Q = 548 lb/yr
Sub-commercial: Q = 242 lb/yr