Estimates of lobster-handling mortality associated with the Northwestern Hawaiian Islands lobster-trap fishery

Gerard T. DiNardo

Edward E. DeMartini

Honolulu Laboratory, Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
2570 Dole Street
Honolulu, Hawaii 96822
E-mail address (for Gerard T. DiNardo): gdinardo@honlab.nmfs.hawaii.edu

Wayne R. Haight

Joint Institute of Marine and Atmospheric Research
School of Ocean and Earth Science and Technology
University of Hawaii, 1000 Pope Road
Honolulu, Hawaii 96822

The commercial lobster fishery in the Northwestern Hawaiian Islands (NWHI) is a distant-water trap fishery that targets the Hawaiian spiny lobster *(Panulirus marginatus)* and slipper lobster *(Scyllarides squammosus)*. The NWHI are an isolated group of islands, atolls, islets, reefs, and banks that extend 1500 nmi west-northwest of the main Hawaiian Islands from Nihoa Island to Kure Atoll (Fig. 1). Reported landings in the NWHI peaked at about 2,000,000 lobsters (spiny and slipper combined) in 1985, and then declined to about 38,000 lobsters from 1986 to 1995 (Fig. 2).

The NWHI lobster fishery is managed under the Fishery Management Plan for the Crustaceans of the Western Pacific Region (Crustaceans FMP) implemented in 1983 and developed by the Western Pacific Regional Fishery Management Council (WPRFMC). The National Marine Fisheries Service (NMFS) is responsible for stewardship of the resource and review and implementation of proposed management measures. A variety of management measures have been adopted in response to declining catches: a limited-entry fishing regime that limited the number of permit holders to 15; a prohibition on fishing from January through June when lobsters spawn; an annual catch quota system; a minimum legal tail width (TW) of 50 mm for spiny lobster and 56 mm TW for slipper lobster, which are close to the sizes at first maturity for these species in the NWHI; a prohibition on landing berried (ovigerous) females; and a requirement that traps be equipped with escape vents to reduce capture of undersize lobsters (WPRFMC[1]). Prior to 1996, fishermen were required to discard all berried and undersize lobsters, which were not counted against the catch quota.

The management plan assumed that escape vents allowed substantial numbers of undersize lobster to escape capture and that undersize and berried lobsters do not die during the discard process. Although research on lobster fisheries has found that escape vents effectively reduce the capture of undersize lobsters (Krouse, 1978; Fogarty and Borden, 1980; Harris, 1980; Everson et al., 1992; Skillman et al.[2]), considerable numbers of undersize (henceforth termed "sublegal") and berried lobsters are caught in the NWHI lobster fishery. Between 1983 and 1995 the reported lobster discard rate increased from 28% to 62% (Fig. 3), resulting from changes in the size- and age-structures of the populations and in the areas fished. The average size of spiny lobsters generally increased northwestward from Nihoa along the Hawaiian Archipelago (Uchida et al., 1980). Although as many as 16 banks within the NWHI have been fished, the spatial distribution of fishing effort has shifted to banks in the southeast of the Hawaiian Archipelago where there is a higher concentration of spiny lobsters.

Qualitative data collected during the early days of the fishery suggested that mortality associated with the handling and discarding practices of the NWHI commercial lobster-trap fishery might be high (Gooding, 1985; Gooding[3]). Unless discard mortality is explicitly considered, fishing policy decisions can be suboptimal, or worse. Where catch quotas are used, the total fishing-induced mortality of the population is greater than expected and can even result in recruitment overfishing. Using an equilibrium yield-per-recruit (YPR) model, Kobayashi[4] found that the reproductive potential of the NWHI lobster population more than doubled, and mean weight per individual increased by 22% in a retain-all fishery (all lobsters brought on deck were retained as catch) if the mortality rate of discarded lobsters was high (>75%). Based on these results, the observed high discard rate of sublegal and berried lobsters (62%), and the presumption that the

[1] Western Pacific Regional Management Council. 1995. Fishery management plan for the crustacean fisheries of the Western Pacific region, amendment 9. Western Pacific Regional Fishery Management Council, Honolulu, Hawaii, 227 p.

[2] Skillman, R. A., A. R. Everson, and G. L. Kramer. 1984. Prospectus escape vent experimental procedure for the spiny lobster fishery under management of the Magnuson Fishery Conservation and Management Act. Southwest Fish. Sci. Cent. Admin. Rep. H-84-13, unpubl. report, 11 p. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish Serv., NOAA, Honolulu, HI 96822-2396.

[3] Gooding, R. M. 1979. Observations on surface-released, sublegal spiny lobsters, and potential spiny lobster predators near Necker and Nihoa. Southwest Fish. Sci. Cent. Admin. Rep. H-79-16, unpubl. report, 8 p. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish Serv., NOAA, Honolulu, HI 96822-2396.

[4] Kobayashi, D. R. 2001. Southwest Fish. Sci. Cent. Admin. Rep., in prep. Simulated effects of discard mortality on spiny lobster (*Panulirus marginatus*) sustainable yield and spawning stock biomass per recruit in the Northwestern Hawaiian Islands. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish Serv., NOAA, Honolulu, HI 96822-2396.

Manuscript accepted 11 May 2001.
Fish. Bull. 100:128–133 (2002).

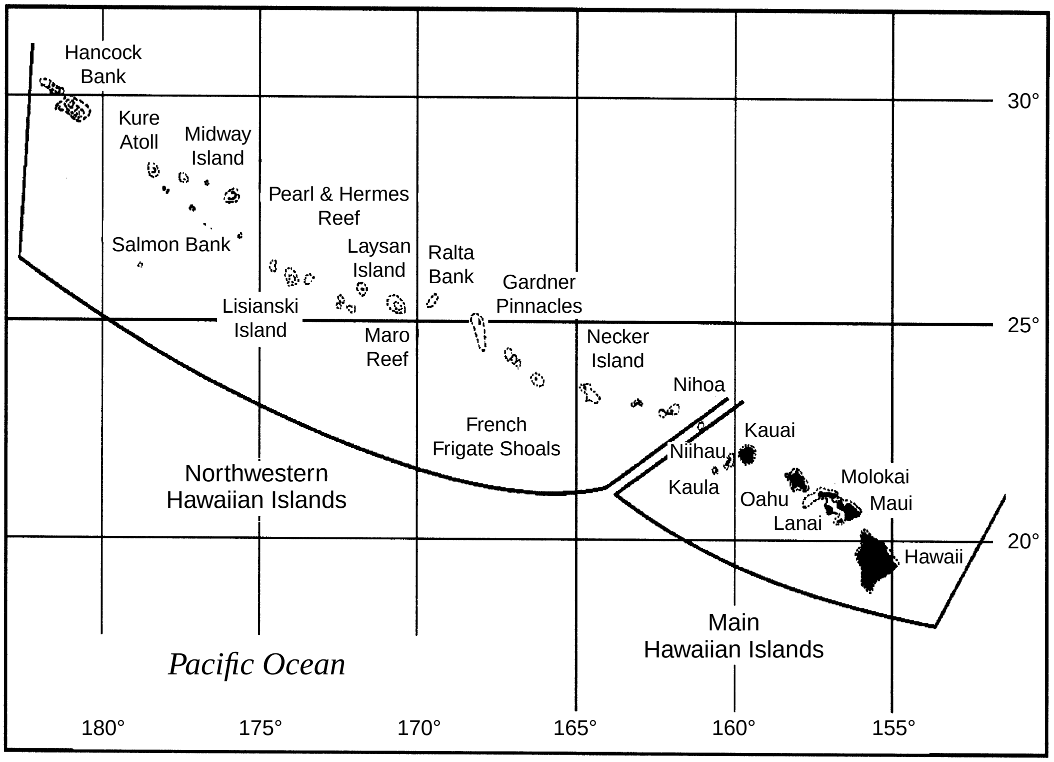

Figure 1

Map of the Hawaiian Archipelago.

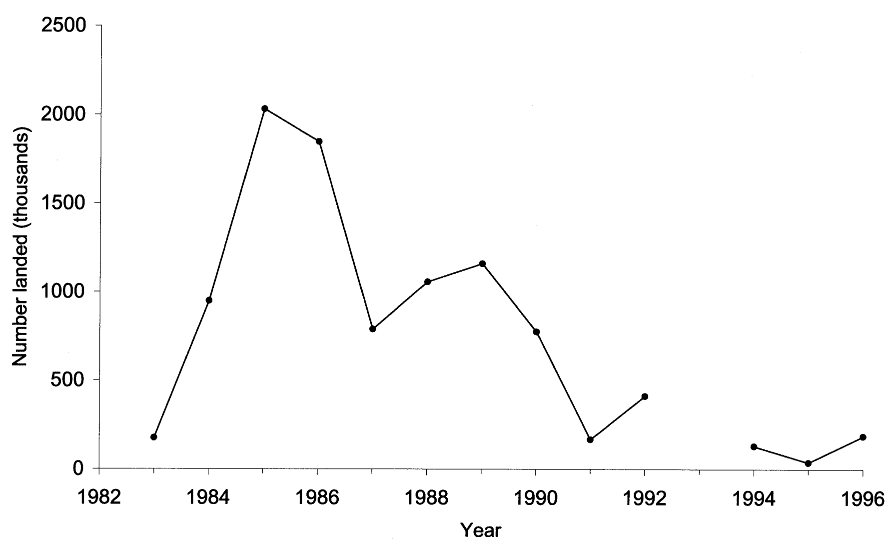

Figure 2

Annual commercial landings for the NWHI lobster fishery, 1983–96.

mortality rate of discarded lobsters is greater than 75%, the WPRFMC amended the Crustaceans FMP in 1996 to allow the retention of all lobsters caught in the NWHI commercial lobster-trap fishery subject to the quota on total catch (WPRFMC[1]). The WPRFMC also recommended that NMFS conduct experiments to assess mortality associated with possible handling and discarding practices.

This study reviews research conducted in the NWHI on fishery-induced mortality of sublegal and berried lobsters. The authors examined on-deck mortality of sublegal and

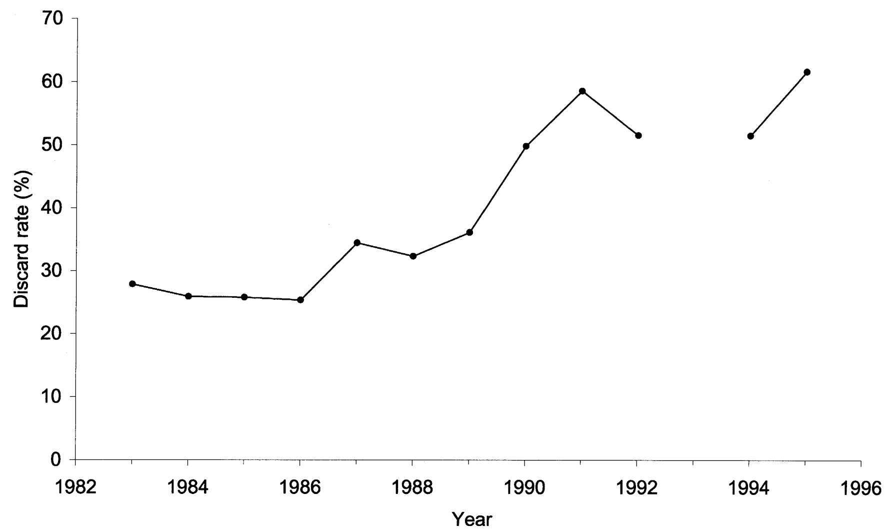

Figure 3

Annual estimates of the reported discard rate of lobsters in the NWHI lobster fishery, 1983–95.

berried spiny and slipper lobsters that occurred within two days after capture under handling methods known to have been used in the NWHI lobster-trap fishery.

Methods

Studies of handling-induced mortality (referred to as "handling mortality" in the remainder of this note) for spiny lobster were conducted at Necker Island onboard the NOAA ship *Townsend Cromwell* during the NMFS Honolulu Laboratory's 1996 NWHI lobster survey from 21 to 26 June 1996 and for slipper lobster at Maro Reef from 4 to 11 July 1996 (see Fig. 1). These locations were chosen because of their historically high lobster catches and their overall importance to the commercial lobster fishery over the past 13 years.

Handling mortalities were estimated for two handling methods: "dry" and "wet." The effects of on-deck exposure time on handling mortality were also estimated for spiny lobsters handled by the dry method. We defined a particular combination of factors (method and exposure time) as an experimental treatment. For dry treatments, lobsters were held on deck in 30-gallon containers without water and in direct sunlight for 1, 2, or 3 hours. In the wet treatment, lobsters were held on deck for 3 hours in shaded 30-gallon containers with circulating seawater. The 2- and 3-h dry treatments represent prevailing commercial fishing practices (Anderson[5]), whereas the 1-h dry treatment and the 3-h wet treatments represent possible handling alternatives or mitigative measures.

Spiny and slipper lobsters were collected in baited commercial lobster traps and sorted (legal, sublegal, and berried). All sublegal and berried lobsters were held in tanks of circulating water until a sufficiently large paired experimental treatment sample (n=200 lobsters) was collected. Experiments with the 3-h wet and dry treatments were done first, followed by experiments involving 1- and 2-h dry treatments. For each treatment, 100 lobsters (sublegal and berried) were randomly chosen from the tank and placed into two 30-gallon treatment containers (dry or wet), 50 lobsters/container. After the exposure time (1, 2, or 3 hours), lobsters were removed from the treatment containers, their condition recorded as active (i.e. lobsters were capable of tail flexion), weak (incapable of tail flexion but able to move appendages when prodded), or dead. Five lobsters were placed in each of 20 lobster-holding traps (commercial lobster traps with sealed entrances) and held in two 1320-gallon baitwells with recirculating seawater (21 gallons/minute) for 2 days. It was assumed that the 2-d holding period would allow ample time for latent effects from a treatment to manifest and that each lobster holding trap was a replicate (n=20 replicates/treatment). To check for possible baitwell effects, five control traps, each containing five previously untreated lobsters, were placed in the baitwells (two traps in the port baitwell and three traps in the starboard baitwell) at the beginning of the holding phase, and their condition was recorded at the beginning and end of the holding phase. At the conclusion of the holding period, the condition of the treated lobsters was again assessed.

Handling mortality for each treatment was computed as the arithmetic mean of the percent mortality (dead/total or (dead + weak)/total—see below) observed in the 20

[5] Anderson, P. 1997. Personal commun. University of Hawaii, Marine Option Program, 1000 Pope Road, Honolulu, HI 96822.
Kazama, T. 1997. Personal commun. Honolulu Laboratory, Southwest Fisheries Science Center, 2570 Dole Street, Honolulu, HI 96822-2396.

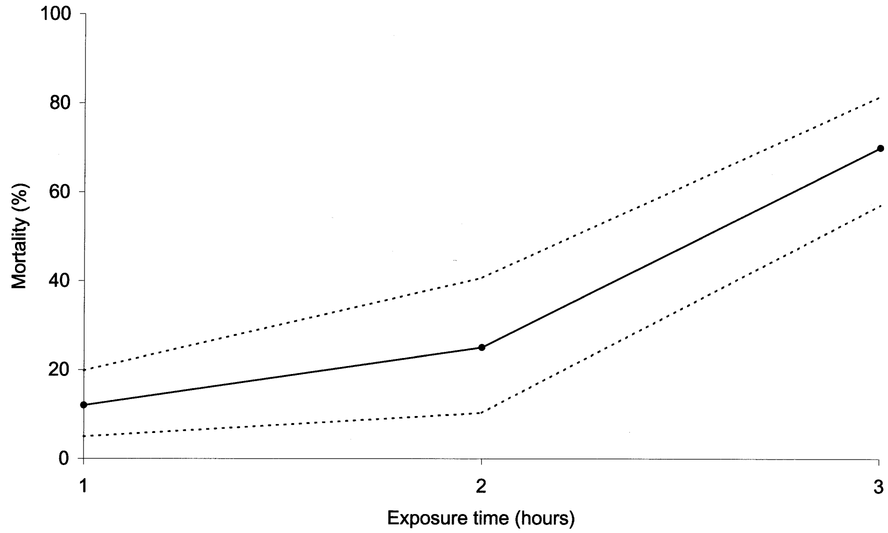

Figure 4

Handling mortality (dead/total) estimates for spiny lobster subjected to 1-, 2- , and 3-h dry treatments. Dashed lines indicate the 95% confidence limits.

treatment replicates. Randomization resampling was used to evaluate estimates of handling mortality. Approximate lower and upper 95% confidence limits for handling mortality were computed as the 2.5% and 97.5% percentiles of the bootstrap distributions by using the computer program RT (Manly, 1994).

Results

Spiny lobster

Spiny lobster sample sizes by discard category were sublegal (n=84–88) and berried (n=12–16) (Table 1). All spiny lobsters subjected to the 3-h wet treatment were active at the conclusion of the 2-d baitwell holding period. For dry treatments, the number of active spiny lobsters decreased with increasing exposure time, whereas the number of dead lobsters increased with increasing exposure time. All control lobsters were active, indicating no baitwell holding effects.

Handling mortality (dead/total) for the dry treatment ranged from 12% for the 1-h treatment to 70% for the 3-h treatment (Fig. 4) and did not differ between berried and unberried lobsters (P>0.05). Pooled dead and weak lobsters resulted in a handling mortality that ranged from 16% for the 1-h treatment to 77% for the 3-h treatment (Fig. 5).

Slipper lobster

Handling mortalities for slipper lobster were estimated only for the 3-h dry and wet treatments. Mechanical failure of the baitwell recirculating water pumps during the first 3-h paired dry and wet experiments forced us to reduce the baitwell holding time to 1 day. After the baitwell pumps failed, we repeated the 3-h dry treatment with a 1-d holding period, suspending the holding and control traps 3 m below the sea surface from the *Townsend Cromwell*.

Table 1

Spiny and slipper lobster sample sizes by discard category for each treatment. NB = nonberried and sublegal; B = berried.

	Spiny lobster		Slipper lobster	
Treatment	NB	B	NB	B
1 hour dry	84	16	—	—
2 hours dry	88	12	—	—
3 hours dry	87	13	87–89	11–13
3 hours wet	88	12	81	19

Slipper lobster sample sizes by discard category (sublegal and berried) for each treatment are shown in Table 1. Most slipper lobsters subjected to the 3-h wet treatment were active at the end of the 1-d holding period. For the 3-h dry treatment, the number of dead lobsters ranged from 14 to 39, and the number of active lobsters ranged from 56 to 83. All control lobsters were active, indicating no baitwell holding effects.

Slipper lobster handling mortalities for the 3-h dry treatment ranged from 14% to 39% with an average estimate of 27% and were unrelated to berried condition (P>0.05). Estimates of handling mortalities with weak and dead lobsters combined ranged from 17% to 44%, with an average of 31%. Handling mortality for the 3-h wet treatment was 1%.

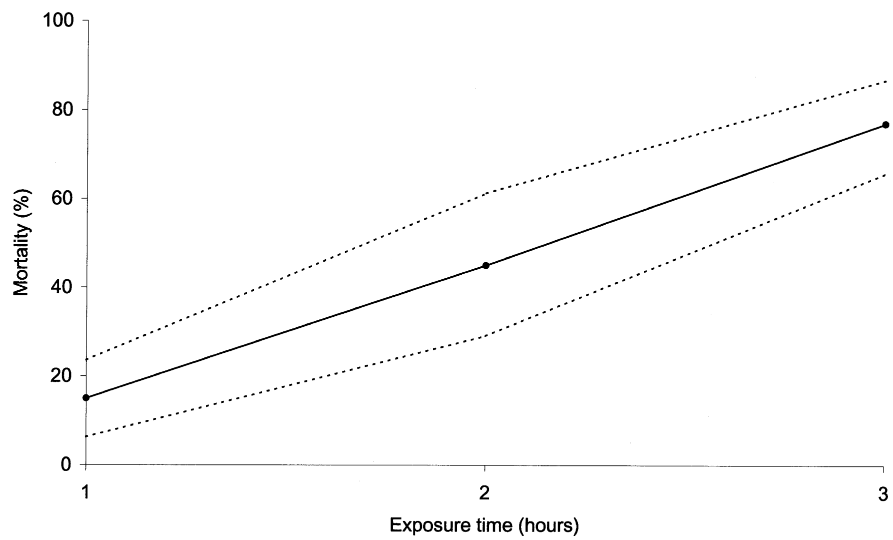

Figure 5

Pooled handling mortality ((dead + weak)/total) estimates for spiny lobster subjected to 1-, 2-, and 3-h dry treatments. Dashed lines indicate the 95% confidence limits.

Discussion

Many factors affect the survival of lobsters discarded in commercial trap fisheries, including capture, handling, and discarding processes. In our experiment we focused on handling factors to assess their impacts on mortality in the NWHI commercial lobster fishery.

If the 2- and 3-h dry experimental treatments typify commercial handling practices, then the mortality of discarded spiny lobster from handling practices on commercial vessels is extreme, ranging from an average of 25% to 45% and 70% to 77%, respectively, depending on how data are pooled. Handling mortality for slipper lobster also appears high (estimated at 31%) but is considerably less than that for spiny lobster; thus spiny lobsters may have a lower handling tolerance than slipper lobsters.

Although there are no published estimates of handling mortality for *P. marginatus* and *S. squammosus*, studies on other lobster species suggest that handling mortality in the NWHI lobster fishery is high. Lyons and Kennedy (1981), reporting on *P. argus*, estimated that 12.3% of lobsters died after 30 minutes of exposure to direct sunlight and an average 24.1% after 1–4 hours of exposures. They also found that lobsters exposed for 2–4 hours tended to die within a week following exposure, whereas those exposed for only 1 hour survived longer. Laboratory experiments by Brown and Caputi (1983) on small western rock lobster, *Panulirus cygnus*, exposed to direct sunlight resulted in an expected time to 50% mortality that decreased with increasing temperature, ranging from 233 minutes at 27°C to 99 minutes at 31–35°C. Time to 50% mortality was 387 minutes for lobsters held in the shade at 26.5–32°C.

Handling mortality, however, represents only a portion of the total mortality of discarded lobsters resulting from their capture, shipboard processing, and subsequent release in the NWHI. Additional mortality resulting from habitat displacement, predation, and other factors associated with discarding might result in total discard mortality estimates that approach 100%. Qualitative evidence suggests that discarded lobsters are subject to high predation from the giant trevally, *Caranx ignobilis*, which aggregate around vessels during fishing operations (Gooding, 1985).

Sorting and discarding lobsters immediately after they are placed on deck appears to reduce total discard mortality. The discarded lobsters would need to be returned to the general vicinity of their capture and as close to the sea floor as possible to avoid the gauntlet of predators in the water column. Brown and Caputi (1986) reported a reduction in recapture rates of displaced undersized rock lobsters compared with nondisplaced rock lobsters and related the reduction directly to predation mortality.

Adoption of the retain-all fishery by the WPRFMC in 1996 significantly reduced fishery-induced handling mortality. Although sporadic discarding occurs, current discard rates are less than 1% and will have no detectable consequence at the population level. The research does, however, provide insight into past fishery-induced handling impacts, which likely contributed to the decline in NWHI lobster catches. If future management again reverted to mandatory discarding practices, this research provides information to assess its impact on fishery-induced mortality. However, to fully understand the synergistic effects of catching, handling, and discarding practices on mortality in the NWHI lobster fishery, additional research to assess the impacts associated with shipboard sorting and releasing (e.g. postrelease predation) is required.

Acknowledgments

Robert Moffitt, Donald Kobayashi, Jerry Wetherall, and the anonymous referees provided helpful comments on the draft, for which we are very grateful. We also acknowledge the crew of the *Townsend Cromwell* and the scientific staff who worked to ensure that good biological information is available for analyses such as this.

Literature cited

Brown, R. S., and N. Caputi.
1983. Factors affecting the recapture of undersized western rock lobster *Panulirus cygnus* George returned by fishermen to the sea. Fish. Res. 2:103–128.
1986. Conservation of recruitment of the western rock lobster (*Panulirus cygnus)* by improving survival and growth of undersize rock lobster captured and returned by fishermen to the sea. Can. J. Fish. Aquat. Sci. 43:2236–2242.

Everson, A. R., R. A. Skillman, and J. J. Polovina.
1992. Evaluation of rectangular and circular escape vents in the Northwestern Hawaiian Islands lobster fishery. N. Am. Fish. Manag. 12:161–171.

Fogarty, M. J., and D. V. D. Borden.
1980. Effect of trap venting on gear selectivity in the inshore Rhode Island American lobster, *Homarus americanus*, fishery. Fish. Bull. 77:925–933.

Gooding, R. M.
1985. Predation on released spiny lobster, *Panulirus marginatus*, during tests in the Northwestern Hawaiian Islands. Mar. Fish. Rev. 47:27–35.

Harris, K.
1980. Escape gaps in rock lobster pots. Fish. Ind. News Tasmania 2:40–43.

Krouse, J. S.
1978. Effectiveness of escape vent shape in traps for catching legal size lobsters, *Homarus americanus*, and harvestable-sized crabs, *Cancer borealis* and *Cancer irroratus*. Fish. Bull. 76:425–432.

Lyons, W. G., and F. S. Kennedy.
1981. Effects of harvest techniques on sublegal spiny lobsters and on subsequent fishing yield. Proc. Gulf. Caribb. Fish. Inst. 33:290–300.

Manly, B. F. J.
1994. RT: a program for randomization testing., version 1.02C. Centre for Applications of Statistics and Mathematics, Univ. Otago, P.O. Box 56, Dunedin, New Zealand.

Uchida, R. N., J. H. Uchiyama, D. T. Tagami, and P. A. Shiota.
1980. Biology, distribution, and estimates of apparent abundance of the spiny lobster, *Panulirus marginatus* (Quoy and Gaimard) in waters of the Northwestern Hawaiian Islands. Part II: size distribution, legal and sublegal ratio, sex ratio, reproductive cycle, and morphometric characteristics. *In* Proceedings of the symposium on status of resource investigations in the Northwestern Hawaiian Islands, Honolulu, Hawaii, April 24–25, 1980 (R. W. Grigg and R. T. Pfund, eds.), p. 131–142. Univ. Hawaii Sea Grant College Program MR-80-04, Honolulu, Hawaii.