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ABSTRACT: An annotated bibliography of 159 references was compiled to document adverse fishery capture and handling practices and their effects on crabs and lobsters. Relevant literature was located through computer searches and review of citation sections of topical references and tables of contents from published journals. References selected for inclusion in the bibliography focus not only on how capture and handling affect crabs and lobsters but also impacts caused by lost gear and ghost fishing. References on tagging effects and historical and comprehensive treatments on the physiology of molting, growth, autotomy, and limb regeneration were not included. Publications were arranged alphabetically by author. Abstracts were included when available; otherwise a short synopsis was provided. References were indexed by keywords describing causative mechanism, resulting effect, species, and major geographic area to provide easy access by subject. The bibliography is believed reasonably complete through 1993, although it excludes some older references considered out of date.

INTRODUCTION

Fishing effects on nonretained crabs and lobsters are a major concern for fishers, fishery researchers, and managers. Injury, limb loss, and mortality are immediate results of capture and handling. Long-term effects include reduced growth, increased intermolt period, egg loss, increased susceptibility to predation, failure to successfully molt, reduced foraging capability, and mortality. Each of these leads to some reduction in fishery productivity. Impacts can vary depending on an animal's molt stage, migration activity, size, sex, diet, reproductive state, and abundance. These impacts can be compounded by environmental factors that increase the animal's sensitivity to stressors, such as disease or recapture and added handling.

It is critical to account for all sources of mortality if sustained yield management is to be effective. Significant progress has been made to identify, quantify, and ameliorate handling and capture mortalities for Australian and New Zealand rock lobsters, *Panulirus cygnus* and *Jasus edwardsii*. In the United States, extensive studies have been completed on the effect of handling on American lobsters *Homarus americanus* and declawing on blue crabs *Callinectes sapidus*. Investigations on Dungeness crabs *Cancer magister* along the U.S. Pacific coast show the effect of shell condition on the magnitude of handling injuries and resultant mortality. Work has been initiated on commercially valuable species in the Gulf of Alaska and Bering Sea. However, bycatch of commercial populations of crabs in trawl and pot fisheries and associated interactions with gear generally have been overlooked until recently. Managers now recognize that sorting and discarding nonretained catch over many years may play a significant role in reproductive success and future harvests. Since 1991 fisheries under the jurisdiction of a U.S. federal fishery management plan (FMP) have required that managers estimate total mortality to prevent overfishing (U.S. Government Printing Office 1989). However, managers have found that fulfilling this mandate for FMP crab stocks is complicated by a lack of quantitative estimates of handling mortality, a component of total mortality.

The purpose of this report is to compile references that document fishery capture and handling practices and their effects on crabs and lobsters. These references should assist researchers in design, implementation, and analysis of studies on effects of handling and capture. A total of 159 references are included.

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Most references report on the direct effects of interactions between fishing gear and animals, such as retention of nontarget animals, ghost fishing, rate of limb loss and mortality, or other injuries. Remaining references concern studies of injuries documented in fisheries but inflicted in a laboratory to study resulting detrimental effects.

METHODS

References were located using computer searches and reviewing citation sections of topical publications and tables of contents from published journals. References were selected from professional publications and government agency reports accessible through 1993. A few references published in 1994 were also included. Reference selection criteria were broad, only requiring documentation of the effects of capture or handling on either crabs or lobsters. References on tagging effects were excluded from the bibliography, as were studies on the physiology of autotomy, molting, growth, regeneration (e.g., Bliss 1960; Kurata 1962; Skinner 1984), and adaptive significance of regeneration (Needham 1953). The reader is encouraged to consult these noted treatises when seeking background on detailed physiological mechanisms and responses often triggered by damage resulting from handling and capture.

An abstract was included when permission to reprint was granted by the author or publisher without a fee. A synopsis was written when no abstract was available. Synopses generally covered study objectives and results.

References are listed alphabetically by principal author and sequentially numbered for indexing by keywords. Keywords identify causative mechanism, resulting effect, species, and major geographic area. Several keywords are used to describe a continuum of subjects as follows: *bycatch* refers to nonretained species or discards in trawl, trap, pot, and rake fisheries; *exposure* means exposure to air, whereas *temperature* is used for conditions in water; *illumination* includes reference to photoperiod and light intensity; *injury* is used as a synonym for damage; *sex/size effects* can be interpreted as having to do with an animal's sex, size, or both; *ghost fishing* refers to capture, retention, and death of animals in lost gear (Sutherland et al. 1983); and *lost gear* documents the number of units lost or rate of loss.

BIBLIOGRAPHY

1. Aiken, D.E., and S.L. Waddy. 1985. Production of seed stock for lobster culture. Aquaculture 44:103–114.

KEYWORDS: *American lobster, Canada, fecundity, handling, laboratory experiment, stress, temperature*

ABSTRACT: "Methods for production of larval lobsters from wild brood stock have been developed and refined during several years of operation of a small lobster culture facility. It is now possible to obtain reliable year-round production of larval lobsters from preovigerous females obtained in spring from the commercial fishery." [Reprinted with permission from Elsevier Science B.V., Amsterdam, The Netherlands.]

2. Aiken, D.E., and S.L. Waddy. 1986. Environmental influence on recruitment of the American lobster, *Homarus americanus*: a perspective. Canadian Journal of Fisheries and Aquatic Sciences 43:2258–2270.

KEYWORDS: *American lobster, environment, handling, recruitment, stress, temperature*

ABSTRACT: "Heredity determines the biological limits within which an organism can function, and environment determines whether those biological limits will be reached. When they are, biological processes essential to the recruitment cycle begin to fail, and recruitment to subsequent life stages is adversely affected. The American lobster, *Homarus americanus*, experiences a spectrum of environmental forces within its natural range. The most important among these are temperature and disease. These, plus anthropogenic changes, fishing pressure, and several factors with local or short-term impact, can cause stress, which is cumulative and debilitating. These factors combine to influence spawning, egg attachment, incubation success, hatching, larval development, growth, maturity, reproductive capability, and geographic distribution of the animal — major elements of the recruitment cycle."

3. Alaska Fisheries Board and Alaska Department of Fisheries. 1954. King crab. Pages 34–43 *in* Annual report 6. Juneau, Alaska.

KEYWORDS: *Alaska, catch statistics, handling, historical reference, mark recapture, mortality, red king crab, shell condition*

SYNOPSIS: An historical review of the domestic and foreign commercial fisheries for king crab in Alaska, including early catch statistics, is presented. Handling mortality of females during the softshell period is documented. Notes on the life history and initial attempts to tag king crab are also discussed.

4. Anonymous. 1980. The fate of undersized rock lobsters returned to the sea. Western Australia Department of Fisheries and Wildlife. The Fishing Industry News Service 13(1):10–12, Perth.

KEYWORDS: *Australia, displacement, escape mechanism, exposure, fishermen behavior, hypoxia, mark recapture, mortality, physiology, sorting, western rock lobster*

SYNOPSIS: Effects of differing levels of exposure on juvenile rock lobsters were investigated using a mark-recapture experiment at sea. Animals exposed for 5 min had a 30% recapture rate, whereas only 10% of the animals exposed 30 min were caught again. Effects of dehydration on respiration, oxygen supply, and growth are discussed. Tag rate returns for animals released in their home range and those displaced did not differ. Recommendations to reduce mortality of nonretained rock lobsters included immediate sorting of catch, using a spray system to keep animals wet, and modifying the pot escape gap to reduce retention of juveniles.

5. Anonymous. 1981. Handling techniques costing western Australia rock lobster fishermen about $3.2 million a year. Western Australia Department of Fisheries and Wildlife. The Fishing Industry News Service 14(2):3–5, Perth.

KEYWORDS: *Australia, economics, exposure, fecundity, fishermen behavior, pressure change, sorting, western rock lobster*

SYNOPSIS: Summaries of previous work on rock lobster exposure are discussed. Percentage of fishermen employing 4 different sorting techniques for juvenile lobsters and amount of time taken to complete the sort are tabulated. Results of an experiment on the effect of exposure on egg survival in berried females showed percentage of dead and empty egg cases increased moderately with the incubation period in animals exposed 15 min or less. Animals exposed 30 min demonstrated a dramatic increase in the percentage of dead eggs and empty egg cases after 10 d incubation. Little effect on egg development was noted for one group of animals subjected to pressure changes through 10 gear pulls from 24 fathoms of water.

6. Ary, R.D., Jr., C.K. Clelmer, K. Bartell, and M.A. Poirrier. 1987. The effects of chelotomy on molting in the blue crab, *Callinectes sapidus*. Journal of Shellfish Research 6:103–108.

KEYWORDS: *Blue crab, chelotomy, growth, laboratory experiment, molt cycle*

ABSTRACT: "Cheliped removal was studied as a possible means of inducting and synchronizing ecdysis in juvenile (40–100 mm) blue crabs, *Callinectes sapidus*. Experiments were conducted in closed, recirculating seawater systems. In experiment I, chelotomy was induced in crabs for which the time period from the last ecdysis was unknown and assumed to be random. In this experiment, chelotomy did not significantly shorten the mean time to ecdysis, but it did reduce the variance of the individual times to ecdysis as compared to controls of similar size. This synchronization effect was attributed to chelotomy and limb regeneration delaying molt in crabs which were approaching proecdysis and accelerating molt in crabs with some physiological preparation for ecdysis. In experiment II, chelotomy was induced in crabs five days after ecdysis. Results showed no significant difference in the molt interval between these crabs and the intact controls. The lack of molt acceleration was attributed to chelotomy not affecting very early intermolt crabs because they have minimal physiological preparation for ecdysis.

"Chelotomized crabs increased in carapace width an average of 16.9% in experiment I and 18.0% in experiment II, compared to a 21.6% and 20.5% increase for intact controls. The regenerated cheliped length in chelotomized crabs increased an average of 5.1% and 5.4% in the respective experiments, compared to a 23.1% and 21.5% increase in controls."

7. Barnett, H.J., and four coauthors. 1973. The overland shipment of live Dungeness crabs by self-contained van. Marine Fisheries Review 35:18–24.

KEYWORDS: *Dungeness crab, exposure, mortality, transport*

ABSTRACT: "The concept of delivering live Dungeness crabs to out-of-the-way markets by truck has been considered from time to time. Because it is difficult to keep the crabs alive beyond 1 or 2 days out of their natural environment, the idea has never proven to be workable. Described here are the results of laboratory experiments to develop such a method. The most successful laboratory method — designed around

a system of vertically stacked trays fed by recirculated, chilled seawater — was scaled up and field tested. In two over-the-road tests, one lasting 3 days and the other 4 days, crab losses averaged less than 10 percent."

8. Barry, S. 1981. Coastal Dungeness crab study. State of Washington, Department of Fisheries Project Progress Report, Project Number 1-135-R (3), October 1, 1979 to September 30, 1980.

KEYWORDS: *Dungeness crab, handling, mortality, shell condition, Washington*

SYNOPSIS: Dungeness crabs with intermediate shell hardness were subjected to simulated commercial handling and placed in holding pots with escape openings wired shut. The softshell mortality in 5 trials of 5–9 crabs each ranged from 11.1% to 50.0%.

9. Barry, S. 1984. Coastal Dungeness crab study. State of Washington, Department of Fisheries Project Progress Report, Project Number 1-167-R (3), October 1, 1982 to December 30, 1983.

KEYWORDS: *Dungeness crab, gear loss, handling, meat yield, molt cycle, mortality, pots, shell condition, Washington*

ABSTRACT: "Shell condition sampling at canneries and at sea indicated heavy molting activity in the ocean occurred late July and early August of 1983. An unprecedented high level of summer fishing effort occurred. The commercial sport seasons were closed on September 2.

"Fishing effort during the 1981–1982 season declined sharply compared to recent seasons due to decreased crab abundance. Fishermen lost an estimated 4,250 pots during the 1981–1982 season — 14% of the estimated total number of pots used during the season. Most fishermen supported a regulation proposal to require pots to be rigged in a manner which would enable crabs to escape from lost pots.

"Experiments clearly indicated mortality due to the handling crab are subjected to in the commercial fishery is related to their shell condition. The mortality rate for soft shelled crab (Grade III) in our experiments was 11.3% and is considered to be a minimum estimate of the mortality occurring under actual commercial conditions.

"The results of analysis of weight-width data indicated this type of work will not provide an improved field method for assessing crab meat condition."

10. Beers, D. 1991. A summary of data contained in the mandatory crab observer database. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K91-14, Kodiak.

KEYWORDS: *Aleutian Islands, Bering Sea, blue king crab, bycatch, catch statistics, fecundity, observer, pots, red king crab, sex/size effect, Tanner crab*

SYNOPSIS: Data from all observed vessels participating in commercial fisheries for king and Tanner crabs in the Bering Sea andAleutian Islands are summarized. Catch per unit effort by size category of the target species and bycatch of other species of crab and fish, length frequency distributions by sex of the target species, and percent egg-clutch fullness are presented for each fishery.

11. Bennett, D.B. 1973. The effect of limb loss and regeneration on the growth of the edible crab *Cancer pagurus* L. Journal of Experimental Marine Biology and Ecology 13:45–53.

KEYWORDS: *Autotomy, chelotomy, edible crab, growth, laboratory experiment, molt cycle, North Sea, United Kingdom*

ABSTRACT: "Male and female crabs (*Cancer pagurus* L.) were subjected to various limb loss treatments to determine the effects of limb loss and regeneration on body growth and timing of moulting. Compared with no limb loss, severe limb loss (2 chelae or 6 legs removed) caused a reduction of the increment in carapace width at moulting by up to 25%. Less severe limb loss marginally reduced body growth. Depending upon the time in the moult cycle of autotomy, limb loss, particularly when severe, appeared initially to inhibit moulting, or to stimulate ecdysis so that the treatment replicates all moulted within a short period. The incidence of chelae loss in the crab stocks in Norfolk, Yorkshire and Devon was approximately 10%.

"It would appear that within a population the reduction in body growth and any initial inhibition of moulting is counteracted to some extent by stimulation of moulting. Although the effect of limb loss and regeneration on the growth rate of *C. pagurus* has not been quantitatively determined, it is unlikely to be a factor greatly affecting the determination of growth for a yield assessment. The process of commercially removing claws or legs and returning the crab to the sea to regenerate new limbs is not recommended." [Reprinted with permission from Elsevier Science B.V., Amsterdam, The Netherlands.]

12. Blackburn, J., and D. Schmidt. 1988. Injury and apparent mortality rates from incidental trawl catches of halibut, king crab and Tanner crab in the Kodiak area, 1977–81. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K88-21, Kodiak.

KEYWORDS: *Halibut, injury, Kodiak, mortality, red king crab, shell condition, Tanner crab, trawl*

SYNOPSIS: Observations on the condition of red king crab *Paralithodes camtschatica*, Tanner crab *Chionoecetes bairdi*, and halibut *Hippoglossus stenolepis* by Alaska Department of Fish and Game observers on domestic trawl vessels fishing in the Kodiak area are summarized. A total of 221 hauls were evaluated from 1978 to 1981 for species composition and prohibited species. Mortality of hardshell king crab averaged 1.2% overall. Mortality of softshell red king crab in 10 hauls ranged from 10% to 50% and averaged 21%. Mortality of Tanner crab averaged 12.6% with the exclusion of one haul with 1,000 pounds of juvenile Tanner crab where mortality was high. The mortality of halibut over all hauls was 21%. There was no significant seasonal trend in presence of dead halibut or Tanner crab in catches. During the 4-month period from February 15 through June 15, 19% of the king crabs captured were dead compared to 0.9% the remaining months of the year.

13. Bowerman, J.H., Jr., L.D. Bartlett, and L.W. Schaeffer. 1983. A bibliography of king (*Lithodes; Paralithodes*), and "Tanner" (Majidae; *Chionoecetes*) crab references. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest and Alaska Fisheries Center Processed Report 83-17, Seattle.

KEYWORDS: *Bibliography, blue king crab, red king crab, snow crab, Tanner crab*

14. Bowerman, J.H., and B.R. Melteff. 1984. A bibliography of references on the genus *Chionoecetes*. University of Alaska Fairbanks, Alaska Sea Grant Report 84-7.

KEYWORDS: *Bibliography, snow crab, Tanner crab*

15. Breen, P.A. 1985. Ghost fishing by Dungeness crab traps: a preliminary report. Canadian Manuscript Report of Fisheries and Aquatic Sciences 1848:51–56.

KEYWORDS: *British Columbia, Dungeness crab, field evaluation, ghost fishing, trap*

ABSTRACT: "This is a preliminary report of a study to determine whether lost crab traps continue to catch and kill crabs (*Cancer magister*). Direct underwater observation of lost crab traps suggests that traps retain the capacity to fish for a considerable time, and that they do catch crabs as long as they are able. Direct observations of stimulated lost traps shows that lost traps continue to fish, but at a lower rate than freshly baited traps, for at least several weeks from the simulated loss. These studies show that deaths within traps and continuous entrance and escape make the actual fishing rate difficult to determine except by closely spaced underwater observations."

16. Breen, P.A. 1987. Mortality of Dungeness crabs caused by lost traps in the Fraser River estuary, British Columbia. North American Journal of Fisheries Management 7:429–435.

KEYWORDS: *British Columbia, Dungeness crab, field evaluation, gear loss, ghost fishing, mortality, trap*

ABSTRACT: "The loss of Dungeness crab *Cancer magister* to 'ghost fishing' (mortality caused by lost traps) was estimated from catches and mortalities in 10 simulated lost traps. Traps were originally baited and then left in place for 1 year at a 10-m depth in Departure Bay, British Columbia. Divers examined the traps at intervals and tagged all the crab caught. In a year, the traps caught 169 Dungeness crabs, which were nearly all males, and about half of which died. Mortality rates of legal and sublegal size crabs were nearly the same. At the end of the study, the traps were all in good condition and continued to catch crab. I also estimated an annual trap loss rate of 11% from a questionnaire of crab fishermen in the Fraser River estuary. From the estimated number of traps fished, loss rate, mortality rate per trap, and other values, I estimated that loss to ghost fishing might be equivalent in weight to 7% of the reported catch in the Fraser River District. This estimate is not directly applicable to other areas, but it is recommended that crab fishery management agencies develop and test inexpensive techniques, as well as regulations, that will prevent crab mortality from lost traps."

17. Breen, P.A. 1990. A review of ghost fishing by traps and gillnets. *In* R.S. Shomura and M.L. Godfrey, editors. Proceedings of the Second International Conference on Marine Debris, U.S.

Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, NOAA-TM-NMFS-SWFSC-154, Honolulu.

KEYWORDS: *Ghost fishing, gillnet, literature review, trap*

ABSTRACT: "Ghost fishing occurs when lost fishing gear continues to catch and kill animals. This paper reviews what is known about ghost fishing in trap and gillnet fisheries, how the information was obtained and how it has been used, how ghost fishing can be prevented, and what regulatory approaches have been taken to address the problem. Some standard terms are proposed to prevent confusion.

"Ghost fishing by traps can occur through several mechanisms. The problem is serious in several fisheries, minor in at least one, and remains unexamined for the majority of trap fisheries. Timed-release devices are simple, inexpensive, and effective at preventing ghost fishing by opening the trap some time after loss. In all Dungeness crab fisheries, such devices are required in crab traps, and other regulations attempt to minimize trap loss. In the American lobster fishery, only Connecticut and Maine address ghost fishing, which is known to be a problem. Ghost fishing by traps is poorly recognized as a problem outside North America.

"Ghost fishing by coastal gillnets has been documented in several locations and may persist for several years. For large pelagic gillnets the limited evidence suggests that lost nets form tangled nonfishing masses. More work, both descriptive and experimental, is required to document the nature, extent, and persistence of ghost fishing by gillnets, especially by pelagic gillnets if their use continues.

"It is not clear how to prevent ghost fishing by gillnets. Preventative measures suggested to date must be examined for possible side effects."

18. Breen, P.A., and J.L. McKoy. 1988. An annotated bibliography of the red rock lobster *Jasus edwardsii* in New Zealand. New Zealand Fisheries Occasional Publication 3, Wellington.

KEYWORDS: *Bibliography, New Zealand, red rock lobster*

19. Brown, R.S., and N. Caputi. 1983. Factors affecting the recapture of undersize western rock lobster *Panulirus cygnus* George returned by fishermen to the sea. Fisheries Research 2: 103–128.

KEYWORDS: *Australia, displacement, exposure, field evaluation, laboratory experiment, limb loss, mark recapture, mortality, predation, western rock lobster*

ABSTRACT: "The rock lobster fishery of western Australia is one of the largest of its kind; its average catch in the years 1974/75 to 1981/82 was almost 10000 tonnes. The fishery has been stable for many years, largely by virtue of license limitation and other management measures. Among the regulatory measures is a requirement that all traps used in the fishery must be furnished with escape gaps and another requires fishermen to return to the sea all undersize lobsters that enter the traps, but fail to escape and consequently are brought on board the fishing boat when the trap is lifted.

"Despite the presence of the escape gaps, considerable numbers of undersize lobsters are brought aboard; the number is estimated to be some 16 to 20 million in each season. Moreover, it has been estimated that about a quarter of these retained undersize lobsters remain on board for 10 min or more, and some have been observed to remain on board for more than two hours.

"Studies were therefore undertaken to ascertain whether this capture-and-release experience was in fact causative of mortality. Laboratory experiments on animals exposed in direct sunlight resulted in an expected time for 50% mortality of 99, 158, and 233 min with increasing temperature compared with a time of 387 min for animals exposed under shade.

"Behavioral observations showed that as exposure time increased, returned animals exhibited a decreasing rate of descent through the water column, a decrease in the percentage of active animals and increased loss from predators. In addition, in ten laboratory experiments on octopus predation, octopus predated on injured animals exposed for 15 to 30 min, despite a recovery period of 3.5–5.5 h, but not on unexposed animals.

"Four tagging operations with over 7000 undersize animals resulted in a significant decrease in recapture rates by commercial fishermen with increasing exposure times. Damage (number of appendages lost) incurred by the rock lobsters and displacement beyond the home range were also generally found to reduce the recapture rates significantly. The combination of all these factors resulted in an estimated reduction in recapture rate of 14.6% in the 1978/79 fishing season and after taking into account natural mortality, this would have resulted in a loss of $A6.4 million to the fishery." [Reprinted with permission from Elsevier Science B.V., Amsterdam, The Netherlands.]

20. Brown, R.S., and N. Caputi. 1985. Factors affecting the growth of undersize western rock lobster *Panulirus cygnus* George, returned by fishermen to the sea. Fishery Bulletin 83:567–574.

KEYWORDS: *Australia, displacement, exposure, field evaluation, growth, handling, laboratory experiment, limb loss, mark recapture, molt cycle, sorting, western rock lobster*

ABSTRACT: "The western Australian fishery for the western rock lobster, *Panulirus cygnus*, yielded about 12,400 t, valued at $A100 million, in 1982–83. It is the largest single species fishery in Australia and one of the largest rock lobster fisheries in the world.

"During a season, between 16 and 20 million undersize rock lobsters are brought aboard the vessels by normal fishing operations, despite the escape gaps in all professional and amateur pots. All undersize animals must be returned by fishermen to the sea, but to accomplish this it took from a few minutes to hours, depending on the sorting technique used. The negative effects of handling on the survival of the undersize lobsters have been previously reported, but another important aspect is the effect of handling (damage, exposure, and displacement) on the growth rate of returned undersize rock lobsters.

"Two laboratory experiments showed that growth increments at the first molt after air exposure was significantly reduced, and in one of the experiments it was also significantly reduced for the second molt after exposure.

"Three field tagging trials were conducted with 6,700 undersize rock lobsters. One trial showed that exposure had a significant detrimental effect; the other trial in which exposure was tested, there was a negative, but not significant, trend. Damage (number of appendages lost) and displacement from the home range significantly reduced the growth increment in each of the three tagging trials. The growth increment of damaged animals was inversely proportional to the number of appendages lost by the animal with sizes ranging from 0.33 to 0.48 mm smaller per appendage missing. The losses to the fishery and other associated problems caused by the reduced growth of the undersize lobsters are discussed."

21. Brown, R.S., and N. Caputi. 1986. Conservation of recruitment of the western rock lobster (*Panulirus cygnus*) by improving survival and growth of undersize rock lobsters captured and returned by fishermen to the sea. Canadian Journal of Fisheries and Aquatic Sciences 43:2236–2247.

KEYWORDS: *Australia, displacement, escape mechanism, field evaluation, handling, mortality, recruitment, western rock lobster*

ABSTRACT: "The western rock lobster (*Panulirus cygnus*) fishery is one of the largest rock lobster fisheries in the world with an average catch (1974–75 to 1983–84) of 10 million kg. On average, 18 million undersize rock lobsters (sublegal size) are caught, handled, and returned to the sea each season despite the release of many through mandatory escape gaps in the traps. Depending on the handling procedure, undersize rock lobsters experience various degrees of exposure, displacement, and damage which adversely affect their survival and growth. Laboratory, field, and tagging experiments showed that handling produced a mortality rate of 14.6% that costs the industry in excess of $A13 million per season (1984–85 values). An education program has resulted in improved handling of undersize rock lobsters, and trials have shown that by increasing the size of the escape gap, the number of undersize rock lobsters handled can be reduced by 40–60%. This would result in a significant enhancement of recruitment to the fishery."

22. Brown, R.S., and C.J. Dibden. 1987. A re-examination of the techniques used for handling undersize rock lobster. Fisheries Department of Western Australia Report Number 78, Perth.

KEYWORDS: *Australia, field evaluation, fishermen behavior, handling, sorting, western rock lobster*

SYNOPSIS: Rock lobster fishermen in western Australia underwent intensive education to alert them of the effects of poor handling practices on undersize animals. Two recommended sorting methods and the proportion of fishermen using each method were evaluated in this study and compared to previous sorting techniques. Potential sources of bias in study results are discussed. Undersize lobsters were handled within 15 min 87.5% of the time compared to 65% of the time before the education program. Less than half (47.8%) of those fishermen sampled were sorting directly from the pot or after each pot, the 2 recommended sorting methods that minimize mortality. The remaining fishermen (52.2%) used a method that could cause significant mortality. Sorting rates of the 2 groups may be similar when catch rates are low. However, when catch rates are high, the continuous sorting method cannot keep up with the constant addition of more animals resulting in longer exposures and potential mortalities.

23. Butler, T.H. 1967. A bibliography of the Dungeness crab, *Cancer magister* Dana. Fisheries Research Board of Canada, Technical Report 1.

KEYWORDS: *Bibliography, Dungeness crab, Pacific coast*

24. Byersdorfer, S., and L.J. Watson. 1992. A summary of biological data collected during the 1991 Bristol Bay red king crab tagging study. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 92-14, Juneau.

KEYWORDS: *Bering Sea, Bristol Bay, field evaluation, injury, life history, red king crab, shell condition, Tanner crab*

ABSTRACT: "Catch composition and biological data were gathered during a tagging study of Bristol Bay red king crab *Paralithodes camtschaticus* conducted in 1991. A total of 330 crab pots were sampled from 141 stations over the 35-d study. New-shell, male red king crab dominated survey catches, followed by Tanner crab *Chionoecetes bairdi*. Legal male red king crabs were widely distributed over the study area and averaged 16.7 crabs per pot. Size of maturity (SM50) of female red king crabs was 93.4 mm carapace length. The overall rate of handling-induced injury or mortality was low (<3.0%). A total of 7,554 male red king crabs were tagged during the survey."

25. Byersdorfer, S., and L.J. Watson. 1993. A summary of biological data collected during the 1992 Bristol Bay red king crab test fishery charter. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 4K93-24, Kodiak.

KEYWORDS: *Bering Sea, Bristol Bay, field evaluation, injury, life history, red king crab, shell condition, Tanner crab*

SYNOPSIS: Catch composition, biological data, and ancillary data and specimens of commercially important crab species were collected during 1992 from a cost recovery fishing charter in Bristol Bay. Fifty pots from 646 set and pulled during the 16-d study were sampled. Red king crab predominated the sampled catches, followed by Tanner, snow, and hybrid crabs. However, red king crab contributed a smaller percentage (56.4%) in 1992 compared to 80.4% in 1991. Tanner crabs in the sampled catch increased from 16.7% in 1991 to 39.6% in 1992. The number of legal red king crabs per pot declined from 12 crabs per pot in 1991 to 6 crabs per pot in 1992. The overall rate of handling-induced injury in red king and Tanner crabs was quite high in 1992 relative to the previous year, but this was attributed to more rigorous examination on the 1992 charter.

26. Carls, M.G., and C.E. O'Clair. 1990. Influence of cold air exposure on ovigerous red king crab (*Paralithodes camtschatica*) and Tanner crabs (*Chionoecetes bairdi*) and their offspring. Pages 329–343 *in* Proceedings of the international symposium on king and Tanner crabs. University of Alaska Fairbanks, Alaska Sea Grant Report 90-04.

KEYWORDS: *Autotomy, exposure, feeding, growth, laboratory experiment, molt cycle, mortality, red king crab, Southeast Alaska, Tanner crab*

ABSTRACT: "Ovigerous red king, *Paralithodes camtschatica*, and Tanner, *Chionoecetes bairdi*, crabs are often caught incidentally in the males-only fishery for these crabs. Effects of low air temperature on ovigerous crabs and their developing larvae were simulated by exposing groups of crabs to cold air (-20 to +5°C) from 0 to 40 minutes. Response to cold air was best described when the units of exposure were the product of temperature (°C) and duration of exposure (h). Short exposure at low temperatures caused the same effects as long exposure at high temperatures when the units of exposure (degree · hours, °h) were equal. Exposure to cold air reduced vigor (measured by the ability of a crab to right itself when placed on its back), feeding rates (Tanner crab), and growth (king crab). Exposure also caused limb autotomy in Tanner crabs, and mortality in both species in severe situations. Median lethal exposures, measured 128 days after emersion, were -8 ± 2 °h for king crabs. Median lethal exposure stabilized after 16 days for Tanner crab at -4.3 ± 0.5 °h. Righting times were reduced immediately after exposure and in sublethal treatments; median exposures causing half the crabs to cease righting immediately after exposure were -8 ± 2 °h (king crab) and -2.1 ± 0.3 °h (Tanner crab). Mean limb autotomy ranged up to 11% for Tanner crabs; some severely treated king crabs lost legs at ecdysis. During ecdysis, severely exposed king crabs often died. Tanner crab feeding rates were depressed ($P < 0.001$), and king crab growth was reduced ($P = 0.02$). However, if the adult crabs survived, hatch timing, percent hatch, and zoeal viability were not affected."

27. Chaisson, A.F. 1932. Factors in the shipment of live lobsters from eastern Nova Scotia. Biological Board of Canada Bulletin 33.

KEYWORDS: *American lobster, Canada, exposure, field evaluation, fishermen behavior, handling, historical reference, hypoxia, illumination, laboratory experiment, temperature, transport*

SYNOPSIS: Quality factors associated with the shipment of live lobsters from eastern Nova Scotia to the Boston market were investigated. Handling of lobsters on fishing vessels and collection vessels is discussed in terms of protection from sunlight, wind, lethal water temperature, oxygen content of water, packaging moisture, and banding of claws.

28. Chapman, C.J. 1981. Discarding and tailing *Nephrops* at sea. Scottish Fisheries Bulletin 46:10–13.

KEYWORDS: *Bait, bycatch, field evaluation, illumination, mortality, North Sea, Norway lobster, temperature, trap, trawl*

SYNOPSIS: Studies were completed to assess effects of fishing on survival of discarded *Nephrops* and dumping of lobster remains on the grounds. Crabs were subjected to catch by trawl and trap gear and held at different water temperatures prior to transfer to traps on the seafloor. Mortality was 40% for crabs caught in trawls but only 3% for crabs caught in traps. Mortality was much higher for crabs held at cooler seawater temperatures (8°C vs. 14°C). Another experiment testing the effect of baiting traps with lobster remains resulted in a 40% reduction in catch compared to normally baited traps.

29. Chapman, C.J., and G.L. Smith. 1978. Creel catches of crab, *Cancer pagurus* L., using different baits. International Council for the Exploration of the Sea 38:226–229.

KEYWORDS: *Bait, edible crab, field evaluation, gear effect, North Sea*

ABSTRACT: "Creel catches of the edible crab, *Cancer pagurus,* were compared using fresh bait with or without the addition of recently killed *Cancer*. The addition of the crab to the fresh bait reduced the catch of live *Cancer* by 54%. The reduction in catch was proportionally less when only part of the crab (carapace or chelae) was added to the fish bait. These results lend some support to the suggestion of Hancock (1974), that chemically induced intraspecific avoidance responses may be well developed in some crustaceans."

30. Chittleborough, R.G. 1975. Environmental factors affecting growth and survival of juvenile western rock lobsters *Panulirus longipes* (Milne-Edwards). Australian Journal of Marine and Freshwater Research 26:177–196.

KEYWORDS: *Australia, autotomy, environment, feeding, growth, hypoxia, illumination, laboratory experiment, limb loss, mortality, starvation, temperature, western rock lobster*

ABSTRACT: "The effects of temperature, photoperiod, oxygen, food supply, crowding, and autotomy of limbs have been measured under controlled conditions in aquaria. Growth rate increased with temperature to a maximum 26°C above which both growth rate and survival declined. Varying the length of photoperiod did not affect growth rate or survival, except that the growth rate was depressed significantly in continuous darkness. A mild deficiency of oxygen (60–67% saturation) resulted in a smaller size increment at a moult; depression to 47–55% saturation caused deaths at ecdysis. Daily feeding was necessary to maintain maximum rate of growth. The first response to decreased food supply was a reduction in frequency of moulting. More severe shortage of food also depressed growth increments per moult. Feeding rates and conversion ratios have been measured. Frequency of moulting (and hence growth rate) was depressed markedly when juveniles were held in isolation. At a moult replacing two lost limbs, the growth rate was not affected; replacement of four limbs reduced that moult increment. Single loss of up to four limbs did not result in an earlier moult, but repetitive loss of two or more limbs at or immediately after each ecdysis led to precocious moulting.

"The impact of these and other components of the environment (shelter, salinity, turbidity, competitors and predators) upon juveniles during the 4 years spent on shallow coastal reefs is discussed. Food supply is emerging as the dominant factor determining growth and survival in the wild population."

31. Cleaver, G.C. 1949. Preliminary results of the coastal crabs (*Cancer magister*) investigation. Washington Department of Fisheries, Biological Report Number 49A, Olympia.

KEYWORDS: *Catch statistics, density, Dungeness crab, growth, historical reference, life history, limb loss,*

mark recapture, mortality, seasonal distribution, shell condition, Washington

ABSTRACT: "The purpose of the coastal crab investigation was to determine the effect of the increasing fishery upon the stocks of crabs in that region. In finding this, it was necessary to investigate certain phases of the life history of the crab. Among the most pertinent facts uncovered are: (1) The fishery was very intense in 1947 and 1948; and (2) There is no danger of overfishing the stocks with regard to total yield. This first conclusion was reached by tagging crabs during the early winter, before the fishery started. In 1947 it was estimated that 78.6 percent of the crabs released were retaken. The corresponding figure for 1948 was 87.2 percent. These estimates were made by first sampling the catches to establish the ratio of tagged to untagged members in the population, and then dividing the total catch by this ratio to estimate the number of tagged crabs which were caught. The percentages actually returned to the investigation were 57.6 and 57.0. While room for error in estimate exists, there is no question but that the fishery was extremely intense in these years.

"Because landings in earlier years were sold by size, reasonably accurate records could be examined of the size of composition of the catch between 1917 and 1948. The percent of the catch composed of large crabs was as great in the last two years as for any time for which records were available. In other words, the fishery had not succeeded in reducing the size or the life span to any important degree. The ringnet catches, which were a relatively stable unit of effort until 1943, showed no decline that might be attributed to fishing.

"Another gauge of abundance, the catch-per-pot per day was followed with log books from 1943 to 1948. It indicated a high population level even through the years of heaviest fishing. There was some evidence that the great increases in quantity of gear fished was affecting the return per unit of gear. This resulted in poorer returns to the fishermen for their efforts in spite of an abundance of crabs.

"The total catch has risen steadily for the past decade. The poorest returns in recent years were in 1931 and 1932, when the crab fishery was near failure. There is no reason to believe that this was in any manner caused by fishing.

"The growth studies show that while some of the crabs are of a marketable size (6¼ inches or more in width) at three years of age, the bulk of the crabs do not reach this size until the latter half of their fourth year of life. Were growth to continue at the same rate past this point, there should have been a greater proportion of large crabs (seven inches or more in width) prior to 1930 than there was in 1947 and 1948, which was not the case.

"The facts of the fishery point to a large dependence upon the survival of young from the hatch of each brood year. Consequently, while the fishery has not diminished the catch, there is every reason to believe that the abundance will fluctuate widely in accord with conditions affecting the earlier stages in the life of the crabs.

"Since the females are not taken for market and there is no lack of a male breeding stock, reproduction is unaffected by fishing.

"Tagged specimens traveled considerably greater distances than were initially expected. The average movement was between 10 and 12 nautical miles after six months of freedom. For those free six months or more 17.6 percent had traveled more than 20 miles. The longest migration was in excess of 80 miles from near Grays Harbor to Tillamook Bay, Oregon.

"The predominant movement was from south to north during the spring and summer months. It was established that the crabs found in water ranging from 40 to 60 fathoms in depth are of the same group as those found inshore and were caught by the inshore fishery to the same degree as were crabs marked on those grounds."

32. Cowan, D.F. 1991. The role of olfaction in courtship behavior of the American lobster *Homarus americanus*. Biological Bulletin (Woods Hole) 181:402–407.

KEYWORDS: *American lobster, Atlantic coast, injury, laboratory experiment, Massachusetts, mating, mortality, reproduction, sex/size effect*

ABSTRACT: "Courtship behavior is well documented in captive lobsters. Sex pheromones contained in *female* urine and perceived by receptors on *male* antennules are thought to act as sex attractants or as signals necessary for pair formation. In this study, the lateral and medial antennules of male and female lobsters were removed. The result of these excisions were meant to indicate the gender-specific role of olfactory chemoreception in lobster courtship behavior. Removal of *male* antennules had little effect on pair bonding and mating. In contrast, removal of *female* antennules resulted in dramatic aberrations in behavior, including postmolt injuries and, in extreme cases, unsuccessful couplings and mortality. Therefore, female olfaction plays the more critical role in the normal reproductive behavior of *Homarus americanus.*" [Reprinted with permission from the *Biological Bulletin.*]

33. Dahlstrom, W.A. 1975. Report of lost crab trap recovery. California Department of Fish and Game, Marine Resources Region, Processed Report, Sacramento.

KEYWORDS: *California, Dungeness crab, escape mechanism, field evaluation, ghost fishing, pots*

SYNOPSIS: Condition and catch of a Dungeness crab trap estimated to have been lost for 10 months are discussed. Catch rates of legal and nonlegal crabs by the lost pot are compared to test gear fished in the same location with escape openings wired shut.

34. Davis, G.E. 1980. Juvenile spiny lobster management or how to make the most of what you get. Fisheries 5(4):57–59.

KEYWORDS: *Caribbean spiny lobster, escape mechanism, growth, habitat, injury, management strategy, mortality, size limit*

ABSTRACT: "Larval production and survival, equitable allocation and efficient harvest among fishermen, and maximization of yield per postlarval recruit are identified as three major elements amenable to management actions in spiny lobster fisheries. Minimum harvestable lobster size, habitat protection and enhancement, trap escape vents, and nursery sanctuaries are some of the means of improving yield per postlarval recruit."

35. Davis, G.E. 1981. Effects of injuries on spiny lobster, *Panulirus argus*, and implications for fishery management. Fishery Bulletin 78: 979–984.

KEYWORDS: *Caribbean spiny lobster, field evaluation, Florida, growth, injury, molt cycle*

SYNOPSIS: This study reports the effects of injuries on growth rates of wild juvenile spiny lobsters *Panulirus argus* in Florida and discusses implications of these effects on the biology and fishery for spiny lobster. Water temperature and lobster condition had the greatest effect on lobster growth. Additionally, these factors caused increased intermolt periods and reduced molt increment.

36. Davis, G.E., D.S. Baughman, J.D. Chapman, D. MacArthur, and A.S. Pierce. 1978. Mortality associated with declawing stone crabs, *Menippe mercenaria*. U.S. National Park Service, South Florida Research Center, Report T-522, Homestead.

KEYWORDS: *Chelotomy, Gulf of Mexico, laboratory experiment, mortality, stone crab*

ABSTRACT: "Claws greater than 7.0 cm propodus length were removed from 201 stone crabs, *Menippe mercenaria*, using commercially accepted techniques. The crabs were held in aquaria before and after declawing. Forty-seven of 101 crabs that had both claws removed died, and 28 of 100 single claw amputees died. Seventy six percent of the casualties died within 24 hours of declawing. The claws constituted 51% of the total weight of the crabs before declawing. Declawing wound width was significantly correlated with survival. Instantaneous crab mortality estimated from measured declawing wounds of four commercial fishermen ranged from 23 to 51 percent."

37. Davis, G.E., and J.W. Dodrill. 1980. Marine parks and sanctuaries for spiny lobster fisheries management. Proceedings of the Gulf and Caribbean Fisheries Institute 32:194–207.

KEYWORDS: *Caribbean spiny lobster, fecundity, field evaluation, Florida, growth, habitat, injury, management strategy, mark recapture, migration, molt cycle*

SYNOPSIS: Spiny lobsters that were studied using a mark-recapture program in 4 areas along the Florida coast represented a variety of habitats and levels of exploitation. Growth rates showed marked seasonal variation with water temperature. Another major factor influencing growth rates of juvenile lobsters was injury. Lobsters retained by sport divers had the highest injury rate at 71%. Incidence of injured lobsters increased from 30% to 50% during the commercial lobster season in the bay. In the lightly fished bay, the incidence of injured lobsters averaged 13% but ranged as high as 35%. Fewer than 25% of the same-sized lobsters at the unfished bay showed injuries, which may reflect the high density of lobster predators in the area. Mean molt increment was 0.5 mm carapace length less and the mean intermolt period was 50% longer for injured lobsters. The extent of injury did not appear to be related to the degree of growth-rate suppression because lobsters missing fewer than 3 appendages had growth rates similar to lobsters missing 5 or more appendages and/or injuries to the abdomen or cephalothorax. A smaller size at first sexual maturity was observed in the exploited areas compared to the area with no fishing. Migration patterns were also discussed in terms of habitat-related movement with age.

38. Defur, P.L., and R. McMahon. 1978. Respiratory responses of *Cancer productus* to air exposure. American Zoologist 18:605.

KEYWORDS: *Canada, exposure, hypoxia, laboratory experiment, physiology, red rock crab*

ABSTRACT: "Scaphognathite (Sc) and heart (H) pumping frequencies (f_{sc} & f_H), postbranchial oxygen tensions (P_aO_2), oxygen content (C_aO_2) and acid-base parameters were measured on unrestrained *Cancer productus* before, during and after 4 hr air exposure. In water, quiescent crabs exhibited low f_{sc}, often unilateral, with frequent Sc and H pauses. Immediately upon air exposure, f_{sc} increased dramatically, becoming continuous and bilateral. F_H remained unchanged but despite this and the elevated f_{sc}, hemolymph P_aO_2 and C_aO_2 declined 80% and 72% respectively, indicating a substantial reduction in oxygen uptake. Hemolymph pH fell from 7.84 ± 0.015 to 7.60 ± 0.047 ($\bar{x} \pm$ S.E.) in air, with no evidence that changes in either C_aCO_2 or NH_4^+ allowed complete compensation for this acidosis. Upon reimmersion, tachycardia and hyperventilation with respect to pre-emersion levels occurred, allowing restoration of hemolymph pH, PCO_2, P_aO_2 and C_aO_2 within 1 hr. F_{sc} and f_H remained elevated for 2–4 hours, while C_aCO_2 and PCO_2 decreased. The present data are compared with those in the literature for another inter-tidal species *Carcinus maenas*."

39. Demory, D. 1971. Abandoned crab pots near Cannon Beach, Oregon. Fish Commission of Oregon, Research Division, Shellfish Investigation Information Report 70-6, Portland.

KEYWORDS: *Cannibalism, Dungeness crab, field evaluation, ghost fishing, Oregon, pots, shell condition*

SYNOPSIS: Over 100 Dungeness crab pots were found unattended and were therefore confiscated. Number, size, sex, and shell condition of crabs retrieved were documented. Consequences of leaving the pots on the grounds were discussed in terms of the recent onset of molt and probable cannibalism that would have resulted.

40. Des Voigne, D.M. 1970. Preliminary observations of the thermal tolerance of selected invertebrate fauna of Sequim Bay, Washington. Northwest Science 44:114–122.

KEYWORDS: *Dungeness crab, laboratory experiment, molluscs, mortality, temperature, Washington*

SYNOPSIS: A study was conducted to determine the thermal tolerance of 7 species of molluscs and the Dungeness crab *Cancer magister*. Of the molluscs tested, Pacific oyster and the bay mussel were the most resistant to elevated temperatures, whereas the butter and horse clams were the least resistant. Dungeness crabs were found to tolerate an elevation in temperature of up to 15°C. Following acclimation, greater changes in temperature could be tolerated; however, growth may be inhibited.

41. Donaldson, W.E. 1990. Determination of experimentally induced non-observable mortality on red king crab. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K90-13, Kodiak.

KEYWORDS: *Field evaluation, injury, Kodiak, mortality, red king crab, shell condition, trawl*

ABSTRACT: "Large hard shell male red king crab, *Paralithodes camtschatica*, were tethered in the path of an Aleutian combination trawl. Six tows were made to estimate the impact of trawl gear on injury rates of crab that were in the trawl path but not caught by the gear. In total, one hundred and sixty nine of the tethered crabs were estimated to be in the six trawl paths as defined by the spread of the doors. Crabs recovered in the trawl onboard the vessel accounted for 21.3% of these crabs. Divers recovered 46.2% of the crabs within the trawl path, leaving 32.5% unrecovered. Three of the 36 (8.3%) crabs recovered in the trawl were injured while two of the 78 (2.6%) crabs recovered by divers were injured. This latter value is an estimate of the otherwise non-observable injury rate of Aleutian combination trawl gear on king crab under conditions tested. Only one crab was caught in a trawl, had injuries assumed to be fatal."

42. Dow, R.L. 1979. The need for a technological revolution in the methods of catching marine fish and shellfish. Marine Technology Society Journal 13(6):3–8.

KEYWORDS: *American lobster, Atlantic coast, Canada, fish, gear technology, management strategy, molluscs, net, shrimp, trap*

SYNOPSIS: Commercial fishing methods are in need of revolution due to significant waste of nonretained resources. Case histories of Georges Bank Haddock and New England cod are used to illustrate resource limits. The Magnuson Fishery Conservation and Management Act and billfish bycatch in the bluefin tuna fishery are discussed as avenues where changes in laws and regulations have potential to minimize the threat of overfishing. Numerous examples are given

of human-induced mortalities caused by fishing. Suggestions are made on methods to improve fishing techniques to reduce incidental destruction of resources.

43. Durkin, J.T., K.D. Buchanan, and T.H. Blahm. 1984. Dungeness crab leg loss in the Columbia River estuary. Marine Fisheries Review 46(1): 22–24.

KEYWORDS: *Columbia River, Dungeness crab, injury, limb loss, regeneration*

ABSTRACT: "Sampling carried out in the Columbia River estuary from 1971 to 1973 to investigate the incidence of leg loss and subsequent regeneration among Dungeness crab, *Cancer magister,* indicated an average of 45 percent of the catch had one or more missing legs. This is more than twice the frequency of leg loss reported in either Washington's Puget Sound or coastal waters. Leg injuries occurred with a high incidence of bilateral symmetry. Claws were lost and regenerated more frequently than any other pair of legs. Possible reasons for the high incidence of leg loss in the estuary are maintenance dredging, commercial crab and finfishing activities, predation, and competition."

44. Easton, D.M. 1972. Autotomy of walking legs in the Pacific shore crab *Hemigrapsus oregonensis*. Marine Behavior and Physiology 1:209–217.

KEYWORDS: *Autotomy, injury, laboratory experiment, Puget Sound, shore crab*

ABSTRACT: "The ease of autotomy *in Hemigrapsus oregonensis* was tested by crushing the propodite of each walking leg. Individual curves of percent autotomy in groups of 18–21 animals were drawn for six different sequences of stimulation. Lumped data show peaks in ease of autotomy for the third anatomical leg of each side and for the second leg stimulated regardless of anatomical position. Later autotomies are more severely depressed when the stimulation sequence is from posterior to anterior. Segmental and lateral interaction and the characteristics of individual responses suggest that autotomy of legs in the crab, while depending upon specific structural features of the legs, is less a unisegmental reflex, than an accident occurring during escape." [Reprinted with permission from Gordon and Breach Science Publishers, Inc.]

45. Edwards, E., and D.B. Bennett. 1980. Survival of discarded *Nephrops*. International Council for the Exploration of the Sea, Council Meeting Document 1980, Shellfish Committee K:10, Copenhagen.

KEYWORDS: *Bycatch, exposure, field evaluation, injury, Irish Sea, mortality, North Sea, Norway lobster, sorting, trawl*

ABSTRACT: "Survival of discarded *Nephrops norvegicus* was estimated during research vessel cruises in the North and Irish Seas. Following capture from 30 min–1 h trawls and 1 h on deck, survival averaged 71–85%. After 24 h in seawater tanks the undamaged and least damaged survived well. Overall 42% of the *Nephrops* in the North Sea experiment and 75% in the Irish Sea experiment survived capture, sorting and 24 h storage. The higher survival in the Irish Sea may have been due to smoother sea conditions and to the use of a side trawler, which is considered to result in less damage to catches than does the use of a stern trawler as in the North Sea experiment. As there was little difference in survival rates between *Nephrops* sorted from the codend and those from the cover, survival rates of *Nephrops* escaping selectively from the codend on the sea bed would certainly be no less than those estimated for discards on deck."

46. Edwards, J.S. 1972. Limb loss and regeneration in two crabs: the king crab, *Paralithodes camtschatica*, and the Tanner crab *Chionoecetes bairdi*. Acta Zoologica 53:105–112.

KEYWORDS: *Bering Sea, limb loss, red king crab, regeneration, sex/size effect, Tanner crab*

ABSTRACT: "The incidence of limb loss and regeneration in two species of benthic crustacea, the king crab *Paralithodes camtschatica*, an anomuran, and the tanner crab *Chionoecetes bairdi*, a brachyuran, is surveyed in populations from the Bering Sea. 29.4% of young juvenile *P. camtschatica* and 14.8% of adults had lost at least one limb. The overall incidence of limb loss in *C. bairdi* was 38.8%, with female adults less prone to damage than males and juveniles.

"Limb loss increases in frequency in more posterior limbs. Right hand limbs are lost more often than left in both species. This 'right handedness' appears to be widespread in crabs and may be due to the greater vulnerability of leading limbs.

"The frequency distribution of limb regenerate lengths in a population of young juveniles suggests that at least four instars must be passed before limb

symmetry is restored." [Reprinted with permission from *Acta Zoologica,* Pergamon Journals, Ltd.]

47. Emmel, V.E. 1905. The regeneration of lost parts in the lobster. Thirty-fifth Annual Report of Commissioners of Inland Fisheries of Rhode Island, Special Paper 20, Providence.

KEYWORDS: *American lobster, Atlantic coast, growth, historical reference, laboratory experiment, limb loss, molt cycle, regeneration, Rhode Island, sex/size effect*

SYNOPSIS: This report reviews previous experimental work and observations on regeneration in lobsters and theories of regeneration. Laboratory experiments were also conducted on young-of-year and juvenile lobsters to examine the extent of the power of regeneration throughout the organism, the length of time required for the reproduction of a normal appendage, the effect of repeated removal of an appendage, and the exact process in the development of a given structure. Chelipeds, walking legs, antennae and antennules, maxillipeds, external reproductive organs, beak, telson, and carapace of lobsters possess the power of regeneration. No positive evidence of regeneration was apparent for eyes or gills. No observations were made on the regeneration of internal organs. The tendency to regenerate a lost appendage was much stronger and more highly developed at the normal breaking plane than at any other level in the limb. No definite statement could be made about the time required for an appendage to restore to its normal size other than ambulatory appendages did not attain normal length at the first molt. Repeated removal of the cheliped of young lobsters showed there was a larger percent difference in length between the regenerated and normal appendage with each successive regeneration. However, comparison of measurements for regenerated cheliped only showed a continuous increase in length. It was concluded that a regenerating limb that passed through ecdysis always molts as a functional appendage.

48. Emmel, V.E. 1906. The relation of regeneration to the molting process in the lobster. Thirty-sixth Annual Report of Commissioners of Inland Fisheries of Rhode Island, Special Report 27, Providence.

KEYWORDS: *American lobster, Atlantic coast, growth, historical reference, injury, laboratory experiment, molt cycle, regeneration, Rhode Island*

SYNOPSIS: The object of a series of experiments on American lobsters *Homarus americanus* was to determine if there was any regulation or interaction between the process of regeneration and molting. Results showed introduction of regeneration will disturb the normal activity of the molting process. This was attributed to the rate of cellular activities involved in the molting process being retarded by the cellular activities concerned in the process of regeneration. This effect increased the length of the period between 2 successive molts directly with the timing of regeneration. Length of molting period was also affected by the degree of injury so that the greater the amount of regeneration, the greater the length of the molting period. The process of regeneration, by retarding both the frequency of molting and the increase in size, retards the growth of lobsters.

49. Ennis, G.P. 1971. Lobster (*Homarus americanus*) fishery and biology in Bonavista Bay, Newfoundland, 1966–70. Fisheries Research Board of Canada Technical Report 289.

KEYWORDS: *American lobster, catch statistics, growth, handling, laboratory experiment, life history, mark recapture, molt cycle, Newfoundland*

SYNOPSIS: Biological characteristics and the nature and extent of fisheries on regionally isolated lobster populations around the coast of Newfoundland were investigated. Length-weight relationships, size at maturity, and growth increment were determined. Tagging studies demonstrated lower molting incidence in lobsters caught prior to molt and retained by fishermen for up to 4 d until purchased and released by field staff.

50. Fee, R. 1986. Saving Florida's spiny lobster fishery from itself. National Fisherman 66(11): 20–22.

KEYWORDS: *Bait, Caribbean spiny lobster, Florida, gear technology, limited entry, management strategy, shorts, size limit, trap*

SYNOPSIS: This article discusses the problems of harvesting sublegal spiny lobsters (shorts) in Florida, either for trap bait or illegal sale. Proposed management measures such as minimum size, escape gaps, and limited entry are discussed.

51. Florey, E., and M.E. Kriebel. 1974. The effects of temperature, anoxia and sensory stimulation

on the heart rate of unrestrained crabs. Comparative Biochemistry and Physiology 48:285–300.

KEYWORDS: *Dungeness crab, hypoxia, laboratory equipment, physiology, red rock crab, stress, temperature, Washington*

ABSTRACT: "1. Electrocardiograms were recorded from unrestrained crabs (*Cancer magister* and *Cancer Productus*) with the aid of implanted electrodes.

"2. Heart rate increases with ambient temperature over the range of 0–22°C; no further increase occurs at higher temperatures. The Q_{10} for the range of 4–19°C is 2.

"3. Replacement of O_2 by either pure N_2 or by 95:5 mixture of N_2 and CO_2 results in bradycardia. Prolonged anoxia up to 1 hr can be tolerated. The heart rate slowly returns to normal after readmittance of oxygen.

"4. Optical and tactile stimuli produce cardiac arrest. The effect is enhanced by general reduction of sensory input and is abolished by an increased level of tactile stimulation. Prolonged sensory deprivation causes bradycardia.

"5. From known data of O_2 consumption and O_2 saturation of arterial and venous blood, and considering the properties of the open circulatory system, it is calculated that even during an inhibition of the heart beat lasting up to 3 min the oxygen reserve of the blood can sustain normal tissue respiration.

"6. While heart rate increases with temperature, cardiac output declines. The increased O_2 delivery to the tissues (required by the rise in oxygen consumption) is made possible by the fact that the half-saturation tension of hemocyanin greatly increases with temperature causing an increased release of the oxygen carried." [Reprinted with permission from *Comparative Biochemistry and Physiology*, Pergamon Journals, Ltd.]

52. Fukuhara, F.M., and D. Worlund. 1973. Incidence of halibut and Tanner crab in catches by the eastern Bering Sea mothership trawl fishery and independent trawlers. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Report by the U.S. National Section to the International North Pacific Fisheries Commission, Seattle.

KEYWORDS: *Bering Sea, bycatch, catch statistics, exposure, halibut, injury, mortality, observer, predation, Tanner crab, trawl*

SYNOPSIS: Canadian and U.S. scientists made biological observations on incidence of Pacific halibut *Hippoglossus stenolepis* and crab landed in the Japanese eastern Bering Sea trawl fishery. Total catch sampled and incidental catch and average size of halibut and crab by time, gear type, and management block are summarized. Inferences concerning the incidence of halibut and Tanner crabs *Chionoecetes bairdi* are discussed. Viability of halibut and Tanner crab was observed. Unanimous opinion of scientists was that most halibut are dead upon return to the sea. Crabs that survived shipboard treatment were in a weakened condition and vulnerable to predation by sea lions. Tanner crab mortality ranged from 50% survival from March to May to 95% mortality from June to August and was due to air exposure, compression in the bins, and damage from high pressure washers. Observations also made in March noted Tanner crabs were glazed with ice within 10 minutes of unloading. Overall mortality to Tanner crabs for the period of observation was estimated to be 60–70%.

53. Ganz, A. 1980. Otter trawl induced lobster damage evaluation. Final Report to U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Environmental and Technical Services Division, Rhode Island Projects 3-279-R and 3-320-R, Wickford.

KEYWORDS: *American lobster, Atlantic coast, bycatch, field evaluation, injury, mark recapture, molt cycle, mortality, Narragansett Bay, trawl*

SYNOPSIS: This report documented the specific types and occurrence of damage in trawl-caught lobsters in Narragansett Bay. Damage was classified and shell condition recorded for all trawl-caught lobsters. A mark-recapture experiment was conducted to determine the extent of trawl-induced mortality and injury to lobsters left behind the trawl. Over 91% of the lobsters sampled were sublegal size. Eleven percent sustained new injuries and 4% lost one or both chelae. Immediate death of trawl-caught lobsters appeared low; however, mortalities may be potentially significant in recently molted or severely damaged lobsters. Incidence of trawl-induced damaged was high immediately following molting periods and comparatively low during other seasons.

54. Gaten, E. 1988. Light-induced damage to the dioptric apparatus of *Nephrops norvegicus* (L.) and the quantitative assessment of the damage. Marine Behavior and Physiology 13:169–183.

KEYWORDS: *Exposure, illumination, laboratory experiment, mark recapture, Norway lobster, physiology, United Kingdom*

ABSTRACT: "In *Nephrops norvegicus* damage to the compound eye following exposure to excess light is not restricted to the photoreceptor layer, but is followed by morphological changes to the dioptric apparatus. Retinula cell damage results in the disruption of the cone cell processes leading to distal retraction of the crystalline tracts. The shape of the cones is also affected and there is a redistribution of the distal pigments. Within two months of exposure the reflective properties of subcorneal elements are changed and damage may be seen in the intact eye. A method based on external observations of the intact eye has been developed for quantitatively estimating the damage to the dioptric layer. The figures obtained were compared with estimates of retinula cell damage in the same eyes calculated using measurements from serially sectioned material. The estimation of ommatidial damage without recourse to sectioning should be of immediate practical benefit." [Reprinted with permission from Gordon and Breach Science Publishers, Inc.]

55. Gaten, E., P.M.J. Shelton, C.J. Chapman, and A.M. Shanks. 1990. Depth related variation in the structure and functioning of the compound eye of the Norway lobster *Nephrops norvegicus.* Journal of the Marine Biological Association of the United Kingdom 70:343–356.

KEYWORDS: *Illumination, injury, laboratory experiment, Norway lobster, physiology, Scotland*

ABSTRACT: "The mobility and quantity of retinula cell proximal screening pigment, and the liability of the eyes to light-induced damage, were investigated in the Norway lobster, *Nephrops norvegicus* (L.), obtained from three separate populations from depths of 18, 75, and 135 m.

"During the morning after capture, the migration of the proximal pigment in response to the onset of illumination below the threshold for damage varied between the three populations. In the eyes of deep water *N. norvegicus*, the proximal screening pigment was located close to or below the basement membrane when dark-adapted and rose to a position midway up the rhabdoms when light-adapted. In the dark-adapted *N. norvegicus* from shallow water the proximal pigment was located more distally than in eyes of deep water animals. After the onset of illumination, the pigment migrated distally to completely cover the rhabdoms. The amount of retinula cell proximal screening pigment was found to decrease linearly with depth.

"When dark-adapted individuals from each depth were exposed to light a positive correlation was obtained between the photon fluence rate (PFR) and the proportion of the retina damaged. For a given light exposure the amount of damage was highest in animals from deeper water. The PFR causing 25% damage was approximately 1 log unit higher in animals from 18 m compared to those from 135 m.

"The amount of damage varied with the delay between capture of the animals and exposure to light. When exposed 2 h after capture significant differences between depths were seen but the results were influenced by the incomplete dark adaptation of some specimens. Animals exposed 4 h after capture (at midnight) were fully dark-adapted and gave maximal differences in the amount of retinal damage between animals from different depths. When exposure was delayed by 26 h animals from all three depths showed reduced damage, similar to that following immediate exposure to shallow water animals.

"These results suggest that ambient light levels are responsible for fine tuning of the structure and functioning of the eye of *N. norvegicus*." [©1990 Marine Biological Association of the United Kingdom (Registered charity no. 226063). Reprinted with permission of Cambridge University Press.]

56. Getchell, R.G. 1987. Effects of V-notching on the lobster, *Homarus americanus*. Canadian Journal of Fisheries and Aquatic Sciences 44:2033–2037.

KEYWORDS: *American lobster, Atlantic coast, injury, laboratory experiment, Maine*

ABSTRACT: "No infections were detected in V-notched lobsters, *Homarus americanus*, held for 56 d in the laboratory. During an outbreak of gaffkemia ('red tail') at a commercial lobster pound, 2 of 20 V-notched lobsters died, but 4 of 10 unnotched controls also became infected. Results from challenge experiments with *Aerococcus viridans* (var.) *homari* showed that V-notched wounds healed sufficiently in 24 h to prevent a 'red tail' infection. Histological observations of this wound repair of V-notched uropods also demonstrated that within 24 h the wound was sealed by a heavy infiltration of hemocytes."

57. Gooding, R.M. 1985. Predation on released spiny lobster, *Panulirus marginatus*, during tests in the northwestern Hawaiian Islands. Marine Fisheries Review 47(1):27–35.

KEYWORDS: *Bycatch, handling, Hawaii, mortality, predation, spiny lobster (Hawaii), trap*

ABSTRACT: "In the Northwestern Hawaiian Islands fishery for spiny lobster, *Panulirus marginatus,* undersized and berried lobsters must be released. Such lobsters released in the conventional way, are very vulnerable to predation by large carnivores. Field tests showed that the white ulua, *Caranx ignobilis,* was an efficient and aggressive predator on released lobsters. Another suspected predator, the galapagos shark, *Carcharhinus galapagensis,* did not prey on released lobsters. Procedures are suggested for use by commercial fishermen that should preclude serious predation on released lobsters."

58. Guillory, V. 1993. Ghost fishing by blue crab traps. North American Journal of Fisheries Management 13:459–466.

KEYWORDS: *Blue crabs, escape mechanism, field evaluation, gear technology, ghost fishing, Gulf of Mexico, mortality, trap*

ABSTRACT: "Ghost fishing by abandoned or lost traps for blue crab *Callinectes sapidus* was evaluated experimentally in the Timbalier Bay estuary, Louisiana. An average of 12.8 blue crabs per trap were captured by the initial baiting, and an additional 34.9 blue crabs later entered each subsequently unbaited trap; of the total captured, 25.8 died and 21.7 escaped per trap. The turnover of blue crabs was fairly rapid; two-thirds of blue crab entering the trap either died or escaped within 2 weeks. The number of blue crabs per trap varied seasonally and was a function of the comparative rates of ingress, mortality, and escapement. Small blue crabs (<120 mm carapace width) were more likely to escape, whereas large individuals (>140 mm) tended to remain in the traps and eventually die. Management measures to ameliorate the adverse effect of ghost fishing on the blue crab resource include escape vents and biodegradable panels."

59. Halcrow, K., and C.G.H. Steel. 1992. Cuticular repair in the mature male snow crab *Chionoecetes opilio* Majidae crustacea in relation to ecdysteroids. Canadian Journal of Zoology 70:314–319.

KEYWORDS: *Atlantic coast, autotomy, Canada, injury, molt cycle, physiology, snow crab*

ABSTRACT: "Morphometrically mature male snow crabs, *Chionoecetes opilio,* are not known to molt; they are believed to lack functional Y-organs and hence molting hormones. Small regions of the dorsal surface of crabs were damaged and the ensuing repair of the cuticle was followed by light microscopy at intervals of up to 60 days. Events within the limb base after forced autotomy of a single pereiopod were also investigated and compared with cuticle deposition in limb bases of pereiopods autotomized before the crabs' arrival in the laboratory. Circulating ecdysteroids were assayed by radioimmunoassay at intervals throughout the experiments. New cuticle was deposited in response to all types of injury and in a manner similar to that described previously. New cuticle was deposited across the breakage plane of autotomized limb bases; a complete and substantial layer was present in many of the bases of previously autotomized legs. Neither basal growth nor premolt growth was detected in the base of any autotomized limb. Ecdysteroids were detectable in the hemolymph of most crabs but at low titers, ranging from 6.0 to 11.6 ng/mL."

60. Hartsock, F. 1975. Live-tanking of snow crab. University of Alaska Fairbanks, Alaska Sea Grant Advisory Program, Alaska Seas and Coasts 3(5):10–11.

KEYWORDS: *Density, Dungeness crab, Gulf of Alaska, hypoxia, injury, king crab, mortality, physiology, snow crab, stress, temperature, transport*

SYNOPSIS: Crabs held in a live tank are vulnerable to multiple stresses. Experiments were conducted to determine the effects of loading density on oxygen consumption for snow, king, and Dungeness crabs. As density of animals in a tank increased, oxygen consumption per pound decreased for all three species. However, Dungeness crabs were far superior to the other two species in their ability to extract dissolved oxygen from the seawater. Increased temperatures caused increased oxygen consumption in all 3 species of crab, particularly in snow crabs. Snow crabs subjected to the weight from a pile of crabs greater than about 4 ft suffered from impaired respiration. Tank conditions that minimize deadloss of snow crabs are recommended.

61. Hartsock, F.B., and P.L. Peterson. 1971. Crab live-tanking and suggestions for improved methods with special reference to Tanner crabs (*Chionoecetes bairdi*). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Technical Report 96, Kodiak.

KEYWORDS: *Density, hypoxia, Kodiak, molt cycle, mortality, salinity, sex/size effect, stress, Tanner crab, temperature, transport*

SYNOPSIS: Experiments were conducted on Tanner crabs in Kodiak to improve live-tank methods and reduce deadloss. Effects of temperature, dissolved oxygen, pollutants, starvation and molt stage, weight bearing on each crab and crowding, and salinity and crab size were investigated. Deadloss can be attributed to respiratory failure due to insufficient oxygen. Tanner crabs are sensitive to temperature changes of 2°F or 3°F above or below their optimum range causing increased oxygen demand, metabolic rate, and stress.

62. Hayes, M.L. 1973. Survival of Tanner crab (*Chionoecetes bairdi*) after capture in trawls and subsequent handling and storage aboard fishing boats. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Report by the U.S. National Section to the International North Pacific Fisheries Commission, Seattle.

KEYWORDS: *Bering Sea, bycatch, exposure, field evaluation, handling, mortality, Tanner crab, trawl*

SYNOPSIS: Bycatch of Tanner crabs in groundfish trawls by Japan and the former USSR in the eastern Bering Sea are to be returned to the sea. Mortality associated with such capture and subsequent handling was investigated. Crabs were subjected to air exposure, storage with other species, and storage in simulated fish bins. More than 50% of the crabs died within the first 12 h of exposure to air and few survived 48 h exposure to air. Similarly, >50% of crabs stored in tubs with other species experienced mortality, and few crabs survived after 12 h of storage. Half the crabs near the surface of simulated fish bins survived after 12 h storage, and few crabs survived when buried in fish more than 0.3 m in depth.

63. Hicks, D., and M.C. Murphy. 1989. A handling study of Dungeness crab at varying air exposure intervals and shell-hardness levels. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fisheries Research Bulletin 89-01, Juneau.

KEYWORDS: *Dungeness crab, exposure, handling, Kodiak, mark recapture, mortality, shell condition*

ABSTRACT: "Excessive handling of soft-shell Dungeness crab (*Cancer magister*), is believed to result in mortality. Estimates of handling mortality could be used to minimize the impact of commercial fishing on soft-shell crab. Dungeness crab were tagged, measured for shell hardness, and exposed to air for a specified period. Differences in recovery rates of crab with different shell hardnesses and air exposure times were not statistically significant. Nonsignificant results were attributed to small sample sizes in shell-hardness categories most sensitive to treatment. Therefore, affects of air exposure and handling on soft-shell crab could not be determined in this study. Recommendations are made for future study designs."

64. High, W.L. 1976. Escape of Dungeness crabs from pots. Marine Fisheries Review 38(4): 19–23.

KEYWORDS: *Dungeness crab, escape mechanism, field evaluation, ghost fishing, pots, predation, Puget Sound, sex/size effect*

ABSTRACT: "Dungeness crab, *Cancer magister*, unable to escape from derelict pots (traps whose buoy lines have parted) could be confined until death and lost to the fishery. Therefore, the National Marine Fisheries Service, in cooperation with the Washington Department of Fisheries and the Fish Commission of Oregon, conducted four experiments to determine whether Dungeness crabs could escape from standard ocean- and bay-style pots. Divers placed marked crabs into pots set without surface buoys on a sand bottom in Puget Sound, Wash. Female crabs and sublegal (carapace less than 6¼ inches across) and legal size male crabs escaped quickly from pots having escape rings open and triggers raised (inoperative). Pots with functional (operative) triggers and open escape rings allowed less escapement, especially for larger crabs. Crabs confined in pots having escape rings closed and with functional triggers were observed at intervals for 74 days, at which time 21 percent of the large and 67 percent of the small crabs had escaped. Of those crabs remaining alive, nearly all escaped within 3 days after the triggers were raised. Study results indicate that 1) escapement is directly related to availability of openings large enough to pass a crab and that 2) triggers are an effective means for reducing escapement."

65. High, W.L. 1985. Some consequences of lost fishing gear. Pages 430–437 *in* R.S. Shomura and H.O. Yoshida, editors. Proceedings of the workshop on the fate and impact of marine debris. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National

Marine Fisheries Service, NOAA-TM-NMFS-SWFC-54, Honolulu.

KEYWORDS: *Confinement, gear loss, ghost fishing, gillnet, Gulf of Alaska, longline gear, mortality, Pacific cod, pots, red king crab, sex/size effect*

ABSTRACT: "Directed studies and incidental observations of derelict crab pots, longline gear, and sunken gill nets show some long-term damage to living marine animals. More than 30,000 crab pots have been lost in the western Gulf of Alaska since 1960. About 20% of legal size and 8% of sublegal king crab in these pots at the time of loss, fail to escape. The king crab which escape pots after a 10-day or more confinement, reenter the fishery at a very low rate, suggesting that relatively short-term confinement contributes to high mortality. Crab which die in a pot tend to repel other crab. Bright, bare hooks on halibut longline gear occasionally take fish, but plated hooks quickly rust or snag on sea floor objects. Although the nylon ground lines and gangions remain intact for several years, the hooks quickly cease to function. Three salmon gill net segments lost by Washington State fishermen have been observed for several years. The deployed segments ranged from 5.5 to 18.3 m (18 to 60 ft) below the surface. Each continued to fish for more than 2 years, taking a variety of fish, invertebrates, and seabirds. Underwater studies of the sunken gill net fishery for Pacific cod, *Gadus macrocephalus,* showed that only about 14% of the entangled cod escape before the net was retrieved. Consequently, most cod gilled, or otherwise tangled in sunken gill nets lost by fishermen remain until they die. Because set net fisheries are often concentrated on rough sea floor areas and among sunken man-made objects, significant loss of nets do occur. Some fishing gears are modified to quickly reduce their fishing capacity when lost."

66. High, W.L., and D.D. Worlund. 1979. Escape of king crab, *Paralithodes camtschatica,* from derelict pots. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Technical Report NMFS-SSRS-734, Seattle.

KEYWORDS: *Bait, confinement, field evaluation, ghost fishing, Kodiak, mark recapture, mortality, pots, red king crab, sex/size effect*

ABSTRACT: "Loss of 10% per season of pots (traps) in the Alaskan fishery for the king crab, *Paralithodes camtschatica,* has raised the question of possible loss of crabs and fishes to the derelict, or lost, pots which continue to fish. We conducted a series of experiments during 1974 and 1975 in which tagged king crab were placed in several types of pots and returned to the bottom (soaked) for periods of 1–16 days. As controls, we released some tagged king crab in Chiniak Bay, Kodiak Island, Alaska. Tagged crab missing from the pots at time of recovery were credited with escape.

"The experiments demonstrated that 92% of undersize and 80% of legal-size crab readily escaped the derelict pots. Mortality among crab held in pots for various experiments ranged up to 12%. Crab that escaped within 1–4 days were recovered by commercial fishermen at about the same rate as those released in Chiniak Bay near the experiment site. However, those released after a 10- to 16-day confinement were returned at a much lower rate. Some commercially valuable fishes — such as Pacific halibut, *Hippoglossus stenolepis* — were also caught in the experimental pots."

67. Hill, B.J., and T.J. Wassenberg. 1990. Fate of discards from prawn trawlers in Torres Strait. Australian Journal of Marine and Freshwater Research 41:53–64.

KEYWORDS: *Australia, bait, bycatch, cephalopod, crustacean, field evaluation, fish, mortality, trawl*

ABSTRACT: "A study was made of the fate of teleosts, non-commercial crustaceans and cephalopods discarded from trawlers in Torres Strait. These groups make up about 80% of the discards by weight, have high mortality rate and are therefore the most likely animals to be eaten by scavengers. The remaining 20% of discards consists of animals such as turtles, sharks, bivalves and sponges, which are caught in low numbers and appear to have a low mortality from trawling.

"Fish made up 78%, non-commercial crustaceans 18%, and cephalopods 3% by weight of the material studied. Nearly all fish were dead when discarded, and about half sank. About half of the non-commercial crustaceans were alive when discarded and all sank when discarded. Few cephalopods were alive when discarded, and around 75% sank.

"Sharks and dolphins were the most common scavengers of floating discards at night. Birds (common and crested terns, and lesser and greater frigates) scavenged only during the day. Discards that sank did so rapidly, taking less than 5 min to reach 25 m depth. A high rate of loss of baits set for 10 min in the water column (24% in trawled area at night) indicated significant scavenging in mid water — probably by sharks. Observations of baits set on the bottom showed

that teleosts (nemipterids) and sharks ate most of the material that reached the bottom; scavenging by invertebrates was negligible.

"In an adjacent area that had not been trawled for 8 years, no dolphins and fewer birds were seen scavenging floating discards but there were more sharks. In this area, significantly fewer fish were attracted to a bait on the bottom at night compared with the trawled area. The cause of the difference in scavenging observed between the two areas is not known; while it may reflect learned behavior by some scavengers such as birds and dolphins, there may also be intrinsic differences between the two areas unrelated to trawling.

"Discarding from trawlers has the effect of transferring large quantities of biological material from the bottom to the surface. This makes available to surface scavengers food that would otherwise be inaccessible."

68. Hunt, J.H., and W.G. Lyons. 1986. Factors affecting growth and maturation of spiny lobsters, *Panulirus argus*, to the south Florida fishery. Canadian Journal of Fisheries and Aquatic Sciences 43:2243–2247.

KEYWORDS: *Caribbean spiny lobster, Florida, growth, injury, mark recapture, molt cycle*

ABSTRACT: "Overall growth rates of sublegal-sized (50–75 mm carapace length (CL)) and large (≥76 mm CL) spiny lobsters, *Panulirus argus*, in the Florida Keys were 0.46 and 0.15 mm CL/wk; growth rates were 48 and 67% less, respectively, in winter than in summer. Injuries caused a significant 39% growth reduction in small (≤60 mm CL) lobsters. Growth decreased dramatically between 74 mm CL (0.46 mm CL/wk) and 76 mm CL (0.23 CL/wk). Between 71–75 and 76–80 mm CL size classes, intermolt periods of females increased 58% and molt increments decreased 16%; male intermolt periods increased 33% but molt increments did not change until 85 mm CL. Consequently, large (≥76 mm CL) males grew 33% faster than females. Changes in growth rates signified a shift in energy use at onset of maturation."

69. Hunt, J.H., W.G. Lyons, and F.S. Kennedy, Jr. 1986. Effects of exposure and confinement on spiny lobsters, *Panulirus argus*, used as attractants in the Florida trap fishery. Fisheries Bulletin 84:69–76.

KEYWORDS: *Atlantic coast, bait, Caribbean spiny lobster, confinement, economics, exposure, Florida, mortality, shorts, trap*

ABSTRACT: "Traps in the south Florida spiny lobster fishery are baited with live sublegal-sized lobsters (shorts), many of which are exposed for considerable periods aboard vessels before being placed in traps and returned to the sea. Average mortality rate of lobsters exposed 1/2, 1, 2, and 4 hours in controlled field tests was 26.3% after 4 weeks of confinement. About 42% of observed mortality occurred within 1 week after exposure, indicating exposure to be a primary cause of death. Neither air temperature during exposure nor periodic dampening with seawater had significant effects on mortality rate. Mortality among confined lobsters increased markedly in the Atlantic oceanside but not in Florida Bay during the fourth week of confinement following exposure, probably because more natural food organisms entering traps from nearby seagrass beds delayed starvation at the latter site. Mortality caused by baiting traps with shorts may produce economic losses in dockside landings estimated to range from $1.5 to $9.0 million annually."

70. Jayakody, D.S. 1991. Fishery, population dynamics and breeding biology of *Panulirus homarus* (L.) on the south coast of Sri Lanka. Doctoral dissertation, University of Stirling, United Kingdom.

KEYWORDS: *Fecundity, gillnet, injury, limited entry, management strategy, recruitment, rings, spiny lobster (Sri Lanka), Sri Lanka, trammel net*

ABSTRACT: "This study is aimed to provide an understanding of the spiny lobster fishery of the south coast of Sri Lanka. Most of the spiny lobster fisheries of the world are subjected to heavy exploitation due to the increasing demand. The use of hazardous fishing methods however is known to cause serious problems in the developing countries, including Sri Lanka where considerable percentage of berried females and under sized lobsters are caught each year.

"The fishery for spiny lobster in the coastal waters of the south coast is carried out by non-mechanized out-rigger small canoes with trammel nets, bottom set gill nets and lobster rings. Around 200 mt of lobsters is caught each year in the study area by a fishing fleet of 315 crafts. Around 80% of the lobster production consisted of *Panulirus homarus*.

"Lobsters were found to occur all year round, but the fishery is restricted to the non-monsoon period (August–March) due to operational difficulties.

"The analysis of catch and effort statistics indicated a maximum sustainable yield of 190–200 mt and an optimal daily effort of 300 crafts. The length-based analysis indicated that the resource is over exploited

and a reduction in effort by about 20.5% is necessary to put the fishery back to an equilibrium level.

"Experimental fishing tests revealed that the lobster rings cause the least damage to the population, while the trammel net was the most harmful by including 77% of sub-legal lobsters in catches. This study indicated the possibility of having two spawning and recruitment pulses separated by an interval of 4–5 months. Fecundity estimates ranged between 116,000–601,000. Nearly two-thirds of the total egg production was contributed by lobsters of 60–79 mm carapace length range. The fishery is reproductively supported by 3–4 year lobsters. This resource in the study area appears to be overfished with respect to its reproductive potential.

"The use of trammel nets and free access to the fishery are the two main points which should be carefully controlled. The fishery should be managed by using less harmful fishing gear (eg. lobster rings) and by introducing a proper licensing system to control fishermen entering into the fishery." [The dissertation titles and abstracts contained here are published with permission of University Microfilms International, publishers of *Dissertation Abstracts International* (copyright ©1991 by University Microfilms International), and may not be reproduced without their prior permission.]

71. Joll, L.M. 1977. The predation of pot-caught western rock lobster *(Panulirus longipes cygnus*) by octopus. Western Australia Department of Fisheries and Wildlife Report 29, Perth.

KEYWORDS: *Australia, economics, gear technology, mortality, octopus, pots, predation, western rock lobster*

ABSTRACT: "The losses to the western rock lobster fishery through the predation of pot-caught rock lobsters by octopus were estimated from samples taken on commercial boats in the four seasons 1972/73–1975/76. In most seasons approximately 200,000 legal-sized rock lobsters were lost. In the 1975/76 season the estimated financial loss from octopus predation was $392,000. The estimated losses probably represent minimum values. Studies of the biology and behavior of octopus were carried out to examine the methods of detection, location and entry into rock lobster pots by octopus. The use of octopus traps in rock lobster pots significantly increased the catch from rock lobster pots without any significant effect on rock lobster catches."

72. Juanes, F., and E.B. Hartwick. 1990. Prey size selection in Dungeness crabs: the effect of claw damage. Ecology 71:744–758.

KEYWORDS: *British Columbia, diet, Dungeness crab, foraging, injury, laboratory experiment, predation*

ABSTRACT: "We investigate prey size selection by *Cancer magister,* a decapod crustacean, feeding on *Protothaca staminea,* a hard-shelled venerid clam, and test predictions of the optimal diet model using three different currencies. We also evaluate the effect of claw damage on crab feeding efficiency.

"The model parameters measured were: energy content of the prey, energy cost of predation, and handling time. All of these variables were positive exponential functions of clam size. The different measures of prey value (or profitability) provided contrasting prey rankings. Both net and gross rates of energy intake [(Benefit-Cost)/Time and Benefit/Time, respectively] predicted that the largest clams were the most profitable. Energetic efficiency (Benefit/Cost) predicted that the smallest clam sizes were the most profitable. Prey-size selection experiments, offering crabs mixtures of two or three clam size classes, showed that crabs always ate more clams from the smallest clam size class offered. Thus the predictions from the energetic model provide the best fit to the results.

"The use of energetic efficiency as a currency requires energy cost to be limiting over the animal's lifetime. In this study we propose claw damage, defined as chela breakage and claw-tooth wear, as a consequence of fatigue failure (breakage of a structure due to repeated loading), to be a limiting cost. A field study of a natural population of *C. magister* indicated that levels of wear and breakage were significant and were related to sex and molting state. Laboratory experiments showed that crabs with broken claws were unable to crack clams. Crabs with artificially worn claw teeth had significantly longer handling times than undamaged crabs. Finally, the ecological effects of claw breakage in decapods are evaluated with reference to growth, molting ability, regeneration load, and reproductive success."

73. Kanciruk, P., W.F. Herrnkind, B.F Phillips, and P.M. Arnaud. 1982. An indexed bibliography of the spiny (rock) lobsters (Decapoda: *Palinuridae*). Commonwealth Scientific and Industrial Research Organization Marine Laboratories Reprint 1274, Oak Ridge National Laboratory, Environmental Sciences Division Publication 1733, Oak Ridge.

KEYWORDS: *Bibliography, lobster*

74. Kendall, R.A., J.C. Van Olst, and J.M. Carlberg. 1982. Effects of chelae immobilization on growth and survivorship for individually and communally raised lobsters, *Homarus americanus.* Aquaculture 29:359–372.

KEYWORDS: *American lobster, cannibalism, chelotomy, growth, laboratory experiment, limb loss, mortality, stress*

ABSTRACT: "Communal rearing systems for juvenile American lobsters, *Homarus americanus,* allow lower production costs than are possible in individual rearing systems, but often result in high levels of mortality due to behavioral interactions such as cannibalism. This study evaluated the effects on growth and survivorship of two methods of bilateral immobilization of chelae (chelae and dactylopodite removal) for stage IV juvenile lobsters treated initially and at monthly intervals for 6 months.

"Replicate groups of lobsters were cultured in communal tanks and individual holding containers. After 6 months in individual containers, mortality was highest in the lobsters in which the chelae were completely removed. Lobsters cultured individually are subjected to dactylopodite removal exhibited less mortality. However, this pattern was reversed in the mass rearing system. Cannibalism appeared to be the major source of mortality for lobsters in the mass rearing control group, whereas mortality in lobsters from which the chelae had been removed was due primarily to treatment stress and non-community based factors.

"Growth was not affected by immobilization of the chelae. Within the mass rearing system, growth rates for the lobsters from the two treatment groups was suppressed after the fourth month when their size and increased survivorship produced a situation where the effective bottom area per animal was smaller than that required for unlimited growth.

"This reduction in mortality with insignificant effect on growth required relatively little investment in man-hours; chelae removal required less than 2 min of effort for each surviving lobster. By using the chelae removal technique on communally raised juvenile lobsters, major equipment and maintenance costs inherent to individual rearing systems probably could be avoided with little or no impairment of growth." [Reprinted with permission from Elsevier Science B.V., Amsterdam, The Netherlands.]

75. Kennedy, F.S., Jr. 1982. Catch rates of lobster traps baited with shorts, with notes on effects of confinement. Page 20 *in* W.G. Lyons, editor. Proceedings of a workshop on Florida spiny lobster research and management. Florida Department of Natural Resources, Marine Research Laboratory, St. Petersburg.

KEYWORDS: *Bait, Caribbean spiny lobster, confinement, Florida, growth, molt cycle, mortality, shorts, trap*

ABSTRACT: "Standard wooden commercial lobster (*Panulirus argus*) traps were fished in the middle and upper Florida Keys from May 1978 through March 1979. Traps were baited with cowhide, cowhide and one lobster, cowhide and three lobsters. Traps were pulled weekly. Mean catch rates were: 1.15 lobsters per week from traps baited with cowhide only; 1.86 lobsters from traps baited with cowhide plus one lobster; 4.20 lobsters from traps baited with cowhide plus three lobsters. Catches from traps baited with cowhide plus lobsters were significantly greater than those from traps baited with cowhide only.

"Average return rate of released non-bait lobsters was 17.9%, whereas average return rate of bait lobsters was 9.3%, only 51.8% of non-bait returns. The difference, 48.2%, may be an estimate of mortality of lobsters used as bait. Growth occurred in 31.1% of released non-bait lobsters and in only 13.1% of bait lobsters. Average times between release or escape and recapture for bait and released lobsters were similar, 3.96 weeks and 4.66 weeks, so it appears that bait lobsters did not molt (grow) as frequently as they should. Incremental changes in carapace length (CL) of lobsters that grew were 7.27 mm CL for releases, 6.15 mm CL for bait after escape or release, and 5.33 mm CL for bait that grew while in traps. Bait in traps grew significantly less (26.7%) than non-bait lobsters, suggesting that growth of bait was stunted while in traps."

76. Kennelly, S.J., D. Watkins, and J.R. Craig. 1990. Mortality of discarded spanner crabs *Ranina* (Linnaeus) in a tangle-net fishery — laboratory and field experiments. Journal of Experimental Marine Biology and Ecology 140:39–48.

KEYWORDS: *Australia, field evaluation, laboratory experiment, limb loss, spanner crab, trap*

ABSTRACT: "Effects of disentanglement from commercial tangle-traps on the mortality of undersize, discarded spanner crabs *Ranina,* (Linnaeus) were determined for a fishery in New South Wales, Australia. First, we quantified the damage sustained by discarded crabs due to the three main methods of

disentanglement used by commercial fishermen: careful removal, causing no damage; quick removal, where any entangled dactyli are broken off (average 3.95 dactyli per crab); and the fastest method where crabs are pulled off and entangled limbs and dactyli are broken off (average 2.9 dactyli and 0.8 limbs per crab). We then tested effects of these various kinds of limb damage on the mortality of undersize *R. ranina* in an aquarium experiment in which replicate crabs were damaged in three ways and compared to undamaged controls. Finally, we did a similar (though shorter-term) experiment in the field using enclosures buried in the substratum near the commercial fishing grounds. The results showed quite significant rates of mortality due to disentanglement: 60–70% of crabs with one or more dactyli removed died within 50 days, whilst 100% of crabs which lost whole limbs (after being pulled off nets) died after 8 days. We discuss the mortality of such discarded conspecifics in terms of the future success of this fishery and the applicability of size restrictions by management." [Reprinted with permission from Elsevier Science B.V., Amsterdam, The Netherlands.]

77. Kimker, A. 1994. Tanner crab survival in closed pots. Alaska Fishery Research Bulletin 1(2): 179–183.

KEYWORDS: *Field evaluation, ghost fishing, Gulf of Alaska, limb loss, mortality, Tanner crab*

ABSTRACT: "Lost and delinquent commercial and sport fishing gear has gained public notoriety recently because of documented waste of fish and shellfish resources. Shellfish and groundfish pots have contributed to the problem. Although escape mechanisms have been developed to allow egress of captured species from pots, imprecise release time of these devices has generated debate exacerbated by inexact estimates of the survival of captured species. To gain information on Tanner crab *Chionoecetes bairdi* survival in pots, we captured large, adult male Tanner crabs and held them in cod pots in the outer portion of Kachemak Bay, Alaska. The pot tunnels were secured shut so the crabs had no chance to escape. No external source of food was provided. The pots were pulled periodically over a 119-d period. A total of 52 (39%) of the original 132 crabs died during the experiment."

78. Krouse, J.S. 1976. Incidence of cull lobsters, *Homarus americanus,* in commercial and research catches off the Maine coast. Fisheries Bulletin 74:719–724.

KEYWORDS: *American lobster, Atlantic coast, bycatch, escape mechanism, field evaluation, limb loss, Maine, regeneration, trap*

ABSTRACT: "Data obtained by port sampling the Maine commercial lobster catch (1968–74) and the natural population near Boothbay Harbor, Maine, with research gear (1969–74) indicate that 6.5% of the commercially harvested lobsters have lost at least one claw while 21.0% of the lobsters (all sizes) in the natural population have missing and/or regenerating claws. An assessment of variations in cull frequencies associated with different seasons, fishing localities, and lobster size distribution suggests a direct relationship between fishing intensity and the incidence of culls. This information further supports Krouse and Thomas' recommendation that all lobster traps be equipped with an escape vent thus minimizing fishermen's needless handling of excessive numbers of sublegal-sized lobsters."

79. Kruse, G.H. 1993. Biological perspectives on crab management in Alaska. Pages 355–384 *in* G.H. Kruse, D.M. Eggers, R.J. Marasco, C. Pautzke, and T.J. Quinn II, editors. Proceedings of the international symposium on management strategies for exploited fish populations. University of Alaska Fairbanks, Alaska Sea Grant Report 93-02.

KEYWORDS: *Alaska, crab, gear effect, handling, life history, lobster, management strategy*

ABSTRACT: "Waters off Alaska support major fisheries for crabs. Survey and fishery data document different stock histories including long-term declines, stocks that crashed and later recovered, and populations that have withstood large fisheries. Although specific regulations are modified routinely, management strategies tend to reflect historical practices, many borrowed elsewhere. Management primarily involves size, sex, and season regulations that are augmented by exploitation rates for enumerated stocks. General perspectives on crab management are presented based on review of applied crab research conducted since the inception of extant harvest strategies in the 1960s.

"In contrast to other Alaskan crabs (*Paralithodes, Lithodes, Chionoecetes*), Dungeness crabs, *Cancer magister*, have traits that tend to be associated with species capable of sustaining relatively liberal harvests: high fecundity, low maximum age, low ages of maturity and recruitment, and high natural mortality. For all species, size limit regulations should acknowledge mating opportunities, and the inability of female

anomurans (such as king crabs) and the ability of female brachyurans (Tanner, *Chionoecetes bairdi*; snow, *C. opilio*; and Dungeness crabs) to store viable sperm for 2 years or more. Management plans should recognize that (1) crab size and complex behavior influence reproductive success, (2) stocks at the extremes of their geographic ranges sustain low yields; (3) recruitment overfishing is likely for highly exploited populations with low frequency of recruitment; and (4) yield may be markedly reduced by handling mortality of discards. In addition, size limits reduce the number of reproducing age classes, thereby thwarting a population's buffer against recruitment failures, and size limits may cause long-term selection against crabs with genotypes associated with rapid growth. Female harvest, particularly at high population levels, should be considered because it may lead to less variability in production and higher long-term yield. Yield models that reflect the unique life history traits of each crab species, coupled with investigations into poorly established biological production parameters, are needed so more specific proposals for management changes can be developed and quantitatively analyzed."

80. Kruse, G.H., D. Hicks, and M.C. Murphy. 1994. Handling increases mortality of softshell Dungeness crabs returned to the sea. Alaska Fishery Research Bulletin 1(1):1–9.

KEYWORDS: *Dungeness crab, exposure, field evaluation, handling, Kodiak, management strategy, mark recapture, molt cycle, mortality, shell condition*

ABSTRACT: "Effects of carapace hardness and air exposure duration on mortality were studied on Dungeness crabs *Cancer magister* off Kodiak Island, Alaska. We captured 516 legal male crabs and marked them with spaghetti tags. Carapace condition was recorded, and crabs were randomly selected for exposure to air for 5, 15, 30, and 60 min. Crabs were then returned to the sea. Subsequent recoveries from commercial catches included 11% of the tagged softshell crabs and 20% tagged hardshell crabs; these differences were statistically different. No statistical difference was found among exposure periods for hardshell crabs; low statistical power due to small sample size precluded similar tests for differences among exposure periods for softshell crabs. Low recovery rates of softshell crabs in Alaska is consistent with previous mark-recapture studies of Dungeness crabs conducted off Oregon and Washington. Previously published results from controlled experiments support our conclusion that differential recovery rates were primarily due to elevated handling mortality of softshell crabs. Our data suggest that softshell crab experienced 45% higher mortality than hardshell crabs. However, this rate may not be representative of handling mortalities experienced during commercial fisheries because (1) during molting periods fisheries catch crabs much softer than those we encountered, (2) we handled crabs much more carefully than would normally occur during commercial operations, and (3) we were unable to derive separate estimates of differential natural and handling mortalities among softshell and hardshell crabs. Findings of handling mortalities of softshell crabs, coupled to considerations of cannibalism in crab pots, indicate that Dungeness crab fishing seasons in Alaska should be structured to avoid major molting periods as is the general practice along the coasts of California, Oregon, Washington and British Columbia. Such regulations will reduce mortality and commensurately increase the abundance of harvestable males and spawning biomass. Extended fishery closures until several months after molting will result in some economic benefits as well. Meat yield and wholesale value are lowest during molting and increase until peaking several months later. These factors, plus other socioeconomic tradeoffs, should be weighed to determine net benefits to changes in fishing seasons for Dungeness crabs."

81. Kruse, G.H., and A. Kimker. 1993. Degradable escape mechanisms for pot gear: a summary report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J93-01, Juneau.

KEYWORDS: *Alaska, escape mechanism, gear loss, gear technology, ghost fishing*

EXECUTIVE SUMMARY: "In Alaska, pots are commonly used in fisheries for crabs, spot shrimps and cod. Pots are lost from several causes, including: storms; strong tidal currents; shifting ice floes (snow crab fishery); gear abandonment; and pot buoys are sometimes cut by vessel traffic, entanglement with other gear, and occasional area disputes among fishermen.

"Ghost fishing occurs when lost pots continue to catch crabs, fishes, and other animals. Ghost fishing causes a variety of sublethal and lethal effects. The former include carapace damage, appendage loss, and decrease in weight. Deaths are primarily due to cannibalism, predation, starvation, and suffocation in pots that are buried by sand.

"Estimates of total crab mortality from ghost fishing are unavailable for Alaskan fisheries because of several unknowns: (1) rate of annual pot loss by fishery, (2) rate at which pots break down, (3) catch rates of lost gear, and (4) effects of entrapment on crabs. However, estimates of pot loss for 2 Alaskan fisheries (10% and 20%) are similar to loss rates (8–25%) for pot fisheries elsewhere where ghost fishing is significant. Also, recent laboratory studies and earlier field studies on Alaskan crab species suggest that ghost fishing has the potential to cause significant revenue loss to the fishing industry in Alaska. Undoubtedly, ghost fishing has been mitigated in recent years because of requirements for degradable escape mechanisms with cotton twine.

"At the request of the Alaska Board of Fisheries (BOF) at its March 1991 meeting, the Alaska Department of Fish and Game (ADF&G) considered the merits of cotton twine versus galvanic timed release (GTR) mechanisms; i.e., a device composed of 2 stable metal eyelets and an active metal cylinder (magnesium alloy) that corrodes in salt water. Specifically, we considered the advantages and disadvantages of the following 4 alternative regulations for degradable mechanisms in shellfish and groundfish pots: (1) cotton twine only (status quo), (2) GTR devices only, (3) cotton twine or GTRs at the prerogative of individual fishermen, and (4) only GTRs after some phase-in period during which either GTR and cotton twine are acceptable.

"The main advantage of the cotton twine is its lower cost, whereas advantages of GTRs are reliability and ease of inspection. Disadvantages of twine are that breakage times are unpredictable and integrity of used twine is difficult to assess. A main disadvantage of GTRs is their cost relative to cotton twine.

"Because the shape of a GTR is much different than the appearance of cotton twine or pot webbing, regulations for GTRs are probably more enforceable than cotton twine. With twine the most difficult part of enforcement is the ability to determine whether the twine is untreated cotton of appropriate thread size. With GTRs the most difficult part of enforcement is verification that the unit is designed to break within the mandated time rather than later.

"Nevertheless, ADF&G strongly recommends degradable escape mechanisms, and breakage at 30 days seems optimal. However, longer average times for degradation of cotton thread (approximately 107 days for 60 thread in Dungeness crab pots and 89 days for 30 thread in all other pots) under current regulations reflects an attempt to achieve a sensible tradeoff between mean and variance of breakage time. That is, the reasoning by fishermen to favor 60 thread over 30 thread for Dungeness crab pots is based more on a desire to delay the time at which twines first begin to break and not so much a preference for a mean breakage time of 107 days rather than 89 days. Such a tradeoff between mean and variance in breakage times is unnecessary for GTRs that degrade at such a predictable rate.

"Compared to pots laced with 30 or 60 thread, the 30-day GTR provides for increased crab survival associated with reduced periods of confinement in lost pots without the disadvantage of unexpected, premature breakage associated with smaller twine sizes. Although GTRs are more costly than cotton twine, these costs may be more than remunerated by increased revenues realized by fewer pots that lose their catches from premature breakages of escape devices.

"ADF&G supports alternative 4, in which GTRs are required after, say, a one-year phase-in period during which discretionary use of either GTRs or cotton twine is allowable. The phase-in period will provide opportunity for voluntary large scale testing of GTRs by industry and would facilitate a smooth transition to these new devices. Yet, in the unlikely event that some unforeseen problems create unsolvable obstacles during this phase-in period, then this GTR-only regulation could be modified. In this regard, ADF&G recommends that the BOF pre-schedule GTRs on its agenda for the spring 1994 meeting cycle. In revisiting this issue, the BOF would be afforded the opportunity to consider regulatory adjustments after hearing public testimony on GTR performance in Alaskan commercial pot fisheries."

82. Kurata, H. 1963. Limb loss and recovery in the young king crab, *Paralithodes camtschatica*. Bulletin of the Hokkaido Regional Fisheries Research Laboratory 26:75–80. (Note: text is in Japanese).

KEYWORDS: *Bering Sea, growth, laboratory experiment, limb loss, molt cycle, red king crab, regeneration*

ABSTRACT: "A total of 371 young crabs, ranging in carapace length from 8.5–30.2 mm, captured in the Bering Sea in May and June of 1961, were examined regarding limb loss and regeneration. Most of them were, then, maintained on board a King crab factory ship, Tokei-maru, in 5 aquaria in running water, to allow them to molt and to enable securing data concerning the growth of regenerating limbs at an ecdysis.

"1. Limb loss or regeneration from the breakage plane was observed in 211 (56.9%) of the total crabs.

"2. Limb loss or regeneration distal to the breakage plane was observed in 37 (10.0%) of the total crabs. It is interesting to note here that loss or regeneration proximal to the distal end of merus (except the breakage plane) was never observed.

"3. Recovery rate (*R*) was determined as: $R = l/L \times 100$, where *l* is the length of merus (or propodus, in the case of chelae) of the regenerating limb, and *L* is the hypothetical length of merus (or propodus) of the same limb when it is assumed that the limb has grown without loss. The length *L* can be calculated by relative growth equations of merus (or propodus) length of each limb against carapace length. These equations were obtained from other normal crabs.

"4. Recovery rate at the first post-regenerational molt was greater in the chelae (38.5%) than in the other walking legs (33.4%).

"5. The relation between the recovery rates before and after an ecdysis seems to give a straight line (Fig. 4). On the basis of this evidence it may be concluded that the process of recovery of a lost limb is determined by the recovery rate at the first post-regenerational molt."

83. Kuris, A.M., and M. Mager. 1975. Effect of limb regeneration on size increase at molt of the shore crabs *Hemigrapsus oregonensis* and *Pachygrapsus crassipes.* Journal of Experimental Zoology 193:353–359.

KEYWORDS: *Autotomy, California, growth, laboratory experiment, molt cycle, regeneration, shore crab*

ABSTRACT: "Size increase at molt is reduced following multiple limb regeneration in the shore crabs, *Hemigrapsus oregonensis* and *Pachygrapsus crassipes.* Limb loss per se does not influence postmolt size. Effect of increasing number of regenerating limbs is additive. Postmolt size is programmed early in the premolt period of the preceding instar and is probably not readily influenced by water uptake mechanics at ecdysis. A simple model for growth, molting, and regeneration in heavily calcified Crustacea is developed from the viewpoint of adaptive strategies and energetic considerations."

84. Lyons, W.G. 1986. Problems and perspectives regarding recruitment of spiny lobsters, *Panulirus argus,* to the south Florida fishery. Canadian Journal of Fisheries and Aquatic Sciences 43:2099–2106.

KEYWORDS: *Caribbean spiny lobster, escape mechanism, Florida, handling, life history, management strategy, recruitment, shorts, size limit*

ABSTRACT: "Inappropriate minimum size, illegal harvest, fishery-induced juvenile growth retardation and mortality, and excessive effort have reduced reproductive contributions and depressed yield-per-recruit in the overcapitalized south Florida spiny lobster (*Panulirus argus*) fishery. Measures recommended to improve yield-per-recruit are as follows: Increase minimum legal size to 85–90 mm carapace length; require escape gaps in traps; eliminate possession of sublegal lobsters aboard vessels; prohibit harvest in nurseries; reduce fishing effort; improve enforcement of fishery regulations; and initiate programs to educate fishermen regarding impacts of fishery practices. International management is recommended to assure larval recruitment among Pan-Caribbean stocks."

85. Lyons, W.G., and four coauthors. 1981. The spiny lobster, *Panulirus argus,* in the middle and upper Florida Keys: population structure, seasonal dynamics and reproduction. Florida Department of Natural Resources, Florida Marine Research Publication 38, St. Petersburg.

KEYWORDS: *Caribbean spiny lobster, catch statistics, Florida, habitat, injury, life history, mating, molt cycle, reproduction, seasonal distribution, sex/size effect*

ABSTRACT: "Data on abundance, distribution, size, sex, mating, spawning, molting, incidence of fouling organisms, and injury rates were obtained from 19,180 lobsters at nine stations in the upper and middle Keys fishery area during April 1978 through March 1979. Mean and modal carapace length (CL) sizes were approximately 73 mm, slightly below legal size (76 mm). Lobsters at deep reef (30 m) stations averaged 80.1 mm CL; size decreased gradually to an average of 65.6 mm CL at shallow (3 m) bay stations. Distribution of lobsters was age and habitat related; immature, principally sublegal lobsters in year class 2+ occupied southern Florida bay station, then moved gradually to nearshore oceanside Keys stations; lobsters in year class 3+ migrated seaward in response to onset of maturity or declining late fall–early winter temperatures. Stations on the north sides of Keys were within the Florida Bay nursery area, where fishery-induced damage to sublegal lobsters probably exceeded legal catch from the area. Legal-sized lobsters constituted 43.7% of total catch; 90% were captured at oceanside stations, and nearly half were from the

deep reef. Greatest mean sizes at all but one station occurred during the closed season or the first month of the open season and represented growth among lobsters at each station. Upper Keys stations were more productive (average +67%) than were comparable middle Keys stations. Marked declines in average size at all stations during winter are attributed to depletion by the fishery of legal-sized lobsters and to seaward emigration of relatively larger lobsters from shoreward subpopulations. Mean total number of lobsters per trap per week was 0.84, constituting 0.70 at bay stations and 0.91 oceanside. Legal catch averaged 0.37 lobsters per trap week, constituting 0.12 at bay stations, 0.50 oceanside. Poundage of legal catch during the open season seldom averaged 1 lb per trap per week except at deep reef stations, indicating weekly catch rates less than one third of those two decades previous.

"Female:male ratio (1.2:1) was strongly influenced by significantly more females than males at seaward reef stations. Virtually all mating, evidenced by external spermatophores on females, occurred among oceanside lobsters, and 88% of all activity was found at two deep reef and one shallow (10 m) reef station. Principal mating season was from April through June. Spawning, evidenced by externally carried eggs, occurred only at oceanside stations; 31.1% of females at two deep reef and one shallow reef station were spawning during peak months of May and June. Size of the smallest spawning female was 65 mm CL, but greatest spawning contribution (24.5%) was in the 81–85 mm size class. Nearly 60% of all eggs were produced by lobsters ≤85 mm CL. Spawning contribution by the Keys population was only 12% of that expected from a comparably sized, unharvested population of larger lobsters.

"Fouling by various sessile invertebrates was slight or absent on most lobsters. No correlation was found between fouled lobsters and capture location.

"Indications of molting averaged only 1% in the total population, but was significantly more frequent at nearshore (3–6 m) than at seaward (9–30 m) stations. Maximum molting frequency (2.7%) during April may have been in response to temperature increases.

"Greatest rates of injury occurred at the ends of the 1977–78 and 1978–79 fishing seasons; injuries declined rapidly due to growth and regeneration during the closed season. Unexplainably low previous-injury rate of sublegal-sized lobsters during the open season suggests they may have experienced considerable mortality due to fishery practices."

86. Lyons, W.G., and F.S. Kennedy, Jr. 1981. Effects of harvest techniques on sublegal spiny lobsters and on subsequent fishery yield. Proceedings of the Gulf Caribbean Fisheries Institute 33: 290–300.

KEYWORDS: *Bait, Caribbean spiny lobster, confinement, density, exposure, field evaluation, Florida, handling, mark recapture, mortality, predation, shorts, starvation, temperature, trap*

SYNOPSIS: Losses to the legal spiny lobster fishery attributable to fishing-induced mortality of shorts used as bait in traps are investigated. Field tests were initiated to determine degree of starvation resulting from confinement over extended periods. Additional tests were conducted to determine effects of tail-clipping, tagging, density, exposure, temperature, and measuring on mortality rates. Results indicated an initial high rate of weight loss within 1 week of capture and return to traps, followed by greater losses thereafter. Weight loss was greater among lobsters confined at densities of 5 per trap compared to that of lobsters confined at 3 per trap. Mortality averaged 50% after 3 weeks but was 69% among lobsters placed 5 to a trap. Tagging and tail-clipping of lobsters was an important source of mortality. Mortality of lobsters held at densities of 5 per trap was 54% greater among tagged lobsters and 57% greater among tail-clipped lobsters than for traps containing 3 lobsters similarly marked. Desiccation due to exposure also contributed to mortality. Mortality was 3.3% for the unexposed control group compared to 21% for those treatments with exposure. Cumulative deaths were similar for exposures of 1–4 h by the end of 4 weeks. Effects of air or water temperature were not evident during exposure tests. Octopus predation was considered higher on confined lobsters due to far less probability of escape. Impacts on the fishery are discussed.

87. McKoy, J. 1981. Rock lobsters handle with care. Catch 8:23–24.

KEYWORDS: *Exposure, handling, illumination, New Zealand, predation, western rock lobster*

SYNOPSIS: In many places around New Zealand up to 80% of the catch is undersized and handled several times before reaching legal size. Handling techniques to minimize mortality and prevent reduced growth are discussed.

88. McLeese, D.W. 1958. Air shipment of lobsters. Department of Fisheries of Canada Trade News 10(9):5–6.

KEYWORDS: *American lobster, Canada, exposure, transport*

SYNOPSIS: Expanding distribution of live lobsters to distant markets requires (1) better insulated packing for overland transport to maintain low temperatures, and (2) a lighter-weight and leakproof method of packing for air shipment. Lobsters were held at temperatures from 35°F to 70°F and packed bare, in wood shavings and in wood shavings with ice. Lobsters could be safely held for 5 d at 35°F. Packing them in wood shavings would extend this safe holding period by 1 d to 6 d. Lobsters could be safely held less than 1 d at 70 °F.

89. McLeese, D.W. 1965. Survival of lobsters, *Homarus americanus*, out of water. Journal of the Fisheries Research Board of Canada 22: 385–394.

KEYWORDS: *American lobster, exposure, laboratory experiment, mortality, physiology, starvation*

ABSTRACT: "Median resistance times (MRT) in moist air at 0, 5, 10, and 15°C were determined for lobsters acclimated at 0, 10, and 20°C. At temperatures above 4–8°C depending on acclimation, there was an inverse relationship between median resistance time and temperature. A break in the relationship occurred at 4–8°C and further lowering of temperature to 0°C had no effect on MRT. Survival time was not increased by continuous sprays of sea water. Exposure to an air-oxygen mixture containing 40% oxygen by volume had no effect; however, lobsters died faster at 55–85% oxygen. Fed lobsters died faster than starved ones. An inverse relationship between MRT and metabolic rate was indicated."

90. McLeese, D.W. 1968. Temperature resistance of the spider crab *Chionoecetes opilio*. Journal of the Fisheries Research Board of Canada 25: 1733–1736.

KEYWORDS: *Canada, laboratory experiment, mortality, snow crab, temperature, transport*

SYNOPSIS: Mortality among groups of snow crab was measured at various temperatures in water and in moist air to provide information on the temperature resistance and on suitable temperatures for live storage. Tests of temperature resistance showed time to 50% mortality increased from 0.07 d at 20°C to 18.8 d at 16°C. Temperatures causing rapid death of snow crabs, 17°C and higher, are more than 10°C higher than reported maximum temperature (4°C) encountered in nature. Temperatures between 12 and 16°C cause up to 20% mortality in 10 d and may be satisfactory for short-term storage. For long-term storage the temperature must be lower than 12°C. Temperature resistance in moist air had a 50% mortality time of 8.5 d at 3°C to 1.9 d at 13°C. None of the crabs in moist air at 3 and 8°C died within 4 d, suggesting live storage in cold moist air may be practical for a few days.

91. McMahon, B.R., P.J. Butler, and E.W. Taylor. 1978. Acid base changes during long term hypoxic exposure in the lobster, *Homarus vulgaris*. Journal of Experimental Zoology 205:361–370.

KEYWORDS: *Exposure, handling, hypoxia, lobster, North Sea, physiology*

ABSTRACT: "Hemolymph O_2 and CO_2 levels and pH were measured in lobsters (*H. vulgaris*) as they settled in normoxic conditions and during prolonged exposure to moderately hypoxic seawater. Initial handling and transfer to the experimental conditions resulted in a marked acidosis. Complete recovery took from 24 to 48 hours. Samples of hemolymph taken after 48 hours yielded 'settled' normoxic levels for O_2 and CO_2 and pH. Subsequent exposure to moderately hypoxic water caused an initial respiratory alkalosis associated with pronounced hyperventilation. The induced pH change was sufficient to cause a marked increase in the oxygen affinity of the hemocyanin, allowing almost complete saturation of post-branchial (arterial) hemolymph despite a 3-fold decrease in hemolymph oxygen tension. Prolonged exposure to hypoxia resulted in an attenuation of the hyperventilation response but hemolymph bicarbonate levels rose substantially and may have maintained pH high and thus kept oxygen affinity above the normoxic level. On return to normoxic water both ventilation volume and hemolymph carbon dioxide decreased and pH and oxygen affinity returned to normoxic levels."

92. McVean, A. 1976. The incidence of autotomy in *Carcinus maenas* (L.). Journal of Experimental Marine Biology and Ecology 24:177–187.

KEYWORDS: *Autotomy, growth, habitat, limb loss, North Sea, sex/size effect, shore crab, United Kingdom*

ABSTRACT: "A total of 1023 individuals of the common shore crab, *Carcinus maenas* (L.), were obtained from the environs of Whitby Harbour and Robin Hood's Bay. The bulk of the sample was taken from the sublittoral zone, but crabs from a sheltered shore were included. Each crab was measured, sexed and

examined for the incidence of autotomized and regenerated limbs.

"There was a positive correlation between the incidence of autotomy and carapace width for crabs in both the sublittoral zone and the exposed intertidal zone. In sublittoral crabs the males suffered a higher incidence of autotomy than did the females and the incidence of cheliped autotomy was higher than for the walking limbs. The discrepancy between the loss of the chelipeds and walking limbs was reflected in a similar discrepancy between the occurrence of the regenerated chelipeds and walking limbs.

"Crabs on an exposed shore suffered a higher incidence of autotomy than did those from a sheltered shore. There were more crabs with cumulative limb losses than would be expected which suggests that once a crab enters into a state of autotomy it becomes increasingly vulnerable to the loss of another limb. Only 1% of the population of sublittoral crabs would be expected to carry the loss of five limbs at once. No crabs were found with six or more limbs missing." [Reprinted with permission from Elsevier Science B.V., Amsterdam, The Netherlands.]

93. McVean, A., and I. Findlay. 1979. The incidence of autotomy in an estuarine population of the crab *Carcinus maenas*. Journal of the Marine Biological Association of the United Kingdom 59:341–354.

KEYWORDS: *Autotomy, habitat, seasonal distribution, sex/size effect, shore crab, United Kingdom*

ABSTRACT: "The incidence of autotomy is described for a discrete population of *Carcinus maenas* in the Yealm Estuary over a period of one year. During this time the crabs showed seasonal trends in distribution whereby during the summer months they congregated at the top of the estuary. This seasonal migration up and down the estuary corresponded with peak rates in the rate of change in temperature of the bottom water. Recruitment occurred in June, July and August. Overall, there were more female than male crabs although the ratio varied throughout the year. All sizes and sexes of crabs autotomized limbs but although autotomy increased with the size of the crabs it showed no obvious relationship with other population parameters. Significantly more chelipeds than walking limbs were lost. There were more multiple autotomies than would be expected if autotomy was a random event. Autotomy is shown to be a rare event for sexually mature *Carcinus* but essential to the survival of immature crabs. The means by which crabs may regulate the incidence of autotomy is discussed." [©1979 Marine Biological Association of the United Kingdom (Registered charity no. 226063). Reprinted with permission of Cambridge University Press.]

94. Meyer, R.M. 1971. A study concerning the problem of derelict pots in the king crab fishery. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, (unpublished manuscript), Kodiak, Alaska.

KEYWORDS: *Field evaluation, ghost fishing, Kodiak, mark recapture, pots, red king crab*

SYNOPSIS: Estimates of pot loss ranging from 10% to 15% in the Bering Sea crab fishery, coupled with a fishable life of as long as 3–8 years and documented retention of up to 100 crabs in a lost pot provide the basis for this study. Field experiments to determine if king crabs can escape from a pot, if crabs will enter an unbaited pot, and deterioration rate of pot web hanging materials were conducted in Kodiak, Alaska. King crabs were found to escape and enter unattended pots. Iron wire (0.061 in) had a slower deterioration rate than #72 cotton twine. None of the nylon hangings failed during the study period (289 d).

95. Meyer-Rochow, V.B., and K.M. Tiang. 1981. Seeing lobsters are correctly treated. Catch '81 (April), Wellington, New Zealand.

KEYWORDS: *Handling, illumination, laboratory experiment, New Zealand, physiology, western rock lobster*

SYNOPSIS: Rock lobsters live in a benthic environment where ambient light has been filtered and reduced in intensity. They have compound eyes which ensure that even in dim light or at night they have optimal acuity paired with high sensitivity. Effects of exposing lobsters to sunlight during capture and handling were investigated by assessing the lobster's visual capacity and sensitivity to light-induced damage. A laboratory study showed rock lobsters can actually see a fair amount of detail and discern ambient light levels and direction of the light. Spectral responses of the lobsters ranged from the near ultraviolet to dark orange. Sensitivity to light did not completely disappear, even after 3 weeks under continuous light of 1,300 lux. Rock lobsters treated this way did not feed well. When exposed to a few seconds of bright, white light of 60,000 lux, long-lasting and severe sensitivity loss was observed. Exposure to 1 h of sunlight caused sensitivity to decrease such that a flash of light visible to an unexposed animal had to be 10,000 times brighter to

be detectable to the lobsters. Rock lobsters exposed to sunlight are affected in ways detrimental to survival: (1) the eye loses sensitivity and the lobster is unable to see predators, (2) unequal damage to both eyes results in the lobster having difficulty in maintaining a normal stance and moving in a straight line, (3) accurate detection of diurnal rhythms is lost, and (4) lobsters with impaired vision are less successful finding shelter.

96. Miller, R.J. 1977. Resource underutilization in a spider crab industry. Fisheries 2(3):9–12, 30.

KEYWORDS: *Bycatch, escape mechanism, exposure, field evaluation, gear loss, gear technology, gillnet, laboratory experiment, Newfoundland, shell condition, snow crab*

ABSTRACT: "Underutilization in a spider crab fishery was large with respect to 1974 landings of 3300 metric tons (t). Potentially 1600 t were lost by not fishing all commercial stocks; at least 264 t were discarded in plants because they were too small, soft-shelled, or dead; an additional unmeasured quantity of small and soft-shelled crabs was discarded at the dock or on the fishing grounds and did not survive; 894 t were lost to the groundfish gill net fishery; and 10 t were lost to lost traps.

"The above losses can be substantially reduced by expanding the fishery to unfished areas, by educating the industry to optimum holding conditions for live crabs, and by the following regulations: (1) providing for a minimum mesh size on traps; (2) requiring that undersized and soft-shelled crabs be returned to the water on the fishing grounds; and (3) providing for ad hoc closure of grounds yielding a high proportion of soft-shelled crabs in catches. No suitable solution has been found to prevent the loss of crabs to the gill net fishery for groundfish and the loss to lost traps was found to be insignificant. While I do not suggest that it is practical to attain maximum sustainable yield (MSY) from unfished stocks or to eliminate all waste, the estimates given suggest the magnitude of the underutilization and what remedial measures have been applied."

97. Miller, R.J., and J.R. Hoyles. 1973. Loss of commercial snow crabs to cod gillnets in Newfoundland. Canadian Department of Fisheries and Oceans, Fisheries Research Board of Canada Technical Report 429.

KEYWORDS: *Economics, field evaluation, gillnet, injury, laboratory experiment, mortality, Newfoundland, sex/size effect, snow crab*

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 subcommercial 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 area 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." [Reproduced with the permission of the Minister of Supply and Services Canada, 1995.]

98. Miller, R.J., and J. Watson. 1976. Growth per molt and limb regeneration in the spider crab, *Chionoecetes opilio*. Journal of the Fisheries Research Board of Canada 33:1644–1649.

KEYWORDS: *Autotomy, growth, laboratory experiment, molt cycle, regeneration, sex/size effect, snow crab*

ABSTRACT: "Spider crabs, *Chionoecetes opilio,* were held in the laboratory for observations on carapace width increments and limb regeneration per molt. The merus (the longest limb segment) of autotomized limbs regenerated to 48 and 73% of their full length, irrespective of crab size, on the first and second molt, respectively. Fitting least squares regressions to percentage increase of carapace width per molt (Y) vs. premolt carapace width (X [in millimeters]) gave the following equations: immature males $Y = 40.7 - 0.363X$; immature females $Y = 45.3 - 0.444X$; mature males $Y = 14.2 + 0.051X$; and females' terminal molt to maturity $Y = 14.0 - 0.014X$. Only the slopes for the first two equations differed significantly from zero. Growth per molt decreased with sexual maturity for both sexes and was significantly less for females molting to maturity than for mature males of the same size. Growth per molt for immature females was significantly greater than for immature males, but the difference was slight."

99. Molyneaux, D.B., and T.C. Shirley. 1988. Molting and growth of eyestalk-ablated juvenile red king crabs, *Paralithodes camtschatica* (Crustacea: Lithodidae). Comparative Biochemistry and Physiology 91:245–251.

KEYWORDS: *Ablation, feeding, growth, laboratory experiment, molt cycle, mortality, red king crab, Southeast Alaska*

SYNOPSIS: Juvenile red king crabs collected in Southeast Alaska were subjected to single- and double-eyestalk ablation in the laboratory. Single ablation resulted in a 20% increase in feeding rate, no decrease in intermolt period, and a 2-fold increase in mortality rate compared to non-ablated crabs. Double ablation reduced feeding rate by 36%, significantly decreased the length of intermolt period, and increased the mortality rate by 4-fold. Mortality rate increased near ecdysis for all experimental groups of crabs. Ablation did not affect growth in wet weight or carapace length.

100. Muir, W.D., J.T. Durkin, T.C. Coley, and G.T. McCabe. 1984. Escape of captured Dungeness crabs from commercial crab pots in the Columbia River estuary. North American Journal of Fisheries Management 4:552–555.

KEYWORDS: *Columbia River, Dungeness crab, field evaluation, ghost fishing, limb loss, mark recapture, mortality, pots, sex/size effect*

ABSTRACT: "Escape of Dungeness crabs (*Cancer magister*) from baited commercial crab pots in the Columbia River estuary was examined. During a 28-day period (12 October – 10 November 1982), 185 male crabs were captured and tagged. Sixty percent of the crabs escaped, the majority within 2 days. Size, leg loss, and leg regeneration were not significant factors in escapement."

101. Nakanishi, T. 1974. Effect of exposure to the air on the heart rate in *Paralithodes camtschatica*. Bulletin of the Hokkaido Regional Fisheries Research Laboratory 40:38–47.

KEYWORDS: *Exposure, Japan, laboratory experiment, physiology, red king crab*

SYNOPSIS: The effect of air exposure on the physiology of king crab was investigated using the electrocardiogram. The heart rate of crabs exposed to air decreased in some crabs and did not change in others, compared with heart rates when in seawater. King crab appear to survive in air for at least 7 h at 5°C.

102. Natural Resource Consultants. 1988. Minimization of king and Tanner crab by-catch in trawl fisheries directed at demersal groundfish in the Bering Sea. Report to the U.S. Department of Commerce, National Oceanic and Atmospheric Administration in fulfillment of NOAA Award 86-ABH-0042, Seattle.

KEYWORDS: *Bering Sea, bycatch, exposure, field evaluation, gear technology, groundfish, handling, injury, laboratory experiment, mortality, red king crab, Tanner crab, trawl*

SYNOPSIS: Bycatch of halibut *Hippoglossus stenolepis,* red king crab *Paralithodes camtschatica,* and Tanner crab *Chionoecetes bairdi* by Bering Sea groundfish trawlers was minimized through innovative changes in trawl gear design. Comparative gear evaluations were completed for a trawl fit with a "crab panel" and another fit with a "crab chute." Field evaluations were conducted in an area that demonstrated commercial quantities of flounder and cod, as well as adequate king and Tanner crab. Catch rates from control trawls were similar for all species, day or night, except for Tanner crab. Bycatch of Tanner crab was more than 5 times higher during hours of darkness than during hours of daylight. The crab panel trawl retained statistically less crab for each metric tonne of flounder and cod caught — 2.7 king crab and 4.6 Tanner crab compared to 5.5 king crab and 15.6 Tanner crab for the control trawl. The crab-chute trawl had flounder and cod bycatch rates essentially identical to those of the control trawls, reduced king crab bycatch by 33%, but failed to appreciably reduce bycatch rates of Tanner crab. King and Tanner crab survival decreased as duration in the net and onboard processing time increased. Initial survival was <50% for durations longer than 10 h. Overall survival of crab bycatch caught, sorted, measured, and held in circulation tanks for 24–48 h was <22%.

103. Natural Resource Consultants. 1990. The nature and scope of fishery dependent mortalities in the commercial fisheries of the Northeast Pacific. Report to the Highliners Association, Seattle.

KEYWORDS: *Aleutian Islands, Bering Sea, bycatch, Gulf of Alaska, longline, pot, red king crab, Tanner crab, trawl*

SYNOPSIS: A compilation of historical bycatch statistics for halibut *Hippoglossus stenolepis,* red king crab *Paralithodes camtschatica,* Tanner crab *Chionoecetes bairdi,* and salmon *Oncorhynchus* in the Bering Sea/Aleutian Islands and Gulf of Alaska are featured by

fishery. The report discusses problems with bycatch and other additional removals. Removal of nontargeted species with emphasis on prohibited species in Bering Sea and Aleutian Island trawl, pot, and longline fisheries is summarized, including historical information. Biological and economic consequences of additional removals are explored and management implications for the northeast Pacific are discussed.

104. New Zealand Marine Department. Undated. Lobsters alive! Handling and measuring rock lobsters. New Zealand Fisheries Information Leaflet 14.

KEYWORDS: *Handling, New Zealand, size limit, western rock lobster*

SYNOPSIS: This is a full-color brochure aimed at educating fishermen that careful handling of lobsters is essential for continuation of a fishery. A lobster, whether undersized, berried, or softshelled, is money in the pocket, if not now then at some stage in the future. The brochure offers practical advice on handling and measuring lobsters. Emphasis is on keeping lobsters cool, wet, and shaded and returning them to natural habitat within 10 min. Once retained, lobsters should be kept in fresh seawater with good circulation or in shaded bins soaked with a deck hose to ensure they are landed alive. The brochure presents a diagram on how to sex lobsters and a 3-step procedure on taking measurements.

105. Niva, K., and H. Kurata. 1964. Limb loss and regeneration in the adult king crab *Paralithodes camtschatica.* Bulletin of the Hokkaido Regional Fisheries Research Laboratory 28:51–55. (Translated from Japanese by Fisheries Research Board of Canada, Translation Series Number 1190).

KEYWORDS: *Bering Sea, field evaluation, injury, molt cycle, red king crab, regeneration, sex/size effect, tangle net*

SYNOPSIS: Injuries and regeneration rates of king crab were estimated for adults captured in tangle nets by a king crab factory ship in the Bering Sea. Walking legs were most often injured and the majority of crabs observed had only 1 limb injured. Of 33,744 male crabs examined, 15.3% had injured walking legs, while 19.5% of the 1,783 female crabs had injured walking legs. The chance of injury was higher for posterior legs. Number of limb losses or regenerations were highest for the fourth leg. A frequency distribution of the recovery rate indicated that the regenerating bud in adult males reached approximately 12% of the normal limb length during the first molt following injury. Recovery rates with each successive molt were 29%, 50%, 65%, 75%, 83%, 87%, and 91% of the normal limb length. Recovery of lost limbs among adults requires an extremely long period compared to young crabs due to the lengthened interval between molts and slower recovery process.

106. Norman, C.P., and M.B. Jones. 1993. Reproductive ecology of the velvet swimming crab *Necora puber* (Brachyura: Portunidae), at Plymouth. Journal of the Marine Biological Association of the United Kingdom 73:379–389.

KEYWORDS: *Fecundity, field evaluation, limb loss, reproduction, United Kingdom, velvet swimming crab*

ABSTRACT: "Monthly samples of intertidal and nearshore *Necora puber* were collected over two years from a commercially unfished area around Plymouth (south-west England). A clear reproductive cycle, consistent between the two years, was observed, and relatively high numbers of ovigerous females were found from January to June. Zoeal release was estimated to occur from April to June. Ovigerous females had developing ovaries, indicating that sequential broods occur. During embryonic development, egg volume increased by 109%, and egg loss was significant, accounting for between 14 and 18.5% of initial brood number. Females suffering limb loss showed a further reduced brood size compared to females with a full limb complement. The sex ratio of immature crabs was 1:1, whereas the ratio for mature crabs was biased to males (1.45:1). Two sperm plugs were observed in 90% of early postmoult mature females, but 10% had only one or no plug intact, suggesting their failure to mate successfully. These results are reviewed in relation to the biogeography of *N. puber* and with reference to the developing fishery in the United Kingdom." []

107. O'Brien, J., D.L. Mykles, and D.M. Skinner. 1986. Cold-induced apolysis in anecdysial brachyurans. Biological Bulletin 171:450–460.

KEYWORDS: *Crab, exposure, laboratory experiment, molt cycle, physiology*

ABSTRACT: "Several integumentary tissues of brachyuran crabs separate from the exoskeleton (undergo

apolysis) when exposed to low temperatures (0°C) for one hour or longer. Apolysis did not occur in crabs held at room temperature for the same length of time following the destruction of the subesophageal ganglia i.e., the phenomenon was not due to the death of the animals. Apolysis did occur in animals chilled following ganglionectomy. Cold-induced apolysis occurred in species of seven families of brachyurans distributed throughout tropical, North Atlantic, or Pacific Northwest habitats. Therefore, it is not merely due to chilling subtropical animals. Adult majid crabs, which are in terminal anecdysis, underwent cold-induced apolysis as did Bermuda land crabs, the latter in all stages of the molt cycle tested. Chilling *in vitro* also induced apolysis in isolated pieces of integumentary tissue. The biological significance of these observations is that the mechanisms underlying apolysis may be activated in the integumentary tissues of anecdysial animals." [Reprinted with permission from the *Biological Bulletin.*]

108. Otwell, W.S., and N.B. Webb. 1977. Investigation of containerization for transportation of live blue crabs, *Callinectes sapidus*. Chesapeake Science 18:340–346.

KEYWORDS: *Atlantic coast, blue crab, exposure, handling, mortality, sex/size effect, transport*

ABSTRACT: "Simulated over-the-road transportation studies were designed to determine the survival rate of blue crabs in various types of containers and at three storage temperatures. Survival rates were evaluated for seven container designs at test temperatures 5, 10, 20°C during a 96-hr storage period. The best survival rate for blue crabs out of water was at 10°C in open baskets with moist burlap packaging (80–95% relative humidity). Mean mortalities under these conditions were 4.2% after 24 hr, 5.0% after 36 hr, and 16.7% after 48 hr storage. Tests on the frequency of handling the crabs indicated that these mortalities were probably high. The results of this study indicated that procedures which encompass an open type container with a method to maintain high humidity, such as moist burlap, and temperature control (approx. 10°C) will substantially improve the survival of blue crabs. Differential survival by sex indicated that the geographical distribution of the crabs deserves further study."

109. Owen, D. 1988. A bottom trawl survey on the west side of Kodiak Island: Viekoda Bay, Spiridon Bay, and Kupreanof Strait (November 1987). Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K88-28, Kodiak.

KEYWORDS: *Bycatch, Dungeness crab, halibut, Kodiak, mortality, red king crab, shell condition, Tanner crab, trawl*

ABSTRACT: "A hard-on-bottom trawl survey was conducted to determine current bycatch rates of prohibited species (halibut and crab) in three areas on the west side of Kodiak Island that are closed to bottom trawl fishing. A total of 18 trawls using a Bering Sea Combination net was made in Viekoda Bay, Spiridon Bay, and Kupreanof Strait in November 1987. Largest catches of fish were made in Spiridon Bay (16,854 kg/hr) consisting mostly of yellowfin sole, starry flounder and flathead sole. Lesser catches were taken in Viekoda (6615 kg/hr) and Kupreanof Strait (5805 kg/hr). Bycatch rates of halibut were lowest in Spiridon Bay (4–6 kg/mt) compared to the other two areas (48–79 kg/mt). Tanner crab were more evenly distributed in the three study areas (6–16 kg/mt). Few king crab were found and only in Viekoda Bay (1 kg/mt). No soft shell crab were caught. Trawl-induced mortalities aboard ship were 12% for Tanner crab, 19% for red king crab, and 0% for Dungeness."

110. Pacific Associates. 1993. Discards in the groundfish fisheries of the Bering Sea/Aleutian Islands & the Gulf of Alaska during 1992. Report to the Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Juneau.

KEYWORDS: *Aleutian Islands, Bering Sea, bycatch, catch statistics, crab, groundfish, Gulf of Alaska, halibut, herring, longline, pot, salmon, trawl*

SYNOPSIS: This report identified the amount and source of discards of groundfish, crab, Pacific halibut *Hippoglossus stenolepis,* Pacific herring *Clupea harengus pallasi,* and salmon *Oncorhynchus* resulting from the commercial groundfish fisheries in the Bering Sea/Aleutian Islands and Gulf of Alaska during calendar year 1992. A significant variance in the amount of groundfish discards reported was found when comparing discard reports by vessel operators or processor to discard reports by independent contract observers. Specific findings are reported for each geographic region by fishery.

111. Pacific Marine Fisheries Commission. 1978. Dungeness crab project of the state-federal

management program. Pacific Marine Fisheries Commission, Portland, Oregon.

KEYWORDS: *Dungeness crab, economics, gear loss, handling, limited entry, management strategy, mark recapture, migration, Pacific coast, pots, shell condition, trawl*

SYNOPSIS: This is a comprehensive document covering relative information concerning the Dungeness crab fishery as compiled by Pacific coast fishery scientists, economists, and managers during the period 1973–1977. The introduction reviews the inception of the State and Federal Fisheries Management Program (SFFMP), the designation of Dungeness crab as the highest priority species under the SFFMP, and the organization and operation of the SSFMP Dungeness crab project. Phase I reviews Dungeness crab resources in Washington, Oregon, and California, as well as associated databases, data management, and sampling techniques. Harvesting of female crab, crab mortality associated with fishing practices, the sport fishery, movement of tagged crabs, and impact of crab seasons are discussed. Phase II reviews the relationship between effort and yield, potential net benefit of effort management, and alternative effort management plans.

112. Parrish, F.A., and T.K. Kazama. 1992. Evaluation of ghost fishing in the Hawaiian lobster fishery. Fishery Bulletin 90:720–725.

KEYWORDS: *Field evaluation, ghost fishing, Hawaii, laboratory experiment, mortality, slipper lobster, spiny lobster (Hawaii), trap*

ABSTRACT: "Mortality due to retention of lobsters in derelict traps was evaluated over a 2-year period using two approaches. First, a string of eight empty, single-chamber, plastic traps was deployed at 40 m depth off Oahu, Hawaii, and monitored periodically by scuba during a 6-month period in 1990. The traps were stable and remained intact despite adverse oceanic conditions. Numerous entries and exits of lobsters were recorded. For the second test, the ability of lobsters to exit traps was tested in a series of field and laboratory trials of trap strings stocked with Hawaiian spiny lobster *Panulirus marginatus* and slipper lobster *Scyllarides squammosus*. The number of lobsters that died in stocked traps was less than 4% of the test population and differed significantly from zero only in the laboratory evaluation ($\chi^2 = 5.42$, $P = 0.02$). The two species exited similarly; however, the pattern of exits in laboratory and field tests differed significantly ($\chi^2 = 23.889$, $P = 0.03$). All lobsters exited within 56 days in a pattern generally approximating an exponential decline. Our evidence suggests that little direct mortality of lobsters is due to the inability to exit traps, and consequently ghost fishing by these traps is not considered a problem for spiny and slipper lobsters."

113. Paul, J.M., A.J. Paul, and A. Kimker. 1994. Compensatory feeding capacity of 2 brachyuran crabs, Tanner and Dungeness, after starvation periods like those encountered in pots. Alaska Fishery Research Bulletin 1(2):184–187.

KEYWORDS: *Dungeness crab, feeding, Gulf of Alaska, laboratory experiment, mortality, shell condition, starvation, Tanner crab*

ABSTRACT: "Food usage rates were measured in 2 brachyuran species, Tanner crab *Chionoecetes bairdi* and Dungeness crab *Cancer magister*, following starvation periods of 0, 30, 60, and 90 d. *F*-tests indicated that there was no compensatory feeding. Food usage rates within species were similar among the 4 test groups, regardless of the length of starvation. Food usage rates were approximately 0.4% body weight per day for Tanner crabs and 1.0% for Dungeness crabs. Neither species markedly increased its consumption rate to compensate for the nutritional deficits. Starvation periods as short as 30 d negatively affected survival of both species under laboratory conditions."

114. Paul, L.M.B. 1984. Investigations into escape vent effectiveness and ghost fishing in captive populations of the spiny lobster, *Panulirus marginatus*. Pages 283–295 *in* Proceedings of the resource investigations of the northwest Hawaiian Islands. University of Hawaii Honolulu, Hawaii Sea Grant Report MR-84-01.

KEYWORDS: *Bait, escape mechanism, ghost fishing, Hawaii, laboratory experiment, sex/size effect, sorting, spiny lobster (Hawaii), trap*

ABSTRACT: "The spiny lobster, *Panulirus marginatus*, comprises one of the major fishery resources of the Hawaiian Archipelago. It is usually captured with a double-chambered wire trap whose mesh size is unregulated. Sublegal lobsters fully recruited into the fishery and caught in traps are sorted on the dock. Dock sorting is time-consuming for the fisherman and frequently damaging to lobsters, and its value as a stock conservation method is now being questioned. This study was designed to determine if spiny lobsters can be effectively 'sorted' on the bottom by fishing with traps equipped with escape vents. This study also

investigated whether lobsters would enter traps 'baited' only with live lobster and thus be subject to ghost fishing. Three types of escape vents, single, bar, and mesh, were tested. The unbaited, vented traps were loaded with individually identified lobsters and left on the bottom of a large tank overnight. Results indicated that the overall escape rate of sublegal lobsters was approximately 60 percent with the escape rate decreasing linearly with increasing carapace length. There was no significant difference in escape rate between males and females. Differences in escape rates between vent types indicated that escape vent effectiveness may depend on total vent area. Since vented traps are able to sort out sublegal lobsters on the bottom, it is recommended either that traps be equipped with escape vents or that a minimum mesh size be required. In all the escape vent trials, ghost fishing did occur. Seven percent of the unloaded females and 9 percent of the unloaded males in the tank population were attracted to the vented traps baited only with live lobsters. It is recommended that lobster trap lids be fastened with biodegradable material. If not, lost traps should be included as part of total fishing effort until their estimated time of deterioration."

115. Pecci, K.J., and four coauthors. 1978. Ghost fishing of vented and unvented lobster, *Homarus americanus*, traps. Marine Fisheries Review 40 (5–6):9–43.

KEYWORDS: *American lobster, escape mechanism, field evaluation, ghost fishing, injury, Maine, Massachusetts, mortality, trap*

ABSTRACT: "Field experiments were conducted in waters near Boothbay Harbor, Maine, and Woods Hole, Mass., with 40 inshore-type lobster traps. Twenty of the traps were fished normally from the surface and 20 were left on the bottom and routinely surveyed by divers. Half of the traps in each group were fitted with sublegal escape vents. Catch-escape panels were also tested. Surface-hauled traps caught 3,425 lobsters in 53 sampling periods; 28 percent of the lobsters had one or more types of body damage. The 'ghost' traps caught 456 lobsters during the same period; 25 percent of the lobsters died by the end of the experiment."

116. Powell, G. 1961. 1960 Annual report of king crab research activities, Part II. Pages 1–13 *in* Special king crab report, Alaska Department of Fish and Game, Commercial Fisheries Division, Biological Research Division Memorandum 3, Kodiak.

KEYWORDS: *Growth, Kodiak, mark recapture, migration, red king crab, shell condition*

SYNOPSIS: This report summarizes early research on red king crab in the Kodiak area, including (1) a tagging experiment conducted from 1954 to 1960 that evaluated tag type, long-term tag retention, crab growth, and migration; (2) documentation of molt timing and details of observed molts; (3) a short-term study of the effects of injuries inflicted on old- and new-shell female red king crabs; and (4) a description of cooperative research efforts with other biological and oceanographic organizations.

117. Reilly, P.N. 1983. Effects of commercial trawling on Dungeness crab survival. Pages 165–174 *in* P.W. Wild, and R.N. Tasto, editors. Life history, environment, and mariculture studies of the Dungeness crab, *Cancer magister*, with emphasis on the central California fishery resource. California Department of Fish and Game Bulletin 172.

KEYWORDS: *Bycatch, California, Dungeness crab, environment, field evaluation, injury, molt cycle, mortality, shell condition, stress, trawl*

SYNOPSIS: Few data exist on Dungeness crab mortality from commercial trawling operations. The impact of trawling on crabs during the closed season when crabs molt and are softshelled was studied using a 400 eastern otter trawl in the Gulf of the Farallones. The study was conducted during July, August, and September because male Dungeness crabs molt during summer and fall. Total mortality of 40 males and 24 females was 1.9% of the total catch (3,296) of Dungeness crabs. Thirty of the dead males were of sublegal size. Nineteen of the dead males and 14 of the dead females had soft shells and were crushed by the weight of the catch. An additional 9 males and 3 females had filling shells that were fractured or crushed. The remaining hardshell mortalities had puncture wounds, broken chelae or legs, or fractured carapaces. Percentages of the total catch of hard, filling, and softshelled males killed from trawling operations were 0.9%, 1.8%, and 20.2%, respectively. Crabs showing stress but no visible injury recovered fully after brief immersion in running seawater. Total mortality was 0.53 crabs per trawling h for all male crabs and 0.12 crabs per trawling h for legal-sized male crabs.

118. Ritchie, L.D. 1972. Octopus predation on pot caught rock lobster — Hokianga area, New Zealand, September – October 1970.

New Zealand Marine Department, Fisheries Technical Report 81, Wellington.

KEYWORDS: *Escape mechanism, field evaluation, New Zealand, octopus, pots, predation, western rock lobster*

ABSTRACT: "Data were collected at Hokianga, September – October 1970, to determine the effect of escape gaps on octopus predation of pot-caught lobsters. 'Normal' predation is estimated at 10% (i.e. 1 pot/10 visited by octopus). At Hokianga the overall predation incidence was 19.6% (1 visit/5.1 pots).

"For 24 hr potnights overall takeable lobster catch/10 pots was 41.8, comprising 47.0 for escape gap pots, and 34.6 for non-escape gap pots. Octopus predation was 15.7% overall comprising 12.8% for escape gap pots and 21.3% for non-escape gap pots.

"For 3–5 day potnights overall takeable lobster catch/10 pots was 35.8, comprising 51.0 for escape gap pots, and 18.6 for non-escape gap pots. Octopus predation was 35.6% overall, comprising 31.4% for escape gap pots and 45.5% for non-escape gap pots.

"Intermediate depths (11–19 fathoms) produced best takeable lobster catches (70.5/10 pots overall) and least octopus predation (7.9% overall). Escape gap pots retained fewer octopuses than non-escape gap pots and were visited less frequently. Some data are available for longer potnights. Diving observations were made in the fishing area. Other lobster predators are discussed, and control measures are outlined."

119. Savage, T., and J.R. Sullivan. 1978. Growth and claw regeneration of the stone crab, *Menippe mercenaria*. Florida Department of Natural Resources, Marine Research Laboratory, Florida Marine Research Publication 32, St. Petersburg.

KEYWORDS: *Chelotomy, Florida, growth, laboratory experiment, molt cycle, regeneration, stone crab*

ABSTRACT: "Laboratory-maintained and feral crabs were observed for incremental carapace width and major and minor claw growth. Morphometric relationships for male and female carapace width against length and carapace width against major and minor claw sizes were derived. Only slopes of carapace width vs. female major and male minor claws were not significantly different at the 95% confidence level. Feral normal male incremental growth exceeded that of normal females for all parameters. Normal laboratory females possessed greater average carapace width growth but less claw growth than did their male counterparts. All laboratory growth was more uniform but incrementally smaller than corresponding field growth. A hypothetical growth plot constructed from incremental growth of several crabs indicated ages at attainment of sexual maturity and legal size to be 10 and 30 months. A pictorial description of stone crab claw regeneration is presented. Minor claws realized greater regeneration after one and two molts (73.5% and 96.5% of pre-autotomized sizes) than did major claws (68.6% and 89.0%). Intermolt interval of laboratory crabs increased with larger carapace width sizes. Claw loss shortened or lengthened duration of the intermolt period depending upon whether the claw was removed shortly after a molt or later in the cycle."

120. Scarratt, D.J. 1972. The effects on lobsters (*Homarus americanus*) of raking Irish moss (*Chondrus crispus*). International Council on the Exploration of the Sea, Council Meeting Document 1972, Shellfish Benthos Committee K:36, Copenhagen.

KEYWORDS: *American lobster, Atlantic coast, Canada, economics, injury, Irish moss, rake*

SYNOPSIS: The principal species of seaweed harvested from the Canadian Atlantic is Irish moss *Chondrus crispus*. All areas where Irish moss grows are also fished for lobster. The seaweed is harvested by towing rakes 3 m wide with power boats. This study investigated the damage to lobsters from commercial rakers on different grounds. Using diving techniques, the numbers of lobsters on Irish moss beds, their reactions to raking, and the numbers of lobsters killed or damaged were examined. A total of 469 tows were observed to retain a total of 73 lobsters, 29 in the rake and 44 in the rake basket. All lobsters were sublegal size. Damage to lobsters by moss raking was related to the roughness of the beds and lobster abundance on them. On smooth beds, lobster populations are low and mortality negligible. On rough grounds, lobster populations are high and damage to them justifies some control of raking activities. Chain-bridled rake and higher tow speeds caused significantly more damage.

121. Scarratt, D.J. 1973. Claw loss and other wounds in commercially caught lobsters *Homarus americanus*. Journal of the Fisheries Research Board of Canada 30:1370–1373.

KEYWORDS: *American lobster, Atlantic coast, Canada, handling, injury, Irish moss, limb loss, rake*

ABSTRACT: "Incidence of claw loss in commercially caught lobsters (*Homarus americanus*) ranged between 5 and 19% but could not be attributed to any single

cause, although factors such as rough handling by fishermen, moving fishing gear, and ice in shallow waters may contribute. The incidence of other wounds ranged between 1 and 11% and there was evidence that serious wounding was related to the local practice of harvesting Irish moss by rakes."

122. Schlieder, R.A. 1980. Effects of desiccation and autospasy on egg hatching success in stone crab, *Menippe mercenaria*. Fishery Bulletin 77: 695–700.

KEYWORDS: *Chelotomy, exposure, fecundity, Florida, laboratory experiment, mortality, recruitment, stone crab*

SYNOPSIS: Most commercial operations maximize daily marketable claw yield from stone crabs by continuously pulling traps and declawing crabs only during the return trip to port. Crabs are kept in containers on deck and exposed to air for up to 8 h. Effects of claw removal from air-exposed ovigerous females and desiccation of exposed egg masses were investigated to determine if current practices reduce larval hatching and recruitment. Desiccation of eggs by air exposure of ovigerous females caused reduction in larval hatching success that was directly related to length of exposure. Desiccation weakened normal crab autotomic muscular reflex, and declawing resulted in 34.4% mortality of crabs exposed 2 h and 52.9% mortality of crabs exposed 5 h. Mean hatching success in experiment I was 91.6% for control crabs and decreased to 78.6% for crabs exposed 2 h and to 60.3% for crabs exposed 5 h. Mean hatching success in experiment II was 86.3% for control crabs, 49.6% for crabs exposed 2 h plus autospasy, and 18.8% for crabs subject to 5 h desiccation and autospasy. Claw loss negatively affected or delayed maternal egg mass preening. When crabs are ovigerous, desiccation causes a reduction in larval hatching success and is related to crab death and reduced overall population recruitment.

123. Sheldon, W.W., and R.L. Dow. 1975. Trap contribution to losses in the American lobster fishery. Fishery Bulletin 73:449–451.

KEYWORDS: *American lobster, cannibalism, gear loss, ghost fishing, Maine, mark recapture, mortality*

SYNOPSIS: American lobster survival in unbuoyed traps was studied in Maine. Lobsters of both sexes and various sizes were tagged and placed in traps and monitored over a 2-year period. Unattended traps continued to catch lobsters for an indefinite period of time. Ghost fishing was highest during June and September. Cannibalism was most prevalent during the summer and fall coincident with molting. More than 1/3 of all lobsters in or entering an unattended trap will be lost due to cannibalism or retention.

124. Shirley, S.M., and T.C. Shirley. 1988. Appendage injury in Dungeness crabs in Southeastern Alaska. Fishery Bulletin 86:156–160.

KEYWORDS: *Dungeness crab, field evaluation, injury, limb loss, mating, molt cycle, pots, regeneration, sex/size effect, shell condition, Southeast Alaska*

SYNOPSIS: Dungeness crabs were examined in Southeast Alaska to determine the incidence of missing, regenerating, and damaged appendages. Incidence of appendage injury was compared between molting and mating periods and the commercial fishing season. Twenty-five percent of the crabs sampled (N = 878) had injured limbs: 18% were missing, 5% were regenerating, and 2% were damaged. There was no correlation between shell condition and appendage injury and no significant differences in appendage injury existed between male and female Dungeness crabs. Mean number of regenerating legs was 1.2 ± 0.1 legs per crab and mean number of damaged appendages was 1.1 ± 0.1 appendages per crab. Appendage injury was significantly correlated with date, more injuries occurring later in the year. Appendage injuries were low in July but increased 157% from July to August, a period encompassing molting, mating, and fishing.

125. Simonson, J.L., and R.J. Hochberg. 1986. Effects of air exposure and claw breaks on survival of stone crabs *Menippe mercenaria*. Transactions of the American Fisheries Society 115:471–477.

KEYWORDS: *Exposure, Florida, laboratory experiment, limb loss, mortality, stone crab*

ABSTRACT: "Only claws are harvested from stone crabs trapped in marine waters off Florida, and crabs are released to regenerate them. In practice, stone crabs often are held in shipboard boxes and declawed as vessels return to port. A direct relationship exists between holding time and stone crab mortality, but mortality is reduced significantly when crabs are dampened periodically with seawater. When crabs held 6 h in boxes were wetted with seawater once every hour, mortality declined from 100% (no wetting) to 23% (periodic wetting). Mortality of both wetted and unwetted stone crabs increased when claws were not broken along the natural fracture plane."

126. Simonson J.L. and R.J. Hochberg. 1992. An analysis of stone crab (genus *Menippe*) claws and their use in interpreting landings on Florida's west coast. Pages 26–35 *in* T.M. Bert, editor. Proceedings of a symposium on stone crab (Genus *Menippe*) biology and fisheries, Florida Department of Natural Resources, Marine Research Laboratory, Florida Marine Research Publication 50, St. Petersburg.

KEYWORDS: *Field evaluation, fishing season, Florida, injury, limb loss, regeneration, stone crab*

ABSTRACT: "Size-specific data on stone crab claw type (crusher, pincer, regenerated), 'handedness' (right crusher, left crusher), and type (good, problem, bad) of break (point at which the claw had been broken from the body) were obtained from claws landed at processing houses in four Florida counties near the openings and closings of the 1983–84 and 1984–85 stone crab harvesting seasons. Right-handed crushers constituted 77% and 60% of all claws examined during the 1983–84 and 1984–85 seasons, respectively. Good breaks (indicative of the highest probability of survival of declawed crabs) were observed on 70% of the claws; problem and bad breaks were observed on 19% (1983–84) and 11% (1984–85) of the claws, respectively. Jumbo claws had the lowest frequency of good breaks. The percentage of claws with good breaks was generally higher in Wakulla County than in Collier County, probably because techniques for handling captured crabs differed in the two areas. Regenerated claws constituted 7.6% of all claws sampled; most were medium-sized pincers and intermediates (claws with dentition intermediate between the patterns characteristic of original pincer and crusher claws). The frequency of regenerated claws decreased significantly as claw size increased. In Collier County, the proportions of regenerated claws found in closing season samples from both seasons were lower than those found in the respective opening-season samples; a similar decrease in the proportion of regenerated claws between the opening and closing of the season was seen in the 1984–85 season at Wakulla County.

"We compared our survey results from Collier County to those of similar surveys conducted in 1970–71 and 1973–74 and with unpublished data from a field study conducted in 1976–77. The proportion of crushers found in samples taken at the closing of each of the 1970–71, 1973–74, 1983–84, and 1984–85 seasons was significantly higher than that found in samples taken at the opening of each season, suggesting that the proportion of smaller crabs bearing only one legally harvestable claw (usually a crusher) has historically increased toward the end of the harvest season."

127. Sinoda, M., T. Ikuta, and A. Yamazaki. 1987. On changing the size selectivity of fishing gear for *Chionoecetes opilio* in the Japan Sea. Nippon Suisan Gakkaishi 53:1173–1179.

KEYWORDS: *Trawl, bycatch, field evaluation, gear technology, Japan, seine, sex/size effect, size limit, snow crab, trap*

ABSTRACT: "At present, management agencies enforce size limit restrictions in the Japan Sea which prevent the landing of male *C. opilio* less than 9 cm carapace width. Since Danish seiners cannot avoid capturing illegal sized crabs, a large number of the crabs are discarded at sea in the hope that they will eventually recruit to legal size. However, catches of the crab have declined accompanied by a reduction in average crab size. We demonstrate that crab yield can be increased by switching the gear to long line traps with 15 cm stretched mesh. Thus, by changing the size selectivity of the gear, crabs smaller than 9 cm width can be protected from the fishery."

128. Skinner, D.M., and D.E. Graham. 1972. Loss of limbs as a stimulus to ecdysis in Brachyura (true crabs). Biological Bulletin 143:222–223.

KEYWORDS: *Ablation, blue crab, fiddler crab, green crab, illumination, laboratory experiment, limb loss, molt cycle, mortality, regeneration, spider crab*

SYNOPSIS: Interrelationships between molting and limb regeneration in Brachyura, true crabs, is examined to determine (1) the effect of limb loss on the duration of the molt cycle, (2) the minimal number of legs that must be removed to cause molting, (3) the effect of the total number of legs removed on the size of regenerated limbs, and (4) the effect of no privacy and light regimen on the duration of the molt cycle. Loss of 6 to 8 legs and chelae triggers precocious molts in the green crab *Carcinus maenas,* the blue crab *Callinectes sapidus,* and the fiddler crab *Uca pugilator,* but not the spider crab *Libinia emarginata.* Mortality rates were negligible compared to animals induced to molt by eyestalk removal. Precocious molt was stimulated in the land crab by loss of 5 to 8 appendages, but loss of all 10 appendages inhibited molt. Loss of a chelae or walking leg had a similar effect. The size of regenerated limbs in the land crab was reduced 33% when 1 to 6 legs were lost and 50% when 8 limbs were lost. Animals maintained under reduced light conditions or

with privacy molted sooner than those under normal light conditions in community tanks.

129. Smith, E.M. 1977. Some aspects of catch/effort, biology and economics of the Long Island Sound lobster fishery during 1976. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Commercial Fisheries Research Development Act, Connecticut Project 3-253-R-1, Waterford.

KEYWORDS: *American lobster, Atlantic coast, catch statistics, Connecticut, economics, fecundity, field evaluation, injury, shell condition*

ABSTRACT: "On January 1, 1975 the Connecticut Department of Environmental Protection initiated a computerized reporting system for lobster to improve the precision of catch per unit effort statistics generated from data supplied by commercial fishermen. The present study was designed: 1) to assess the reliability of the Commercial Fisheries Logbook Reporting System in representing catch and effort for the entire fishery, 2) to observe aspects of lobster biology and the condition of the fishery, and 3) to provide socio-economic information on the lobstering labor force. Information on catch, effort, and biology was obtained during sampling trips on the vessels of commercial lobstermen. Socio-economic information was collected during personal interviews of commercial fishermen and during telephone interviews of personal use (recreational) license holders.

"The computer summaries appear to be accurate in illustrating monthly variations in catch per unit effort for the commercial fishery. Claw loss and other mutilation to the trapable portion of the population is approximately 33%. Newly-recruited lobsters comprise about 90% of the legal portion of the catch with the highest proportion occurring in western Long Island Sound. Slightly over 50% of the gravid lobsters were below the minimum legal size. The incidence of gravid lobsters which were observed carrying an abnormally low proportion of the estimated complement of eggs was approximately 10–15% during the fall of 1976. Abnormal eggbearers occurred primarily in western Long Island Sound.

"The results of the socio-economic survey indicate that the labor force is highly over-capitalized chiefly through the use of excessive numbers of traps, and is highly polarized with 24% commercial fishermen and 76% personal use (recreational) participants. In addition, 86% of all commercial license holders are part-time participants. Of the part-time men who operate for profit, approximately 11% of their annual income is derived from lobstering, however, 48% of the part-time men questioned derived little or no money from the fishery. The average full-time man works longer hours for less pay than do men employed in the two occupations in which part-time men are most commonly employed.

"Many part-time commercial, and virtually all personal use fishermen use their vessels predominantly for sportfishing or other pleasure activities."

130. Smith, E.M., and P.T. Howell. 1987. The effects of bottom trawling on American lobsters, *Homarus americanus*, in Long Island Sound. Fishery Bulletin 85:737–744.

KEYWORDS: *American lobster, Atlantic coast, bycatch, exposure, field evaluation, injury, laboratory experiment, Long Island Sound, molt cycle, mortality, pot, trawl*

ABSTRACT: "American lobsters taken in the commercial trawl fishery in Long Island Sound, U.S.A., were inspected for incidence of damage and immediate mortality associated with bottom trawling. Similar sampling was conducted in the pot fishery. American lobsters from trawl and pot catches were held in controlled conditions for 14 days to determine the level of delayed mortality associated with the two fisheries. Trawl-caught lobsters were exposed to subfreezing (-9.5 °C) temperatures for periods from 30 to 120 minutes and then returned to seawater to determine the rate of freeze-induced mortality. Major damage rates due to trawling ranged from 12.6–14.0% during molting periods to 0–5.6% during intermolt periods. Delayed mortality ranged from 19.2% during the July molt to 1% during August and appeared to be related to the incidence of damage, molt condition, and temperature. Mortality of American lobsters held in subfreezing temperatures occurred after 30-minute exposure and reached 100% at 120-minute exposure."

131. Smith, L.D. 1990. Patterns of limb loss in the blue crab *Callinectes sapidus* Rathbun, and the effects of autotomy on growth. Bulletin of Marine Science 46:23–36.

KEYWORDS: *Autotomy, blue crab, Chesapeake Bay, growth, laboratory experiment, limb loss, molt cycle, regeneration*

ABSTRACT: "A substantial proportion of the blue crab (*Callinectes sapidus* Rathbun) population in a subestuary of the Chesapeake Bay was either missing or

regenerating at least one limb in 1986 (24.8%) and 1987 (18.8%). Most crabs were missing a single cheliped; loss of four or more limbs was rare. Between June and November 1987, laboratory experiments were conducted in which one cheliped or both chelipeds and two pereopods were removed from blue crabs to examine the long-term effect of autotomy on growth and molting frequency. Crabs with all appendages intact served as controls. Loss of a single cheliped did not alter the molt increment, percent wet weight increase, or molting frequency of crabs compared to animals experiencing no limb loss. Multiple limb loss, however, significantly reduced the molt increment and percent weight increase in the first post-autotomy molt but did not affect the duration of the intermolt. By the second molt following autotomy, molt increments for crabs missing four limbs did not differ significantly from those of intact or singly autotomized animals. Regenerating limbs were 85–88% of the lengths of undamaged, contralateral limbs in the first molt following autotomy. Up to three molts were required to regenerate 100% of the contralateral limb length. Removal of the major, crusher cheliped in both single and multiple autotomy treatments resulted in crabs possessing two minor, cutter claws after regeneration. Crabs failed to regenerate a distinct crusher even after three molts following autotomy. Although multiple autotomy reduced the molt increment in laboratory experiments, the rarity of severe limb loss in the Rhode River indicates that growth in the population is not affected greatly by autotomy."

132. Smith, L.D. 1990. The frequency and ecological consequences of limb autotomy in the blue crab, *Callinectes sapidus* Rathbun. Doctoral dissertation, University of Maryland, College Park.

KEYWORDS: *Autotomy, blue crab, Chesapeake Bay, field evaluation, foraging, growth, laboratory experiment, limb loss, predation, regeneration*

ABSTRACT: "Many taxa are capable of autotomizing (casting off) body parts after injury or when threatened. While an autotomy response has immediate survival benefits, little is known about: (1) causal agents; (2) potential costs of appendage loss to growth, ability to locomote and forage, predator avoidance, or mate acquisition and defense; and (3) spatial and temporal variation in injury frequency in populations. I addressed these topics, examining limb autotomy in the blue crab, *Callinectes sapidus* Rathbun. Surveys of blue crab populations in a subestuary of central Chesapeake Bay (1986–1989) demonstrated that the frequency of autotomy varied annually from 18–25% with highest levels of injury occurring in larger animals. Frequencies of injury in the Rhode River, Maryland were significantly lower than those recorded elsewhere in Chesapeake Bay and southeastern United States. At all sites, the majority of blue crabs were missing a single cheliped; severe multiple limb loss was rare. Laboratory and field experiments tested for costs of limb loss by comparing performance of intact animals with those of crabs missing one cheliped or multiple limbs. Growth experiments showed that only multiple autotomy significantly reduced size increase at the molt. Regeneration of normal limb length occurred in two to three molts. Field tethering experiments indicated that blue crab susceptibility to predation was greatest for smaller crabs missing multiple limbs. Field enclosure experiments, however, demonstrated that small, untethered crabs were capable of escaping larger conspecifics even when missing one or more limbs. Foraging effectiveness of blue crabs on soft-shell clams was reduced only when both chelipeds were missing. Male ability to compete for females was negatively impacted by both single and double cheliped loss. High frequencies of limb loss observed in blue crab populations suggest important fitness benefits of the autotomy response as an escape mechanism. The most common form of autotomy (loss of a single cheliped) had no significant impact on foraging ability, escape response, or growth, but did reduce defensive effectiveness against predators and male competitive ability for mates. Severe multiple autotomy lowered performance in all areas tested. Larger conspecifics were indicated as principal agents of autotomy." [The dissertation titles and abstracts contained here are published with permission of University Microfilms International, publishers of *Dissertation Abstracts International* (copyright ©1990 by University Microfilms International), and may not be reproduced without their prior permission.]

133. Smith, L.D., and A.H. Hines. 1991. Autotomy in blue crab *(Callinectes sapidus* Rathbun) populations: geographic temporal and ontogenetic variation. Biological Bulletin 180:416–431.

KEYWORDS: *Atlantic coast, autotomy, blue crab, cannibalism, Chesapeake Bay, density, Gulf of Mexico, injury, limb loss, regeneration, sex/size effect*

ABSTRACT: "Blue crab (*Callinectes sapidus* Rathbun) populations were examined at four sites in Chesapeake Bay and three additional sites along the southeastern Atlantic coast and Gulf of Mexico; the aims were to assess the incidence of limb autotomy and to determine whether injury patterns varied temporally,

geographically, and ontogenetically. These data, which include four years of information from one site (Rhode River, Maryland [USA] a subestuary of central Chesapeake Bay), make this study the most extensive and intensive survey of limb autotomy yet conducted in arthropods. A substantial percentage (17–39%) of the blue crab populations were either missing or regenerating one or more limbs, suggesting that autotomy is an important mechanism for their survival. The frequency of limb autotomy varied, both within and between years, and over broad geographical scales. Injury levels were generally correlated positively with crab size. Limb autotomy was independent of sex and molt stage, and frequencies varied little among sites in the Rhode River. Patterns of limb injury in *C. sapidus* were remarkably consistent among all sites. The most frequent injury involved loss of a single cheliped. Swimming legs suffered the least damage. Severe multiple limb loss was rare. Right and left limbs were lost with equal frequency in most populations. This consistency of autotomy pattern suggests differential vulnerability of limbs and standard behavioral responses by blue crabs to various injury-causing agents. The frequency of autotomy was density-dependent in the Rhode River, indicating that intraspecific interactions (e.g., cannibalism) may be a major cause of limb loss in populations in the Rhode River subestuary and elsewhere." [Reprinted with permission from the *Biological Bulletin.*]

134. Smolowitz, R.J. 1972. Shipboard procedures to decrease lobster mortality. Commercial Fisheries Review 34(5–6):44–48.

KEYWORDS: *Hypoxia, lobster, temperature, transport*

SYNOPSIS: Biological requirements of lobsters stored on vessels for transport are reviewed. A system is described for shipboard storage of live lobsters that is engineered to avoid suffocation and thermal shock .

135. Smolowitz, R.J. 1978. Annotated bibliography on lobster trapping and related subjects. Marine Fisheries Review 40(5–6):68–77.

KEYWORDS: *Bibliography, lobster, trap*

ABSTRACT: "This bibliography contains 159 entries that have useful information for those studying lobster trapping. The subjects covered include behavior, general biology, catch statistics, ecology, fishing methods, ghost fishing, management, materials testing, trap design, and selectivity. The brief reviews following each entry are not full abstracts but only serve as a guide to what the reference contains of interest to the trap researchers. The key words serve the same purpose."

136. Smolowitz, R.J. 1978. Trap design and ghost fishing: an overview. Marine Fisheries Review 40(5–6):2–8.

KEYWORDS: *American lobster, Atlantic coast, catch statistics, escape mechanism, ghost fishing, literature review, management strategy*

SYNOPSIS: The northeast Atlantic lobster fishery and management are reviewed, followed by a discussion of ghost fishing and escape vents.

137. Spicer, J.I., A.D. Hill, A.C. Taylor, and R.H.C. Strang. 1990. Effect of aerial exposure on concentration of selected metabolites in blood of the Norwegian lobster *Nephrops norvegicus* (Crustacea: Nephropidae). Marine Biology 105: 129–135.

KEYWORDS: *Exposure, handling, hypoxia, laboratory experiment, mortality, Norway lobster, physiology, Scotland*

ABSTRACT: "The Norwegian lobster *Nephrops norvegicus* (L.) collected from Firth of Clyde, Scotland between December 1987 and March 1988, was unable to survive longer than 18 h experimental emersion at 10°C. During this time the partial pressure of oxygen ($P^{v}O_2$) in the venous blood decreased rapidly and the lobster supplemented cellular energy requirements by anaerobic metabolism. This was indicated by the rapid accumulation of *L*-lactate in the blood. Although the survival rate increased (to ca 36 to 48 h) if lobsters were kept on ice, the accumulation of *L*-lactate in the blood was not significantly different from lobsters at 10°C, despite the temperature difference. There was no indication that *N. norvegicus* was able to further metabolize circulating *L*-lactate during emersion. On emersion there was also a marked hyperglycemia in the blood due to the stress of handling and asphyxiation. There was fairly good agreement between results obtained during laboratory studies and simulated fishing activity in the Firth of Clyde. Both sets of results are discussed in the context of adaptation to air breathing within the Crustacea and an assessment of post-harvest treatment of lobsters." [Reprinted with permission from Springer-Verlag New York, Inc.]

138. Spivak, E.D. 1990. Limb regeneration in a common South American littoral crab *Cyrtograpsus*

angulatus. Journal of Natural History 24: 393–402.

KEYWORDS: *Argentina, autotomy, growth, laboratory experiment, limb loss, molt cycle, regeneration, South American littoral crab*

ABSTRACT: "The intermoult period (time elapsed between two successive moults) is shortened, its variation among individuals and the size increment at moult are reduced, in juveniles of the littoral crab *Cyrtograpsus angulatus* when the number of regenerating limbs increase. Bud growth rates of regenerating limbs are calculated from plots of R_4 (length of third or fourth limb bud · 100/carapace width) as a function of relative time, considering that the intermoult period corresponds to 100%. Bud growth rates remain similar for crabs with a different number of limbs autotomized soon after moult. Regeneration of a second set of autotomized limbs follows autotomy if it occurs before the growing buds of a first set have a relative size R_4<16. Buds of contralateral limbs autotomized at different times during the moult cycle have similar final R_4 values because their growth rates are higher for limbs lost later. Buds of limbs, autotomized after part of the moult cycle has elapsed since moult, also tend to grow faster than those lost earlier. Neither the intermoult period nor the size increment at moult are modified by a second autotomy, after or before the critical R_4 value, and by the autotomy of a single limb in different moments of the moult cycle." [Reprinted with permission from the *Journal of Natural History,* Taylor and Francis, publishers.]

139. Spurr, E.W. 1978. An assessment of short term effects of otter trawling on large epibenthic invertebrates. Final Report to the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Commercial Fisheries Research Development Act, New Hampshire, Project 3-248-R, Concord.

KEYWORDS: *American lobster, Atlantic coast, bycatch, crab, field evaluation, fish, habitat, injury, New Hampshire, seasonal distribution, trawl*

ABSTRACT: "The effect of otter trawling on lobsters in the near shore environment was examined. During the two years in which work on the project was conducted lobsters were found on trawlable substrata only in the months of July, August, and September. Highest catch per unit of effort for lobsters occurred in August. The percent of lobsters sustaining injuries from trawling varied from eleven to seventy five percent and averaged twenty three percent. The most common site of injury was the chelae. Forty five percent of those lobsters receiving injuries sustained injury to the chelae."

140. Stevens, B.G. 1990. Survival of king and Tanner crabs captured by commercial sole trawls. Fishery Bulletin 88:731–744.

KEYWORDS: *Bering Sea, bycatch, field evaluation, injury, limb loss, mortality, red king crab, shell condition, Tanner crab, trawl*

ABSTRACT: "King crabs *Paralithodes camtschaticus* and Tanner crabs *Chionoecetes bairdi* captured incidentally by Bering Sea trawlers were examined for immediate mortality, vitality, and injuries resulting from trawl capture. A number were held aboard ship for 2 days in seawater to determine delayed mortality. Overall survival, including immediate and delayed effects, was 21% (± 2.0%) for king crabs and 22% (± 3.6%) for Tanner crabs. Immediate mortality of king crabs decreased significantly with shell age, and increased significantly with time in captivity prior to assessment, from 0% at 3 hours to 100% at 17 hours. Vitality, an index of spontaneous activity level, was a better predictor of delayed mortality than was the presence/absence of injuries. The effect of leg and body injuries on mortality of king crabs was similar, but injuries to leg segments proximal to the plane of autotomy resulted in higher mortality than injuries distal to the autotomy plane, autotomization alone."

141. Stevens, B.G., and R.A. MacIntosh. 1993. Preliminary results of the 1992 survival experiment for crabs discarded from commercial pot fisheries. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (unpublished manuscript), Kodiak.

KEYWORDS: *Bristol Bay, bycatch, field evaluation, injury, limb loss, mortality, pots, red king crab, Tanner crab*

SYNOPSIS: A preliminary experiment was conducted on board a commercial crab vessel in Bristol Bay, Alaska, to determine proportion of captured crab with injuries and subsequent mortalities of discards. Fifteen percent of the red king crabs and 27% of the Tanner crabs were injured. The majority of injuries were broken spine tips for red king crabs, and damaged or autotomized limbs for Tanner crabs. None of the crabs

examined were softshells. Average overall mortality was 5.2% for red king crabs and 11.0% for Tanner crabs. Experimental conditions were marginal and the authors recommended results be viewed cautiously.

142. Stewart, J.E., and H.J. Squires. 1968. Adverse conditions as inhibitors of ecdysis in the lobster *Homarus americanus*. Journal of the Fisheries Research Board of Canada 25:1763–1774.

KEYWORDS: *American lobster, confinement, diet, illumination, laboratory experiment, mark recapture, molt cycle, Newfoundland, starvation*

ABSTRACT: "The molting incidence for male lobsters (*Homarus americanus*) subjected to a variety of conditions was compared with that for free male lobsters. The data show that, for free western Newfoundland lobsters, molting reached the 90% level by the end of September. During the same period, mildly restrictive conditions reduced the molting incidence to 50% or less, and when lobsters held under these conditions were also tagged or marked the molting incidence was reduced to 30% or less. A reduction in molting, equivalent to or greater than that produced by tagging or marking plus mildly restrictive conditions, was achieved by highly restrictive conditions which enforced a high degree of association between lobsters. The diets used in these experiments did not appear to have any influence on the molting incidence. The data suggested that darkness plus starvation under highly restrictive conditions was even more inhibitory than any of the other conditions applied. Other light intensities tested under the highly restrictive conditions had no apparent effect on the molting incidence; however, stimulation of molting by light could have been negated by the inhibitory effects of this form of captivity."

143. Sullivan, J.R. 1979. The stone crab, *Menippe mercenaria*, in the southwest Florida fishery. Florida Department of Natural Resources, Marine Research Laboratory, Florida Marine Research Publication 36, St. Petersburg.

KEYWORDS: *Florida, growth, limb loss, mark recapture, regeneration, seasonal distribution, stone crab*

ABSTRACT: "A total of 14,343 stone crabs were tagged during the 1975–76 commercial trapping season in southwest Florida, and 4,563 crabs were tagged during the summer closed season; return rate of tagged crabs was 4.4%. Inshore movement in fall and offshore movement in spring is indicated. Summer returns suggest little movement by spawning females.

"Spawning females occur during every month but most frequently between March and September. Size frequencies of ovigerous females correspond to that of nonovigerous females. Monthly modal sizes of all crabs were most frequently 96–99 mm and 100–103 mm CW, well above legal size. Year II crabs comprise a large recruitment base of sub-legal sizes; legal portions of this population consist primarily of Year III and Year IV crabs.

"Females have longer carapace lengths than do most males for all carapace width sizes. Males are heavier and gain weight faster than nonovigerous females; gravid females weigh more than similarly-sized nonovigerous females and maintain an equivalent percent weight difference with increasing size-related fecundity. Males have larger claws and grow by greater increments than females for all CW sizes.

"Crushers constitute 60% of legal claws available to the fishery, and 80% of crushers are from right-handed crabs. Carapace width, claw growth and regeneration rates from this study are higher than previously reported. Claw regeneration to harvestable size within one year is demonstrated. Clawless crabs had the second highest return rate of all tagged crabs. From 20–25% of legal sized crabs were undergoing some form of claw regeneration, implying intense fishery pressure but indicating survival of declawed crabs. Estimates of population size ranged from 9,057 to 32,036 legal sized crabs available to a trap line during one week; highest numbers occurred at the beginning of the commercial season. Fishermen caught 3–8% (average 5%) of the available population each time traps were pulled, indicating that most legal sized crabs were captured during each commercial season. A southwest Florida stone crab population successfully withstanding present fishery pressure is indicated."

144. Tanino, Y., and K. Ito. 1968. Studies on the tagging experiments of Zuwai crab, *Chionoecetes opilio* (O. Fabricius), in the Japan Sea (II). Considerations on the validity of currently used tagging method in relation to limb loss and regeneration. Japan Sea Regional Fish Research Laboratory, Bulletin 20:43–48 (Note: text is in Japanese).

KEYWORDS: *Japan, limb loss, mark recapture, regeneration, snow crab*

ABSTRACT: "Observations on 19,708 specimens of zuwai-crabs, *Chionoecetes opilio* O. Fabricius, collected from the sea off Kasumi, Hyogo Prefecture,

during the period from 1963 to 1965, revealed that there were 1,093 specimens with regenerated limbs and 6,819 specimens with limb losses.

"Based on these results, the validity of the tagging method for attaching the tag around the limb was considered. The specimens with regenerated limbs attained about 6 percent of both male and female crabs, but this ratio tended to decrease as the developmental stage proceeded. On the other hand, although a similar trend was also noticed for the limb loss specimens, they occupied a very high percent as compared with the former. It is sure that the limb losses after the catch were greatly responsible for this high ratio. No differences were found in the frequencies of limb loss occurrences on both sides, but the posterior limbs are likely to be damaged. Consequently, in the limb tagging research for the zuwai-crabs, it seems better to attach the tag to the anterior limbs, so far as possible."

145. Tegelberg, H.C. 1970. Dungeness crab study, annual progress report, August 15, 1969 through June 30, 1970. U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, Washington Project 1-52-R, Olympia.

KEYWORDS: *Confinement, density, Dungeness crab, field evaluation, handling, laboratory experiment, mark recapture, meat yield, mortality, shell condition, Washington*

ABSTRACT: "Softshell crab handled under the usual conditions found in the commercial fishery suffered 15–16% mortalities when placed in holding pots for 2 days. Hard shell crab handled in the same manner suffered 4% mortalities. Holding densities of 15, 25, 40 and 60 softshell crab per pot did not effect mortality; however, holding crab 6 days increased mortality to 22% and handling crab three times in 6 days increased mortality to 33%. Tagging crab with Petersen disc tags increased mortalities 6% to 12% over untagged crab. Injuring softshell crab by dropping them on the deck caused 57% mortality after 2 days.

"Of the various methods under development as a standardized method of determining crab condition, shell hardness proved to be a fairly good general indication of condition; however, there was no way of predicting meat yield. The volume of the live crab was about as effective as the weight of the live crab in determining condition by the meat recovery method. Substituting dried meat for picked meat in both methods indicated variations in the water content. This may be a source of error in picked meat methods."

146. Tegelberg, H.C. 1971. Condition, yield, and handling mortality studies on Dungeness crabs during the 1969 and 1970 seasons. Washington Department of Fisheries, Processed Report, Olympia.

KEYWORDS: *California, Dungeness crab, field evaluation, handling, laboratory experiment, meat yield, molt cycle, mortality, Oregon, shell condition, Washington*

SYNOPSIS: Dungeness crab seasons along the Pacific coast are established to avoid the principal molting and softshell periods. Geographical differences and cyclic changes in the timing of the softshell period has resulted in open seasons during periods of high incidence of softshells in certain areas along the coast. Oregon, California, and Washington investigated crab condition, including shell condition and meat yield along the Pacific coast. Effects of fishing and discard handling on softshell crabs was also investigated. Meat yield and shell condition records from December 1, 1969, fishery openings indicated the season was earlier than desirable from northern California to Washington. Softshell crabs were not as hardy as hardshell crabs. Short-term mortality of softshell crabs was 15% to 20%. Experiments on indices of condition indicate that conventional measures of pickout have some shortcomings as a measure of overall quality. Comparison of wet and dried meat yields to weight and volume displacement showed, for a given volume of crabs, the softshell crabs weigh less than hardshells. Opening crab seasons too early can cause economic losses to the fishery through mortality of softshell crabs due to handling and lower production from crabs not in prime condition.

147. Tegelberg, H.C. 1971. Dungeness crab study, completion report, July 1, 1969 to June 30, 1971. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington Project 1-52-R, Olympia.

KEYWORDS: *Dungeness crab, laboratory experiment, mark recapture, meat yield, molt cycle, mortality, shell condition, Washington*

ABSTRACT: "Shell grading was useful in determining the percentage of soft shelled Dungeness crabs, and would have direct application in considering potential mortality from commercial fishing during periods of soft shell abundance. Condition indices based on yield confirmed the poor quality of soft shell crabs (Grade III). However, these condition indices indicated

within-grade variation during the year and between the two years of study. Four condition factors were considered: wet and dry meat recoveries as functions of live weight and volume displacement. The use of volume displacement and dried meat weights appears to eliminate water drainage as a source of error — both in the live weight and the picked meat. However, the relationship between weight and displacement volume needs further examination.

"The Bergman-Jefferts coded wire tag was implanted in small Dungeness crabs in a preliminary experiment. Tag loss was significant, but some tag retention was evident through two to five molts. This indicates that the coded wire tag is potentially useful as a crab tag, but that there is need to concentrate work on tag placement and to experiment with larger crabs."

148. Tegelberg, H.C. 1972. Dungeness crab study, annual progress report, July 1, 1971 to June 30, 1972. U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, Washington Project 1-76-R, Olympia.

KEYWORDS: *Diet, Dungeness crab, field evaluation, handling, injury, laboratory experiment, limb loss, mark recapture, meat yield, molt cycle, mortality, shell condition, Washington*

ABSTRACT: "Due to problems with holding facilities and infrequent molting, experimental tagging results were insufficient to draw conclusions on the percentage retention of coded wire tags in Dungeness crabs within one or two growth molts of legal size.

"Approximately 8% mortality occurred among soft crabs held 4 days after handling; no mortality occurred among hard shells in this experiment. Lower mortality of soft crabs than in previous experiments was due to better condition of the soft crabs in this experiment. Mortality rate was high (42%) when the claw or first walking leg was broken, but surprisingly low (7%) when the carapace edge was crushed with pliers.

"Condition indices were obtained for ocean and Willapa Bay crabs, and variables affecting these indices are discussed. Shell grading was shown to be a useful field technique, but a condition index based on meat yield is also necessary. The proportion of leg meat increased with size of crabs, but crab measurements were not shown to be an essential parameter in using a condition factor based on total meat yield.

"Crab stomach analysis showed that small clams of two types (razor clams and an unidentified white clam), small Dungeness crabs, snails, and small fish were the predominant foods. Worms and sand dollars were also important."

149. Tegelberg, H.C. 1974. Dungeness crab study, annual report, July 1, 1973 to June 30, 1974. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington Project 1-92-R, Olympia.

KEYWORDS: *Density, Dungeness crab, ghost fishing, meat yield, molt cycle, pots, sex/size effect, shell condition, Washington*

ABSTRACT: "Dungeness crabs in the ocean off Washington were of high quality from December 1973 to April 1974. Based on condition sampling during the closed period in the fall, a December 1 opening date was recommended. Ocean crabs sampled this contract period appeared to be in better condition than in previous years. Apparently related to low abundance, the molting period has become earlier and has extended over a longer time period so that the percentage of hard shells remained above 75% all year.

"Dungeness crabs in Willapa Bay were different than ocean crabs, as soft shells made a significant appearance in February 1974. This was also true in 1973, indicating a need to better delineate the ocean and bay stocks near the mouth of Willapa Bay and to consider the possibility of separate regulations.

"Pot-run samples of female crabs showed only 9.5% were over 6-1/4 inches (legal male size). Larger females were not abundant, but were found to be reproductive in a percentage similar to or only slightly lower than for smaller females. Larval release appeared to be earlier than in 1973, and mostly completed by mid-February. Yield from large females was 55 to 60% of the meat obtained from males per unit live weight; added plant costs and dead loss would make them worth less than half as much as males at the fisherman level. Based on these findings, continued protection of females is recommended.

"Interviews made during the contract year showed an estimate of 41,000 pots fished by 147 Washington coastal crabbers in the 1972–73 season. Only three transient boats made crab landings. Preliminary data indicate a decline in the crab fleet in 1972–73 to 124 boats with less than 33,000 pots. These figures compare to a fleet of 70 coastal crabbers in the 1967–68 season.

"Losses were estimated at 22.6% of the total pots fished. Fishermen estimated mortality of about 23,000 crabs trapped in pots that became sanded in

and required pumping to recover about 18% of the pots in use.

"The staff participated in the State-Federal crab management project, including working with the research team, providing data on various aspects, and participating in scientific, advisory, and policy committee meetings."

150. Tracy, D. 1994. Alaska Department of Fish and Game biological summary of the 1992 mandatory shellfish observer program database. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 4K94-10, Kodiak.

KEYWORDS: *Aleutian Islands, Bering Sea, blue king crab, bycatch, catch statistics, fecundity, fish, golden king crab, Korean hair crab, molt cycle, pots, red king crab, sex/size effect, snow crab, Tanner crab*

SYNOPSIS: Data have been compiled from observer deployments during commercial king and Tanner crab fisheries in the Bering Sea and Aleutian Islands that occurred during the 1992 calendar year. Scope of the data presented has been narrowed to include only size frequency and molt stages of commercially retained crabs, the documented occurrences of illegally retained crabs, and the results of random sampling of pot contents.

151. Velazco-Dominguea, A.T. 1981. Feasibility and desirability of holding juvenile spiny lobsters (*Panulirus argus* Latreille) in wire or tire cages. Master's thesis, University of Puerto Rico, Mayaguez.

KEYWORDS: *Caribbean spiny lobster, confinement, field evaluation, Gulf of Mexico, limb loss, mortality*

ABSTRACT: "The potential use of wire and tire cages to hold juvenile *Panulirus argus* (Latreille, 1804) in captivity was evaluated. The spiny lobsters were stocked at a rate of ten lobsters per square meter. The average percent mortality in wire cages (WC) was 1.8 ± 0.3%, 26.7 ± 2.5% for horizontal bottom tire cages (TCB), and 12.5 ± 0.7% for vertical hanging tire cages (TCH_2). Mean weights and carapace lengths per lobster in WC were significantly greater than those of TCB or TCH_2.

"Another study was conducted to determine the effects of stocking rates on the lobsters in hanging tire cages (TCH). The average percent mortality in TCH_2 (10 lobsters/m^2) was 12.5 ± 0.7%, 26.7 ± 4.2% for TCH_3 (15 lobsters/m^2), and 19.6 ± 3.2% for TCH_4 (20 lobsters/m^2). Treatment differences were not significant, possibly due to high variabilities and octopus predation. Mean weight per lobster, carapace length, and leg-loss values in all three TCH groups did not differ significantly.

"Mean oxygen and ammonia values in both studies approximated the values for the seawater samples outside the cages. Results of the studies showed that wire cages were more effective for holding the lobsters." [The dissertation titles and abstracts contained here are published with permission of University Microfilms International, publishers of *Dissertation Abstracts International* (copyright ©1981 by University Microfilms International), and may not be reproduced without their prior permission.]

152. Vermeer, G.K. 1987. Effects of air exposure on desiccation rate, hemolymph chemistry, and escape behavior of the spiny lobster, *Panulirus argus.* Fishery Bulletin 85:45–51.

KEYWORDS: *Caribbean spiny lobster, exposure, Florida, laboratory experiment, physiology, stress*

ABSTRACT: "Desiccation rates and hemolymph pH, lactic acid and ammonia concentrations of spiny lobsters, *Panulirus argus*, exposed in air for up to 2 hours were measured. Desiccation rates were faster in smaller lobsters. During a 2-hour exposure, hemolymph lactic acid levels increased more than 11 times, pH decreased more than one-half unit, and ammonia concentrations nearly doubled. Exposure-induced changes in hemolymph parameters occurred most rapidly in the first 30 minutes and began to level off by 2 hours. Lobsters exposed for 2 hours, then reimmersed for 24 hours, survived and had normal hemolymph chemical values. However, 75% of the reimmersed spiny lobsters had a delayed or absent tail-flip escape response; most individuals also exhibited diminished antennal defensive motions. Results suggest that desiccation and hemolymph chemical changes, caused by exposure, do not directly cause mortality, but rather induce secondary physiological damage, manifested as aberrant defensive and escape behavior."

153. Waldron, K.D. 1958. The fishery and biology of the Dungeness crab (*Cancer magister* Dana) in Oregon waters. Fish Commission of Oregon, Contribution 24, Portland.

KEYWORDS: *Catch statistics, Dungeness crab, field evaluation, growth, laboratory experiment, limb loss, mark recapture, migration, molt cycle, Oregon, predation, shell condition*

ABSTRACT: "Results of studies beginning in 1947 on the biology of the Dungeness crab (*Cancer magister*) in Oregon coastal waters are reported. A review is made of the history of the fishery with regard to trend of the catch by magnitude, area, and season; the development and conduct of the fishery itself; and the regulations governing the fishery. The first reported commercial crab landings in Oregon were 6,628 pounds in 1880. The fishery expanded slowly until 1933 after which the catch rose sharply to a peak of about 11 million pounds in 1943. Landings in recent years have fluctuated between 6 and 11 million pounds from a commercial fishery which is carried out along the major portion of the Oregon coast. During the period 1947–50, 6,249 tagged crabs were released in offshore and bay waters of Oregon and 34.6 per cent of the tags were subsequently recovered. The average movement of 1,042 recoveries of crabs released in offshore waters, as measured by the distance from the tagging site, was 8.3 miles (range 0–133 miles) in 80 days. For crabs released within bays, 606 recoveries averaged a minimum distance traveled of 4.2 miles (range 0–81 miles). Fifty-seven per cent of the recoveries of offshore releases and 84 per cent of the recoveries of bay releases were made within 4 miles of the respective tagging sites. Over 90 per cent of the recoveries of offshore releases were made within 6 months, although 3 crabs were out more than a year with 1 at liberty 878 days. Tagged crabs moved from offshore to bays, from bays to bays, and from bays to offshore. There was no significant difference in percentage recovery for crabs with or without missing appendages. Egg-bearing female crabs are present in offshore waters during the period October to March, inclusive. Larval crabs assumed to be *C. magister* were observed in offshore waters from April to July, inclusive. Considerable variation in early growth of post larval crabs was observed in laboratory experiments. The amount of growth of crabs between 6.4 and 146.0 mm., as observed by measuring them before and after molting, increases until a shoulder width of about 95 mm. is reached. The increase with each subsequent molt thereafter remains relatively constant. Macroplankton-eating fishes feed upon free swimming crab larvae. Adult crabs up to at least 114 mm. in shoulder width are preyed upon by voracious fish such as ling-cod (*Ophiodon elongatus*), the great marbled sculpin (*Scorpaenichthys marmoratus*), wolf eel (*Anarrhichthys ocellatus*), halibut (*Hippoglossus stenolepis*), and some of the rock fishes of the genus *Sebastodes*."

154. Wassenberg, T.J., and B.J. Hill. 1989. The effect of trawling and subsequent handling on the survival rates of the by-catch of prawn trawlers in Moreton Bay, Australia. Fisheries Research 7:99–110.

KEYWORDS: *Australia, bycatch, crustacean, fish, handling, mortality, trawl*

ABSTRACT: "The fate of by-catch discarded by the Moreton Bay prawn trawl fishery was studied between September 1983 and March 1986. The composition and biomass of the by-catch were ascertained and the effect of trawling and handling on its survival was measured. The by-catch was made up of 52% crustaceans, 15% elasmobranchs, 8% bony fish, 18% echinoderms, 3% cephalopods and 4% debris by weight.

"Trawl hauls lasted about 60 min. and the catch was sorted in about 20 min. About 85% of the Crustacea and about 20% of the bony fish were still alive 8 h after sorting." [Reprinted with permission from Elsevier Science B.V., Amsterdam, The Netherlands.]

155. Wassenberg, T.J., and B.J. Hill. 1993. Selection of the appropriate duration of experiments to measure the survival of animals discarded from trawlers. Fisheries Research 17:343–352.

KEYWORDS: *Australia, bycatch, exposure, fish, handling, invertebrate, laboratory experiment, mortality, trawl*

ABSTRACT: "The survival rate of ten species of invertebrates (n = 39 – 50) and four species of fish (n = 50 – 68) was determined from specimens collected from the by-catch of night trawl catches. They were observed in laboratory tanks for 7 days, as these provide better holding conditions than can normally be achieved at sea. Except for the alpheids, crustaceans and echinoids, the invertebrates were more tolerant than the fish: over 70% remained alive after 7 days. Although the species of fish were chosen for their relative robustness, only one species (*Centropogon marmoratus*) had a survival rate above 30% and most deaths occurred during the first 3 days after capture. This result agrees with published data on survival of temperate fish captured in trawls indicating that 4 days is an adequate length of time for experiments to measure survival of animals discarded from trawl catches. Animals returned to the sea may continue to die over a longer period but this cannot be determined in tanks." [Reprinted with permission from Elsevier Science B.V., Amsterdam, The Netherlands.]

156. Watson, L.J., and D. Pengilly. 1994. Effects of release method on recovery rates of tagged red

king crabs *Paralithodes camtschaticus* in the 1993 Bristol Bay commercial fishery. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 4K94-40, Kodiak.

KEYWORDS: *Bering Sea, Bristol Bay, displacement, fishermen behavior, handling, mark recapture, pots, red king crab, shell condition*

SYNOPSIS: The study compared the effects of 2 at-sea handling-and-release methods on the recovery rate of tagged new-shell and old-shell legal male red king crabs released in the month prior to, and recovered during, the 1993 Bristol Bay red king crab commercial fishery. A total of 2,061 control crabs were released by placing, not dropping, each tagged crab in the onboard water trough, with the abdomen of the crab facing down while the vessel remained stationary. A total of 2,110 treatment crabs were released by dropping each tagged crab overboard from the rail, a distance of approximately 168 cm, with the dorsal carapace of the crab facing down and the vessel moving at a speed of 7.5 knots.

An overall recovery rate of 27% was realized in the 1993 commercial fishery for crabs released in the study. Old-shell crabs had a lower recovery probability than new-shell crabs released from the same pot. However, in crabs of either shell age there was little evidence for a difference between the recovery rates of control and treatment crabs. Differences in recovery rates were attributed to differences in seasonal movements or other behavior that make an old-shell crab less likely than a new-shell crab to be captured during the 1- to 2-week Bristol Bay commercial fishery.

157. Weis, J.S. 1976. Effects of environmental factors on regeneration and molting in fiddler crabs. Biological Bulletin 150:152–162.

KEYWORDS: *Ablation, Atlantic coast, autotomy, density, environment, fiddler crab, displacements, habitat, illumination, limb loss, molt cycle, regeneration, salinity, sex/size effect, temperature*

SYNOPSIS: Effects of altering light, density, starvation, temperature, salinity, and habitat on the fiddler crab were studied. Animals were subjected to a loss of 6 legs and 1 chela or removal of only 1 leg. The presence of other crabs retarded limb regeneration in males exposed to light. In one group light retarded limb regeneration in the males. Light and grouping had no effect on female crabs. At lowered temperatures there was no indication of even basal growth. At elevated temperatures animals showed a greatly accelerated regeneration rate and molt cycle. Crabs at lowered salinities delayed initiation of regeneration; therefore, limb buds were smaller than those in the control group. Crabs in the hypersaline environment had significantly smaller limb buds than the control group and a molting was retarded. Crabs were able to regenerate and molt regardless of food intake. Animals regenerated more slowly in mud habitat than in water alone, but at the same rate in water as in their normal sandy habitat. Regeneration in crabs autotomized shortly after ecdysis was much slower than crabs autotomized later in the molt cycle. Removal of eyestalks accelerated the rate of regeneration in crabs also autotomized. Effects of regeneration and molting are discussed with respect to ecology of the fiddler crab.

158. Weis, J.S. 1976. Regeneration in the fiddler crab, *Uca pugilator*, after injury or removal of limb buds. Journal of Experimental Zoology 197: 21–30.

KEYWORDS: *Ablation, Atlantic coast, autotomy, fiddler crab, growth, injury, laboratory experiment, limb loss, molt cycle, regeneration, sex/size effect*

ABSTRACT: "After autotomy of seven appendages and partial regeneration, crabs (*Uca pugilator*) were subjected to removal of one, three, or six developing limb buds at different stages of limb growth. Removal of one limb had no effect on the growth of the remaining limb buds or the time of ecdysis, and the limb bud removed was not replaced before ecdysis. Removal of six limb buds early in the regenerative period caused a retardation of growth in the remaining bud until the reamputated buds could be replaced. Ecdysis was postponed in these animals. Removal of six limb buds at a later stage, or removal of three limb buds at any stage, produced a slight delay in growth of the remaining bud(s) which was not always statistically significant. The inhibition of growth in the remaining bud(s) was greatest in those individuals which went on to replace the reamputated buds. Such individuals also exhibited a longer time to ecdysis.

"No inhibition of growth or delay in ecdysis was produced in small crabs (11–12 mm carapace width) by removal of one, three, or six limb buds. These were generally not replaced.

"Animals which had six limb buds removed early in regeneration showed a greater inhibition of growth in the remaining limb bud than those which had eyestalks as well as six limb buds removed. This latter group, however, did show a significant retardation. This is considered evidence for the production of limb-

growth inhibiting substances in other sites in addition to the eyestalks.

"Limb buds which had been injured grew more slowly than contralateral control limbs initially, but the difference diminished as the crabs approached ecdysis. Ecdysis was not delayed by the presence of this one incomplete limb bud. This is consistent with the lack of effect of removal of a single limb bud, seen in the previous experiments."

159. Winkler, P. 1987. Effects of handling on the *in situ* oxygen consumption of the American lobster (*Homarus americanus*). Comparative Biochemistry and Physiology 87:69–72.

KEYWORDS: *American lobster, Atlantic coast, handling, laboratory experiment, physiology*

SYNOPSIS: The effects of recent handling on the in situ standard metabolism of the American lobster were studied. Respirometers were deployed in the field over 1 year. Animals were allowed 12 h of initial respirometer acclimation prior to 3 d of replicate testing. Resting metabolism decreased during 3- to 6-d trials. The highest VO_2s were recorded on the first (70%) and second (30%) days. Lowest VO_2s were generally recorded on the third day. Rehandling of escaped lobsters resulted in VO_2s similar to first-day values or higher.

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