Results of a Questionnaire on Research and Management Priorities for Commercial Crab Species in Alaska

Margaret C. Murphy, William E. Donaldson, and Jie Zheng

Results of a Questionnaire on Research and Management Priorities for Commercial Crab Species in Alaska

Margaret C. Murphy, William E. Donaldson, and Jie Zheng

ABSTRACT: A questionnaire was sent to the majority of researchers involved with Alaska shellfish to identify crab research and management priorities. Subjects and commercially exploited crab species were prioritized using a weighted rank frequency. The highest priority research need was assessment of handling/gear mortality in pot and trawl fisheries followed by evaluation of alternative stock assessment methods. Research targeting red king crabs *Paralithodes camtschaticus* was highest species priority among respondents, followed by golden king crabs *Lithodes aequispina*, Tanner crabs *Chionoecetes bairdi*, and snow crabs *c. opilio*.

INTRODUCTION

The International Symposium on King and Tanner Crabs held in Anchorage, Alaska, in November 1989 provided a forum for fisheries professionals of varied backgrounds and interests to debate shellfishery topics. Many unresolved issues raised at the symposium prompted us to develop a questionnaire to identify crab research and management priorities. The questionnaire was sent to shellfish professionals who research or manage crab fisheries in Alaska in the hope that results would be useful for long-term project and budgetary planning.

METHODS

Data Collection

We selectively distributed the questionnaire to our shellfish professionals in the Alaska Department of Fish and Game (ADF&G), National Marine Fisheries Service (NMFS), the University of Alaska (UA) and the University of Washington (UW). Participation in the survey was voluntary, and response was requested within 30 d. Questionnaires were confidential to ensure the privacy of respondents (ASA 1990).

We asked participants to (1) consider 43 distinct subjects related to needed crab research and management in Alaska, (2) rank each subject on a 1–10 scale, with number 1 being high (comprehensive section of the questionnaire), and (3) identify their top-10 subjects for study (*top-10 section*). Participants were given the opportunity to add and similarly rank other topics for crab research and management that were not included in our listing. To examine priorities among species, participants were also asked to rank, number 1 being top priority, the relative importance of expanding research on eight commercially exploited crab species in Alaska (*species section*) and recommend research subjects and corresponding priority by species. If a section of a questionnaire was improperly filled out — i.e., rankings were incomplete — the entire section was discarded from the data analysis.

The participant's employer and pay scale were requested to allow examination of results for possible differences between responses grouped by work orientation and experience. Four pay scales were defined to examine response rate: scale A < 40,000, scale B = $40,000 – $44,999, scale C = $45,000 – $52,000, and scale D > $52,000 per year.

Data Analysis

Ranking of questions within each section were examined with a subject score or a weighted rank frequency divided by the total number of respondents:

$$\text{Subject Score}_i = \Sigma\left(f_{i,j} \cdot w_j\right)/N \;, \qquad (1)$$

where $f_{i,j}$ is the frequency that subject i was assigned weighted rank j and N is the total number of respon-

Authors: MARGARET C. MURPHY is statewide shellfish biometrician and JIE ZHENG is a biometrician for the Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, P.O. Box 25526, Juneau, AK 99802-5526. WILLIAM E. DONALDSON is a shellfish research biologist with the Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, 211 Mission Road, Kodiak, AK 99615.

dents that completed the section. A weight, w_j, of *10* was assigned to the highest rank (1) and a value of 1 to the lowest rank (10). Therefore, the highest ranked subject had the highest subject score; equal subject scores were placed in the same rank. Subject scores by pay scale were calculated with equation (1), but both the numerator and *N* reflected just those respondents within the pay scale. Species scores were computed by equation (1) as well, but the weights ranged from 8 for a rank of 1 to 1 for a rank of 8.

RESULTS

Questionnaire Response

Questionnaires were mailed to 69 individuals canvassing the majority of researchers involved with Alaska shellfish: 38 from ADF&G, 19 from NMFS, and 12 from two universities. Responses were received from 27 participants for a 39% response rate. Response by agency was equal for ADF&G and NMFS at 42%; the combined UA and UW response rate was 25%.

Of the 27 questionnaires returned, we summarized results for only those sections of questionnaires correctly completed: 24 for the top-10 section, 19 for the comprehensive section, and 10 for the species section.

The response rate from UA and UW was low, considerably less than the rate from ADF&G and NMFS and precluded analyzing results by agency. Response rate varied by pay scale but showed no identifiable trend for either ranking method. Of the 24 surveys with complete ranks for the top-10 section, 4 were from pay scale A, 7 from pay scale B, 7 from pay scale C, and 6 from pay scale D. Of the 19 surveys with complete ranks for the comprehensive section, 3 were from pay scale A, 6 were from pay scale B, 6 were from pay scale C, and 4 were from pay scale D.

Summary of Questionnaire Results

Comprehensive and top-10 ranks and scores for each question are presented in Appendix A according to priority assigned by comprehensive rank. "Assessment of handling and gear mortality" was ranked the highest priority. Second was "evaluation of alternative stock assessment methods." Third in importance was "increase forecasting precision for estimates of population size." Ranking fourth and fifth based on comprehensive scores was "improve tagging/fishing mortality programs, and growth and mortality studies on king crab."

A comparison of the overall five highest priority subjects ranked by comprehensive scores to those ranked by top-10 scores showed correspondence for two subjects. "Increase forecasting precision for estimates of population size," was ranked first by top-10 score and third by comprehensive score. "Assess handling and gear mortality" was ranked second based on top-10 score and first by comprehensive score. Additional subjects needing research based on top-10 score included "develop ecosystem evaluation" (priority 3), "develop a 5-year plan for funding shellfish research" (priority 4), and "expand stock assessment surveys in areas and for species presently not surveyed" (priority 5).

Frequencies that subjects were ranked number 1 through 10, subject scores and ranks for all pay scales combined and the subjects rank for each pay scale are presented in Table 1. The same information based on top-10 results is presented in Table 2.

Comments were received from seven respondents in the section soliciting other topics for crab research and management. Specific needs identified were recruitment and environmental indices; population dynamics of golden king crabs *Lithodes aequispina* and Dungeness crabs *Cancer magister;* stock abundance, bioeconomic, and energy budget simulation models; habitat mapping; and research funding and prioritization (Appendix B).

Ranks By Pay Scale

Rank by pay scale for the five highest priority subjects is summarized in Table 3 for each ranking method and more inclusively in Appendices A and B.

In addition to having the highest overall rank, "handling and gear mortality," was ranked second highest based on comprehensive rank by respondents with pay scale A, B, and D, and pay scale C ranked it third highest. "Evaluation of alternative stock assessment methods" was ranked second overall, and first by respondents with pay scales C and D, and second by pay scale A. Respondents with pay scales A and B ranked "improvement of tagging/fishing mortality programs" first. The need to "conduct growth and mortality studies on king crab" was ranked first by pay scale C respondents. Correspondence between the overall and by-pay-scale five highest priority subjects from the comprehensive section was good, 14 out of the 20 possible ranks (5 ranks multiplied by 4 pay scales) having values between 1 and 5 (Table 3).

Correspondence between five highest priority subjects based on top-10 ranks overall and each pay scale

Table 1. Comprehensive section results: frequencies that subjects were selected in a 1–10 rank, subject score, and rank for all pay scales combined and rank for each pay scale.

Subject (Question) No.	Subject Frequency by Rank[a]											Subject Score[b]	Subject's Rank				
	1	2	3	4	5	6	7	8	9	10	Total		Scales Comb.	A	B	C	D
1		2	3	1	3	4	2	2		2	19	5.42	24	8	18	17	15
2	3		3	2	2	1	1	2	4	1	19	5.47	23	5	16	15	21
3		3	2	3	2	1	1	2	4	1	19	5.26	27	6	17	16	22
4	7	2		1	3	2	3	1			19	7.26	9	6	12	2	7
5	5	4			3	3			1	3	19	6.53	17	11	20	3	4
6	8	2	6	2			1				19	8.63	1	2	2	3	2
7	3	4	6	1	2	1	1			1	19	7.53	6	4	3	8	10
8	1	1	4	3			1		1	8	19	4.53	30	10	17	20	16
9	3	6	2	2	4					2	19	7.37	7	1	8	11	5
10	6	2	2		4	1		2		2	19	6.89	11	7	6	13	7
11	4	1	3		1	2		2	1	5	19	5.37	25	7	16	18	18
12	6	3	6	1	1			1	1		19	8.05	2	2	11	1	1
13	4	2	3	3	4	1	1		1		19	7.26	9	6	6	4	12
14	5	3	1	3	3		1	2	1		19	7.16	10	5	6	3	16
15	3	2	1	4	3	1	1	2	1	1	19	6.32	19	9	13	7	15
16	1	2	1	2	4				4	5	19	4.58	29	15	19	15	21
17	4	2	4	5	2	1	1				19	7.68	5	5	9	1	6
18	3	4	4	3	2		1	1		1	19	7.32	8	8	13	2	4
19		1	5	2	2		1		1	7	19	4.63	28	15	21	18	14
20	7	4	1	4		1				2	19	7.84	4	1	1	12	7
21	5	2	3	2	1		3	1		2	19	6.79	13	10	11	6	9
22	5	5		2	3	2				2	19	7.32	8	2	7	14	3
23	3	2	3	2	3	1	1	1	2	1	19	6.37	18	6	14	12	8
24	7	2	1	5	3					1	19	7.89	3	3	4	5	6
25	6	2	1	2	1	2		2	2	1	19	6.68	14	12	10	7	8
26	1	2	1	2	1	1	1	3		7	19	4.26	31	12	25	18	15
27	5	2	2				3	3	2	2	19	5.84	20	7	18	13	12
28	2	1	1	8	2	4				1	19	6.63	15	6	9	9	13
29		3	3	2	2	3	3	1	1	1	19	5.79	21	9	18	9	15
30	2	1	6	2	2	3	1	1		1	19	6.63	15	9	11	6	13
31	1	2			6			1	5	4	19	4.26	31	13	17	20	17
32	2	3	2	5	3	1	2			1	19	6.84	12	9	5	13	8
33		1	1	1	1			2	4	9	19	2.79	34	16	26	22	17
34	2	4	3	2	2		3	1	1	1	19	6.53	17	8	11	15	6
35			2		2	2		1	1	11	19	2.84	33	17	23	21	22
36	3	4	1	4	4	1	1	1			19	7.26	9	4	10	8	6
37	2		2		3	2	2	2	4	2	19	4.63	28	4	24	17	20
38		1		1	2	1	2	3	2	7	19	3.21	32	18	27	19	23
39	4	1	2	4	4	1		2	1		19	6.84	12	4	11	5	15
40	1		1	3	3	3	1	2	1	4	19	4.63	28	16	20	14	19
41		1	6	5	3		3	1			19	6.58	16	8	14	5	11
42	2		3	3	5		2		2	2	19	5.74	22	5	15	11	21
43	1	2	3	1	1	3	1	4	2	1	19	5.32	26	14	22	10	8

[a] Frequency that the subject was assigned that rank by the 19 respondents completing the top-10 section.
[b] Based on 24 participants; N=19 in equation (1).
[c] Pay scale A:<$40,000 (n=4), B:$40,000 – $44,999 (n=7), C:$45,000 – $52,000 (n=7), D:>$52,000 (n=6).

Table 2. Top-10 section results: frequencies that subjects were selected in a 1–10 rank, subject score, and rank for all pay scales combined and rank for each pay scale.

Subject (Question) No.	Subject Frequency by Rank[a]											Subject Score[b]	Subject's Rank				
	1	2	3	4	5	6	7	8	9	10	Total		Scales Comb.	A	B	C	D
1	1					1			1	1	4	0.75	21			10	14
2						1	1				2	0.38	28	13		17	
3								1			1	0.13	32	14			
4	1	2	2	2	1						8	2.67	5	4	12	3	7
5	3	1	1	1	1						7	2.50	6	8		1	4
6	2	1		1	3	4		2	2	3	18	3.63	2	3	4	10	1
7		2						2		1	5	1.04	18	14	5	19	
8	1		1					1			3	0.88	19	8		11	
9	1	1			1	1	1	1	1	1	8	1.67	13	1	17	10	16
10	4	1	1			2		1			9	2.79	4	6	1	8	10
11	1	3								2	6	1.63	14	16	11	13	5
12		1	2	1		4		2	1		11	2.50	6	12	6	9	2
13		1	1	1		4		1			8	1.63	14	15	9	18	3
14	1		2	2	1	1	2	1			10	2.38	8	10	7	7	6
15		1		1		1	2			2	7	1.13	17		9	14	13
16		1						1	1	1	4	0.58	25		10	19	
17		1	3		2	3		1			10	2.21	10	8	16	6	6
18		1	1	1	1	1	1	1	1		8	1.83	12	10	15	6	10
19				2					2		4	0.67	23	11	16	16	
20			2	3	1		1	2		1	10	2.25	9	7	1	15	13
21	3			1	2	1		2			9	2.42	7		2	5	13
22		1	1			1	2	1	1	1	8	1.50	15	5	14	18	8
23	2		1	1						1	5	1.42	16	16	6	12	14
24	2	3	5		1			1		1	13	4.00	1	2	3	4	3
25	1	3	1	1	1	2				3	12	2.96	3	9	8	2	4
26		1				1		1			3	0.63	24		17	18	11
27	1	1	1	2		1					6	1.88	11	10	7	4	
28			1	1	1						3	0.75	21	11		17	13
29				1				1			2	0.33	29		12		
30				1	2		1				4	0.79	20		7	17	
31			1			1					2	0.50	26		9		
32				1	1			2		2	6	0.79	20	16	10	19	15
33		1						1			2	0.46	27				9
34				1	1	1	1		1	1	6	1.04	18		9	19	10
35											0						
36				1		2		1			4	0.67	23	15	14		12
37										1	1	0.04	34			21	
38											0						
39				1			1	2			4	0.71	22	14	11		15
40											0						
41				1							1	0.29	30		13		
42					1						1	0.25	31			16	
43									1		1	0.08	33			20	
Other								1	1	2	4						

[a] Frequency that the subject was assigned that rank by the 24 respondents completing the top-10 section.
[b] Based on 24 participants; N=24 in equation (1).
[c] Pay scale A:<$40,000 (n=4), B:$40,000 – $44,999 (n=7), C:$45,000 – $52,000 (n=7), D:>$52,000 (n=6).

Table 3. Rank by pay scale for five highest priority subjects (or question number) by ranking method.

Ranking Method	Five Highest Priorities		Rank of Subject by Pay Scale [a]				Frequency in Five highest Priorities [b]
	Rank	Subject	A	B	C	D	
	1	6	2	2	3	2	4
Comprehensive	2	12	2	11	1	1	3
Score	3	24	3	4	5	6	3
	4	20	1	1	12	7	2
	5	17	5	9	1	6	2
		Number of Respondents =	3	6	6	4	14
	1	24	2	3	4	3	4
Top-10	2	6	3	4	10	1	3
Score	3	25	9	8	2	4	2
	4	10	6	1	8	9	1
	5	4	4	12	3	7	2
		Number of Respondents =	4	7	7	6	12

[a] Pay scale A:<$40,000, B:$40,000 – $44,999, C:$45,000 – $52,000, D:>$52,000.
[b] Frequency that the subject was ranked by all pay scales among the five highest priorities.

was moderate, 12 out of the 20 possible ranks having values between 1 and 5 (Table 3). "Increased forecast precision for estimates of population size" was ranked highest overall by the top-10 ranking method and ranked second in importance by respondents with pay scale A, third by pay scales B and D, and fourth by pay scale C. Using the top-10 ranking method, only two of the subjects ranked among the five highest overall received a top rank of 1 by any pay scale . "Assessment of handling and fishing mortality" was ranked second overall using the top-10 ranking method and was ranked first by pay scale D, third by pay scale A, and fourth by pay scale B. A top rank of 1 was also assigned "Development of a 5-year plan for funding statewide crab research" by pay scale B, which was ranked fourth overall.

The five highest priority subjects determined by pay scale are summarized by ranking method in Table 4. "Increase crab research and management staff" was considered highest priority by respondents with pay scale A based on both ranking methods. "Improve tagging/fishing mortality programs" was also ranked highest by pay scale A respondents based on comprehensive rank and by pay scale B respondents based on both ranking methods. Additionally, "development of a 5-year plan" was ranked first by pay scale B according to the top-10 ranking method. First priority for pay scales C and D based on comprehensive rank was

"evaluate alternative stock assessment methods." Pay scale C ranked "conduct assessment surveys for species presently not assessed" first in importance based on the top-10 ranking method. Highest priority for pay scale D respondents based on top-10 ranking method was "assess handling and gear mortality."

Ranking of Commercially Exploited Crabs

Results from the final section of the questionnaire, which asked respondents to rank eight commercially exploited crab species on a scale of 1–8, are presented in Table 5. Participants were also asked how they would expand research on each of the commercially exploited species of crab in Alaska and then to prioritize the research on a scale of 1–10 (Appendix C).

Research on red king crabs *Paralithodes camtschaticus* was the highest priority among the 10 respondents completing this section. Second in importance was golden king crabs, followed by Tanner crabs *Chionoecetes bairdi* and snow crabs *Chionoecetes opilio*. Blue king crabs *P. platypus,* Dungeness crabs, Korean hair crabs *Erimacrus isenbeckii* and other species rounded out the list of species priorities in that order.

Of research suggested and ranked, "stock assessment through expansion and increased precision in population surveys" was important for all crabs. "As-

Table 4. Five highest priority subjects (or question number) by pay scale and ranking method.

Ranking Method	Rank	Subject (Question No.) by pay scale [a]				
		Combined	A	B	C	D
Comprehensive Score	1	6	9,20	20	12,17	12
	2	12	6,12,22	6	4,18	6
	3	24	24	7	5,6,14	22
	4	20	7,36,37	24	13	5,18
	5	17	2,14,17,42	32	24,39,41	9
		Number of Respondents = 3	6	6		4
Top-10 Score	1	24	9	10,20	5	6
	2	6	24	21	25	12
	3	25	6	24	4	13,24
	4	10	4	6	24,27	5,25
	5	4	22	7	21	11
		Number of Respondents = 4	7	7		6

[a] Pay scale A:<$40,000, B:$40,000 – $44,999, C:$45,000 – $52,000, D:>$52,000.

sessment of handling mortality" was recommended for all species except Korean hair crabs. "Basic life history information on mortality, growth and molting" was also frequently mentioned research priorities.

DISCUSSION

The three sections of the questionnaire each independently produced the same four broad priorities for crab research in Alaska: (1) determine handling and gear effects on crab health/mortality, (2) assess stock abundance through improved analytical and tagging methods and expansion of population surveys,

(3) develop a long-term research focus, and (4) conduct basic life history studies.

The intercorroboration, however, may have been caused, in part, by similarities in question content among the sections.

Questionnaire results may have been improved by explicitly stating expectations, such as completion of all requested ranks is necessary for inclusion of a participant's response in the analysis. Additionally, the number of subjects presented (43) was probably too detailed and demanding for most respondents to comparatively rank each subject; Meyers (1993) suggested that to be effective surveys should be limited to 30 questions (10 questions would be preferable). A hierarchical categorization of subject areas into broad

Table 5. Species section results: frequencies that species were assigned each rank, score, and rank of each species as a research priority.

Species	Species Frequency by Rank								Score [a]	Rank
	1	2	3	4	5	6	7	8		
Red king crab	3		5	1	1				6.30	1
Brown king crab	2	3	2	2		1			6.20	2
Tanner crab	1	3	1	4		1			5.80	3
Snow crab	3	2	1	1	1		2		5.70	4
Blue king crab		1			6	3			4.00	5
Dungeness crab	1	1		1	1	3	3		3.90	6
Korean hair crab				1	1	2	5	1	2.60	7
Other species			1					9	1.50	8

[a] Based on 10 participants; N=10 in equation (1).

topics then ranking of topics and subjects within topics may have simplified the participants' task and enhanced the overall interpretation, accuracy, and utility of the survey.

LITERATURE CITED

American Statistical Association. 1990. Surveys and Privacy [A Brochure] Prepared by the American Statistical Association Committee On Privacy and Confidentiality. Amstat News, December 1990.

Meyers, B. 1993. Editorial evaluation: mail surveys. Presented at the Council of Biology Editors Meeting, May 1993, San Diego, California.

— Appendix A. —

Appendix A. Questions prioritized by comprehensive rank and corresponding subject score: top-10 rank and
    score are also presented.

| Comprehensive | | | Top-10 | |
Rank	Score	Question (and Question No.)	Rank	Score
1	8.63	Assess handling and gear mortality in pot and trawl fisheries. (Question 6)	2	3.63
2	8.05	Evaluate alternative stock assessment methods, survey design, universal sampling gear, submersible/ROV, etc. (Question 12)	6	2.50
3	7.89	Increase forecasting precision for estimates of population size. (Question 24)	1	4.00
4	7.84	Improve tagging/fishing mortality programs including development of invisible tags. (Question 20)	9	2.25
5	7.68	Conduct growth and mortality studies on king crab. Which species? (Question 17)	10	2.21

Species	Frequency[a]
Red king crab	12
Brown king crab	8
Blue king crab	8

| Comprehensive | | | Top-10 | |
Rank	Score	Question (and Question No.)	Rank	Score
6	7.53	Improve incidental catch observer programs and reporting. (Question 7)	18	1.04
7	7.37	Increase crab research/management staff including biometric expertise. Where? (Question 9)	13	1.67

Location	Frequency[a]
NMFS	1
Kodiak	2
Dutch Harbor	3
Adak	1
Bering Sea/Aleutian Islands	1
Westward Bering Sea	1
Headquarters	2
Region I	4
Region II	1

| Comprehensive | | | Top-10 | |
Rank	Score	Question (and Question No.)	Rank	Score
8	7.32	Conduct growth and mortality studies on Tanner crab. Which species? (Question 18)	12	1.83

Species	Frequency[a]
Tanner crab	8
Snow crab	8

| Comprehensive | | | Top-10 | |
Rank	Score	Question (and Question No.)	Rank	Score
8	7.32	Evaluate alternative management strategies. (Question 22)	15	1.50
9	7.26	Expand stock assessment surveys in areas and for species presently surveyed. (Question 4)	5	2.67
9	7.26	Conduct fisheries oceanographic studies on larvae: drift studies, timing of release, etc. (Question 13)	14	1.63

Appendix A. (2 of 4)

Comprehensive		Question (and Question No.)	Top-10	
Rank	Score		Rank	Score
9	7.26	Time/area studies of crab bycatch rates in trawl gear. (Question 36)	23	0.67
10	7.16	Conduct early life history studies on king crab. Which species? (Question 14)	8	2.38
11	6.89	Develop 5-year plan for funding statewide crab research. (Question 10)	4	2.79
12	6.84	Estimate catchability coefficients for survey gear. (Question 32)	20	0.79
12	6.84	Studies on breeding pairs/reproductive success. (Question 39)	22	0.71
13	6.79	Develop a permanent tag for Tanner crab. (Question 21)	7	2.42
14	6.68	Develop ecosystem evaluation: quality of environment indicators to use in forecasting and determining management strategies. (Question 25)	3	2.96
15	6.63	Expand electrophoretic or other genetics work to identify distinct populations of king and Tanner crab. (Question 28)	21	0.75
15	6.63	Determine molting seasonality and interannual variability for Tanner crab. Which species? (Question 30)	20	0.79

Species   Frequency[a]

Tanner crab   10
Snow crab   11

Comprehensive		Question (and Question No.)	Top-10	
16	6.58	Relationships of crab distribution to bottom temperature and sediment type. (Question 41)	30	0.29
17	6.53	Conduct assessment surveys for species presently not assessed. (Question 5)	6	2.50
17	6.53	Analysis of CPUE: relationships to survey estimates of abundance, season, tide stage, etc. (Question 34)	18	1.04
18	6.37	Evaluate historical databases and studies and document through reporting. (Question 23)	16	1.42
19	6.32	Conduct early life history studies on Tanner crab. Which Species? (Question 15)	17	1.13

Species   Frequency[a]

Tanner crab   11
Snow crab   10

Appendix A. (3 of 4)

Comprehensive			Top-10	
Rank	Score	Question (and Question No.)	Rank	Score
20	5.84	Establish an Alaskan crab research institute/committee to direct, coordinate, and help fund research. (Question 27)	11	1.88
21	5.79	Determine molting seasonality and interannual variability for king crab. Which species? (Question 29)	29	0.33

Species	Frequency[a]
Red king crab	8
Brown king crab	9
Blue king crab	3

Comprehensive			Top-10	
Rank	Score	Question (and Question No.)	Rank	Score
22	5.74	Evaluate sex ratios for king, Tanner, and Dungeness crabs. (Question 42)	31	0.25
23	5.47	Determine major king crab predators. (Question 2)	28	0.38
24	5.42	Develop disease study capability. Where? (Question 1)	21	0.75

Location	Frequency[a]
Juneau	4
Auke Bay	1
Bering Sea (monitoring)	1

Comprehensive			Top-10	
Rank	Score	Question (and Question No.)	Rank	Score
25	5.37	Develop marine laboratory facilities: aquaria, etc. Where? (Question 11)	14	1.63

Location	Frequency[a]
Kodiak	8
Dutch Harbor	1
Seward	1
Auke Bay	1
NMFS	1

Comprehensive			Top-10	
Rank	Score	Question (and Question No.)	Rank	Score
26	5.32	Expand information exchange with other countries. (Question 43)	33	0.08
27	5.26	Determine major Tanner crab predators. (Question 3)	32	0.13
28	4.63	Conduct growth and mortality studies on Dungeness crab. (Question 19)	23	0.67
28	4.63	Crab fecundity studies. Which species? (Question 37)	34	0.04

Species	Frequency[a]
Red king crab	4
Brown king crab	4
Blue king crab	2
Tanner crab	3
Snow crab	4

Appendix A. (4 of 4)

| Comprehensive | | Question (and Question No.) | Top-10 | |
Rank	Score		Rank	Score
28	4.63	Evaluation of effective area fished by crab pots. (Question 40)	NA[b]	
29	4.58	Conduct early life history studies on Dungeness crab. (Question 16)	25	0.58
30	4.53	Investigate aquaculture and transplanting of red king crabs. (Question 8)	19	0.88
31	4.26	Hire or contract expertise to determine socioeconomic goals to be considered in developing management strategies. (Question 26)	24	0.63
31	4.26	Studies on gear design for legal-sized crabs. (Question 31)	26	0.50
32	3.21	Documentation of subsistence harvests. (Question 38)	NA[b]	
33	2.84	Studies on cannibalism in Dungeness pots. (Question 35)		
34	2.79	Seasonal marketability studies: meat yield, quality, etc. (Question 33)	27	0.46

[a] Response to request for information on location or species was not complete therefore frequency is not representative of total number of participants ranking the question.

[b] NA: Not Applicable: This subject area was not considered among the top-10 by any respondent.

— Appendix B. —

Appendix B. Summary of other topics for crab research and management and rank (1-10) assigned that suggestion by the participant.

Rank	Other Research and Management
1	• Have ADF&G in Juneau back shellfish research to the level it needs to be, i.e., increase greatly!! The research has never been adequately funded to match the value of these resources.
	• Observations and recording of egg predators should be done on all surveys and on all observer trips. Please note there never has been shown a greater predator on crabs!
	• Close subsistence, sport, and personal use fishing in areas where commercial fishing has been closed for a particular species for a long time, i.e. red king crabs from Cook Inlet to Dutch Harbor. We need to protect the depressed populations adequately.
	• Use general funds to fund the full amount for the post larval red king crab indexing study using artificial collectors in Kodiak. If this 5-year project is successful it may serve as a great forecasting tool for both agencies and the crab industry by allowing them to predict relative crab population level four to five years earlier than can be done now.
	• Determine molting seasonality and interannual variability for Dungeness crab.
	• Determine molting seasonality and interannual variability for Brown king crab.
	• Recruitment indices: annual abundance indices for age 1-2-3 for red king, Tanner and snow crabs
	• Indices of environmental quality, including phytoplankton production, timing, population/species structure, wind structure and direction, and sea temperature.
	• Modeling studies relating recruitment to environmental quality. Old data is useless for this tasks because of aging problem.
	• New techniques for age determination: histochemical /morphological studies on lipofuscin granule abundance vs. *known* age of crabs.
	• Shell age, true age, molt history: what is the real relationship?
	• Physiology: effects of climate and habitat on respiration, scope for growth, energy budget, feeding rates, etc.
	• Install and operate existing bioeconomic simulation model of king crab fishery in ADF&G computers.
2	• In areas of patchy habitat, sonar mapping of bottom types to improve trawl assessments, especially PWS, Kodiak, and S. Penn.
	• Feedback on results of this survey.
	• Need more input from, and information about Soviet stocks. They survey our stocks, why don't we survey theirs, or require that they provide us timely assessment data on their stocks in exchange for letting them survey ours. There are contiguous or continuous stocks and yet we know virtually nothing about how their stocks fluctuate relative to ours. Need more input/information on S. America *Centolla* and on Norwegian *Lithodes ingia.* How do they compare to Alaska crab in biology and growth?
	• Expand bioeconomic model of king crab fishery to include:
	• Brown and blue crab biological models;
	• Russian production and market impact;
	• Brown and blue crab market models.
	• Develop new simulation models of crab populations.
3	• Determine molting seasonality and interannual variability in Dungeness crab.
	• Study effects of trawl gear on crabs not caught.
4	• Study golden king crab habitat/depth distribution by size, sex, and season.
	• Evaluate terminal molt in snow crabs.
	• Further crab fishery economic studies.
6	• For Adak brown king crab populations: careful planning of observer data collection, by ADF&G personnel, not unreliable SCAB observers;
	• differential growth across Aleutian Islands;
	• need for different size limits;
	• stock-recruit problems with removal of large males.
	• Shellfish should get funding equal to its value compared to salmon.
7	• Determine king crab, Tanner crab and Dungeness crab prey.
8	• Examine effects of climate and habitat on crab physiology.
9	• Determine relationship between shell age, true age and molt history.
10	• Develop new simulation models of crab populations.
	• Determine molting seasonality and interannual variability for Dungeness crabs.
	• Establish an advisory board to advise ADF&G research. It is regarded as top priority in the belief that it would provide support and a formality which would raise our standards of planning, execution, data archiving and publication. As a No. 1 priority the "board" could review and establish all the other priority set here. Thus it must come first.

Appendix B. (2 of 2)

Rank	Other Research and Management

Miscellaneous
- Incidental catch and mortality are hot political issues. These need to be studied FAIRLY so that relative magnitudes of problems are identified and management policy set. The current hot air situation is extremely damaging to the industry.
- We have an almost complete lack of information on the basis of production in the North Pacific. We have a general idea of ocean currents, some knowledge of food organisms of commercial resources and the various organisms that live in the ocean. But no specific information pertinent to any years, and none on year to year variations. Solving this information gap is far too big for ADF&G to address alone. What we could do is to spearhead, or promote, or contribute to interagency attempts to collect information. NOAA satellites could provide information; university of Alaska could contribute and perhaps others.
- If we are being realistic, I would concentrate on what could be done regarding population (stock) boundaries, structure, abundance, and response to fisheries. Response to fisheries would include studies on gear, seasons, sorting/handling mortalities, optimum size at harvest, bycatch, etc. We should also, as a lower priority, study the role of and place in the ecosystem of these exploited species and how they interacted with other major species.

General comments by one carcinologist:

- *Major Biological Problems:* My top 10 list includes long term problems in understanding population recruitment relative to environmental change, plus the facilities and planning necessary to conduct research of this type. The major problem here that, in order to model the effects of environment or other parameters on population recruitment, a *recruitment index* is needed, which should be an annual index of age 1 to age 3 crabs of any species (esp. Red king, Tanner and snow crabs). Specifically, crabs of accurately known age must be collected by specially dedicated gear in specific habitats. Only when we have an age-specific recruitment index, can we then start to model the effects of environment, predation, mortality, and other abiotic effects on population abundance and fishery performance. Inherent in this approach is the development of techniques to age crabs which are independent of size or area specific growth models.

  Secondly, we need a major program to understand the environmental variables responsible for controlling year-class strength. The APPRISE program was a good start, but too specific to Auke Bay. A FOCI-like approach should be undertaken in both the Bering Sea and Kodiak, since these are two different environments.

  Prior to doing any of this, though, the community of Alaskan Bio-Carcinologists (ABCs) should develop a long-term plan for coordinating research on various topics, and we need to develop the facilities, such seawater laboratories, where they are needed. Good sites for this would be Kodiak, or even the Pribilof Islands.

- *Management Problems:* Items ranked as #2 include problems relative to improvements in stock assessment and management. Better techniques, such as geostatistical estimation with kriging, dedicated sampling gear, and improved sampling designs, are currently available, but without the funding or a mandate from NMFS to employ them, they are of little use. The major improvement to be made here is not in precision, which would require major investments in time, money, and personnel for relatively minor improvements, but rather in accuracy. NMFS survey catchability is currently defined as 1 for all crab species, yet probably underestimates Tanner crab abundance by factors of 2 or greater. Simply understanding catchability could make great improvements in abundance estimation.

- *Minor Biological Problems:* Ranks of 3 and 4 cover such things as predation, mortality, aquaculture, tagging, fecundity, etc. All of these are important problems from a biological viewpoint, but will make little improvement in real-world management. Such items as fecundity, mortality and predation may be important and useful, but may be too variable to estimate accurately.

- *Non-Problems:* Although they may be important to somebody, this category includes ranks of 5 or greater and such things as gear efficiency, marketability, subsistence, economic impacts, bycatch documentation and other items that are essentially not biological problems.

— *Appendix C.* —

Appendix C. Summary of research studies and associated ranks, on a scale of 1-10, for commercially exploited crab species in Alaska.

Species	Rank	Study
Red king crab:		
	1	• Handling effects; • Expand surveys in SE & Aleutians; • Increase precision estimates of abundance; • Analysis of CPUE; • Find an index of recruitment at the earliest life stage possible; • Determine breeding success of age classes of male crab related to management strategies. • Handling mortality/gear escapement. • Male reproductive potential.
	2	• Time/area studies of bycatch; • Focus on ways to cost-effectively raise larva for aquaculture purposes; • Continue post larval indexing using artificial collectors to see if correlation exists between.
	3	• Evaluate historic data basis on growth, etc.; • Determine the season for the high natural mortality of red kings statewide from what appear to be adequate brood stocks. • Larval ecology, early life history & mortality.
	4	• Conduct growth and mortality studies; • Assess handling mortality.
	6	• Behavioral studies on phenomenal production/response based on size/age at maturity.
	7	• Male sizes of maturity on Pribilof Islands and Norton Sound.
Brown king crab:		
	1	• Handling effects; • Genetic study of stocks; • New/expand surveys; • Stock assessment and population process studies • Almost anything. • Male size at maturity.
	2	• Adak stock mortality estimate (F + M) and then population/harvest modelling.
	3	• Conduct assessment surveys; • Assess handling mortality; • Population assessment.
	4	• Basic life history and population estimate on Adak stocks and continue such study on all stocks statewide as resources permit; • Reproduction and life history studies; • Population estimate/indexing.
Blue king crab:		
	2	• Expand surveys in Pribilofs and St. Matthew. • Larval ecology and early life history.
	3	• Handling mortality/gear escapement. • Genetic study of stocks.
	5	• Assess handling mortality. • Additional work on reproduction and size at maturity. Biennial breeding may impose management constraints not indicated for red and Brown king crab; • Improve population estimate/index for Pribilofs and St. Matthew stocks.

Appendix C. (2 of 3)

Species	Rank	Study

Tanner crab:

1 • Handling effects;
• Genetic study of stocks;
• Increase precision estimates of abundance;
• Mortality estimate, molting probability, growth/molt by use of persistent tags.
• Assess handling mortality;
• Evaluate alternative stock assessment methods;
• Terminal molt, early life history, larval ecology, growth and mortality.

2 • Handling mortality/gear escapement.
• Permanent tag/growth/mortality study;
• Time/area studies of bycatch;
• Determine molting frequency and terminal molt;
• Develop a permanent tagging technique.

3 • Heritability study of growth of male crab (both growth/molt and probability of molting).

Snow crab:

1 • Determine molt frequency and terminal molt;
• Develop a permanent tagging technique;
• Determine the reason for tremendous population increase in Bering Sea, i.e., large growth increment on
  survey estimates;
• Need more studies on this species;
• Mortality estimate, molting probability, growth/molt by use of persistent tags.
• Terminal molt, early life history, larval ecology, growth and mortality.

2 • Evaluate alternative stock assessment methods;
• Handling mortality/gear escapement.
• Catchability coefficient;
• Permanent tag/growth/mortality study;
• Evaluate the stock resilience paradigm.

Dungeness crab:

2 • Further handling studies.

3 • Seasonality and interannual variation of molting/mating;
• Growth study.

4 • An overall study of biology at Kodiak, PWS and a selected site in SE.

6 • Examine recruitment mechanisms, e.g., wind aided
  larva drift, etc.

8 • M estimates as a function of size and age.

9 • F estimates on heavily exploited stocks (estimating F on mature animals needs behavioral (clasping pair)
  data).

N/A • Identify critical early life habitats and get some data on annual variations in production.

Korean hair crab:

4 • Need overall study with year round collections in Pribilofs.

6 • Growth/mortality tagging study.

7 • Reproduction studies, size at maturity, and growth and molting.

Appendix C. (3 of 3)

Species	Rank	Study
Korean hair crab:		
	N/A	• Molting.
Other crab species:		
	8	• Distribution mapping of all commercial important species of crab statewide.
	10	• Study commercial potential of *C. angulatus*, *L couesi*, etc., and deep sea crab.

N/A: Not Applicable; no rank assigned.