WESTERN
PACIFIC
REGIONAL
FISHERY
MANAGEMENT
COUNCIL

Amendment 9

Fishery Management Plan for the Crustacean Fisheries of the Western Pacific Region

(includes Environmental Assessment,
Regulatory Impact Review and
Proposed Regulations)

November 1995

Western Pacific Regional Fishery Management Council
1164 Bishop Street, Suite 1405
Honolulu, Hawaii 96813

Amendment 9

Fishery Management Plan
for the
Crustacean Fisheries of the Western Pacific Region

(includes Environmental Assessment,
Regulatory Impact Review and
Proposed Regulations)

November 1995

Western Pacific Regional Fishery Management Council
1164 Bishop Street, Suite 1405
Honolulu, Hawaii 96813

Telephone (808) 522-8220
Fax (808) 522-8226

CONTENTS

APPENDICES

Amendment 9

Fishery Management Plan for the Crustacean Fisheries of the Western Pacific Region

1.0 INTRODUCTION

This amendment would modify the management plan for lobster fishing in the Northwestern Hawaiian Islands (NWHI).

1.1 Responsible Agencies

The Western Pacific Regional Fishery Management Council (Council) was established by the Magnuson Fishery Conservation and Management Act to develop Fishery Management Plans (FMPs) for fisheries operating in the US Exclusive Economic Zone (EEZ) around American Samoa, Guam, Hawaii (including the Northwestern Hawaiian Islands), the Northern Mariana Islands, and other US possessions in the Pacific[1]. Once an FMP is approved by the Secretary of Commerce (Secretary), it is implemented by federal regulations which are enforced by the National Marine Fisheries Service (NMFS) and the US Coast Guard, in cooperation with state and territorial agencies. For further information, contact:

Kitty M. Simonds
Executive Director
Western Pacific Regional
Fishery Management Council
Suite 1405
1164 Bishop St.
Honolulu, HI 96813
Tel (808) 522-8220
Fax (808) 522-8226

Hilda Diaz-Soltero
Director
NMFS Southwest Region
Suite 4200
501 W. Ocean Bl.
Long Beach, CA 90802-4213
Tel (310) 980-4001
Fax (310) 980-4018

1.2 Public Review and Comment

The Council advised commercial and recreational fishing interests and other interested parties of the development, completion, and submission of Amendment 9 for Secretarial review. A proposed rule will be published in the *Federal Register* for review and comment. This ensures that those who might be affected by new management measures have an opportunity to submit

---

[1] Howland and Baker Islands, Jarvis Island, Johnston Atoll, Kingman Reef and Palmyra Island, and Wake Island.

ideas and suggestions for potential actions by the Council, and to be involved in the decision-making process.

The Council's Crustaceans Advisory Panel and Crustaceans Plan Team discussed the proposed changes to the management system at a public meeting held on 28-29 June 1995. The Council's SSC reviewed and refined the proposed changes at a public meeting on 19 July 1995. The recommendations of these advisory groups were discussed at the Council's public meeting held on 9 August 1995 in Makaha, Hawaii. The Council approved the content of Amendment 9, and directed its staff to complete the amendment for submission to the Secretary for review and approval in time for the regulatory changes to become effective before the 1996 lobster fishery opened in the NWHI, i.e., on 1 July 1996. The approval process will include publication of the proposed regulations for public review and comment. A draft of the regulations is included in this amendment (see Appendix 7).

1.3 List of Preparers

Amendment 9, the Environmental Assessment and the Regulatory Impact Review were prepared by (listed alphabetically within agencies):

Western Pacific Regional Fishery Management Council:	Robert Harman
NMFS Honolulu Laboratory:	Gerard DiNardo, Jeffrey Polovina, Samuel Pooley
NMFS Southwest Region:	Ray Clarke, Svein Fougner, Alvin Katekaru

2.0 NAMES, ABBREVIATIONS and ACRONYMS

<u>Entities</u>

AA	Assistant Administrator for Fisheries, NOAA
Advisory Subpanel	Crustaceans Advisory Subpanel of the Western Pacific Council
Council	Western Pacific Regional Fishery Management Council
Honolulu Laboratory	Honolulu Laboratory, Southwest Fisheries Science Center, NMFS
NMFS	National Marine Fisheries Service
Plan Team (PT)	Crustaceans Plan Team of the Western Pacific Council
RD	Regional Director, Southwest Region, NMFS
Secretary	US Secretary of Commerce
SSC	Scientific and Statistical Committee of the Western Pacific Council

<u>Documents</u>

Amendment 9	Amendment 9 to the Fishery Management Plan for the Crustacean Fisheries of the Western Pacific Region
CFR	Code of Federal Regulations - a codification of the general and permanent rules published in the *Federal Register*

regulations for each stock are based on the principles of Optimum Yield (OY), i.e., management based on Maximum Sustainable Yield (MSY) as modified by relevant ecological, social and economic considerations. The existing regulations include the following measures:

- To prevent overfishing (protect reproductive potential), minimum size limits, measured as tail width, are: spiny lobsters--5.0 cm, and slipper lobsters--5.6 cm. Minimum sizes for slipper and spiny lobsters were determined so that the spawning stock biomass per recruit (SSBR), when fishing mortality was equal to natural mortality, would be 50% of the SSBR in the absence of fishing.

- Recruitment overfishing is defined to be a level at which the spawning potential ratio (SPR) is 0.2 or below. SPR is the spawning stock biomass produced, on average, by a post-larval recruit in a fished population versus an unfished population, measured for a specific fishing area.

- To protect lobster spawning biomass, the NWHI lobster fishery is closed during the months of January through June, and egg-bearing lobsters cannot be retained.

- To further support sustainable yields, the FMP established a quota system in 1992 under which NMFS determined annually a harvest quota (total allowable catch) that may be taken by the fleet. Once the quota was taken in a given year, the fishery was closed for the year. The quota system was designed to allow fishing only when the minimum adult biomass did not fall below about 1.4 million lobster at the end of the year.

- Commercial fishing gear is restricted to traps. To prevent entrapment of Hawaiian monk seals, the trap entrance must not exceed 6.5 inches in diameter. To facilitate the escape of sublegal lobsters, every trap must have two escape panels, each with four circular, 67-mm diameter holes.

- To minimize overcapitalization in the fishery, entry to the fishery is limited to 15 vessels, and no vessel may carry more than 1100 traps. Permits are transferable.

- To protect lobster stocks and marine mammals in the NWHI, no commercial fishing is allowed in EEZ waters shallower than 10 fm, within lagoon waters, or within 20 nm of Laysan Island. These refuges amount to about 16% of the total NWHI lobster habitat.

- To provide relevant and timely fishery information for management purposes, fishermen are required to have a federal lobster fishing permit and to supply catch and sales reports after each trip.

- To facilitate monitoring of catches and catch rates, determination of the final quota, and determination of the date the quota is reached so the fishery can be closed, the Regional Director establishes in-season reporting requirements for permit holders during the year.

EA	Environmental Assessment, NEPA
EO	Executive Order
FMP	Fishery Management Plan for the Crustacean Fisheries of the Western Pacific Region, as amended. (Named "FMP for the Spiny Lobster Fisheries of the Western Pacific Region" until 1987.)
FR	*Federal Register*; the publication for federal regulations

<u>Terms</u>

EEZ	Exclusive Economic Zone
MSY	Maximum Sustainable Yield
NWHI	Northwestern Hawaiian Islands
Slipper lobster	Any crustacean of the Family Scyllaridae
Spiny lobster	*Panulirus marginatus* or *P. penicillatus*
SPR	Spawning Potential Ratio (related to SSBR, spawning stock biomass per recruit)
VMS	Vessel monitoring system

<u>Legislation</u>

APA	Administrative Procedure Act
CZMA	Coastal Zone Management Act
ESA	Endangered Species Act
Magnuson Act	Magnuson Fishery Conservation and Management Act
MMPA	Marine Mammal Protection Act
NEPA	National Environmental Policy Act
PRA	Paper Work Reduction Act
RFA	Regulatory Flexibility Act

3.0 EXISTING MANAGEMENT MEASURES

The FMP for the Crustacean Fisheries of the Western Pacific Region was developed by the Council and approved by the Secretary; the final rule implementing the FMP regulations became effective on 9 March 1983 (48 FR 5560[2], 7 February 1983). Please refer to the FMP for details (WPRFMC, 1983).

The FMP has been amended eight times in response to changing conditions in the fishery. The FMP regulates fishing for crustaceans (mostly spiny and slipper lobsters) in EEZ waters around the NWHI (50 CFR 681 Subpart B). The FMP also regulates fishing in the EEZ around the main Hawaiian Islands (50 CFR 681 Subpart C), even though most lobster fishing in the main Hawaiian Islands occurs in state, not federal, waters. There are currently no regulations for EEZ waters around the Commonwealth of the Northern Mariana Islands, US Pacific island possessions, American Samoa, and Guam because no substantial lobster fisheries exist there. Regulations for the latter two areas would be developed at the first indications of any significant fishery. The

[2] 48 FR 5560 is read "*Federal Register*, Volume 48, page 5560".

4.0 BACKGROUND AND NEED FOR ACTION

4.1 Management Objectives

The objectives set by the Council in the original FMP were (WPRFMC, 1983):

- To ensure the long term productivity of the stock and prevent overfishing.
- To promote the efficient contribution of the spiny lobster resource to the US economy.
- To collect and analyze biological and economic information about the lobster fishery and improve the basis for conservation and management in the future.
- To prevent unfavorable impacts of the fishery on the Hawaiian monk seal and other endangered and threatened species.

The Council affirms that these objectives continue to be appropriate for the fishery, but acknowledges that the explanation of the meaning of the first objective, as expressed on page 33 in the original FMP, needs to be understood in the context of current information. In that explanation, the Council, based on information available at the time, indicated that ensuring the long-term productivity of the stock meant (among other things) "preventing the harvest and incidental mortality of small or juvenile lobsters, which is biologically and economically wasteful." At the time, it was not known (as it is now) that the mortality of captured and discarded lobsters could be very high. It was then thought that there would not be a significant loss from handling small lobsters and from predation on caught and discarded lobsters by fish and other animals. The Council included an escape vent requirement to prevent the capture of small lobsters, but the amounts of sub-legal and egg-bearing (berried female) lobsters harvested still remained high (50% or more of the total catch in some areas). Please refer to Section 5.1.2 for a description of how the Council proposes to remedy this situation.

4.2 Description of Fishery

Please refer to Dollar (1995), attached as Appendix 1.

Establishment of Limited Entry and Quota System

The NWHI lobster fishery is managed by NMFS and the Council under the FMP adopted in 1983. The FMP defined a minimum legal size for harvested lobsters, required the use of escape vents on traps, prohibited the retention of egg-bearing females, and required vessel captains to submit logbooks of daily catch and fishing effort. Lobster landings reached a maximum in 1984 and gradually declined during the years 1985 through 1989. A substantial decrease in landings and catch-per-unit-effort (CPUE) was observed in 1990 and continued through 1991, prompting an emergency closure of the fishery from 8 May through 11 November 1991. In response to the substantial decline in CPUE in 1991, the FMP was amended in 1992 (Amendment 7) to include an annual 6-month closed season from January through June, limit entry into the fishery and establish an annual catch quota. The catch quota procedure, based on a dynamic population model, set harvests at a level that would provide an economically viable CPUE (1.0 lobster/trap-haul), while protecting spawning stock biomass from over-harvest. The quota was based on an optimal biomass (constant escapement) approach, which allowed surplus production to be harvested if the population was above the optimal level. Table 1 summarizes the relative catch of adult, sub-adult and berried female lobsters from the NWHI fishery.

Table 1. NWHI Combined Spiny and Slipper Lobster Catch Composition.

Year	No. Legal	%	No. Sublegal	%	No. Berried	%	Total
1985	2,034,164	74.2	451,400	16.5	253,491	9.3	2,739,055
1986	1,848,838	74.7	352,537	14.2	274,210	11.1	2,475,585
1987	802,206	65.9	269,625	22.2	144,340	11.9	1,216,171
1988	1,061,839	67.8	348,400	22.2	156,207	10.0	1,566,446
1989	1,166,032	64.0	438,044	24.0	217,755	12.0	1,821,831
1990	777,444	50.3	520,447	33.6	248,439	16.1	1,546,330
1991	167,054	41.3	200,713	49.8	35,110	8.7	402,877
1992	427,013	48.6	340,331	38.7	112,140	12.7	879,484
1993	Fishery Closed						
1994	130,979	48.5	88,859	32.9	50,297	18.6	270,135
1995*	38,257	37.6	42,505	41.7	21,058	20.7	101,820

* One vessel operating under experimental fishing permit

Summary of the Fisheries since 1992

Fishery performance has been variable since the quota system went into effect. In 1992, catch and effort from the NWHI lobster fishery in 1992 were 427,013 spiny and slipper lobsters harvested by 721,682 trap-hauls, respectively, resulting in an annual CPUE of 0.59 lobster/trap-haul. A portion of this catch was made early in 1992, before the new quota and limited entry system were implemented. After the limited-entry portion of the FMP was approved in April 1992, the fishery was closed until July. During the July-December fishing season, 353,221 lobsters (81% of the final quota) were caught by 582,801 trap-hauls, for an average fishing season CPUE of 0.61 lobster/trap-haul. The 1990 and 1991 CPUEs were 0.66 and 0.56 lobster/trap-haul, respectively.

Analyses based on commercial fishery data from 1983 through 1992 indicated that recruitment to the fishery dropped by 50% after 1989. Parameter estimates from this analysis were used to forecast the 1993 quota formula as outlined in Amendment 7 to the FMP. Under the guidelines in Amendment 7, the forecasted-population model indicated that lobster population would not have recovered sufficiently by July 1993 to allow a commercial fishery that could attain an average CPUE of 1.0 lobster/trap-haul during the 1993 fishing season. Therefore, the NMFS closed the fishery.

Research trapping during June 1993 indicated that spiny lobster CPUE increased slightly from 1992 to 1993 at Maro Reef and Necker Island. The spawning biomass in both areas increased, but remained low compared to earlier years of the fishery. Using commercial fishery data from 1983 through 1992, the dynamic population model estimated a preliminary 1994 harvest quota of 200,000 lobsters (combined spiny and slipper species). The final quota was determined in August 1994 to be 20,000 lobsters, using a combination of pre-season research data and commercial logbook data from the first month of fishing.

Attempt to Resolve Problems with Amendment 8

Against this backdrop, the Council developed and submitted proposed Amendment 8, based on the recommendations of a review group of scientists, managers and permit holders. The review group had reported to the Council that the discussion in the FMP of the annual quota determination was unclear regarding the revision of quota formula parameters. The group recommended that it be clarified that the formula does not change, but the parameter estimates used in the formula are updated annually. Some confusion had also arisen regarding use of the term "initial quota". The review group indicated its view that the Council intended to use the "initial quota" as early notice to fishermen of what the quota was likely to be for the year. Fishermen could then make their business decisions early in the year, and vessels would not be forced to fish in July if the quota was small and likely to be unprofitable.

In addition, the review group recommended that changes be made to the regulations to provide a discretionary mechanism regarding closure of the fishery when the forecasted quota is zero or very low. With such changes, the Regional Director (RD) with concurrence from the Council, would be able to 1) close the fishery, or 2) allow some level of fishing for some period of time (to be determined by the RD and Council) with the intention of collecting fisheries data or alleviating special economic hardship cases, or unusual hardship cases (e.g., illness or loss of vessel).

These measures, along with elimination of the "use-or-lose" provision, were proposed in Amendment 8. As noted earlier, the framework procedures and associated definition of "forecast quota" rather than "initial quota" were disapproved. The events of 1994 and 1995 made it clear that there were more fundamental problems that needed to be resolved.

First, in 1994, the fishery was opened July 1 with an initial quota of 200,000 lobsters. The fishery harvested more than 65,000 lobsters in the first month with a CPUE of 0.9 lobster/trap-haul. Data from the first month of fishing, and the target CPUE of 1.0 lobster/trap-haul, were used to derive a final quota of just 20,000 lobsters. This made it clear that the quota formula was overly sensitive to small changes in CPUE. Indeed, a 10% change in CPUE resulted in a 90% change in the quota. NMFS used emergency rules to close the fishery and minimize any further fishing in excess of the final quota. Nonetheless, total harvest by the time the fishery closed was about 130,000 lobsters, less than the initial published quota, but far greater than the final quota.

Second, upon finding that the initial quota for 1995 would be only 38,000 lobsters, NMFS concluded that it could not be assured of limiting the fishery to that level due to administrative procedural requirements. NMFS therefore announced that the commercial fishery would be closed and that NMFS would work with permit holders to determine if experimental fishing, as permitted under the FMP, could allow a harvest to generate much-needed commercial-style fishery data without a risk of exceeding what would have been the quota level. An EFP was approved and the data from the vessel's one trip is summarized in Table 1 (above).

4.3 Status of NWHI Lobster Stocks

Please refer to Haight and DiNardo (1995), attached as Appendix 2.

After discovery in the mid 1970s, the lobster fishery grew rapidly with landings reaching a peak of 2.37 million pounds (combined spiny and slipper lobsters whole weight) in 1985. After the initial period of growth in 1982-86, the fishery declined, both in terms of ex-vessel revenue and landings. The NMFS research assessment cruise in 1990 documented that the significant reduction in spiny lobster CPUE values for adult lobster caught in the commercial fishery extended to all spiny lobster age classes at Maro Reef. The depressed CPUE continued from 1991-94. This trend persists despite significant reductions in commercial fishing effort at Maro Reef during 1991-92 and 1994, and a fishery closure in 1993. A similar trend was observed nearby at Laysan Island (70 nm to the northwest of Maro Reef), an area in which commercial harvest has been prohibited since the beginning of the commercial fishery.

This allopatric reduction in abundance suggests that the larval recruitment mechanism of the two areas may be linked by local oceanographic conditions. In contrast, recruitment of 2-yr-old lobsters to Necker Island, 360 nm to the southeast of Maro Reef, remained fairly constant throughout the time series. Polovina and Mitchum (1992) found recruitment of spiny lobster to Maro Reef to be correlated with the strength of the subtropical countercurrent, suggesting that mesoscale oceanographic features may impact the transport and survival of lobster larvae during their 11-12 month pelagic larval cycle. Continued recruitment of spiny lobster to Necker Island suggests that the lower southeastern end of the NWHI is not linked to the same oceanographic or recruitment processes as the northwestern end of the archipelago. Because the oceanographic processes which appear to affect recruitment at the northwestern portion of the NWHI occur in approximately decadal cycles (Polovina and Mitchum, 1992; Polovina, et al., 1994), the spiny lobster stocks may remain at the present lower level of production for several years.

4.4 Management Operations -- Permits and Quota Reporting

Please refer to Wetherall, et al. (1995), attached as Appendix 3.

The NWHI lobster quota is monitored by the NMFS primarily through at-sea reports and daily logbooks. Each year, the Regional Director is authorized to establish in-season reporting requirements as needed to monitor the fishery against the quota. Generally, at-sea reports are sent from vessel operators to land bases which, in turn, call them into the NMFS Pacific Area Office. These reports must be received at least weekly while the vessel is fishing, and there have been few difficulties with this system. The fishery is closed by publication of a notice in the *Federal Register* announcing the date the quota is expected to be taken and the date after which further landings of lobster would be prohibited. For the purposes of achieving a timely closure of the fishery, however, the Council has concluded that the Regional Director should be able to close the fishery by direct notice to permit holders, with a notice in the *Federal Register* to be processed as quickly as practicable. This would minimize the probability of premature closure and of excessive harvest due to procedural delays.

4.5 Comparison of NWHI fishery to Other Lobster Fisheries

Fisheries for spiny lobsters occur around the world and management of these fisheries use many of the same measures as this FMP, but there are also some notable differences among them.

There are several different lobster species and fisheries in Australia. The largest fishery is the Western Australian rock lobster (*Panulirus cygnus*) fishery with annual catches exceeding 10,000 mt from 668 licensed vessels generating a gross income of $250 million. Management measures in this fishery include minimum size, ban on retention of egg bearing females, closed season, limited entry, and escape vents in traps. The Australia spiny lobster stock is heavily exploited with current egg production estimated at 15-20% of unexploited levels (Brown and Phillips, 1994).

The New Zealand spiny lobster fishery for *Jasus edwardsii* lands about 4,000 mt annually from 650 vessels with management measures consisting of a limited entry, transferable quotas, and a minimum size.

There are currently four US lobster fisheries managed under the Magnuson Act -- American lobsters off the mid-Atlantic and New England states, spiny and slipper lobsters off the Gulf of Mexico and South Atlantic states, spiny lobsters around Puerto Rico and US Virgin Islands, and spiny and slipper lobsters in the western Pacific region.

The Florida fishery for *P. argus* lands 2500 mt annually and is regulated with a minimum size and trap limits. The Florida fishery permits the capture and retention of lobsters below the minimum size for use as bait in their traps. No more than 100 sublegal lobsters may be carried on board for use as attractants (50 CFR 640.21). It is estimated that 47% of these sublegal lobsters die as a result (Hunt, 1994). There is no quota, and there is no requirement for escape vents in the traps.

The spiny lobster fishery in Puerto Rico and US Virgin Islands also has minimum size and harvest limitations (50 CFR 645.20 and 645.21). In this fishery, both sub-legal and egg-bearing lobsters may be retained for use as bait. There is no requirement for escape vents in the traps.

The NWHI lobster fishery has management measures similar to those of the other fisheries, including limited entry, escape vents, and a 6-month closed season (January through June). Further, the NWHI has the added unique measure of closing waters within 20 nm of Laysan Island and waters shallower than 10 fm at all other islands to lobster fishing. With the exception of the New Zealand fishery, the NWHI fishery is the only fishery to have a harvest quota which is thought to be a more effective measure in limiting exploitation rate than effort and size limit controls as used in the Australian fishery.

4.6 Need for Action

The quota system established by Amendment 7 to the FMP is not achieving the desired objectives, and the measures approved in Amendment 8 did not resolve some of the fundamental problems of the management system. The system, which includes a formula for establishing a quota in a two-step process each year, is intended to be conservative by ensuring a healthy adult biomass, and to be responsive to the need to provide industry with effective notice in advance of the likely quota for the year. The February notice of the initial, or forecast, quota is to provide the lead time for permit holders to decide whether to enter the fishery. The August setting of the final quota based on actual catch and effort data is intended to ensure that accurate and current stock and fishery information is used to set the final quota. As the system has operated, however, several problems arise:

- Quota Instability. From year to year, the quota can vary widely from zero to over one million lobsters per year. While the quota formula accommodates for uncertainty, the in-season adjustment reintroduces variability into the quota process;

- Unpredictability. There is no clear relationship between adult biomass in one year and successful recruitment to the stock in a succeeding year. There is no ability to predict with certainty what the quota level would be in a future year based on stock size and fishing in prior years.

- Questionable Statistical Validity. The use of data from a single fishing month to derive the final quota was intended to refine the final quota as much as possible, so that optimal benefits could be obtained from the fishery. It has become apparent that this approach may not be justified, especially if the initial quota is low and the amount of data from the first month of fishing is small.

- Manageability. Under the existing closure procedures, the quota cannot be effectively managed in a year when the initial quota is small. The fleet capacity is sufficient to harvest a small quota very quickly, and a small quota can easily be exceeded. While this probably does not have long-term adverse effects on the stocks (because the quota the following year would reflect the over-harvest the preceding year), it creates a perception that the fishery is not being effectively managed.

- Administrative Complexity. Due to procedural requirements in the FMP and regulatory process, it is difficult to complete and process quota determinations (especially the final quota) and closure notices on a timely basis with adequate notice to fishermen, while still protecting the stock from overfishing or harvesting beyond the quota level.

These management problems should be viewed against the backdrop of concern about the status and productivity of the lobster stocks of the NWHI. The original quota system was developed when the lobster stocks apparently were more productive than is now the case. At that time, it was believed that a standing stock of about 1.4 million adult lobsters would support a fishery of up to one million lobsters per year with a CPUE of 1.0 lobster per trap haul. This was based on catch and effort rates for the fishery in the 1980s. Actual experience, however, suggests that lobster stock productivity is now at a lower level, corresponding to prevailing environmental conditions in the NWHI.

4.7 Analysis of Alternative Harvest Policies for the NWHI Lobster Fishery

Please refer to DiNardo (In prep.), attached as Appendix 4.

In 1994, the Council held a technical review of the scientific advice and catch quota setting procedure for the NWHI lobster fishery. The review was in response to concern among the fishing industry, the Council, and NMFS that the existing quota setting procedure was overly-sensitive to fluctuations in CPUE which resulted in highly variable quotas and has required closures for all or part of recent seasons. The review panel recommended that revised quota setting procedures be investigated, where the uncertainty in the assessment is incorporated and the goal is to find a harvest guideline based on a low risk of the stock being overfished in any specified year.

In response to the technical review, the Council asked NMFS to investigate new procedures for establishing a harvest guideline. The Council and NMFS acknowledge that the relationship between spawning stock and recruitment is poorly understood, and that this adds to the uncertainty associated with these models used to determine the preferred management action. A key objective of NMFS and the Council is to assure that in setting the catch limit the lobster spawning biomass is not reduced to levels so low as to undermine future recruitment to the population. NMFS staff identified alternative harvest policies, described how the efficacy of alternative harvest policies is assessed and discussed the analytical methodology used to compute long-term effects of policies on the dynamics of NWHI lobster populations and lobster fishery. To account for uncertainties related to the stock-recruitment relationship, the model includes very conservative assumptions that are designed to offset such uncertainties.

The work conducted by the NMFS to investigate alternative harvest policies in the NWHI lobster fishery is described in detail in Appendix 4. The advantages and disadvantages of the three alternatives are summarized briefly in Table 2. A-stet

Table 2. Summary table of harvest strategy pros and cons (from DiNardo, In prep.).

Constant Escapement		
Con:	a)	overly-sensitive to uncertainty
	b)	higher risks of overfishing
	c)	High incidence of closing the fishery unnecessarily
	d)	gives the appearance of an overfished stock
Pro:	a)	promotes "faster" rebuilding of stocks due to unnecessary closures of the fishery
	b)	low to moderate catch variability
Constant Catch		
Con:	a)	does not insure protection of the population during bust years nor does it reap benefits during boom years
Pro:	a)	robust to uncertainty
	b)	lowest overall catch variability
	c)	high allowable catch rates and highest CPUEs
	d)	highest average annual SPRs relative to tested levels of risk
Constant Harvest Rate		
Con:	a)	highest catch variability
	b)	lowest average annual SPRs relative to tested levels of risk
Pro:	a)	insures protection of the population during bust years and during boom years benefits are realized
	b)	highest allowable catches with moderate to high CPUEs
	c)	robust to uncertainty

5.0 PROPOSED ACTIONS AND IMPACTS

5.1 Proposed Actions for Amendment 9

5.1.1 Establish an annual harvest guideline system based on constant harvest rate and specific risk of overfishing.

The proposed Constant Harvest Rate management policy would establish a harvest guideline for the NWHI lobster fishery that is proportional to the estimated exploitable population size. The guideline would be set annually by the Regional Director, using fishery and research data, the harvest guideline formula, and other relevant information. The harvest guideline is expressed in terms of the allowable total number of lobsters (spiny and slipper lobsters combined) to be caught. In approving the new harvest guideline system for the NWHI lobster fishery, the Council believes that the Constant Rate Harvest policy best ensures the protection of the lobster population during poor years, and optimizes fishery benefits during the good years. The new program gives fishermen the highest average annual catches with moderate to high CPUEs, and enables fisheries scientists to better assess the stocks. Under the proposed system, with retain-all lobsters and a fixed level of risk of 10%, the lowest identified annual SPR is about 0.5. This is still more than twice as high as the overfishing definition of SPR=0.2, and provides a large buffer that will ensure that overfishing does not occur.

The annual harvest guideline would be derived using two models: a population model described in FMP Amendment 7 (Section 4.2.2), and a harvest guideline strategy model contained in this amendment (See Appendix 4). Information used by NMFS in formulating the annual harvest guideline is obtained from daily lobster catch and sales reports from previous years, as well as research cruises and other sources. The NMFS is responsible for assessing the status of the NWHI lobster stocks each year. These stock assessments provide estimates of population size which are the annual data input used to formulate the annual harvest guideline.

The population model expresses the number of exploitable lobsters in a given month, as a function of the number of exploitable lobster in the previous month, as adjusted for natural mortality, fishing mortality, and recruitment. Monthly catches of spiny and slipper lobster are pooled across fishing areas, or banks, to calculate a NWHI monthly average CPUE (see Haight and Polovina, 1993).

The harvest guideline model relates a given level of risk to a resultant SPR level and generates a harvest rate for each level of risk. The models calculate the annual harvest guideline in the following manner:

$$\text{Harvest Guideline} = (\text{preferred harvest guideline policy})(N_{opt})$$

where the preferred harvest guideline policy is expressed as the percent of the exploitable lobster population that would be harvested at a specific level of risk, and N_{opt} is the number of exploitable lobsters derived from the population model. It should be noted that if the preferred policy was the Constant Catch strategy described in Appendix 4, the policy's target would be expressed as number of lobster which is independent of N_{opt} obtained from the annual stock assessment. Please refer to Section 4.7.3 and Appendix 4 for a description of the model used to simulate the population dynamics and performance statistics for the constant harvest rate policy.

For example, the annual harvest guideline derived under the preferred Constant Harvest Rate strategy for a retain-all fishery, minimum size at capture equal to 36.0 mm, risk level of 10%, and a conservative tail width at maturity of 50.6 mm, the corresponding harvest rate applied to the estimated stock would be about 22%. If the exploitable stock (N_{opt}) is estimated to be 1,300,000 lobsters, the projected harvest guideline would then be about 286,000 lobsters.

The harvest guideline would be announced in the *Federal Register* no later than 31 March in each year, prior to the fishing season which begins on 1 July. NMFS also would directly notify all current permit holders in the fishery about the harvest guideline.

5.1.2 Allow retention of egg-bearing female lobsters and eliminate size limits.

Please refer to Kobayashi (In prep.), attached as Appendix 5.

The proposal to retain all landed lobsters would eliminate the existing minimum size regulation and prohibition on retaining berried female lobsters in the NWHI fishery. The change to a retain-all fishery is a response to two unique aspects of the NWHI ecosystem and fishery.

First, the NWHI lobster fishery is unique from all other spiny lobster fisheries in that there is only a very small fishery in the NWHI that is directed at only some of the natural predators of these lobsters. These predators include snappers, jacks, sharks, octopuses, and others, but the handful of boats that fish for bottomfish in the NWHI target only snappers, and sometimes jacks. Other spiny lobster fisheries around the world occur relatively close to ports and population centers where recreational and commercial fisheries have reduced the abundance of lobster predators. The high abundance of predators in the NWHI has resulted in natural lobster mortality that may be twice the level as other areas. For example, it is estimated that annually 40 % of the NWHI spiny lobsters suffer natural mortality largely due to non-human predation, while natural mortality for the Australian spiny lobster population is estimated at about one-half that level.

Second, in the NWHI fishery vessels operate by setting strings of traps composed of 60 to 300 traps per string, compared to other spiny lobster fisheries that haul one or a few traps at a time. In retrieving these strings in the NWHI fishery, traps are brought onboard the vessel at a rate of about one trap per 15-20 seconds. All the traps are stored on board the vessel until they are re-baited and prepared for setting the next morning. Currently, some vessel operators continuously discard undersized and egg-bearing lobsters, along with used bait, as traps are brought aboard. Other operators leave the lobsters on board until all traps from a string are boated.

The mandatory escape vents reduce the number of undersized lobsters caught in the traps by about 50 %, but the proportion of undersized lobsters caught can still be large. These small lobsters can suffer broken appendages from handling, mortality or blindness from exposure to the tropical sun while on deck, and predation between the time they are discarded and reach benthic shelter (see also Section 5.2.6). In the Australian fishery, it is estimated that 15% of the discarded lobsters die as a result of exposure, displacement, predation and handling injuries (Brown and Caputi, 1986). In the NWHI fishery this mortality rate has not been determined, but it is likely to be higher due to the greater abundance of predators, the use of long strings of traps and, and strong ultraviolet radiation.

Handling mortality can be very high. The NMFS Honolulu Laboratory has documented on video predation by large jacks and other predators that are abundant in the NWHI. Further, there is now more information on fishing procedures than when the FMP was first developed, and it is clear the risk of injury and subsequent mortality to handled lobsters is quite high. Thus, the existing system may prevent some capture of sub-legal lobsters but it does not prevent the incidental mortality of sub-legal and egg-bearing female lobsters that are caught and discarded. Further, the quota set under the existing system fails to account for such mortality. The proposed new measures, however, would continue to prevent the capture of about 50% of the small lobsters that enter traps (through mandatory escape vents). In addition, there would be little incidental post-capture mortality of small and egg-bearing lobsters because all lobsters caught would be kept and counted against the annual harvest guideline. The harvest guideline would equate to estimated total fishery mortality, and the current uncertainty associated with the unknown rate of mortality of small and egg-bearing female lobsters would be eliminated.

Yield-per-recruit calculations have shown that, given the high natural mortality of NWHI lobsters, a "retain-all" fishery would improve the yield-per-recruit (see Kobayashi, In prep., Appendix 5). With harvest guideline management, spawning biomass can be protected, so together, a retain-all and harvest guideline strategy addresses both recruitment and growth overfishing. While the mortality of discarded lobsters is not known, several documented cases indicate that it can be very high due to handling as well as due to predation by jacks (f. Carangidae). The harvest guideline together with allowing the retention of all lobsters should be an effective approach for the unique conditions in the NWHI fishery to protect spawning biomass while reducing waste and bycatch.

A key economic issue in the retain-all fishery is the trade-off between catch rate and price discounts for small or berried lobsters. Instead of "yield per recruit", we could call this "revenue per recruit", although we are actually referring to revenue per unit effort (*rpue*) in the catch of lobsters under the alternative retention scenarios. Analyses show that the price discount for a catch that includes currently legal and small lobsters is 23% per lobster retained, while the price discount for currently legal, berried *and* small lobsters is 29% per lobster. However, the *rpue* does not vary as dramatically because of the higher catch rate under the liberalized retention options. The highest *rpue* under the 10% risk level is Option No. 1 (Constant Catch, no berried, and 0% discard mortality), but the *rpue* under the proportional harvest strategy for *no berried* is only a 9% lower level of revenue, while the equivalent *legals only* (No. 16) is a 29% loss in revenue. The preferred alternative, *retain-all* (No. 22), is a 15% loss in revenue per trap. Please see Appendix 8.

The Council acknowledges that a potential consequence of a retain-all fishery is the selective retention of certain size-classes of lobsters (high-grading). This could be true especially if the market for smaller lobsters is limited, or there are significant price differentials between small, berried, and legal-sized lobsters. While there appears to be an established market for small lobsters in Hawaii, a price differential based on size and condition of lobsters does exist. When high-grading occurs, the true catch is greater than the reported landings. This causes the actual SPR to be lower then predicted for a specified level of catch. This may increase the risk of overfishing if the adopted catch level is already high, and the associated SPR is close to the overfishing definition threshold.

High-grading is not, however, likely to be problematic in the NWHI lobster fishery because of the type of harvest guideline and the distant-water nature of this fishery. Presently, a total fleet harvest guideline is set, and fishing trips generally last for 4-8 weeks. Vessels operate independently, and fishermen are likely to retain all lobsters caught to ensure a profit. Because the potential for high-grading exists, the Council selected the Constant Harvest Rate (CHR) strategy. Additional safeguards to the population are achieved by using a conservative level of risk (10%), or a conservative estimate of exploitable biomass. Under the CHR strategy, an annual assessment of lobster abundance is required to determine the fishing harvest guideline. Significant shifts in population size resulting from high-grading would be detected during the assessment and accounted for when setting the next years' harvest guideline in the form of a reduced allowable catch. In essence, the CHR strategy is self regulating and can account for unpredictable removals of lobsters from the population either through natural or unnatural causes.

The new program provides two additional mechanisms which would reduce the risk of high-grading, or offset the effects if high-grading occurs. First, the total catch will be monitored to determine when the harvest guideline has been reached and the fishery should be closed. If fishermen report catches of small and berried lobsters but do not retain them, the catch will still be counted against the harvest guideline. If fishermen do not record any small or berried lobsters in their catch, then landings packing slips that indicate sales of such lobsters will be evidence of non-compliance with the requirement to maintain accurate logbooks. Further, if there are no records on catch and/or sales of small and berried lobsters, there will be no data on these catches to enter into the database for use in calculating the next year's harvest guideline, which is based on total exploitable biomass, including small and berried lobster. This would have the effect of lowering the estimated exploitable biomass and, in turn, lowering the harvest guideline for the next year.

5.1.3 Eliminate in-season harvest guideline adjustment.

This amendment removes from current federal regulations (50 CFR 681.31) the in-season quota adjustment procedures that were established under Amendment 7. Under the new harvest limitation program, unless authorized under the framework process or emergency rule, there would be no adjustment to the annual harvest guideline during the fishing season (1 July - 31 December, or until the harvest guideline is reached). The Council had previously approved an adjustable quota to account for any lobster recruitment or growth that had occurred during the six-month closed season immediately preceding the opening of the fishery. This approach, however, has resulted not only in increasing the level of uncertainty in stock assessments, but also has proven to be operationally and administratively cumbersome. The Council believes that without an in-season adjustment to the harvest guideline, assessment of the lobster stocks, and management and operation of the NWHI lobster fishery will be substantially improved.

5.1.4 Authorize NMFS Regional Director to close the fishery.

The Council believes that the existing procedures for closing the fishery can be streamlined by allowing the Regional Director to close the fishery by direct notice to the fishery participants. Further, the Council believes that the subsequent closure announcement to the public via publication in the *Federal Register* should not impede prompt closure of the fishery, but should be accomplished on as timely a basis as practicable. Because the NWHI is so remote, closure of the lobster fishery must be executed without delay when the annual harvest guideline has been reached to minimize lobster catches that are in excess of the established annual harvest guideline. Amendment 9 ensures prompt closure of the fishery by authorizing the Regional Director to 1) determine, on the basis of information received during the open season from fishing vessels, when the harvest guideline will be reached, 2) notify both the permit holder and operator of each fishing vessel of the specific date after which fishing for lobsters and/or further landings of lobsters harvested in the NWHI would be prohibited, and 3) make the closure notice announcement not less than 7 days prior to the effective date of the closure.

5.1.5 Establish framework procedures

Amendment 9 establishes frameworking procedures that enable the Council to change the regulatory regime governing the lobster fishery through a rulemaking process. The procedures specify how certain new measures (e.g., area-specific harvest limits, individual transferable quotas, bycatch limits) may be promulgated in response to changes that may occur rapidly in the fishery, as well as how established measures (e.g., area closures, fishing season, gear requirements) may be revised without the Council having to develop and implement an FMP amendment. The management flexibility afforded to the Council does not, however, preclude the Secretary from taking emergency regulatory action under the Magnuson Act, if such action is deemed necessary.

The framework procedures would be triggered by new information demonstrating that there are biological, social or economic problems in the fishery. These concerns and supporting information might be brought to the Council's attention by the Plan Team, Advisory Panel, SSC, participants in the lobster fishery, enforcement officials, NMFS, or other sources. At an ensuing Council meeting, discussion would consider whether changes to existing or new conservation and management measures would resolve the problem(s). If the Council determines that action is needed, a document that describes the problem and proposed regulatory action(s) would be prepared and submitted to the Regional Director, including a recommendation to initiate rulemaking procedures. If the Regional Director approves part or all of the Council's recommendations, the new measures may be promulgated following their publication as a final rule in the *Federal Register*.

The Council has determined that existing (established) measures are measures that have been evaluated and applied in the past. Adjustments under the framework procedures must be consistent with the original intent of the measure, and within the scope of analysis in previous documents supporting the existing measures. New measures, on the other hand, are those that have not been used before in the fishery. Included in this definition are measures that have been previously considered by the Council but rejected. Also, their specific impacts on the stocks and on permit holders have not been evaluated in the context of current conditions.

5.1.6 Conduct five-year review.

The Council has determined that a comprehensive review of the NWHI lobster management system should be undertaken after five years to evaluate the overall effectiveness of the management program. Although an annual fishery report would be prepared by the Plan Team, the five-year review would give the Council a broader perspective on whether, and how, the performance of the management program could be improved.

5.1.7 Evaluate vessel monitoring systems for application in the lobster fishery.

There is potential for using a remote electronic fishing vessel monitoring system (VMS) in the NWHI lobster fishery. The Council believes that the ability to monitor the locations of fishing vessels and their activities, and to communicate electronically with vessel operators via a remote VMS could increase the effectiveness of fishery management programs in the western Pacific region. A VMS is now being used in a three-year pilot program for the Hawaii-based pelagic longline fishery, and preliminary results indicate the system is providing the intended benefits, i.e., enforcement of closed areas.

Although the Council generally supports the use of VMS, it believes that a requirement for a system in the NWHI lobster fishery is premature. A number of administrative and operational questions have yet to be addressed and resolved, such as who is to bear the cost of VMS acquisition and installation, and what are the logistics under which vessel operators should be required to report lobster catch and effort data via electronic messaging, and others. Before the Council makes a determination on the application of VMS in this fishery, it must evaluate the 1995 experimental lobster fishing program, which included the use of VMS. The Council also must hold discussions on VMS with lobster permit holders, vessel operators, data managers and other involved agencies and individuals. The Council may approve the use of VMS in the future under the framework process proposed in this amendment.

5.2 Rejected Alternatives

5.2.1 Quota systems

The Council is aware that the term "quota" has a particular use or meaning in the context of fishery management plans. Quotas are viewed as rigid and immutable harvest levels which should never be exceeded. To exceed a quota is viewed by some to mean a fishery has been overfished, and fishing in excess of a quota is taken to warrant emergency action to prevent further fishing, even if there is no likely long-term adverse impact on the stocks. As such, a quota can result in the appearance of overfishing, even if it is not the reality. The Council wishes to avoid the potential for this misunderstanding. Therefore, the Council would replace the term "quota" with "harvest guideline". A harvest guideline is meant to establish a limit on the harvest; the fishery should be closed as closely as practicable to the level of the harvest guideline. However, it is recognized that the Regional Director will face uncertainty in projecting the date on which the harvest guideline would be expected to be reached. Catch rates and total deployed effort can change very rapidly, and the Regional Director's projection could allow fishing beyond the harvest guideline by some amount, presumably small, or could result in harvest below the allowable level. The Council recognizes the potential for incorrect projections and believes these will not be to the long-term detriment of the stocks or the fishery. Since the total catch would be incorporated into the model for derivation of the next year's harvest guideline, harvesting slightly above the harvest guideline in one year would result in a lower harvest guideline the following year.

5.2.2 Harvest guideline based on constant escapement

The existing system entails a quota based on ensuring that the adult biomass at the end of a fishing year will be at least a minimum size (1.4 million lobsters at present). Under the existing quota formula, this approach results in a quota with enormous variability and with a relatively high proportion of years in which the quota is zero and the fishery is closed. This can be very difficult for the harvesters and marketers, who need some supply of lobster each year, however small the supply, to maintain a place in the lobster market. The Council believes that this approach is unnecessarily rigid and has the unintended consequence of putting Hawaii lobster fishermen and dealers at a disadvantage relative to foreign lobster fisheries, whose products readily occupy empty market niches. The Council believes the Constant Harvest Rate approach would better provide for ongoing participation in the fisheries and markets.

5.2.3 Harvest guideline based on constant catch

Under this approach, the harvest guideline would be set at a fixed level for a number of years. The intent would be to stabilize the fishery and markets. However, this approach would not provide the flexibility to take advantage of a rebound in the lobster stocks that could occur at any time in the next few years, and could result in too high a rate of exploitation in years of low abundance.

5.2.4 Maintain in-season quota adjustment

The existing system calls for the Regional Director to announce an initial quota and then, after the first month of fishing, to announce the final quota for the fishing year. The use of actual catch and effort data was intended to ensure that current stock conditions would be used, to the extent possible, in setting the final quota. This has not been an effective approach. The initial quota was not meant to be an actual quota but rather a notification of likely quota, but it has been used as a quota to prevent opening of the fishery. Further, while the initial quota is derived from a formula in which uncertainty has been reduced, the use of the first month of actual fishery data reintroduces uncertainty back into the quota system. The final quota has demonstrated the exceptional sensitivity of the formula to small changes in catch rates, for example, to the extent that a 10% drop in catch rates resulted in a 90% drop in the final quota in 1994. The Council wishes to avoid such problems in the future, and concluded that the in-season adjustment should be eliminated.

5.2.5 Harvest guideline based on higher or lower levels of risk of overfishing

The Council considered a wide range of potential levels of risk of overfishing. The Council noted that the difference in projected average annual catches and SPRs was fairly small between the 5% and 10% risk levels. The Council's SSC indicated that, in its view, given the essentially conservative nature of the fishery model and underlying assumptions, any level of 10% or less would be reasonable. In all cases within this range, the average SPRs were well above the level at which the stocks would be considered overfished. In the Council's judgment, a risk level of 10% provides strong assurance that the stocks will not be overfished. A lower risk level would unnecessarily restrict the fishery, a higher risk level might lead to exceeding the defined level of overfishing, and a range of risk levels would unnecessarily complicate the annual task of establishing a harvest guideline. The 10% level of risk is risk-averse and very conservative, and is probably lower than the risk levels implied in fishery management programs from other areas. This is the first time that a Regional Council has set an explicit level of risk-of-overfishing in an FMP.

The proposed five-year review provides an additional safeguard in that the overall effectiveness of the proposed harvest guideline program can be evaluated with five years of performance and stock assessment data. It also is noted that there will continue to be an annual stock assessment, as well as framework procedures in the event it is found that new measures are needed or a different level of risk is more appropriate.

5.2.6 Modify trap configuration

Escape vents in traps substantially reduce the catch of small lobsters, thus decreasing the risk of overfishing. Escape vents also often increase the catch of larger lobsters, thus improving the optimal use of the resource. Existing NWHI regulations require the use of two panels of four, 67-mm circular escape vents in each trap. The NMFS evaluated the effectiveness of escape vents of various sizes, shapes and placement on the trap, in the laboratory, on research vessels, and on commercial fishing vessels. Everson et al. (1992) concluded that the current escape vent configuration is optimal for reducing the catch of small lobsters and retaining larger lobsters. Larger or smaller escape vents, and vents of different shapes or placement on the traps, are less effective. In addition, given the fact that each trap contains eight escape vents, there is no indication that a larger or smaller trap mesh size would influence either the capture of different sized lobsters or, in turn, the potential for overfishing.

5.2.7 Maintain size limits and prohibition on retention of egg-bearing lobsters

The existing FMP objectives continue to be valid, including the objective of preventing incidental mortality and waste of lobsters. The requirement to discard juvenile and egg-bearing lobsters guarantees waste. While the mortality of discarded lobsters is not clearly understood, there is evidence that it can be high. Experiments conducted by NMFS in the NWHI on lobsters caught in traps and subsequently discarded showed that these lobsters were subject to stress and/or injury resulting in high mortality. The factors inducing stress or injury include 1) the length of time out of the water and subsequent exposure to air, sunlight, and heat, 2) injury resulting from handling, 3) release onto an unsuitable substrate, 4) release into an area outside their home range, 5) general disorientation which may make the lobster more vulnerable to predation, and 6) presence of lobster predators in the vicinity of the fishing vessel at time of discard. The NMFS experiments were conducted in the presence of scuba divers, and showed that, on several occasions, spiny lobsters released in the presence of fish predators (large jacks) were eaten almost immediately. On one occasion, about 10 spiny lobsters were eaten within 10 seconds after being released near the bottom. In addition to predation by jacks, spiny lobsters are known to be eaten by tiger sharks, snappers, other fish, and octopuses that are common in the NWHI.

In addition, NMFS observers aboard commercial NWHI lobster vessels have made similar observations. For example, on the trip recently completed under a NMFS experimental fishing permit, the NMFS observer noted that small and berried lobsters made up a large proportion of the total catch. These lobsters were often left on deck for extended periods of time and appeared moribund upon their discard into the water.

Studies conducted in Australia have shown that a 15% mortality on undersized lobsters occurred if they were transported more than 100 meters away from their home reefs. Undersized spiny lobsters normally are discarded well away from where they were caught. Other studies in Australia show that average damage due to handling (1.5 legs lost per lobster) and average exposure to air (eight minutes) resulted in mortality of undersized spiny lobsters of approximately

15% (Brown and Caputi, 1986). Experiments in Florida also have found evidence that the handling of sublegal spiny lobsters had a negative impact on the stocks (Hunt, 1994).

In summary, the high mortality of sublegal and egg-bearing lobsters that must currently be discarded is wasteful, and adds little to the long-term productivity of the lobster stock. Under Amendment 9, as long as the harvest guideline system controls the total output of the fishery (i.e., fishing mortality), there is little rationale for maintaining the existing minimum size limits and prohibition on the retention of egg-bearing lobsters in the NWHI fishery. The Council's SSC indicated that a 75% mortality rate was appropriate for use in comparing the results of the different management combinations. The SSC favored the retain-all option, which directly incorporates all lobster fishery mortality into the harvest guideline program, and as such, enhances the spawning potential ratio of the lobster stocks.

5.2.8 Require, rather than allow, retention of all lobsters caught

The Plan Team, SSC and Council discussed whether the retain-all provision should be a requirement to retain all lobsters caught, or an option. There was concern that an allowance for retaining all lobsters would lead to high-grading (the retention of only larger lobsters), thus reducing the effectiveness of the retain-all provision. Fishermen and market representatives noted that there is a ready market for all sizes of lobsters, and that under a fleet quota system as exists in the FMP, the possibility that fishermen will high-grade is remote. (This scenario could change if the management system were modified to include individual fishermen's quotas.) The Council, on advice from NMFS Enforcement and NOAA General Counsel, agreed that a *requirement* to retain-all would be impractical and unenforceable.

5.2.9 Limit authority of the Regional Director

In one sense, the Regional Director's authority is quite limited -- the harvest guideline would be derived by formula without opportunity for adjustment following review of a proposed harvest guideline. In other ways, the authority of the Regional Director is enhanced. For example, the Regional Director would be authorized to close the fishery by notice to the permit holders, with a notice to be published in the *Federal Register* on as timely a basis as practicable. The Regional Director would continue to have the authority to direct permit holders with respect to in-season reports so that the progress of the fishery relative to the harvest guideline can be monitored closely and accurately. The Regional Director also would be authorized to institute certain changes in conservation and management measures under specific procedures in the amendment, including consultation with the Council. The Council believes that the Regional Director should have this degree of authority, and that limiting this authority could prevent timely responses to new information about the stocks or the fishery.

5.2.10 Immediately implement a vessel monitoring system

Major uses of remote fishing vessel monitoring systems (VMS) are to determine positions of fishing vessels and, in some cases, their fishing activity, transmit real-time catch and environmental data, and allow efficient ship-to-shore and ship-to-ship messaging. The Council supports the use of VMS in certain fisheries for specific uses, but it has not determined at this time if or how a VMS should be required for the NWHI lobster fishery. Although some lobster fishery permit holders have VMS equipment on their vessels becasue of the requirement in the longline fishery, some vessels do not. Further, longline vessels did not have to bear the cost--NMFS provided the units and their installation. The cost of a VMS unit is several thousand dollars, plus communications costs, and the Council notes that this expense should not be imposed on lobster vessels until it is clear that the benefits warrant the cost. The results of trial evaluations of VMS on the 1995 experimental fishing trip aboard the F/V *Pacific Pride* will be available to the Council and permit holders for consideration. The framework process, described in Section 5.4.1, provides the mechanism by which a VMS requirement can later be instituted by the Council.

5.3 Evaluation of Impacts of Proposed Actions

5.3.1 Biological Impacts

Impacts on Lobster Stocks

The proposed actions are expected to ensure long-term maintenance of healthy lobster stocks. The models developed by the Honolulu Laboratory indicate that lobster stocks will remain healthy over the long term under the new system, with an average SPR above 0.5. This level is well above 0.2 level at which the stocks would be considered overfished. The annual harvest guideline would vary in direct proportion to the estimated adult biomass, and would be higher when stocks were larger. The average harvest guideline would be about 280,000 lobsters per year, with all lobsters taken expected to be retained. The estimated average spawning biomass would be about 1.4 million lobsters, or roughly the target spawning biomass under the existing program. The portion of the stocks in waters within 20 nm of Laysan and shallower than 10 fm around other islands would remain protected from fishing. This closes about 16% of total habitat and should further protect the stocks from overfishing as well as maintaining potential nursery areas for lobsters.

The retain-all approach is relatively untested in lobster fisheries. As noted earlier, there are some unique attributes to this fishery that make the approach attractive. First, it is expected that there would be significant predation on discarded lobsters. The NWHI is far removed from population centers, and there is no commercial or recreational fishery that targets large fish that are predators on lobster, for example, sharks, jacks and octopuses. A video produced by the Honolulu Laboratory documented that predation occurs, although the complete extent of such predation is not known. Second, it is likely there is high mortality associated with the handling and discard of sublegal and egg-bearing lobsters. In some cases, lobsters may be exposed to sunlight and air for extended periods of time and suffer dehydration or blindness. Some lobsters may suffer the loss of one or more appendages. Such lobsters could have serious difficulty surviving even if they were not subject to predation by other animals. There is no scientific evidence demonstrating the actual level of incidental mortality under the existing regulations, but the retain-all approach effectively incorporates what would have been incidental mortality into the overall harvest guideline and thus total fishing-induced mortality is used in the model used to project future harvest guidelines and SPR levels. This is important because sublegal and egg-bearing lobster may make up 50% or more of the total catch in some areas or years (see Table 1 above).

The NMFS has simulated the effects of discard mortality on spiny lobster yield and spawning stock biomass per recruit (Kobayashi, In prep., Appendix 5). That study concluded that if all discarded lobsters survive, then a retain-all fishery would have only minor impacts on lobster stocks. If mortality of the discarded lobsters is high, however, then a retain-all fishery would probably have a positive effect on the stock. The study also noted that evidence to date suggests that high discard mortality is likely, favoring the adoption of a retain-all management plan.

Impacts on Protected Species

The fishery as it would operate under the proposed new program is not expected to affect the status of Hawaiian monk seals or any other listed species or critical habitat.

There are two potential types of effects: direct (i.e., interaction between monk seals and fishing operations) and indirect (fishing activity results in changes in behavior of monk seals or their health). Except for one monk seal that became entangled in a trap bridle and drowned over a decade ago, there is no information to indicate that there have been direct interactions between the lobster fishery and monk seals: no reports of interaction have been submitted by permit holders, and no reports have been received from NWHI field personnel of dead or live monk seals with scars or injuries that suggest interaction with lobster fishing gear. While it is not certain that no interactions have occurred, the best available information indicates there have been no direct interactions.

There has been little fishing in recent years, and the fishery could expand under the proposed new management program, within regulatory limits. This could increase the potential for direct interactions, but the fishery is not likely to expand to former, higher levels in the foreseeable future. The risk of interactions and associated harm to monk seals appears relatively low. The principal fishing areas have been Necker Island, Maro Reef, and Gardner Pinnacles. While monk seals have been observed at these areas, they are not the principal haul out areas where populations are most abundant. Also, fishing is not permitted in waters shallower than 10 fm, which generally encompasses nearshore waters. It is reasonable to expect that the farther the fishery is operating from shore, the less the likelihood of direct interaction or disturbance from fishing activities.

It is unclear whether the fishery has indirect effects on monk seals. The productivity of the stocks of spiny and slipper lobster has declined since the early 1980s. A significant reduction in the catch per unit effort (CPUE) by research vessels was first observed at Maro Reef in 1990 and has persisted despite significant reductions in fishing at Maro Reef during 1991-92 and 1994, and a closure in 1993. A similar trend in research CPUE was observed at Laysan Island, where the fishery has been prohibited since the FMP went into effect. In contrast, recruitment of age 2 lobster to Necker Island remained fairly constant throughout the time series. Recruitment of spiny lobster at Maro Reef appears to correlate with the strength of the subtropical countercurrent, suggesting that mesoscale oceanographic features may impact the transport and survival of lobster larvae in their pelagic stage. The oceanographic processes that appear to affect recruitment occur in approximately decadal cycles.

The proposed new management program is intended to protect the long-term productivity of lobster stocks. Under the new harvest guideline formula, the projected average harvest guideline level would be significantly lower than the one million lobsters per year harvest level the FMP earlier estimated that the stocks could support. The average SPR (the measure of the health of the stocks) would be well above the level at which the stocks would be deemed overfished. To the extent the health of the lobster stocks is maintained, the availability of lobsters as forage for monk seals should be maintained. Lobster exoskeleton remains have been found in monk seal scats, but the relative importance of lobsters in the monk seal diet is unknown. If most fishing occurs in areas where the fishery has been most active in the past, then the populations of lobsters in waters in closest proximity to principal haul out areas would not likely be affected substantially by the fishery.

The relative importance of waters most used by the fishery to the principal haul out areas for Hawaiian monk seals is not known. However, it appears that recruitment at Necker Island, one of the primary fishing areas, has remained relatively constant, while recruitment at Maro Reef has been reduced. This suggests that fishing has not been responsible for the decline of lobster populations. In fact, the NMFS Honolulu Laboratory has not been able to define a stock-recruitment relationship for spiny lobster.

While not known with certainty, there appears to be little risk that the fishery will result in disturbance of seals or modification of their behavior. Fishing is prohibited in waters shallower than 10 fm, and within 20 nm of Laysan Island. The fishery has not been active in waters in proximity to the primary haul out areas. There is no information to indicate that seals change their behavior due to the proximity of lobster fishing vessels.

The FMP, as noted above, would contain broad frameworking procedures to facilitate rapid rulemaking if necessary to deal with problems identified after the amendment is in effect. This would include additional, or new, measures to protect monk seals. Existing measures authorize the RD to close the fishery upon a report of fishery-related mortality of a monk seal, and to require a vessel to carry an observer if necessary.

Impacts on Other Biological and Ecological Resources

No impacts are expected on other living marine resources. The level of fishing and associated use of petroleum resources and discharge of waste products are not significant. Anchors of the vessels could result in slight disturbance of bottom resources, but the impacts would be minor.

5.3.2 Economic impacts (including administrative costs)

Please refer to Regulatory Impact Review, attached as Appendix 8.

Positive economic impacts are expected as a result of this amendment. First, there should be greater stability for the fishery. Inter-annual harvest variability would be reduced, and the probability of a closure of the fishery (and disruption of market relationships) would be greatly reduced. No new costs would be imposed on vessel owners and operators, and the landing of lobsters in ports in the Council's area of concern would not be affected. Vessel operators would have advance notice of the quota to allow them to plan whether to gear up for the lobster fishery.

The ability to monitor and close the fishery on a timely basis would be improved. Framework procedures will allow timely changes in fishery regulations, if needed, to improve the administration of the regulatory program. This amendment will not have an economic effect of more than $100 million, and there will be no major increases in costs to consumers, individual industries or government agencies. There will be no significant adverse effect on competition, employment, investment, productivity, or the ability of US industries to compete with foreign enterprises. There could be a slight increase in NMFS administrative costs to carry out the framework procedures. However, there would be a decrease in costs if future changes in management can be made without having to develop a full amendment to the FMP. The administrative burden associated with reporting requirements will not change.

5.3.3 Social impacts

No social impacts are expected as a result of Amendment 9. The Council has not proposed any significant new measures in the amendment which would affect employment, community structure, families, or other social elements. A maximum of 15 vessels is allowed to operate in the NWHI fishery under the existing limited entry program, established in 1992 by FMP Amendment 7. There are no significant social or cultural aspects to this fishery. However, the proposal under the amendment to allow the harvest/retention of egg-bearing and small or juvenile lobsters may elicit some negative reaction from the public, a concern discussed by the Council and SSC. This concern can be allayed, as explained in Section 4.5, by the fact that small and egg-bearing lobsters can sometimes make up a large proportion of the catch (50% or more of the total catch in some areas and years). The discard of small and berried lobsters is wasteful, and contributes little to protecting spawning stock biomass or the long-term productivity of the lobster stock. **Under the proposed retain-all fishery, every lobster that is brought on board the fishing vessel would be counted against the annual harvest guideline; therefore, the problem of incidental mortality of egg-bearing and small or juvenile lobsters, prevalent under the existing management regime, would be eliminated**. Under Amendment 9, the harvest guideline would become the estimated total fishery mortality.

5.3.4 Evaluation of proposed actions relative to FMP objectives

As indicated earlier, the Council has not changed the objectives of the FMP but believes the proposed management program will be more likely to achieve those objectives, as follows:

1. To assure the long term productivity of the stock and prevent overfishing

The FMP, with this amendment, is expected to preventing overfishing of NWHI lobster stocks. The fishery model is conservative in nature, reflecting the current level of lobster stock productivity which is lower than during the period when the fishery started. The harvest guideline formula is set with a very low risk of overfishing. The projected SPR level of 0.5 is well above the threshold associated with overfishing. The annual stock assessment will provide a scientific determination of the status of the stocks relative to the definition of overfishing, and framework procedures would allow rapid regulatory change if new information demonstrates it is needed. The 5-year review provides a mechanism to review the effectiveness of the overall management program. Waste would be eliminated by the retain-all policy, under which handling, displacement, and other such "incidental" mortality should be very low. Escape vents will still allow smaller size classes of lobsters to escape so they will not suffer mortality from handling and discard.

2. To promote the efficient contribution of the spiny lobster resource to the United States economy

The FMP with this amendment is expected to result in a profitable fishery which will make a positive contribution to the economy of the USA. The fishery is expected to produce positive net revenues to the permit holders. Under the limited entry program, overall capitalization of the fishery is limited, and permit holders would be free to decide whether or not to participate in the fishery in a given year. The annual harvest guideline determination will be made early in the year to allow permit holders to evaluate the pros and cons of participating and to plan their conversion to the lobster fishery if they decide to participate. The annual review of the fishery will provide an assessment of the economics of the fishery, and the 5-year review will provide an overall evaluation of the effectiveness and impacts of the management program. Framework procedures would allow rapid regulatory change if needed to improve the economic performance of the fishery, within the constraint of preventing overfishing.

3. To collect and analyze biological and economic information about the spiny lobster fishery and improve the basis for conservation and management in the future.

No changes are made in data collection and reporting requirements. Vessel operators are required to maintain logbooks detailing catch by species and effort as well as sales information such as sales by size classes of lobsters. This information is vital to understanding the status of the stocks and the effectiveness of the management program, especially with respect to the effects of the retain-all policy. In addition, NMFS is expected to supplement commercial catch and effort data through their annual research cruises and/or chartered private vessel, subject to funding availability.

4. To prevent unfavorable impacts of the fishery on the Hawaiian monk seal and other endangered and threatened species.

The measures implemented under earlier amendments to the FMP to protect Hawaiian monk seals will remain in place. These include gear requirements (minimum size for trap openings), area closures (no fishing within 20 nm of Laysan Island or in waters shallower than 10 fm), reporting requirements (any interactions with endangered or threatened species must be reported), and framework procedures (allowing the Regional Director to close the fishery if mortality of a monk seal is reported or confirmed). The FMP will protect the long-term productivity of the stocks, such that the fishery will not adversely affect food supplies for Hawaiian monk seals. It should be noted that the principal fishing areas (Necker Island, Maro Reef, Gardner Pinnacles) are not among the principal haul out areas used by the Hawaiian monk seal, so the risk of interactions is very low. No interactions have been reported under the FMP, or during the 1995 experimental fishing program (12 July - 5 October 1995) aboard the F/V *Pacific Pride*.

5.3.5 Evaluation of Proposed Actions Relative to Magnuson Act National Standards

This section evaluates the proposed actions in terms of meeting the Magnuson Act national standards.

1. Prevent Overfishing While Achieving the Optimum Yield (OY)

The proposed new management program is expected to prevent overfishing. Overfishing is defined in the FMP in terms of spawning potential ratio (SPR). If the SPR falls below 0.2, the lobster stocks are deemed overfished and management action must be taken. As indicated in section 5.1, the projected SPR under the proposed measures would be 0.5, which is more than twice the 0.2 threshold level[3]. The SSC and Council indicated that a 10% risk of overfishing in any given year is very conservative and acceptable as a management guideline. The SSC and Council also note that the assumptions underlying the overall model are all risk-averse and conservative. Further, there will continue to be annual stock assessments and a five-year overall program review, so there will be effective monitoring to give the Council early notice if the lobster SPR is approaching the overfishing threshold, and to ensure that the program is not resulting in overfishing. The proposed amendment includes framework procedures to facilitate rapid response in the event new information demonstrates any problems. In the Council's view, the proposed harvest limitation program will prevent overfishing.

The proposed program also will produce OY from the fishery. The fishery is projected to yield positive net revenues to participants with minimal probability of the fishery having to be closed due to overfishing. Maintenance of markets is an important consideration to permit holders

2. Best Scientific Information Available

The amendment incorporates the best scientific information available. The modeling carried out for the amendment was recommended by a formal review team of NMFS and non-NMFS experts who reviewed the stock production model and its use in the existing management program. The new models were fully reviewed by the SSC as well as experts from the review panel. The SSC concluded that the models produce reasonable and credible results. The amendment acknowledges that there are limitations in the data, e.g., inability to use separate stock models for spiny and slipper lobster and inability to account for bank specific variability in abundance and yields. However, the SSC noted that, given these limitations, the model is the best available at this time.

[3] For comparative purposes, the threshold for recruitment overfishing in the American lobster fishery is SPR=0.10. This fishery, from coastal Maine through southern New England and Long Island Sound, as a whole, is currently overfished.

3. Management as a Unit

The amendment acknowledges that spiny and slipper lobster are best managed as a unit, even though there are differences in some life history variables and characteristics. This is largely because of the difficulties in separating fishing effort statistics between species, precluding reliable estimates of CPUE for use in population model. Thus, the full range of the fishery is encompassed in the management program.

4. Discrimination Based on State Residency

The amendment does not discriminate based on state of residency in any aspect of the management program. There is no change in the limited entry program in which permits are freely transferable. State of residency does not affect permit eligibility. The amendment does not make allocations of lobster to any particular permit holders; all are equally eligible to decide whether or not to participate in the fishery in a given year.

5. Promote Efficiency

The amendment promotes efficiency in the fishery by leaving to permit holders the decision whether to participate each year. The provision to retain all lobsters would reduce waste from mortality of discarded lobsters while eliminating most of the time needed for sorting and releasing sublegal and egg-bearing female lobsters. The harvest guideline should be achieved efficiently. The proposed management program is expected to result in positive net revenues to permit holders.

6. Allow for Variations

The proposed management program allows for variations by establishing framework procedures to facilitate rapid regulatory changes if necessary. The annual stock assessment will provide the basis for setting an annual harvest guideline based on the condition of the stocks.

7. Minimize Costs and Duplication

The FMP with this amendment should prevent overfishing and achieve OY in a cost-effective manner. The FMP with this amendment does not duplicate any other federal regulations or state fishery management measures.

5.4 Monitoring of Proposed Actions and Possible Council Responses

5.4.1 Reporting Requirements

All NWHI lobster vessels are required to have a federal permit and provide completed logbooks to the NMFS after each fishing trip. The logbooks provide information on, among other things, catch, effort and fishing location. In addition, under the proposed actions, all vessels would be required to report their catch while at sea on a periodic basis (this would be decided on before the start of the season, and needs to remain flexible until the logistics are worked out) to the NMFS in Honolulu. Violators face civil and criminal penalties under the Magnuson Act. If logbook information shows that the conservation and management measures are inadequate to preserve the stocks, the actions proposed by this amendment are frameworked to allow the NMFS Regional Director, after approval by the Council, to adjust the number of permits issued under the limited access system, the length of the closed season, or harvest guideline and reporting requirements.

5.4.2 Establish Framework Procedures for Regulatory Changes

Changes may be made in the management program through rulemaking if new information demonstrates that there are biological, social, or economic concerns in the fishery. The following framework process allows for modifying the regulatory measures that govern the fishery, such as gear restrictions, species-specific harvest guidelines, fishery input (effort), fishery output (catch), etc., if the information supports such changes.

Regulatory Procedure 1: Modification of Established Measures

Established measures are those that are or have been in place via rulemaking procedures for the fishery, including: the new harvest guideline model implemented by this amendment; logbooks and other reporting requirements; area closures; trap and other gear requirements; fishing season; and lobster size limits used in the model. The estimated and potential impacts of these measures have been evaluated in past FMP amendments and associated documents and in Amendment 9. Changes in established measures and models would be made under the following procedure:

1. The Council would identify problems that may warrant action through the annual report described above, or a separate report from the Plan Team, the Advisory Subpanel, SSC, permit holders, enforcement officials, NMFS, or other sources.

2. At a Council meeting following completion or receipt of a report identifying a problem, the Council would discuss whether changes to established conservation and management measures would resolve the problem. Notice to the public and news media preceding the meeting would indicate that the Council intends to discuss and possibly recommend regulatory adjustments through the framework process for established measures to address the issue or problem. The notice must summarize the issue(s) and the basis for recommending the measures being reviewed and would refer interested parties to the document(s) pertaining to the issue.

3. Based on discussions at the meeting, which include participation by the Plan Team, Advisory Subpanel, SSC, or other Council organizations, the Council would decide whether to recommend action by the Regional Director.

4. The Regional Director would be asked to indicate any special concerns or objections to the possible actions being considered under the framework process and, if there are any concerns or objections, would be asked for ways to resolve them.

5. If the Council decides to proceed, a document would be prepared describing the problem and the proposed regulatory adjustment to resolve it. The document would demonstrate how the

adjustment is consistent with the purposes of the established measure and that the impacts had been addressed in the document supporting the original imposition of the measure. The document would be submitted to the Regional Director with a recommendation for action. The Council may indicate its intent that the recommendations are to be approved or disapproved as a single action.

6. If the Regional Director approves part or all of the Council's recommendation, the Secretary, in accordance with the Administrative Procedure Act, may implement the approved change in an established measure by publishing a final rule, waiving advance notice and comment. This does not preclude the Secretary from deciding to provide additional opportunity for advance notice and comment, but contemplates that the Council process will satisfy the requirements of the Magnuson Act and Administrative Procedure Act regarding prior notice and comment. Established measures are measures that have been evaluated and applied in the past, and adjustments under this framework must be consistent with the original intent of the measure and within the scope of analysis in previous documents supporting the existing measure.

Regulatory Procedure 2: Establishment of New Measures

New measures are those that have not been used before in managing the crustaceans fishery. New measures may have been previously considered but rejected in a past FMP amendment or document, but the specific impacts on the stocks and on permit holders have not been evaluated in the context of current conditions. Potential new measures include, but are not limited to species- or area-specific harvest guidelines, individual transferable quotas, fractional licensing, bycatch limits, a VMS requirement, or additional measures to protect Hawaiian monk seals and other protected species. The procedure for establishing new measures is as follows:

1. A Plan Team report (annual or in-season), or input from advisors, NMFS, or other agencies will first bring attention to a problem or issue that needs to be addressed at the next Council meeting. In its notice announcing the meeting, the Council would summarize the concern or issue raised, the party that has raised the problem, and the extent to which it is a new problem or a problem that may require new management measures. The Council would seek to identify all interested persons and organizations and solicit their involvement in discussion and resolution of this problem through the Council process, and the Council meeting notice in the *Federal Register* would emphasize that this problem will be discussed and that proposed actions may result.

2. The document presenting the problem to the attention of the Council would be distributed to all advisory bodies of the Council who have not yet received it, with a request for comments. The document also would be distributed to the Council's mailing list associated with the FMP to solicit comments and to indicate the Council would take up action at the following meeting. The Council's chairperson may request the Council's Crustaceans Standing Committee to discuss the issue and review the comments, if any, of the Plan Team, Advisory Panel, or SSC, and develop recommendations for Council action.

No. 3.

4. At the meeting, the Council would consider the recommendations of its Crustaceans Standing Committee, if any, and other Council organizations and would take comments from the public concerning the possible course of action. If the Council agrees to proceed with further action under the framework process, the issue would be placed on the agenda for the following meeting.

A document describing the issue, alternative ways to resolve the issue, the preferred action, and the anticipated impacts of the preferred action, would be prepared and distributed to the public with a request for comments. A notice would be published in the *Federal Register* summarizing the Council's deliberations and preferred action and indicating the time and place for the Council meeting to take final action.

5. In its notice for the following meeting, the Council would indicate that it may take final action on the possible adjustment to regulations under this section. At the meeting, the Council would consider the comments received as a result of its solicitation of comments and take public comments during the meeting on the issue or problem. The Council would consider any new information presented or collected and analyzed during the comment period. The Regional Director would be asked to indicate any objections or concerns about any or all components of the measures being considered. The Council would then decide whether to recommend the establishment of new management measures.

6. If the Council decides to proceed, it would submit its proposal to the Regional Director for consideration, with supporting rationale and an analysis of the estimated biological, economic, and social impacts of the proposed action. The Council may indicate its intent that all components of its recommendations be approved or disapproved as a single action.

7. If the Regional Director concurs in whole or in part, the Secretary, in accordance with the Administrative Procedure Act, may implement the approved new measures by publishing a final rule, waiving advance notice and comment. Nothing in this procedure is intended to preclude the Secretary from deciding to provide additional opportunity for advance notice and comment in the *Federal Register*, but contemplates that the Council process (which includes two Council meetings with opportunity for public comment at each) would satisfy that requirement.

8. If a new action is approved and implemented, future adjustments may be made under the procedure for established measures (see Regulatory Procedure 1, above). The above procedures do not limit the authority of the Secretary to take emergency action under section 305 of the Magnuson Act.

5.4.3 Annual Report

By June 30 of each year, the Plan Team would prepare an annual report on fisheries in the fishery management area, containing the following:

- (i) Fishery performance data (e.g., landings, effort, value of landings, species composition);
- (ii) Summary of recent research and survey results;
- (iii) Habitat conditions and recent alterations;
- (iv) Enforcement activities and problems;
- (v) Administrative action (e.g., data collection and reporting, permits);
- (vi) State and territorial management actions; and
- (vii) Assessment of need for Council action (including biological, economic, social, enforcement, administrative, and state/federal needs, problems, and trends). Indications of potential problems warranting further investigation may be signaled by indicator criteria. These criteria could include, but are not limited to, important changes in: Mean size of the

catch; estimated ratio of fishing mortality to natural mortality; catch per unit effort; ex-vessel revenue; turnover of limited entry permits in the fishery; species composition of the landings; research results; habitat or environmental conditions; or level of interactions between crustacean fishing operations and protected species;

(viii) Recommendations for Council action; and

(ix) Estimated impacts of the recommended action.

The annual report would specify any recommendations made by the Plan Team to the Council. Recommendations may cover actions suggested for federal regulations, state/territorial action, enforcement or administrative elements, and research and data collection. Recommendations would include an assessment of urgency and the effects of not taking action and would indicate whether changes involve existing measures, which may be changed under Procedure 1, or new measures, which may be implemented under Procedure 2.

5.4.4 Research Needs

The SSC suggested the following general research categories that would support information needs to effectively administer the NWHI lobster management system under Amendment 9:

- Population Modeling
  - a) develop bank- and species-specific models
  - b) develop recruitment indices
  - c) develop models for predicting catches/CPUE

- Biological Research
  - a) develop maturity curves
  - b) determine fecundity
  - c) characterize growth

- Commercial Fishery Data
  - a) characterize age/size of catch
  - b) develop gear selectivity curves
  - c) conduct experiments on discard mortality
  - e) estimate fishing mortality

- Stock Assessment
  - a) integrate research and commercial fishery data
  - b) refine and advance risk-based assessment techniques

6.0 RELATIONSHIP OF AMENDMENT 9 TO OTHER APPLICABLE LAWS AND POLICIES

6.1 Administrative Procedure Act (APA)

The APA (§§ 551-553) requires a 45-day comment period for proposed rules that would implement an FMP/amendment. The proposed rule for Amendment 9 will be published for public comment with the requisite comment period after NMFS receives the proposed amendment and regulations. At this time, the Secretary has not determined that the amendment is consistent with the national standards or other provisions of the Magnuson Act, and other applicable law. In making that determination, the Secretary will take into account the data, views, and comments received during the comment period on the proposed rule to implement this amendment.

6.2 Coastal Zone Management Act (CZMA)

The CZMA requires a determination that an FMP or amendment has no effect on the land or water uses or natural resources of the coastal zone, or is consistent to the maximum extent practicable with an affected State's approved coastal zone management program. The proposed elimination of lobster size limits and the prohibition on retaining egg-bearing female lobsters harvested in the NWHI will result in differences between federal and state regulations governing the management of lobster resources within the EEZ and state waters, respectively. Existing state regulations contain size limits and non-retention requirements for berried lobsters harvested in state waters. Because the NWHI fishery is predominantly within the EEZ where only federally-permitted vessels are allowed to fish, the inconsistency between federal and state measures will not affect either the federal or state NWHI lobster management programs.

The inconsistency in measures resulting from Amendment 9 are, however, a potential issue because the landing of sublegal and berried female lobsters would potentially be prohibited in Hawaii ports, even though these lobsters were legally harvested in the NWHI. This matter can be resolved through the issuance of State of Hawaii NWHI Taking Permits to only federally-permitted lobster vessels allowing them to land lobsters that would otherwise be prohibited in the main Hawaiian Islands (Hawaii Revised Statutes Section 188-37 and Department of Land and Natural Resources Administrative Rules Section 13-46-2). State laws require lobsters from the main Hawaiian Islands to be landed whole, not processed, and prohibit fishing from May through August. The special NWHI takings permits are currently being issued to allow federally-permitted lobster vessels to land lobsters taken from the NWHI during the main Hawaiian islands closed season (August is currently the only month of overlap). The permits also allow NWHI vessels to land processed lobsters (i.e., tails only). Continued issuance of NWHI taking permits by the state, with modification to allow landings of small and berried female lobsters by federally-permitted NWHI lobster boats, would eliminate the potential inconsistency between federal and state lobster management programs.

The Council has concluded that Amendment 9 is consistent to the maximum extent possible with State of Hawaii's approved coastal zone management program. The NMFS has sent a copy of the amendment to the Hawaii Office of State Planning, Governor's Office, for review and comment.

6.3 Endangered Species Act (ESA)

Under the ESA, the NMFS is required to prepare and provide an impact assessment, which may serve as the biological assessment for consultation under Section 7 of the ESA, on the impacts of the fishery, as it would operate under this amendment, upon endangered and threatened species and their critical habitats. The Council has concluded that Amendment 9 is not likely to have any significant adverse effect on any listed endangered or threatened species, or the habitat of those species. The NMFS will conduct a consultation under ESA Section 7, and Appendix 6 is the biological assessment that will be used in the consultation.

6.4 Marine Mammal Protection Act (MMPA)

If the fishery affects marine mammals, the potential impacts must be identified and analyzed under the MMPA. All fisheries in the Western Pacific Region are designated as Category 3, meaning that fishermen must report interactions with marine mammals, but they are not required to obtain exemption certificates in order to fish. The NMFS has determined that reclassification of the western Pacific crustacean fisheries is not necessary for the purposes of Amendment 9.

6.5 National Environmental Policy Act (NEPA, also see Environmental Assessment in Section 7)

NEPA requires that the effects of Federal activities on the environment be assessed. For Amendment 9, an Environmental Assessment has been prepared. The amendment has been written and organized in a manner that meets NEPA requirements, and is intended to serve as an Environmental Assessment. The Council has determined that the proposed actions will not have a significant adverse impact on the human environment, so an environmental impact statement has not been prepared. The sections of this amendment that address specific NEPA requirements are:

Section 4	Purpose and need for action
Section 5.1	Proposed actions
Section 5.2	Rejected alternatives
Section 5.3	Impacts of proposed actions

6.6 Paperwork Reduction Act (PRA)

The PRA requires federal agencies to minimize paperwork and reporting burdens whenever collecting information from the public. Amendment 9 does not include any changes to collection of information requirements previously approved by the Office of Management and Budget under NMFS collections 0648-0204 and 0648-0214. However, the implementing regulations eliminate the annual permit renewal requirements; permits will be valid indefinitely. Also eliminated is the requirement for vessel operators to notify NMFS prior to departing on a fishing trip. These changes reduce the annual reporting burden by about 10 hr.

6.7 Regulatory Flexibility Act (RFA) (also see Regulatory Impact Review, Appendix 8)

The RFA establishes the principle that federal regulations should be tailored to the regulated entity's (e.g., fishermen's) capacity to bear the regulatory burden. Amendment 9 will not have a significant economic impact on a substantial number of fishermen. The NWHI lobster fishery is currently limited to 15 permit holders. To the extent there are impacts, they are beneficial as there will likely be fewer years in which the fishery is closed. Also, fishermen will have advance notice of the harvest guideline at least 3-4 months, allowing them to plan whether or not to enter the fishery in that year. A regulatory flexibility analysis has not been prepared. A Regulatory Impact Review is attached as Appendix 8.

6.8 Executive Order 12866

EO 12866 applies to the issuance of new rules and in particular the benefits and costs of the proposed regulatory actions. Amendment 9 is not considered a major action in that it will not have an effect on the economy of more than $100 million, and there will be no major increase in costs or prices for consumers, individual industries or government agencies. There will be no significant adverse effect on competition, employment, investment, productivity, or ability of US industries to compete with foreign enterprises. The basis for these conclusions is presented in Section 8.

6.9 Executive Order 12612

EO 12612 requires that a "federalism assessment" certifying federal compliance with the executive order be prepared if the proposed actions have sufficient federalism implications. The Council did not identify any federalism issues relative to the proposed actions contained in Amendment 9. The State of Hawaii, through its participation on the SSC and Plan Team, has been involved in developing this amendment. The ex-officio voting member of the Council representing Hawaii has not expressed federalism-related opposition to adoption of this amendment. Thus, the Council determined that preparation of a federalism assessment is not necessary.

6.10 Executive Order 12630

EO 12630 on Government Actions and Interference with Constitutionally Protected Property Rights requires that NMFS prepare a takings implication assessment for any of its administrative, regulatory, and legislative policies and actions that affect, or may affect, the use of any real or personal property as a result of federal action. Management measures limiting fishing seasons, areas, harvest guidelines, fish size limits, and bag limits do not appear to have any taking implications. The Council determined that the proposed actions of Amendment 9 will not significantly affect the use of any real or personal property. Thus, no takings implication assessment is required to be prepared.

6.11 Executive Order 12778

EO 12778 on Civil Justice Reform provides a process to improve regulatory drafting to reduce needless litigation. The NMFS will submit, with the regulatory package for Amendment 9, a certificate signed by NOAA General Counsel for Fisheries that the proposed regulations meet the applicable standards of the Executive Order.

6.12 Indigenous Peoples' Fishing Rights

There is no formal agreement between the US government and the indigenous people of the region that allocates preferential fishing rights to native people (i.e., Carolinian, Chamorro, Hawaiian and Samoan). The Council is now exploring the legality and necessity of granting such rights. At present, Amendment 9 does not appear to affect any native Carolinian, Chamorro, Hawaiian or Samoan cultural or religious practices.

6.13 Vessel Safety Considerations

The Council did not identify any vessel safety issues in the proposed actions. The US Coast Guard has been asked to review this amendment from the standpoint of vessel safety.

7.0 ENVIRONMENTAL ASSESSMENT

A. Purpose and Need for Action

A detailed description of the recent history of the fishery and the need for action is contained in Section 4 and in Dollar (1995, Appendix 1). This section has been prepared in accordance with the requirements of the National Environmental Policy Act to assess the potential for environmental impacts (including the human environment) that may result from Amendment 9 to the Crustaceans FMP. The proposed action is believed to be consistent with the goals and objectives of the FMP, National Standards of the Magnuson Act, and revised guidelines for the national standards (50 CFR Part 602). The proposed actions are deemed to be the preferred alternative.

B. Analysis of Impacts of the Preferred Alternative

1) The preferred alternative is expected to help prevent recruitment overfishing of the crustacean resources and, thus, ensure the long-term maintenance of the spawning stock.

2) The preferred alternative provides a safeguard against the potential for significant and irreversible damage to the ocean and coastal habitats. All fishing operations are subjected to stringent terms and conditions including, but not limited to, gear

and area restrictions.. The lobster habitat is afforded full continued protection under the preferred alternative.

3) The preferred alternative is not expected to have any adverse impact upon public health or safety. The market for Hawaiian spiny and slipper lobsters has established high quality standards. The preferred alternative will not affect fishermen's ability to meet these standards.

4) The preferred alternative will not impact protected (endangered or threatened) species or marine mammals. Protected species are already afforded protection by gear requirements and closed areas, and a six-month closed season added protection to these species.

5) The preferred alternative is not expected to generate controversy or have significant adverse social and economic effects. The Council intends to exercise the best informed judgement in preventing any lobster stocks from closely approaching or reaching an overfished state.

6) The preferred alternative will not have any effect upon flood plains and wetlands, or trails and rivers listed, or eligible for listing, on the National Trails and Nationwide Inventory of Rivers.

C. Agencies and People Consulted

The Council sent Amendment 9 to the Hawaii Coastal Zone Management office for review, as well as the US Coast Guard, Fish and Wildlife Service, lobster fishermen and industry representatives, and others.

D. Finding of No Significant Impact

Based on the information contained in the combined Amendment 9 and EA, it is concluded that the action proposed by the FMP amendment will not have a significant effect on the human environment. Therefore, the preparation of an environmental impact statement is not required.

8.0 REFERENCES

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. Can. J. Fish. Aquat. Sci. 43: 2236-2242.

Brown, R.S. and B.F. Phillips. 1994. The current status of Australian rock lobster fisheries. In: Phillips, B.F., J.S. Cobb and J. Kittaka (eds.). Spiny Lobster Management. Fishery News Books. 550 p.

DiNardo, G.T. In prep. Alternative harvest guidelines for the Northwestern Hawaiian Islands lobster fishery. Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service. (see Appendix 4)

Dollar, R. 1995. Annual Report of the 1994 Western Pacific Lobster Fishery. Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service, Admin. Rept. H-95-06. (see Appendix 1)

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. J. Fish. Man. 12(1): 161-171.

Haight, W.R. and G.T. DiNardo. 1995. Status of Lobster Stocks in the Northwestern Hawaiian Islands, 1994. Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service, Admin. Rept. H-95-03. (see Appendix 2)

Haight, W.R., and J.J. Polovina. 1993. Status of lobster stocks in the Northwestern Hawaiian Islands, 1993. Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service, Admin. Rept. H-93-17.

Hunt, J.H. 1994. The status of the fisheries for *Panulirus argus* in Florida. In: Phillips, B.F., J.S. Cobb and J. Kittaka (eds.). Spiny Lobster Management. Fishery News Books. 550 p.

Kobayashi, D.R. 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 Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service. (see Appendix 5)

Polovina, J.J. and G.T. Mitchum. 1992. Variability in spiny lobster *Panulirus marginatus* recruitment and sea level in the Northwestern Hawaiian Islands. Fish. Bull U.S. 90: 483-493.

Polovina, J.J., G. Mitchum, N. Graham, M. Craig, E. DeMartini and E. Flint. 1994. Physical and biological consequences of a climatic event in the central North Pacific. Fish. Oceanogr. 3(1): 15-21.

Wetherall, J.A., W.R. Haight and G.T. DiNardo. 1995. Computation of the preliminary 1995 catch quota for the Northwestern Hawaiian Islands lobster fishery. Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service, Admin. Rept. H-95-04. (see Appendix 3)

WPRFMC. 1983, as amended. Fishery management plan for the crustacean fisheries of the western Pacific region. Western Pacific Regional Fishery Management Council, Honolulu, Hawaii. Var. pag.

Appendix 1

Dollar, R. 1995
Annual Report of the 1994 Western Pacific Lobster Fishery
Honolulu Laboratory, Southwest Fisheries Science Center
National Marine Fisheries Service
Admin. Rept. H-95-06

Southwest Fisheries Science Center
Administrative Report H-95-06

ANNUAL REPORT OF THE 1994 WESTERN PACIFIC LOBSTER FISHERY

Robert A. Dollar

Honolulu Laboratory
Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96822-2396

with contributions from

Southwest Region
Pacific Area Office
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96822-2396

Western Pacific Regional Fishery Management Council
Honolulu, Hawaii 96813

Southwest Enforcement
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96850

August 1995

NOT A PUBLICATION

PREFACE

The Fishery Management Plan (FMP) for the western Pacific crustacean fisheries was prepared by the Western Pacific Regional Fishery Management Council (Council) and went into effect in 1983. Lobster permits are issued by the Regional Director (RD), Southwest Region, National Marine Fisheries Service (SWR, NMFS). These permits allow lobster fishing operations in the U.S. Exclusive Economic Zone (EEZ) from 3 to 200 nmi offshore American Samoa, Guam, Hawaii, the Northern Mariana Islands, and U.S. possessions in the western Pacific. The Fishery Management and Economics Program (FMEP) of the Honolulu Laboratory, Southwest Fisheries Science Center, NMFS, NOAA, collects biological and economic information exclusively from vessels permitted to fish in the Northwestern Hawaiian Islands (NWHI). All information presented in this report pertains only to NWHI since no Federally permitted lobster vessels fished in the main Hawaiian Islands (MHI), American Samoa, Guam, or the U.S. Pacific Island possessions.

In addition to the FMEP, other NMFS agencies contributed to this report: The Stock Assessment Program of the Honolulu Laboratory provided a summary of the biological research and quota assessment on the fishery, and Alvin Z. Katekaru of the SWR, Pacific Area Office, (PAO), NMFS, provided information on administrative activities. Council's staff prepared information on Council activities, and Southwest Enforcement (SWE), NMFS, furnished details on enforcement operations.

CONTENTS

INTRODUCTION

The Northwestern Hawaiian Islands (NWHI) are an isolated range of islands, islets, banks, and reefs which extend 1,500 nmi northwest of the main Hawaiian islands from Nihoa Island to Kure Atoll (Fig. 1). The commercial lobster fishery has operated in the NWHI for almost 17 years, targeting primarily two species: spiny lobster, *Panulirus marginatus*, and common slipper lobster, *Scyllarides squammosus* (henceforth referred to as slipper lobster). Two other species--green spiny lobster, *P. pencillatus*, and ridgeback slipper lobster, *S. haanii*, are caught incidentally in low abundance.

This report details commercial lobster fishing activity in the Exclusive Economic Zone (EEZ) of the NWHI. Current catch, effort, and revenue statistics are based on federal logbook data and revenue reports. Statistics are presented for the main target species in tabular format, and brief summaries illustrate key points. Evaluations of current conditions of the fishery are also provided. This report concludes with separate sections on administrative and enforcement activities in the fishery.

RECENT DEVELOPMENTS

During the past 2 years, the NWHI lobster fishery has faced two major developments: a complete closure in 1993 and an emergency closure after the season opened in 1994. The 1993 closure was under the standing procedures of the FMP when the preseason estimate of catch rates in the fishery resulted in a zero quota. No trips were taken in 1993 although a small amount of live lobster was landed in January 1993 from trips initiated in 1992. The 1994 closure occurred when in-season reports of catch rates were less than those anticipated by the stock assessment, leading to an emergency closure 8 weeks into the fishery. The fishery remained closed for the remainder of 1994 and there is a minimal quota for 1995 with the fishery operating under an experimental permit system. The quota setting procedure is being evaluated by the NMFS and the Council during 1995 with a new quota system expected for the 1996 fishing season.

The fishery and environmental causes of the 1993 closure are discussed in Haight and Polovina (1992). In brief, stock assessment biologists believe that the spawning stock biomass at Maro Reef (a major bank in the NWHI lobster fishery) declined dramatically due to poor post-larval recruitment and subsequent fishing down of the remaining population in the years following 1986. The recruitment problem appears associated with a shift in oceanographic regime (higher sea level heights) which changed patterns of larvae lobster transport.

In 1994, the Stock Assessment Program, NMFS Honolulu Laboratory, used a dynamic production model to simulate the effect of the 1993 closure on the lobster population and to estimate a CPUE value for the start of the 1994 fishing season. Based on the model estimate of July 1994 CPUE, the preseason or initial quota forecast of 200,000 spiny and slipper lobsters combined was announced in the *Federal Register* (59 FR 6912) on February 14, 1994. In May 1994, the annual lobster assessment expedition conducted by the NOAA ship *Townsend Cromwell* to the NWHI found CPUE values at Necker Island and Maro Reef to be very close to those predicted by the dynamic production model. However, after the commercial lobster fishery opened on July 1, 1994, CPUE values during the first month based on call-in catch reports were below the model forecast CPUE and also fell below the FMP target CPUE level of 1.0 lobsters per trap-haul.

Although the FMP contains procedures for closing the fishery if the catch in the first month of fishing exceeds the final quota when it is calculated, NMFS decided to close the lobster fishery through emergency action because the actual catch (131,000 lobsters) during the months of July and August had substantially exceeded the final quota 21,000 lobsters (only 10% of the initial quota). As a result, the fishery was closed on August 25, 1994 on an emergency basis after less than 8 weeks of fishing.

During the 1994 lobster season, only 5 of the 15 permit holders fished (the fewest number of permittees who have participated in the fishery since the lobster FMP was implemented) with resulting landings and revenue also at the lowest level in the history of the FMP-regulated fishery. The other 10 permit holders decided to sit out the 1994 lobster season or participate in other fisheries primarily because of the low quota and shortened fishing season.

Following the 1994 season, the Council proposed Amendment 8 to the FMP for the Crustacean Fisheries of the Western Pacific Region. The amendment proposed three changes in the FMP: a framework approach to the annual quota system, revocation of the use-it-or-lose-it requirement for permit holders, and changes to various arrival notification procedures. However, some of the quota management-related provisions of Amendment 8 were not approved by NMFS (see Western Pacific Regional Fishery Management Council Activities section for further details).

Several concerns related to the quota management system were identified by NMFS and industry representatives alike as a result of the 1994 lobster season. The wide disparity between the initial quota (200,000 lobsters) and the final quota (21,000) lobsters) shows that the quota determination methods can be extremely susceptible to small changes in CPUE. The purpose of the initial quota was to provide an early indication or forecast of the expected quota so that fishermen could decide whether to fish when the season opens in July. The excessive differences between the initial and final quota resulted in much skepticism about the usefulness of the preseason quota in the NWHI lobster FMP and caused much speculation about the outcome of the 1994 season if all 15 of the NWHI lobster permit holders had decided to fish.

The majority of the fishermen who participated in the 1994 lobster season as well as several non-participants felt that they should have been given the lower quota figure initially or given at least a more consistent figure so that they could have made better decisions. The order of magnitude higher quota tended to cause some operators to believe that the initial quota represented at least the minimum number of lobsters available for harvest. For most participants, drastically reducing the quota mid-season after so much time and effort had been expended to gear up to fish for lobster was very disappointing. In general, fishermen felt that they lost at least 3 to 4 months of fishing time which could have been used more profitably in another fishery.

At the close of the 1994 season, fishermen reported that slipper lobster stocks appeared much healthier than spiny lobster stocks and expressed interest in having separate quotas for slipper and spiny lobsters or perhaps separate quotas for designated banks and islands. Other concerns involved marketing difficulties, which for some operators were particularly troublesome because of the abbreviated season. More than half the participants resorted to consigning their product with brokers on the mainland and then having to wait for 3 months to realize any sales. A number of these issues are being considered in 1995 as the Council and NMFS review the quota system.

LANDINGS AND REVENUE

The total combined landings of legal lobsters in number, pounds (wet weight), and ex-vessel revenue during 1983-94 are shown in Table 1. NWHI fleet landings and revenue of spiny and slipper lobsters in pounds and metric tons (t) are presented in Table 2. (Tables 1 and 2 contain updates from Clarke and Pooley, 1988; Clarke, 1989; and Landgraf et al., 1990). Estimated landings, ex-vessel prices, and ex-vessel revenue by product type (frozen tails, frozen whole and live) are shown in Table 3. The long-term trend in annual landings is shown in Figure 2, and long-term revenue is shown in Figure 3.

During the July-August 1994 season, 131,000 legal spiny and slipper lobsters were landed, having a total estimated weight of 72 t and a total gross revenue of $837,000. No direct comparison can be made to 1993 because of the fishery closure that year, but during the same monthly (July-August) in 1992, approximately

220,800 legal lobsters (106 t) were landed at a value of $1.1 million.

FISHING EFFORT

Fishing effort in 1994 was the lowest since 1983 (Fig. 4). Out of the 15 vessels with limited entry lobster permits issued under the new management system in 1992, only 5 vessels fished. The average number of trap-hauls per fishing day for 1994 was 847, compared to 808 in 1992. Total effort in 1994 was 168,500 trap-hauls compared to 721,700 in 1992.

Effort was mainly concentrated on two banks--Gardner Pinnacles and Necker Island--and is reflected in the CPUE by area (Table 4). Annual fishing data collected from vessel logbooks indicate there were only 199 fishing days during 1994 because of the emergency closure of the fishery in August by the NMFS (the lowest in the history of the fishery (Table 5).

CPUE

Table 4 shows 1994 CPUE by area except for confidential data which is combined under "other" because fewer than three vessels fished in some areas.

Combined CPUE increased to 0.78 in 1994 compared to the 1992 showing of 0.59 but still failed to compete with the totals of the years prior to 1990 (Fig. 5). The CPUE for legal spiny lobster rose to 0.51 and increased slightly to 0.27 for legal slipper lobster (Table 4).

Commercial lobster fishing logbooks for the first month of the 1994 season indicated that CPUE was 0.50 for legal lobsters per trap-haul, the lowest recorded during that period since 1983 (when such data were first recorded). By comparison, the CPUE for the same period in 1991 and 1992 was 0.54 and 0.51, respectively.

Research survey information and commercial fishing logbook data have indicated that recruitment of lobster to the NWHI varies considerably between banks. Necker Island recruitment has remained fairly strong since 1985. Necker Island had a legal spiny lobster CPUE of 0.61 in 1994; higher than any of the other areas. Gardner Pinnacles followed with a CPUE of 0.43 and all other areas combined had a CPUE of 0.36 (Table 4). Historically, Maro Reef accounts for approximately 40% of the catch from the NWHI but has had comparatively low CPUE since 1990, although the number of legal slipper lobsters caught increased during 1994 to 0.95 compared to the 1992 showing of 0.65.

VESSEL OPERATIONS

Sea days analysis of the NWHI lobster fleet in 1994 is reported only in "unadjusted" modes (Table 6). In previous annual reports, adjusted data "annualized" trip activity was presented by deleting incomplete or experimental trips and by projecting partial year participation for individual vessels to a full year's activity. However, adjusted data were not included the past 3 years because of the fishery closures. Based on unadjusted data, the number of fishing days per vessel was lower for all classes of vessels for 1994 compared to previous years, primarily a result of the shortened fishing season. Operations for class I and III vessels that participated in the fishery are not included in the vessel operations figures because fewer than three vessels fished.[1]

Table 7 indicates entry and exit patterns of NWHI lobster vessels during 1990-94 (the period in which the fishery started to show dramatic declines in catch and effort) (Dollar et al., 1992).

ECONOMIC INFORMATION

In 1994, as in most of the previous years, frozen spiny lobster tails represented the predominate product of the NWHI lobster fishery and accounted for the largest source of income (71% of sales), whereas frozen slipper lobster tails were second, representing about 29%. Only a few live lobsters were landed (< 1%), and no frozen whole lobsters were sold. Landings of spiny tails in the 6-8 oz. range were the most prevalent and in the most demand, with the 8-10 oz. and 4-6 oz. sizes representing second and third place. Frozen spiny tails in the 4-6 oz. range and below category, however, seem to have more marketing obstacles because of increasing "cold water" imports of frozen tails in this size range at more competitive prices.

Changing market conditions greatly influence the price and salability of seafood products. During 1993 and early 1994 there was a significant shortage of frozen Hawaii lobster tails due to the fishery closure in 1993. Nonetheless, market conditions and prices in 1994 did not meet fishermen's expectations. Vessel operators anticipated prices beginning at $19.00 per pound for spiny lobster tails during the 1994 season since the peak price was $18.80 for this product in 1992. However, the peak price in 1994 reached only $16.50 (Fig. 6). Demand for 4-6 oz. and 6-8 oz. size tails was fairly strong, and the overall average price for spiny tails was $16.34 (up from $14.25 in 1992). To secure

[1]Vessels were categorized into size, activity, and class by Clarke and Pooley (1988): classes I and I-S are the largest vessels.

this price and move their product, however, several vessel operators had to utilize consignment brokers on the U.S. mainland, thus substantially delaying payment. Operators also complained that there seemed to be little intra-industry cooperation in the promotion of Hawaii lobster products.

Brokers, on the other hand, said that the 1993 closure hurt the Hawaii lobster product both locally and in mainland U.S. markets since the lobsters are no longer available on a timely and consistent basis in the quantities and sizes preferred by restaurants and other retailers. Because of this, one broker decided to quit handling Hawaii lobster products. In general, almost everyone in the industry was unhappy with the impact of the seasonal and full-year closures on the market for Hawaii lobsters.

The market for Hawaiian slipper lobster tails was somewhat more predictable in 1994. Since there is only one closely competitive product (the Brazilian slipper lobster, *S. brasiliensis*), the effect of competitive products on Hawaiian slipper tail prices tends to be insignificant. All the vessels that fished found immediate markets at comparable prices upon landing. Ex-vessel prices tended to be about a dollar or so higher than the 1992 market (in the $9 per pound range) with the exception of a few vessels products that were sold for slightly higher prices. Slipper tails in the 4-6 oz. category, representing the largest number of Hawaii slipper lobster landings, were most in demand with the 6-8 oz. and 8-10 oz. categories ranking second and third.

QUOTA INFORMATION

The Stock Assessment Investigation of the Honolulu Laboratory is responsible for calculating the preliminary and final quota for the NWHI commercial lobster fishery. The average CPUE used to calculate the final quota for 1994 was based on catch rates in the commercial fishery during the first month of fishing in July 1994. The reported CPUE data from the five active vessels were weighted to adjust for the distribution of effort throughout NWHI. The weighted average CPUE of 0.91 was divided by the "catchability" coefficient to estimate a population of 1,241,600 legal lobsters. Because this population is less than that needed to maintain a target CPUE of 1.0 lobster/trap, the 1994 quota became 20,900 lobsters (Haight et al., 1995).

The initial catch quota for the 1995 NWHI lobster fishing season as determined by the Stock Assessment Investigation, using Amendment 7 quota procedures (Dollar, 1993), is 38,500 lobsters (legal spiny and slipper lobsters combined). The preliminary quota figure was submitted to the NMFS Southwest Region in January 1995 for evaluation and further action. Because of the low number of lobsters available for harvest, the difficulty of closing the fishery to prevent exceeding a small quota, and other considerations, NMFS determined that the most effective management approach was to announce a zero initial and final quota and allow no open fishing season during 1995. However, the *Townsend Cromwell* will be conducting its annual NWHI lobster assessment survey from June 22-July 16, 1995 and NMFS has invited NWHI lobster permit holders to participate in a controlled, experimental fishing program during July 1995 for the purpose of improving stock assessment and helping to determine the 1996 quota.

RESEARCH [2]

Biological Research

The NMFS Honolulu Laboratory collected fishery independent information on the biology and relative population size of lobster in the NWHI during annual research surveys 1983-88 and 1990-94. Research on lobster trapping conducted by the *Townsend Cromwell* provided data on species composition, length frequency, sexual development, and CPUE at quadrants standardized temporally, spatially, and by gear type at several locations in the NWHI. In 1994, research trapping was conducted at standardized quadrants at Maro Reef and Necker Island during May 8-28, 1994. Additional exploratory trapping for juvenile lobsters was conducted from small boats in the shallow lagoon at Maro Reef, continuing a time series of data collection which began in 1993.

At Necker Island, juvenile spiny lobster (< age 3) appear to occupy the same habitat as the adults, which increases the probability of juveniles being caught in the commercial fishery. At Maro Reef, juvenile lobster appear to utilize shallow reef areas. In 1993, an area of high juvenile abundance was located during exploratory research trapping in the shallows of Maro Reef. In 1994, the same lagoonal areas were fished, and the area of high juvenile abundance was extensively surveyed. Of the shallow lagoon areas trapped in 1994, only the northwest reef spur site exhibited high juvenile CPUE values. It appears that the juvenile lobster are associated with the north portion of the reef spur and are more abundant in shallow waters next to the spur. The deeper station to the south of the spur had relatively low CPUE values compared to the shallow water stations.

A significant reduction in research CPUE values for all spiny lobster age classes at Maro Reef was first observed in 1990. The depressed CPUE continued from 1991 through 1994. This trend has persisted despite significant reductions in commercial fishing effort at Maro Reef during 1991-92 and 1994 and a fishery closure in 1993. A similar trend was seen at Laysan Island, 70 nmi to the northwest, an area which has been closed to commercial

----

2 This section is excerpted directly from Haight, DiNardo and Wetherall (1995).

harvest since the beginning of the commercial fishery. Reductions in CPUE of age-2 to age-4 spiny lobster were first observed at Laysan Island in 1991, consistent with the declines seen at Maro Reef. In contrast, recruitment of age-2 lobster to Necker Island, 360 nmi to the southeast of Maro Reef, remained fairly constant throughout the time series. Recent research indicates recruitment of spiny lobster to Maro Reef is correlated with the strength of the subtropical countercurrent, suggesting that meso-scale oceanographic features may impact the transport or survival of lobster larvae during their 11-12 month pelagic larval cycle. Continued stable recruitment of spiny lobster to Necker Island suggests that the lower southeast end of the NWHI is not linked to the same recruitment process as the northwest end of the archipelago (Haight, 1995). Since spiny lobsters are the primary target of the NWHI commercial lobster fishery, the main focus of the biological research has been to study this species. However, since there has been increasing interest in initiating a fishery with separate quotas for slipper lobsters, biological research on this species will possibly be conducted in the near future.

ENDANGERED AND THREATENED SPECIES INTERACTIONS

Summaries of interactions with endangered and threatened species in the NWHI lobster fishery are based on information received from the daily lobster catch reports and are outlined in Table 8.

It should be noted that these data are unedited and that fishermen most likely see greater numbers of protected species than are indicated in the catch reports. Most often, sightings of protected species are not reported by fishermen who do not want to take the time to record them due to typically busy fishing conditions. Either no interactions occurred, or perhaps fishermen did not want to report any incidental interaction with protected species for fear of being prosecuted by NMFS. Consequently, the numbers of sightings or interactions shown are not necessarily an accurate indicator of the actual number of encounters between fishermen and protected species. The degree to which sightings of or interactions with protected species are not reported or underreported is unknown.

WESTERN PACIFIC REGIONAL FISHERY MANAGEMENT COUNCIL (COUNCIL) ACTIVITIES

The Council is the policy-making organization for the management of fisheries in the EEZ around American Samoa, Guam, Hawaii, the Northern Mariana Islands, and other U.S. island possessions in the Pacific. The Council prepares and modifies Fishery Management Plans (FMPs) for domestic and foreign fishing in the region based on advice from scientific and industry advisors as well as input from the general public. Regulations are administered by the National Marine Fisheries Service, and are enforced jointly by agents of the U.S. Coast Guard and National Marine Fisheries Service. In addition, the Hawaii Division of Conservation and Resources Enforcement and the Hawaii State Marine Patrol provide assistance in enforcing FMP regulations under a cooperative agreement between the State and NMFS. The FMP for crustaceans (primarily lobsters) was implemented in 1983 and has been amended 8 times as conditions in the fishery have changed.

Amendment 8 was submitted to the Secretary of the Department of Commerce to review in July 1994. The changes to the limited entry program and quota management system proposed in Amendment 8 were recommended during a 1993 review of the operational details of the fishery under limited entry and quota management. Provisions included elimination of the landing requirement for limited entry permit renewal, and establishment of framework procedure for considering modification to the quota management (i.e., adjustments to the target CPUE or allowing some level of fishing when the initial quota was zero). The Council decided to remove the landing requirement since it forces fishermen to participate in the fishery at least every other year, even if the stocks can support only a very limited annual quota. The framework procedures were proposed to improve the Council's ability to respond to changing conditions and use the best scientific information available. Amendment 8 also proposed modifying notification and reporting procedures to improve data collection, as well as enforcement and administration.

In October 1994, the NMFS Southwest Regional Director informed the Council that Amendment 8 had been partially disapproved. Approved provisions included the elimination of the landing requirement and modifications to the notification and reporting procedures. The final rule implementing these measures was published in the *Federal Register* on November 10, 1994, and became effective on December 12, 1994.

Neither of the proposed framework provisions were approved. The regional director cited the recent decrease in recruitment and the Council's decision to review the quota system as reasons why the provisions were neither necessary nor appropriate for management of the fishery. The Council disagreed with this decision.

The Council initiated a review of the quota management system following the August closure of the 1994 fishery. Since implementation of the quota management in 1992, the fishery has experienced highly variable quotas, seasonal closures, and differences between initial and final quotas. This situation has resulted in severe marketing difficulties and has diminished the usefulness of an initial quota as a preseason planning tool for fishermen. The 1994 season also illustrated the sensitivity of the quota formula to small changes in catch rates and raised concerns about the impacts of a small number of vessels participating in the lobster fishery on final quota calculations.

On October 27, 1994, a technical panel of scientists met in Hawaii with members of the Crustaceans Plan Team and the Advisory Sub-panel to review the existing quota management system and to discuss alternatives to identified concerns. The review panel identified two possible alternatives to the present quota-setting procedures and recommended a series of analyses to evaluate the trade-off between alternatives. In addition, the review panel suggested ways to test the validity of underlying assumptions and results of the stock assessment model. The Plan Team and Advisory Sub-panel concurred with the review panel's recommendations, which were presented to the Council on November 9. At that time, the Council requested that the NMFS Honolulu Laboratory, with assistance as needed, conduct the recommended analyses. Based on the results of this evaluation, the Council in all likelihood will propose modifications to the quota management system in 1995.

ADMINISTRATIVE ACTIVITIES

The Regional Director, SWR, issued the maximum of 15 NWHI limited entry permits to vessel owners for the 1994 lobster season (Table 9). Three new permit holders acquired their permits via the permit transfer process allowed under the FMP. Twelve permit holders initially received their permits in 1992 when the limited entry program was established.

During July, the first month of fishing, the PAO, coordinated with the Honolulu Laboratory all lobster catch and effort data reported by vessel operators at sea. PAO received a total of 21 call-in reports which were received in a predetermined format (Fig. 7). The reports were forwarded to the Honolulu Laboratory for use in calculating the final quota for the 1994 season according to the FMP quota formula.

ENFORCEMENT ACTIVITIES

In coordination with the United States Coast Guard (USCG) Office of Law Enforcement in Honolulu, numerous aerial and vessel patrols were conducted in the NWHI before, during, and after the 1994 lobster season. These patrols were scheduled to ensure that lobster fishermen were complying with the closed season and closed area requirements. In addition, these patrols and boarding efforts concentrated on retention of egg-bearing female lobsters and log book requirements. Several of these patrols were conducted by USCG vessels home-ported other than in Honolulu. Back-to-back patrols used 110-foot and 378-foot Coast Guard cutters from Honolulu.

NMFS agents accompanied the majority of the aerial patrols and one cutter patrol. USCG and NMFS agents documented only one violation of lobster regulations--using properly marked traps. This excellent compliance record is also due to acknowledgment by limited entry fishermen of the importance of this resource as well as their accountability toward this fishery.

The purpose of the patrol, other than to ensure compliance with the lobster regulations, was a mutual learning experience on all aspects of the lobster fishing operations. All five of the participating lobster vessels were inspected on the grounds for trap compliance, logging and permit requirements, and USCG regulations with special attention focusing on the handling or release of sublegal and berried lobsters.

The careless handling of berried and undersized lobsters during harvest operations or release was monitored by a Honolulu NMFS agent who accompanied a cutter patrol. The NMFS agent also provided considerable training for the USCG personnel who continually patrolled the NWHI lobster fishing grounds, boarding lobster vessels for inspection.

Because all permitted lobster vessels were using the gauges designed and provided by Honolulu enforcement, no problems with inaccurate gauges were documented.

Catch and effort logging was enforced both at sea and during dockside inspection. All five of the Federally permitted lobster vessels were boarded at sea--some several times. Many were reboarded at dockside when they returned. Boarding teams at sea and in Honolulu reported that all logs inspected complied with logging requirements. Vessel arrival notification was reported by all vessels upon arrival in Honolulu. However, because of time constraints, reported logbook catch data and the actual number of lobsters landed were not verified.

ACKNOWLEDGMENTS

I would like to thank Sam Pooley for his editorial comments and suggestions and the Honolulu editorial staff for their assistance. Also, thanks to Alvin Z. Katekaru for his editorial review, Western Pacific Regional Fishery Management Council, the Southwest Office of Enforcement, and the Stock Assessment Investigation, Honolulu Laboratory for their valuable contributions to this report.

CITATIONS

Clarke, R. P.
1989. Annual report of the 1988 western Pacific lobster fishery. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-89-5, 28 p.

Clarke, R. P., and S. G. Pooley.
1988. An economic analysis of Northwestern Hawaiian Islands lobster fishing vessel performance. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFC-106, 46 p.

Clarke, R. P., and S. S. Yoshimoto.
1990. Application of the Leslie model to commercial catch and effort of the slipper lobster, *Scyllarides squammosus*, fishery in the Northwestern Hawaiian Islands. Mar. Fish. Rev. 52(2):1-7.

Clarke, R. P., S. G. Pooley, P. A. Milone, and H. E. Witham.
1988. Annual report of the 1987 western Pacific lobster fishery. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-88-5, 48 p.

Dollar, R. A., and K. C. Landgraf.
1992. Annual report of the 1991 western Pacific lobster fishery. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-92-10, 26 p.

Dollar, R. A.
1993. Annual Report of the 1992 western Pacific lobster fishery. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-93-09.

Haight, W. R., and J. P. Polovina.
1992. Status of lobster stocks in the Northwestern Hawaiian Islands, 1991. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-92-02, 21 p.

Haight, W. R., G. T. DiNardo, and J. A. Wetherall.
1995. Status of lobster stocks in the Northwestern Hawaiian Islands, 1994. Honolulu, Lab., Southwest Fish. Sci. Cent., Natl Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish Sci. Cent. Admin. Rep. H-95-03.

Landgraf, K. C., S. G. Pooley, and R. P. Clarke.
1990. Annual report of the 1989 western Pacific lobster fishery. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-90-6, 30 p.

TABLES

Table 1.--Annual landings (number and pounds), ex-vessel revenues (US$), fishing effort (trap-hauls, vessels, and trips), catch-per-unit-effort (CPUE; number of legal lobsters per trap-haul), and prices (US$/lobster) of slipper and spiny lobsters combined from the Northwestern Hawaiian Islands, 1983-94. Data are from vessel logbooks and revenue reports.

Year	Landings No.	Landings Pounds[a]	Revenue[b] ($)	Trap-hauls (No.)	Vessels (No.)	Trips (No.)	Combined legal CPUE[c]	Price/ lobster
1983[d]	234,700	203,000	591,000	84,870	4	19	2.77	2.52
1984	872,400	1,017,000	2,624,000	363,000	11	38	2.40	3.01
1985	1,812,700	2,368,000	5,887,000	983,062	16	62	1.80	3.21
1986	1,787,400	2,202,000	3,982,000	1,352,580	16	60	1.32	3.35
1987	737,800	969,000	3,988,000	804,723	11	38	0.92	5.41
1988	1,057,600	1,405,000	5,000,000	845,200	9	28	1.25	4.73
1989	1,160,250	1,470,000	6,291,000	1,071,538	11	33	1.08	5.42
1990	774,300	949,000	4,887,000	1,182,485	14	45	0.66	6.31
1991	166,700	183,000	1,028,000	296,648	9	21	0.56	6.16
1992[e]	424,400	466,000	2,093,000	721,682	12	28	0.59	4.93
1993	----------------------FISHERY CLOSED----------------------							
1994	131,000	159,000	837,000	168,498	5	5	0.78	6.38

[a]Includes the weight of frozen lobster tails expanded to represent whole weight (spiny lobster tail weight = 35.6% of whole weight; slipper lobster tail weight = 33.3% of whole weight).
[b]Revenue is reported on a per-trip basis. Some trips overlap years; revenue for those trips is pro-rated to each year.
[c]Legal CPUE for slipper lobster before 1988 is calculated as 0.72 multiplied by the number of retained slipper lobster.
[d]The 1983 annual values were estimated from logbook returns from the latter 9 months of the year.
[e]A few live lobsters were landed in January 1993 from fishing completed during December

Table 2.--Estimated landings, ex-vessel prices (US$/1b), and ex-vessel revenues (US$) of spiny and slipper lobsters landed from the Northwestern Hawaiian Islands, 1983-94. Data are from vessel logbooks and revenue reports.

	Spiny lobster				Slipper lobster			
Year	Pounds[a]	Metric tons	Price ($/1b)	Revenue ($)	Pounds[b]	Metric tons	Price ($/1b)	Revenue ($)
1983	203,000	92	2.91	591,000	--[c]	--[c]	--[c]	--[c]
1984	935,000	424	2.66	2,490,000	82,000	37	1.63	134,000
1985	1,438,000	652	2.94	4,227,000	930,000	423	1.78	1,660,000
1986	1,149,000	521	3.23	3,710,000	1,053,000	479	2.16	2,272,000
1987	530,000	241	4.67	2,479,000	439,000	200	3.44	1,509,000
1988	1,218,000	553	3.66	4,453,000	186,000	85	3.12	581,000
1989	1,266,000	574	4.44	5,624,000	203,000	93	3.28	667,000
1990	784,000	356	5.51	4,319,000	165,000	75	3.43	567,000
1991	150,000	68	6.06	911,000	33,000	15	3.54	117,000
1992	318,000	144	5.20	1,654,000	148,000	69	2.96	439,000
1993	----------------------------------FISHERY CLOSED------------------------------------							
1994	113,000	51	5.92	670,000	46,000	21	3.65	166,000

[a]Includes frozen lobster tails expanded to represent whole weight (tail weight = 35.6% of whole weight).
[b]Includes frozen lobster tails expanded to represent whole weight (tail weight = 33.3% of whole weight).
[c]Data for slipper lobster not available for 1983.

Table 3.--Estimated landings, ex-vessel price (US$/lb), and ex-vessel revenue (US$), by product type, from the Northwestern Hawaiian Islands, 1990-94. Data are from vessel revenue reports; dash indicates the data are not available or are confidential and therefore, excluded.

			Spiny lobster				Slipper lobster					
Year	Product	Type	Pounds	Metric tons	Price ($)	Revenue ($)	Pounds	Metric tons	Price ($)	Revenue ($)	Vessels (No.)	Trips (No.)
1990	Live		57,900	26	7.27	421,300	6,000	3	6.66	41,000	6	16
	Frozen	Whole	500	--[a]	8.00	4,000	--	--	--	--	--	--
	Frozen	Tail	258,300	117	15.07	3,894,000	53,200	24	9.94	526,800	14	43
1991	Live		5,900	3	8.02	47,400	2,500	1	7.63	19,200	4	11
	Frozen	Whole	350	--[a]	10.49	3,700	--	--	--	--	--	--
	Frozen	Tails	51,300	23	16.77	859,900	10,000	5	9.61	97,900	9	14
1992	Live		10,100	5	9.77	98,700	2,100	--[a]	9.62	20,500	4	10
	Frozen	Whole	--	--[a]	--	--	--	--	--	--	--	--
	Frozen	Tails	110,000	50	14.19	1,554,200	50,500	23	8.66	437,500	11	23
1993	----------------FISHERY CLOSED----------------											
1994	Live		--	--[a]	--	--	--	--	--	--	--	--
	Frozen	Whole	--	--	--	--	--	--	--	--	--	--
	Frozen	Tails	40,100	18	16.68	668,900	15,200	7	10.90	166,400	5	5

[a]Less than 1 metric ton landed.

Table 4.--Annual fishing effort (days fished and trap-hauls) and catch-per-unit-effort (CPUE; number of lobsters per trap-haul) for spiny and slipper lobsters in the Northwestern Hawaiian Islands, 1994. Data are from vessel logbooks.

Area	Days fished (No.)	Trap-hauls (No.)	Catch-per-unit-effort: Spiny lobster				Slipper lobster			
			Legal	Sublegal	Berried	Total	Legal	Sublegal	Berried	Total
Necker	102	80,708	0.61	0.39	0.27	1.28	0.21	0.03	0.03	0.27
Gardner Pinnacles	69	69,259	0.43	0.40	0.22	1.04	0.18	0.20	0.08	0.46
Other[a]	28	18,531	0.36	0.10	0.09	0.55	0.89	0.59	0.17	1.65
Total	199	168,498	0.51	0.36	0.23	1.10	0.27	0.16	0.07	0.50

[a]Includes totals when less than three vessels fished for other Northwestern Hawaiian islands banks, reefs or shoals.

Table 5.--Annual fishing effort for active vessels in the NWHI lobster fishery, 1983-94. Fishing days per vessel for 1983-90 are adjusted (see Table 6). Data are from vessel logbooks.

Year	Vessels	Trips	Fishing days	Fishing days/ per vessel	Trap-hauls
1983	4	19	279	--	84,870[a]
1984	11	38	822	--	363,000
1985	16	62	1,653	--	983,062
1986	16	80	2,166	--	1,352,580
1987	11	38	1,217	120	804,723
1988	9	28	1,617	139	845,200
1989	11	33	1,323	120	1,071,538
1990	14	45	1,468	109	1,182,485
1991	9	21	432	48[b]	296,648
1992	12	28	893	74	721,682
1993	---------------------FISHERY CLOSED---------------------				
1994	5	5	199	40	168,498

[a]Estimated from Clarke and Yoshimoto (1990).
[b]Fishing days/per vessel for 1991-92 and 1994 are unadjusted because of the fishery closures during portions of those years.

Table 6.--Number of vessels, trips, and sea days, by vessel class, for the lobster fleet in the Northwestern Hawaiian Islands, 1994. Adjusted figures, which correct for vessels fishing less than full time and for incomplete trips, are not used for 1994 because the fishery was closed for part of the year. Standard deviations are in parentheses; data are from vessel logbooks. Dashes indicate that the data are not available or are confidential and therefore, excluded.

Vessels				Mean number of sea days by activity per vessel						
Class	No.	Trips (No.)	Sea days	Fishing	Traveling	Running	Weather	Breakdown	Rest/deck work	Missing
Unadjusted										
I	-	-	--	--	--	--	--	--	--	--
II	4	4	53.5 (6.1)	38.8 (6.1)	8.5 (2.4)	7.8 (9.3)	6.0 (2.4)	0.0 (0.0)	0.3 (0.5)	0.0 (0.0)
III	-	-	--	--	--	--	--	--	--	--
Total fleet	5	5	53.4 (5.3)	39.8 (7.8)	7.8 (2.6)	7.0 (8.2)	4.8 (3.4)	1.2 (2.7)	2.8 (5.7)	0.6 (1.3)

Table 7.--Entry and exit paradigms of permitted lobster fishing vessels in the Northwestern Hawaiian Islands (NWHI), 1990-94. Vessels are coded for purposes of confidentiality. Data are from vessel logbooks and shoreside monitoring.

Vessel code	1990	1991	1992[b]	1993[c]	1994[d]
A	F	O	F	O	O
B	F	F/L	F	L	L/F
C	F	F/L	F	L	L
D	F	F/O	O/F	I	I/F
E	F	F/O	O	O	O/F[e]
F	F	L/X[a]	--	--	--
G	F	L/F	F	L/O	O
H	F	F/B	F	I/T	I
I	F	I/F	F	I/S	S
J	L	L/O	O	O	O
K	F	L	L/F	L	L
L	F	F/O	F	L	L/F
M	F	O	O/F[2]	O	O
N	F	B/F	F	B	B
O	F	O	O	O/L	L/F

KEY: F = fished for lobster in the NWHI; X = fished for lobster in the main Hawaiian islands; L = longlined in Hawaii (HI); I = idle in HI; O = fished outside HI (mainland or other countries); B = bottom-fished in HI; S = fished for shrimp in HI; T = transshipped shark fins from foreign vessels operating outside HI Exclusive Economic Zone. Two entries indicate vessels engaged in two types of activities during the year (e.g., O/F indicates that the vessel fished outside of HI for the first part of the year and fished for lobster the latter part).

[a]This vessel sank in November 1991.

[b]Emergency closures were initiated in June through October 1991 and April 10 through June 30, 1992. The NWHI lobster vessel limited entry (LE) program and quota was implemented on April 27, 1992. A final rule to Amendment 7 was issued in March 1992 to establish an annual closed season January 1-June 30. The LE program allows a maximum of 15 vessel permits to be effective at any time (permits are transferable).

[c]The NWHI lobster fishery was closed in 1993.

[d]The NWHI lobster fishery opened for 2 months during July-August 1994.

[e]Original vessel's permit transferred to replacement vessel in 1994.

Table 8.--Reported sightings of or interactions with endangered or threatened species by the lobster fleet in the Northwestern Hawaiian Islands, 1994. Data are from the vessel logbooks.

Area	No. of sightings by No. of animals: One animal	No. of sightings by No. of animals: Two animals
Monk seals observed in statistical area		
Gardner Pinnacles	0	0
Necker Island	7	0
Other[a]	0	0
Monk seals observed in vicinity of fishing gear		
Gardner Pinnacles	0	0
Necker Island	1	0
Other	0	0
Monk seals observed preying on released lobsters		
Gardner Pinnacles	0	0
Necker Island	1	0
Other	0	0
Turtles observed in statistical area		
Gardner Pinnacles	0	0
Necker Island	0	0
Other	0	0

[a]Includes totals for less than three vessels that fished at other Northwestern Hawaiian islands, banks, reefs, or shoals.

Table 9.--Fishing vessels with limited entry permits for the 1994 Northwestern Hawaiian Islands lobster fishery.*

Vessel	Permit holder	Fished in 1994
Aleutian Spray	K. Knutsen/D. Gunn	No
Archer	Jerry Ray	Yes
Betty N	Gengo Nabeshima	No
Bounty	Pacific Seafoods, Inc.	Yes
Fortuna	Blue Hawaii Enterprise, Inc.	No
Liberty	Yochum Trust	No
Lusty	Lusty Voyages, Inc.	No
Magic Dragon	Dragon Fishing Co., Inc.	No
Marie M	Marie M. Corp.	No
Miss Jessico	Pacific Seafoods, Inc.	Yes
Pacific Pride	Pacific Seafoods, Inc.	Yes
Petite One	Ka'upu, Ltd.	No
Sea Spray	Parker Seafoods, Inc.	Yes
No vessel	DGA, Inc.	N/A
No vessel	Jack Johnson	N/A

*For the 1994 fishing season, the National Marine Fisheries Service issued the maximum of 15 Northwestern Hawaiian Islands lobster limited entry permits. There were three new permit holders: Blue Hawaii Enterprise, Jack Johnson, and Ka'upu Ltd., who acquired permits through the transfer process. One permit holder, Pacific Seafoods Inc., transferred its permit to a replacement vessel, *Pacific Pride*, which it owned.

FIGURES

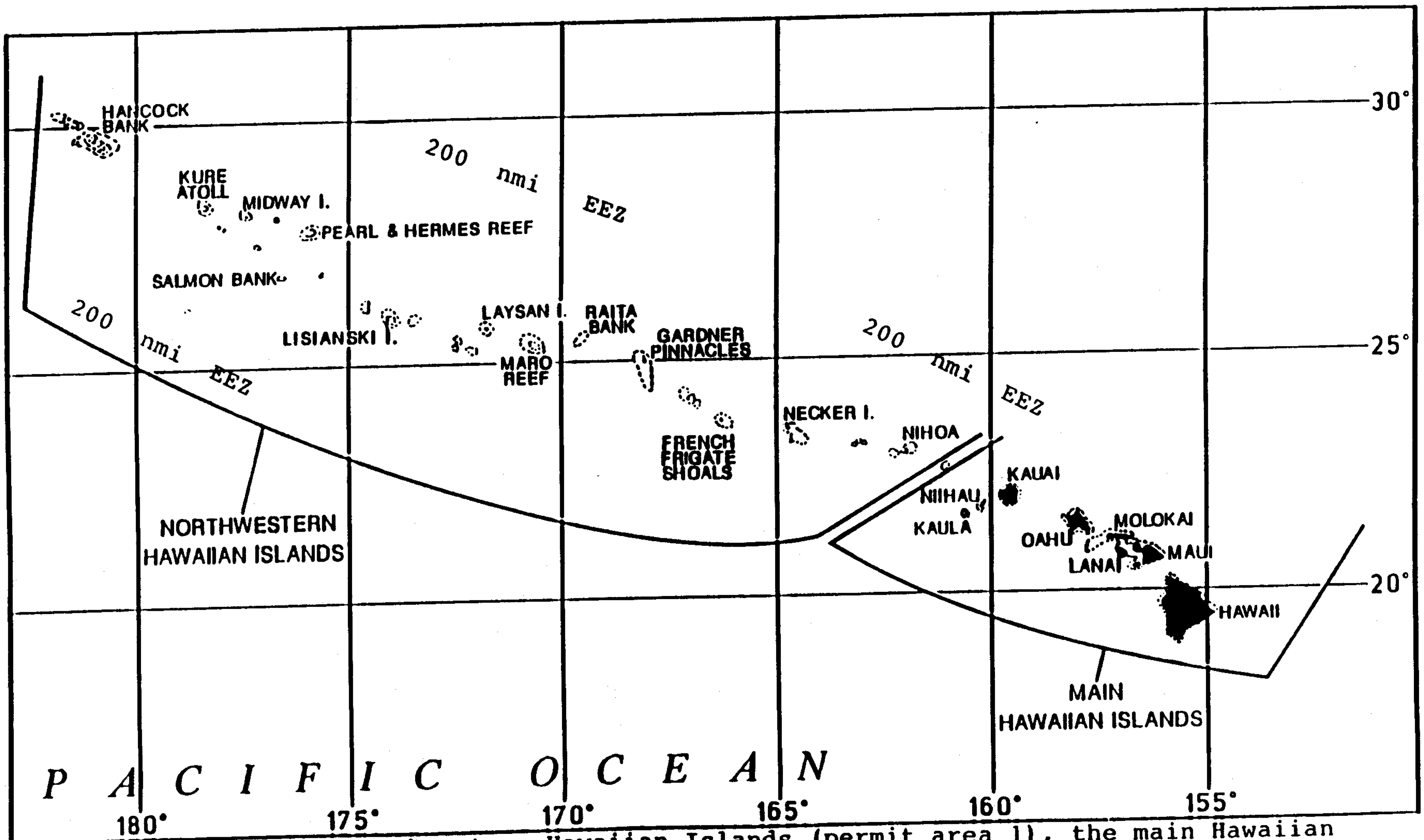


Figure 1.--Map of the Northwestern Hawaiian Islands (permit area 1), the main Hawaiian Islands (permit area 2) and the 200 nmi Exclusive Economic Zone (EEZ).

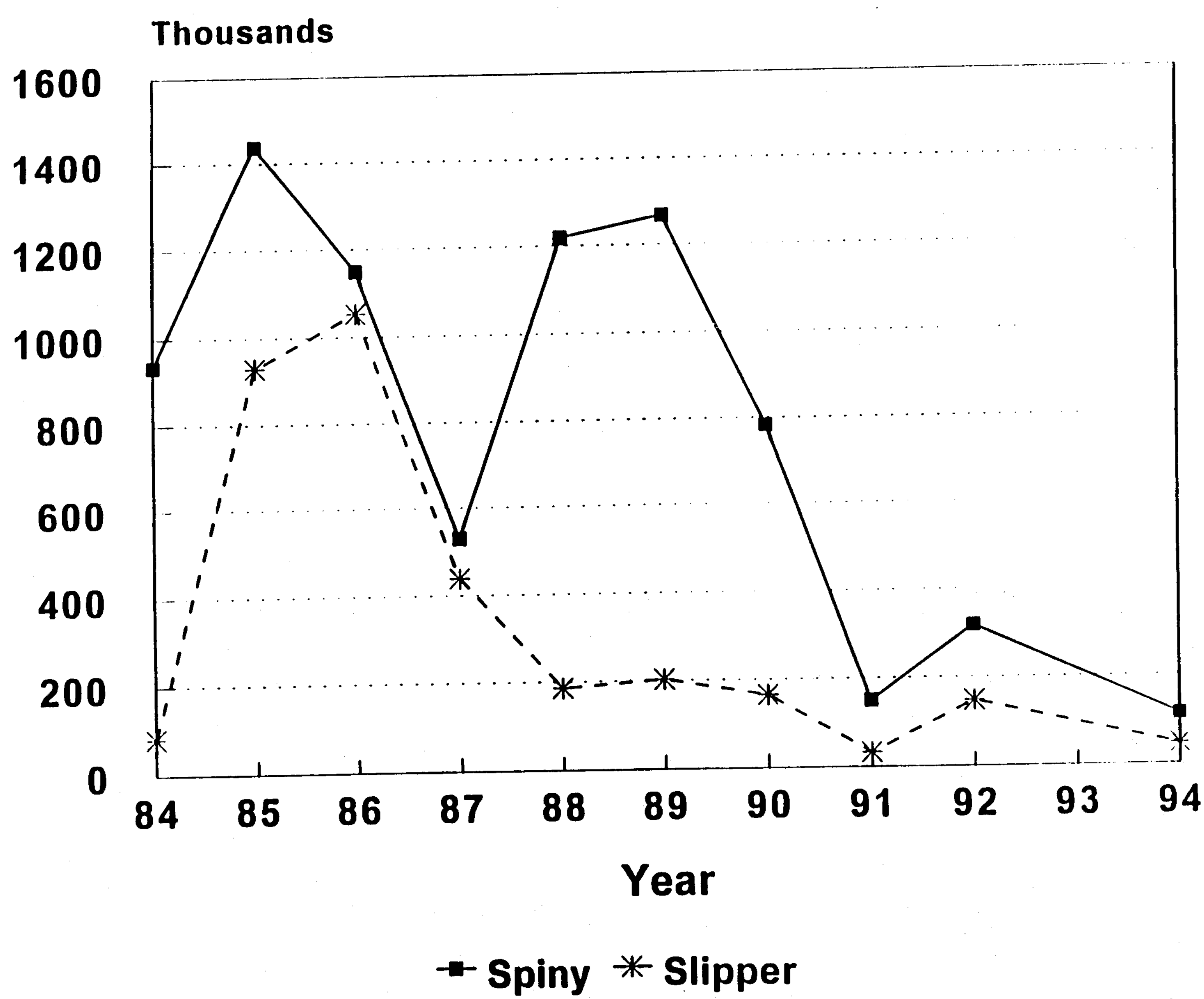


Figure 2.--Estimated annual landings (wet weight) of spiny and slipper lobsters in the Northwestern Hawaiian Islands 1984-94.

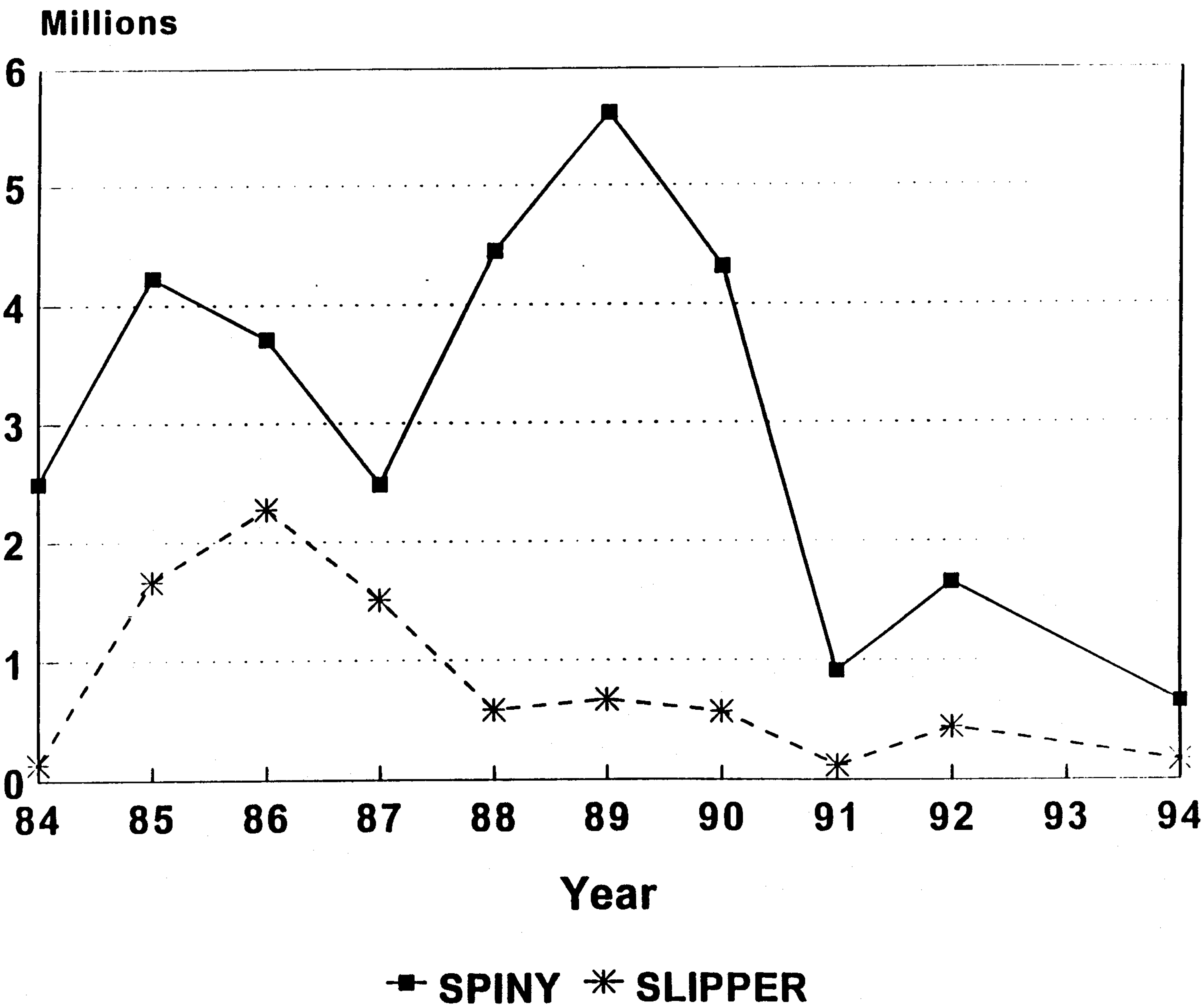


Figure 3.--Ex-vessel revenue for spiny and slipper lobsters from the Northwestern Hawaiian Islands, 1984-94.

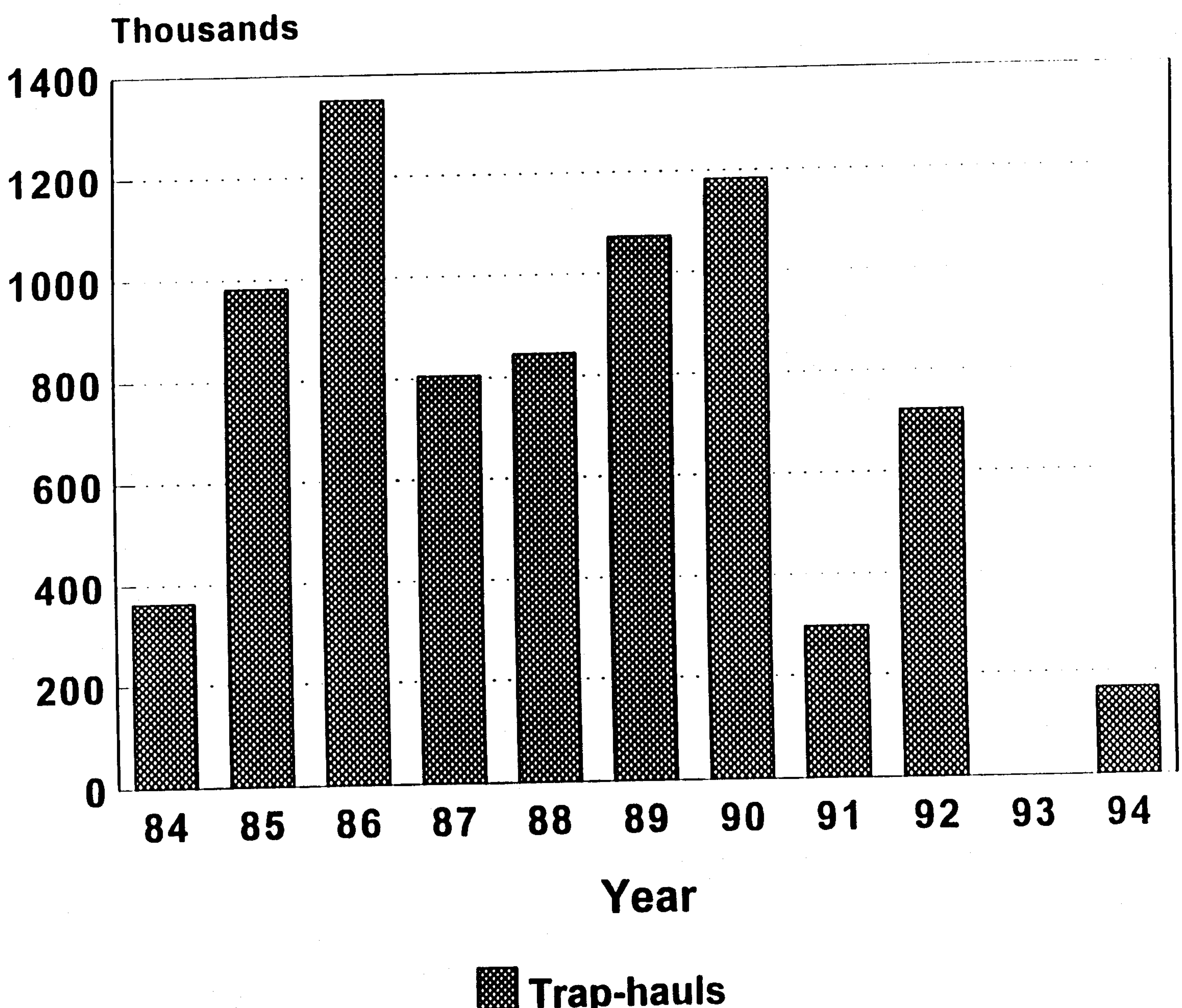


Figure 4.--Fishing effort (trap-hauls) by the lobster fleet in the Northwestern Hawaiian Islands, 1984-94.

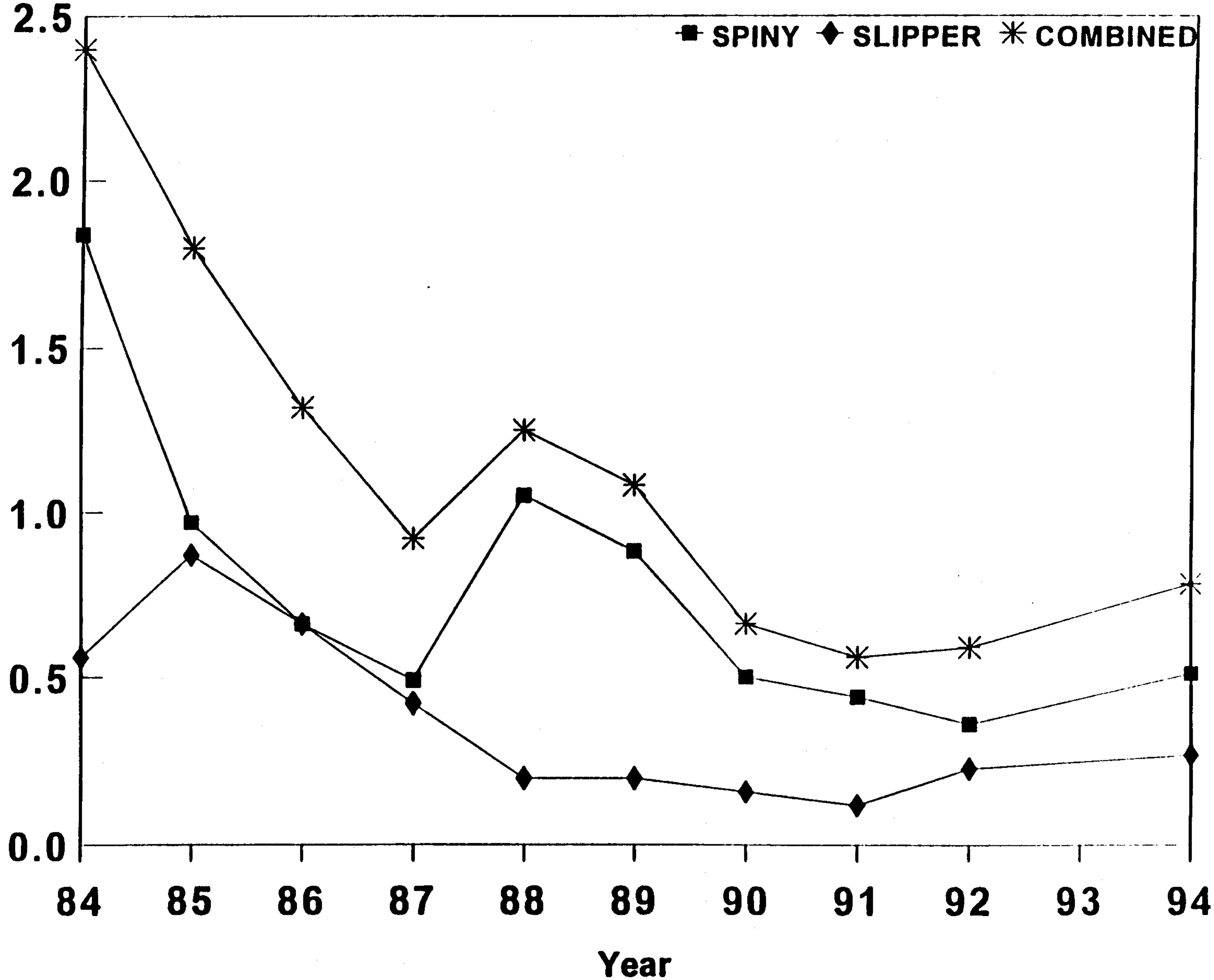
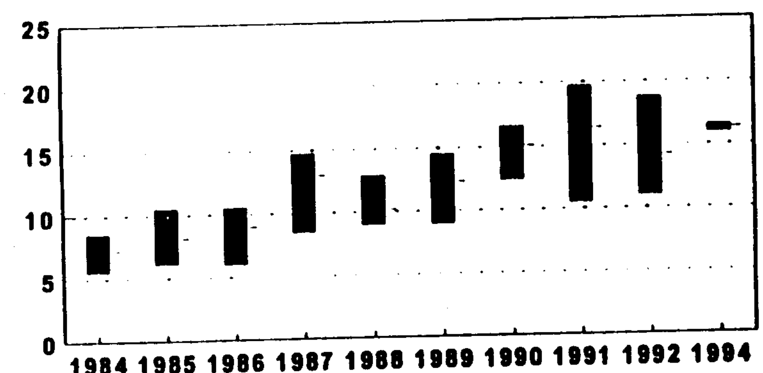


Figure 5.--Catch-per-unit-effort (CPUE) for spiny and slipper lobsters from the Northwestern Hawaiian Islands, 1984-94. (CPUE for slipper lobster is calculated as 0.72 multiplied by the number retained before 1988).

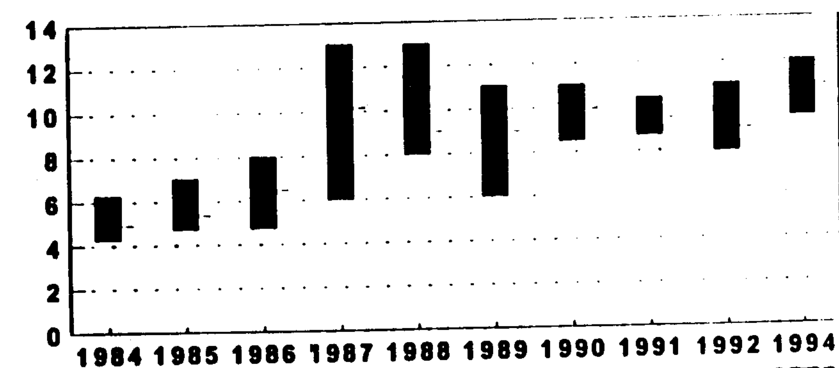
SPINY LOBSTER



	1984	1985	1986	1987	1988	1989	1990	1991	1992	1994
High	8.5	10.5	10.5	14.65	12.79	14.44	16.6	19.68	18.78	16.51
Low	5.57	6.16	6.03	8.5	9	9.01	12.37	10.51	11.01	16.01
MEAN	7.23	8.13	8.96	13	10.19	12.29	15.07	16.43	14.25	16.34

High Low - MEAN

SLIPPER LOBSTER



	1984	1985	1986	1987	1988	1989	1990	1991	1992	1994
High	6.25	7	8	13	12.98	11.03	11.04	10.41	11	12.01
Low	4.25	4.71	4.75	6	8	6.02	8.51	8.73	7.94	9.51
MEAN	4.92	5.35	6.47	10.16	9.03	8.98	9.94	9.49	8.99	10.9

High Low - MEAN

Figure 6.--Low, mean, and high ex-vessel prices of frozen spiny and slipper lobster tails from the Northwestern Hawaiian Islands, 1984-94.

Fisheries Management/Operations
Pacific Area Office, Southwest Region
National Marine Fisheries Service

1994 NWHI LOBSTER CATCH/EFFORT DATA CALL-IN SHEET

PHONE IN THE FOLLOWING INFORMATION ([redacted] BLOCKS) EACH WEEK TO:

(808) 973-2939 Georgia Matsukawa or Al Katekaru

AREA FISHED (ISLAND/BANK): ______________________

Please Use a Separate Sheet for each Area Fished

Trap Haul Day Month/Day	Number of Traps Hauled	Number of Spiny Lobsters Kept	Number of Slipper Lobsters Kept
Mon. /			
Tues. /			
Wed. /			
Thurs. /			
Fri. /			
Sat. /			
Sun. /			
TOTAL:			
Week No. (See Below):			
Vessel Code Name:			
Caller's Name:			

***** July and August Schedule for Call-In Reports to NMFS *****

Week No.	Period Fished: Mon. through Sun.	Report to NMFS No Later Than Tues:	Check Here: ✓
1	July 1 through 3	July 5	
2	July 4 through 10	July 12	
3	July 11 through 17	July 19	
4	July 18 through 24	July 26	
5	July 25 through 31	August 2	
The schedule below is subject to change depending on fishing effort and the total amount of lobsters harvested during July.			
6	August 1 through 7	August 9	
7	August 8 through 14	August 16	
8	August 15 through 21	August 23	
9	August 22 through 28	August 30	

Figure 7.--1994 Northwestern Hawaiian Islands Catch/Effort Data Call-in Sheet

Appendix 2

Haight, W.R. and G.T. DiNardo, 1995
Status of Lobster Stocks in the Northwestern Hawaiian Islands, 1994
Honolulu Laboratory, Southwest Fisheries Science Center
National Marine Fisheries Service
Admin. Rept. H-95-03

Southwest Fisheries Science Center
Administrative Report H-95-03

Status of Lobster Stocks in the Northwestern Hawaiian Islands, 1994

Wayne R. Haight[1] and Gerard T. DiNardo[2]

[1]Honolulu Laboratory
Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
2570 Dole Street, Honolulu, Hawaii 96822-2396

[2]Marine Resource Dynamics and Assessment Program
Joint Institute for Marine and Atmospheric Research
University of Hawaii
1000 Pope Road
Honolulu, Hawaii 96822

March 1995

INTRODUCTION

The Northwestern Hawaiian Islands (NWHI) trap fishery for spiny lobster *(Panulirus marginatus)* and slipper lobster (*Scyllarides squammosus*) began in the late 1970's after federal and state exploratory research cruises located lobster stocks in quantities suitable for commercial exploitation (Uchida et al., 1980). Lobster landings reached a maximum in 1984 and gradually declined during the years 1985 through 1989. A substantial decrease in lobster landings and catch-per-unit-effort (CPUE) was observed in 1990 and continued through 1991, prompting an emergency closure of the fishery from May 8 through November 11, 1991 (Haight and Polovina, 1992). To allow the lobster population to rebuild to a sustainable exploitation level, the lobster fishery has been managed under a quota and limited entry system since 1992.

A fishery independent survey is conducted annually by the National Marine Fisheries Service (NMFS) Honolulu Laboratory to provide additional information on the dynamics of the NWHI lobster population. The results of the analyses of research and commercial fishery data are presented in this report, the 10th in an annual series of NWHI lobster status reports. In addition, a detailed description of the quota methods outlined here can be found in Wetherall et al. (1995).

FISHERY MANAGEMENT

The NWHI lobster fishery is managed by NMFS under the Crustaceans Fishery Management Plan (FMP) adopted in 1983 by the Western Pacific Regional Fishery Management Council. The FMP defines a minimum legal size for harvested lobsters, requires the use of escape vents on traps, forbids the retention of berried females, and requires that vessel captains submit logbooks of daily catch and fishing effort. In response to substantial declines in CPUE in 1991, the FMP was amended in 1992 to include an annual 6-month closed season (January-June), limit entry into the fishery and establish an annual catch quota.

The annual quota is derived as a two-step process (1) a pre-season forecast quota is issued in February based on the results of commercial and research fishing from the previous year, and (2) an in-season (August) adjustment is made based on CPUE information from the first month of commercial fishing. The quota is set at a level that provides an economically viable CPUE (1.0 lobster/trap-haul), while protecting spawning stock biomass from over-harvest. The NWHI lobster quota is based on an optimal biomass approach, allowing surplus production to be harvested if the population is above the optimal level. The quota methodology was first applied during the 1992 fishing season. The 1993 preseason forecast indicated that the lobster stock size would be insufficient to permit a commercial fishery in 1993. Based on this information, the fishery remained closed from 1993 through June of 1994. The 1994 pre-season forecast indicated that the population would rebuild to a level which would allow a fishery during the 1994 season, and the fishery was opened July 1,

1994. Commercial CPUE from the first month of fishing indicated the population was smaller than predicted, and the fishery was subsequently closed.

RESEARCH PROGRAM

A fishery independent trap survey is conducted annually by the NMFS Honolulu Laboratory to collect length frequency, sexual development, and relative abundance data from lobster stocks in the NWHI. The survey uses a fixed site design stratified by depth and spans the years 1986-88 and 1990-94. The number of sample sites varied temporally as did trap type. Seven sites were sampled at Necker Island and six sites at Maro Reef each year from 1986 through 1988. Beginning in 1990, six sites were sampled at Necker Island and five sites at Maro Reef. At each site, shallow water (≤20 fathoms) and deep water (>20 fathoms) stations were sampled. Ten strings of eight traps each were set at the shallow station and two to four strings of 20 traps each were set at the deep station. Between 1986 and 1990 wire traps were used as the primary sampling gear. In 1991, a combination of wire and plastic traps were fished to facilitate the estimation of gear conversion formulae (wire trap CPUEs to plastic trap CPUEs); plastic traps have been used exclusively since 1991. Traps are fished overnight and baited with frozen mackerel. - the fishers don't leave the traps in the water overnight

Length frequencies of spiny lobster are converted to age frequencies by applying a growth curve estimated by Polovina and Moffitt (1989). Based on this growth curve, recruitment of spiny lobster to the commercial fishery is estimated to occur approximately 3 years after settlement onto the benthos. Age-specific CPUE values are calculated by dividing total number of spiny lobster of each age class by the total number of traps fished at each bank and are standardized by applying the conversion factor for gear type.

In 1994, standard research trapping was conducted at Maro Reef and Necker Island from May 8 to May 28. Additional exploratory trapping for juvenile lobsters was conducted from small boats in the shallow lagoon at Maro Reef, continuing a time series of juvenile abundance data collection which began in 1993.

ABUNDANCE

A significant reduction in research CPUE values for all spiny lobster age classes at Maro Reef was first observed in 1990. The depressed CPUE continued from 1991 through 1994 (Fig 1.). This trend has persisted despite significant reductions in commercial fishing effort at Maro Reef during 1991-92 and 1994, and a fishery closure in 1993. A similar trend was observed at Laysan Island, 70 nmi to the northwest (Haight and Polovina 1992), which has been closed to commercial harvest since the beginning of the commercial fishery. In contrast, recruitment of age 2 lobster to Necker Island, 360 nmi to the southeast of Maro Reef, remained fairly constant throughout the time series (Fig. 2). Polovina and Mitchum (1992) found recruitment of spiny lobster to Maro Reef to be correlated with the strength of the subtropical countercurrent, suggesting that mesoscale oceanographic features may impact the transport and survival of lobster larvae during their 11-12 month pelagic larval cycle. Continued recruitment of spiny lobster to Necker Island suggests that the lower southeastern end of the NWHI is not linked to the same oceanographic or recruitment processes as the northwestern end of the archipelago. Because the oceanographic processes which appear to affect recruitment at the northwestern portion of the NWHI occur in approximately decadal cycles (Polovina and Mitchum, 1992; Polovina et al., 1994), the spiny lobster stocks may remain at the present level of production for several years.

At Necker Island, juvenile spiny lobster (<age 3) appear to occupy the same habitat as the adults (Parrish and Polovina 1994), which increases the probability of being caught in the commercial fishery. It is likely that fishery-related mortality (handling stress, predation on discards) of juvenile lobster is quite high. At Maro Reef, juvenile lobster appear to utilize shallow reef areas not associated with fishing. In 1993, an area of high juvenile abundance was located during exploratory research trapping in the shallows of Maro Reef (Haight and Polovina 1993a). In 1994, the same lagoonal areas were fished, and the area of high juvenile abundance was extensively surveyed. Age specific CPUE values from inside Maro Reef were significantly higher than the CPUE values from outside the reef (Fig. 3). Of the shallow lagoon areas trapped in 1994, only the northwestern reef spur site exhibited high juvenile CPUE values (Fig. 4). It appears that the juvenile lobster are associated with the northern portion of the reef spur and are more abundant in shallow waters next to the spur (Fig. 5). The deeper (12 m) station to the south of the spur had relatively low CPUE values compared to the shallow water stations.

SPAWNING STOCK BIOMASS

The spawning potential ratio (SPR), based on the spawning stock biomass per recruit, is specified in the FMP as the measure of overfishing for the NWHI lobster stocks. The FMP defines a SPR value of ≤0.20 as the indicator of recruitment overfishing. The 1994 SPR value of 0.76 indicates that the amount of fishing effort in 1994 (168,498 trap-hauls) would be insufficient to cause recruitment overfishing under average conditions.

The SPR value however, does not consider changes in the level of recruitment and subsequent trends in spawning biomass. An index of spawning stock biomass can be calculated from research CPUE. This index is the ratio of the current year's spawning biomass (kg/trap-haul) to the spawning biomass for the unexploited population. To determine the spawning biomass for a given year, the size at onset of sexual maturity must first be determined. A standard method of determining this parameter is the size at the onset of egg production in female lobsters (Haight and Polovina, 1993a). A hyperbolic tangent function (Polovina, 1989) was fit to the 1994 research data to determine the size at which 50% of the females were ovigerous. This value was then used to calculate the biomass of reproductively mature spiny lobster for 1994. The 1994 value was compared to the value for the unexploited stock (pre-fishery data from 1977) to calculate the spawning biomass index value. The index values declined substantially in 1990, concurrent with the commercial fishery CPUE decline, and remained low until 1992. Since 1992 there has been a gradual trend toward increased spawning biomass at Necker Island (Table 1).

The difference in the two approaches above should be noted. The SPR indicates that on the average, 168,000 trap-hauls would not result in recruitment overfishing, whereas the spawning biomass ratio indicates the reproductive potential of the stock, especially at Maro Reef, has substantially decreased from pre-exploitation levels .

DYNAMIC POPULATION MODEL

Several approaches have been used since 1983 to model the lobster population in the NWHI. From 1985 to 1987, lobster yield was estimated using surplus production methods. After 1988, a dynamic population model was fit to the commercial data to estimate population size and biological parameters. This model expresses the number of exploitable lobster in a given month as a function of the number of exploitable lobster in the previous month, adjusted for natural mortality, fishing mortality, and recruitment. Because of spatial and temporal fluctuations in fishery dynamics, the monthly catches of both lobster species were pooled across banks to calculate a NWHI monthly average CPUE. The model predicted CPUE values for the years 1983 to 1989 fit the general commercial CPUE trend quite well; however, after 1989 the predicted CPUE values were consistently higher than the actual commercial CPUE values. Based on oceanographic and research assessment information (Polovina and Mitchum, 1992; Haight and Polovina, 1993b) it was assumed that the disparity between the estimated and actual CPUE values reflected a change in recruitment and not in natural mortality or catchability. The model was subsequently updated to incorporate variable recruitment, and refit to the commercial CPUE data (Haight and Polovina, 1993b).

QUOTA COMPUTATIONS

To provide the 1994 preliminary quota forecast, the dynamic population model was used to estimate a CPUE value for the first month of fishing based on commercial data through December 1992. The forecast July 1994 CPUE was 1.037 lobster/trap-haul. This resulted in a preseason forecast quota of 200,000 lobster. Research trapping prior to the commercial fishing season indicated that lobster stocks were at the level predicted by the dynamic population model. However, commercial CPUE from the first month of fishing was lower than predicted by the dynamic population model (0.91 vs 1.037) resulting in a reduction of the quota to 20,900 lobster (Fig. 6). Because the commercial catch exceeded the in-season final quota when announced, the fishery was closed in mid-August. During the 1994 fishery, a total of 130,979 lobster were caught in 168,498 trap-hauls. Spiny lobster comprised 65% of the total lobster caught (Table 2).

The large in-season reduction in the 1994 quota caused concern among fishery managers and the fishing industry. Therefore, to address the apparent sensitivity of the quota procedure to relatively small changes in CPUE, the NMFS formed an ad hoc review panel of fishery experts to investigate modifications to the lobster population modelling and quota methodology. After a thorough examination of the data time series, population modelling and quota methodology, the review panel suggested the following additional research to improve the quota procedure: (1) investigate standardizing the CPUE time series for confounding effects (fluctuating fishery dynamics, changes in fishing power) using general linear modelling procedures; (2) examine the hypothesis that the decline in the CPUE time series reflects a change in recruitment. Check this against the possibility that changes in vessel efficiency, targeting or changes in natural mortality or catchability could have been factors in the decline; (3) investigate a revised quota setting procedure, where uncertainty in the assessment is incorporated, and the goal is to find a quota which gives a low risk of the stock being overfished in any year.

UPDATED POPULATION MODEL AND QUOTA FORECAST

The review panel recommended sensitivity analyses to determine how large a change in the model estimate of catchability (q) and natural mortality (M) would be needed to explain the observed pattern in catch rate data. To address this recommendation, the population model was run allowing q to vary after 1989, while holding recruitment and M constant; this resulted in an approximately 50% reduction in q. There is no evidence from the commercial fleet to support a drop in q of this magnitude; fishing strategies and vessel efficiencies have remained fairly constant. Also, this result is inconsistent with research vessel CPUE data which detected a drop in CPUE, similar to that observed in the commercial CPUE series, between 1989 and 1990. When the model estimates of recruitment and q were held constant, and M allowed to vary after 1989, M increased by a factor of about three. Currently, there is no evidence to support a change in M of this magnitude. In summary, it is likely that the observed changes in catch rate between 1989 and 1990 were the result of changes in recruitment and not q or M.

Previously, monthly lobster abundance indices had been computed as the observed arithmetic average CPUE. As recommended by the review panel, a general linear model (GLM) analysis of CPUE was conducted to determine the effects of various factors on average CPUE and to compute indices of abundance adjusted for such effects. After investigating various factors, the data were adjusted to include spatial fluctuations in CPUE across the time series.

The dynamic population model was fit to the adjusted 1983-94 commercial CPUE data to estimate the July 1995 CPUE. Using this value (0.952 lobster/trap-haul), the population at the beginning of the 1995 fishing season is estimated to be 1,328,202 lobsters. Using the population estimate in the FMP quota formula yields a 1995 preliminary catch quota of 38,513 lobster. For a detailed description of the above procedures see Wetherall et al. (1995).

DISCUSSION

The objective of regulations outlined in Amendment 7 to the Crustaceans FMP is to protect the NWHI lobster stock from overfishing, ensure the maintenance of optimal spawning biomass, and allow the fishery to harvest surplus production. Implemented in 1992, Amendment 7 provided a framework with which to rebuild the NWHI lobster stock. Under the provisions outlined in the amendment, the lobster population was allowed to rebuild beginning with a quota in 1992, a closure of the fishery in 1993, and a small fishery in 1994. By examining the model-based estimate of the average NWHI exploitable population size, it can be seen the population has increased every year since 1992 (Fig. 7). The spawning biomass ratio also reflects this trend (Table 1). It appears that the recruitment process in the NWHI differs between the southeastern and northwestern portions of the archipelago, and that recruitment remains low in the northwestern portion relative to the pre-1990 level. There is also indication that spawning biomass has not increased substantially in the northwestern region. Future research, and associated management decisions must integrate several factors, including the dynamics of NWHI spiny lobster recruitment, the potentially high mortality of discarded sublegal lobsters, and the sensitivity of the FMP Amendment 7 quota formula to small changes in CPUE. The NMFS Honolulu Laboratory Stock Assessment Investigation is currently studying ways to refine the population modeling procedure, and to develop a new quota system that minimizes the risk of overfishing while providing greater quota stability and dependability (see Wetherall et al. 1995).

ACKNOWLEDGMENTS

Figures 1 and 2 were created using the Generic Mapping Tools (version 2.1.4) program (Wessel and Smith 1991).

REFERENCES

Haight, W. R., and J. Polovina.
1993a. Status of lobster stocks in the Northwestern Hawaiian Islands, 1993. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-93-17, 13 p.

Haight, W. R., and J. Polovina.
1993b. Status of lobster stocks in the Northwestern Hawaiian Islands, 1992. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-93-04, 23 p.

Haight, W. R., and J. Polovina.
1992. Status of lobster stocks in the Northwestern Hawaiian Islands, 1991. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-92-02, 19 p.

Parrish, F. A., and J. J. Polovina.
1994. Habitat thresholds and bottlenecks in production of the spiny lobster (*Panulirus marginatus*) in the Northwestern Hawaiian Islands. Bull. Mar. Sci. 54(1):151-163.

Polovina, J. J.
1989. Density dependence in the spiny lobster, *Panulirus marginatus*, in the Northwestern Hawaiian Islands. Can. J. Fish. Aquat. Sci. 46:660-665.

Polovina, J.J., and G.T. Mitchum.
1992. Variability in spiny lobster *Panulirus marginatus* recruitment and sea level in the Northwestern Hawaiian Islands. Fish. Bull., U.S. 90:483-493.

Polovina, J. J., and R. B. Moffitt.
1989. Status of lobster stocks in the Northwestern Hawaiian Islands, 1988. Honolulu Lab., Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-89-03, 10 p.

Polovina, J. J., G. Mitchum, N. Graham, M. Craig, E. DeMartini, and E. Flint.
1994. Physical and biological consequences of a climatic event in the central North Pacific. Fish. Oceanogr. 3(1):15-21.

Uchida, R. N., J. H. Uchiyama, R. L. Humphreys, Jr. and D. T. Tagami.
1980. Biology, distribution, and estimates of apparent abundance of spiny lobster *Panulirus marginatus*, in waters of the Northwestern Hawaiian Islands. *In*: Grigg, R., and R. Pfund (eds.), Proceedings of the symposium on the status of resource investigations in the Northwestern Hawaiian Islands, Honolulu, HI, April 24-25, 1980. UNIHI-SEAGRANT-MR-80-04. University of Hawaii Sea Grant College Program, Honolulu.

Wessel, P., and W. Smith.
1991. Free software helps map and display data. EOS Trans. Amer. Geophys. U. 72:441, 445-446.

Wetherall, J. A., W. Haight, and G. DiNardo.
1995. Computation of the preliminary 1995 catch quota for the Northwestern Hawaiian Islands lobster fishery. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-95-04, 30 p.

Table 1. Ratio of exploited/unexploited spawning stock biomass (kg/trap-haul) for spiny lobster.

Year	1977	1988	1990	1991	1992	1993	1994
Necker Island	1[a]	0.51	0.27	0.27	0.36	0.36	0.45
Maro Reef	1[b]	0.80	0.17	0.09	0.07	0.08	0.08

[a] Necker Island - 2.45kg/trap-haul
[b] Maro Reef - 2.14kg/trap-haul

Table 2. Annual landings of spiny and slipper lobster (1,000's), trapping effort (1,000 trap-hauls), and the percentage of spiny lobster in the landings, 1983-92[a].

Year	Spiny lobster	Slipper lobster[b]	Total lobster	Effort	CPUE	Percent spiny lobster
1983[c]	158	018	176	64	2.75	90
1984	677	207	884	371	2.38	78
1985	1,022	900	1,902	1,041	1.83	57
1986	843	851	1,694	1,293	1.31	54
1987	393	352	745	806	0.92	57
1988	888	174	1,062	840	1.26	84
1989	944	222	1,166	1,069	1.09	81
1990	591	187	777	1,182	0.66	76
1991[d]	131	035	166	296	0.56	79
1992[e]	260	164	424	722	0.59	61
1994[f]	085	046	131	168	0.78	65

[a] Data are provided to the National Marine Fisheries Service as required by the Crustacean Fishery Management Plan of the WPRFMC and are compiled by the Fishery Management Research Program, Honolulu, Laboratory.

[b] Slipper lobster landings, 1984-87 are 72% of those reported. The adjustment was made to account for a minimum size change in 1987.

[c] April-December 1983.

[d] January-May, November-December 1991

[e] January-April, July-December 1992

[f] July-August, 1994

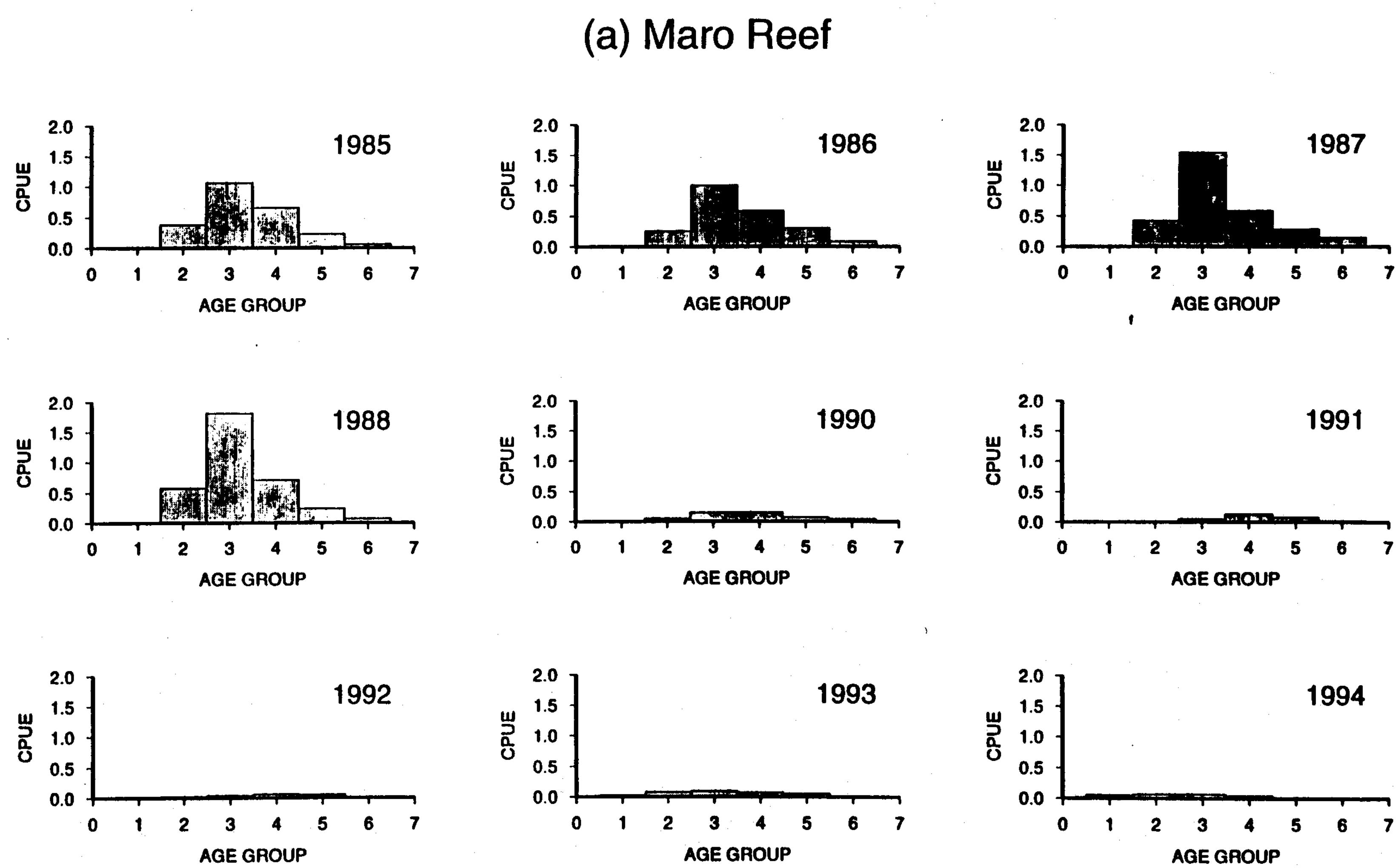


Figure 1. Age-specific CPUE of spiny lobsters caught in the *Townsend Cromwell* research surveys at Maro Reef.

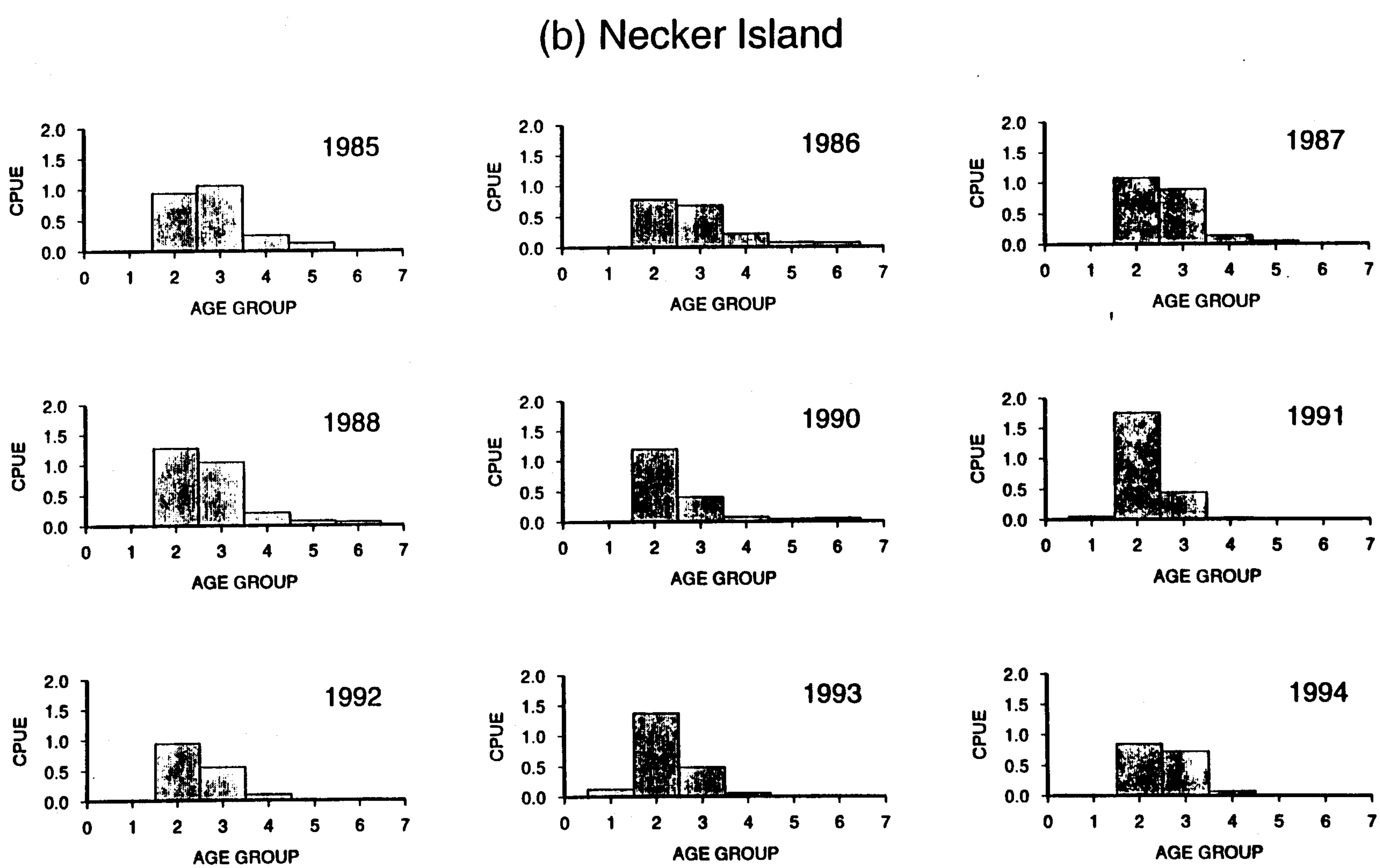


Figure 2. Age-specific CPUE of spiny lobsters caught in the *Townsend Cromwell* research surveys at Necker Island.

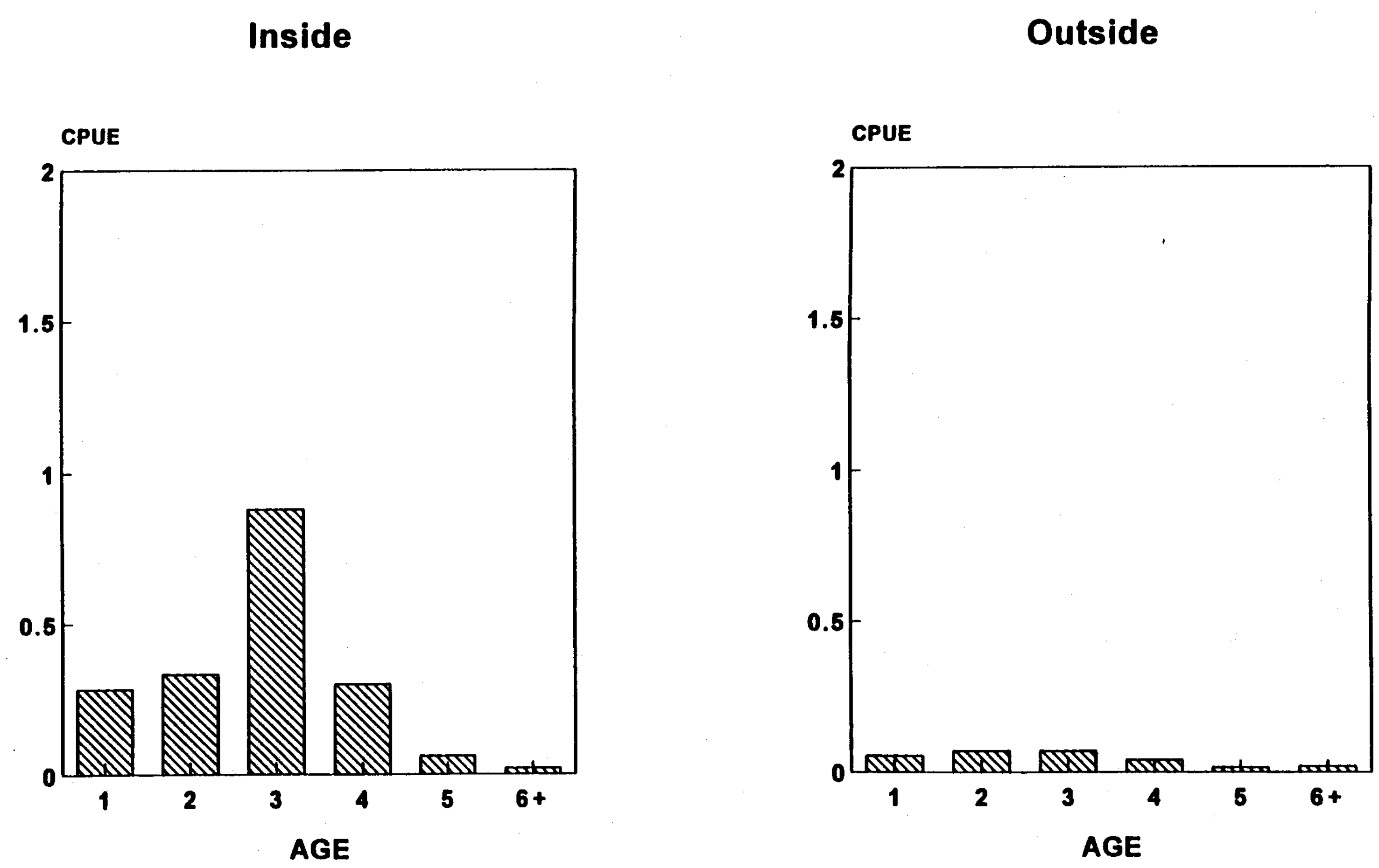


Figure 3. Age-specific CPUE of spiny lobsters caught in the *Townsend Cromwell* research surveys, inside vs outside Maro Reef.

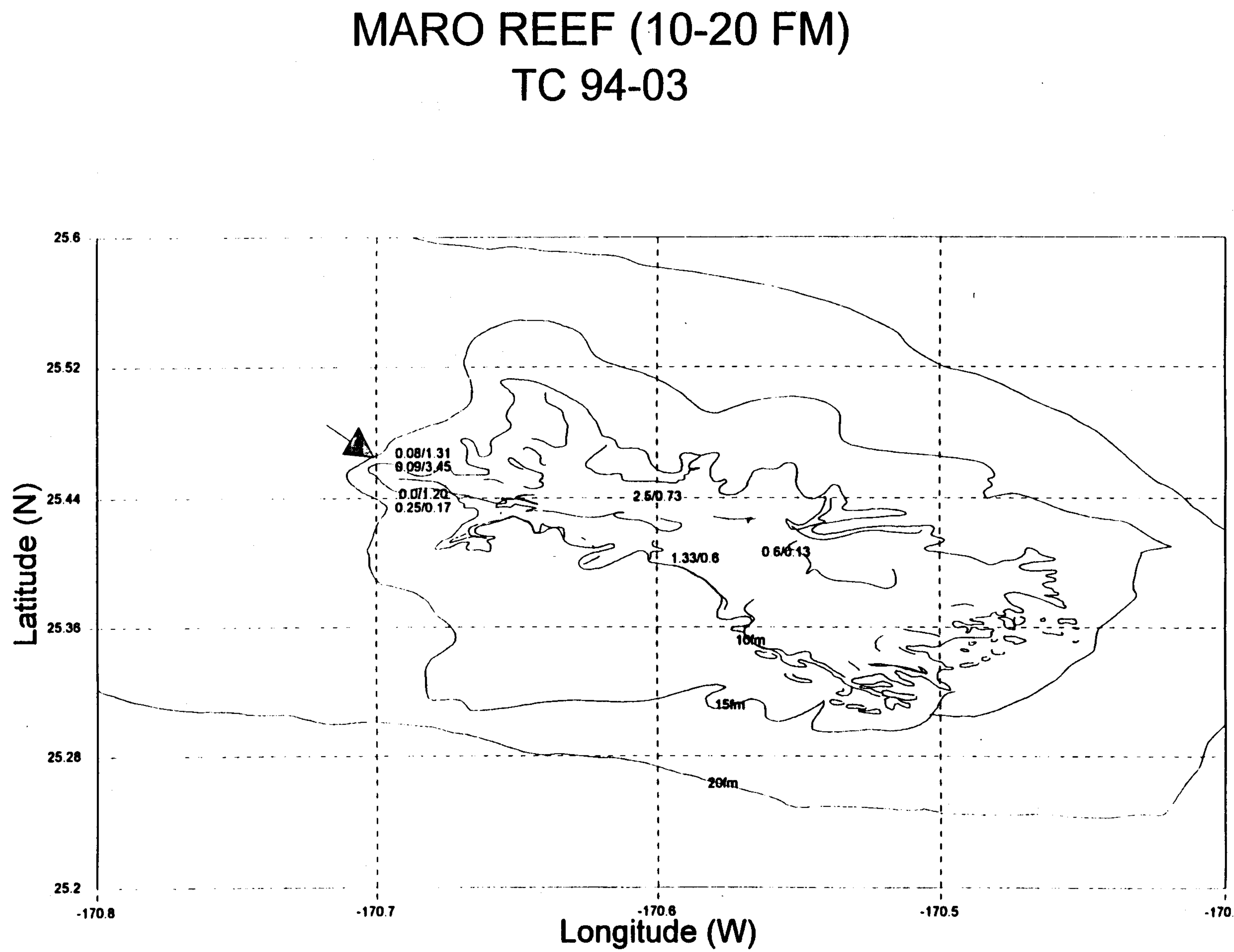


Figure 4. Research CPUE values inside Maro Reef. The adult CPUE value is to the left of the backslash, the juvenile to the right. The arrow denotes the area of high juvenile abundance.

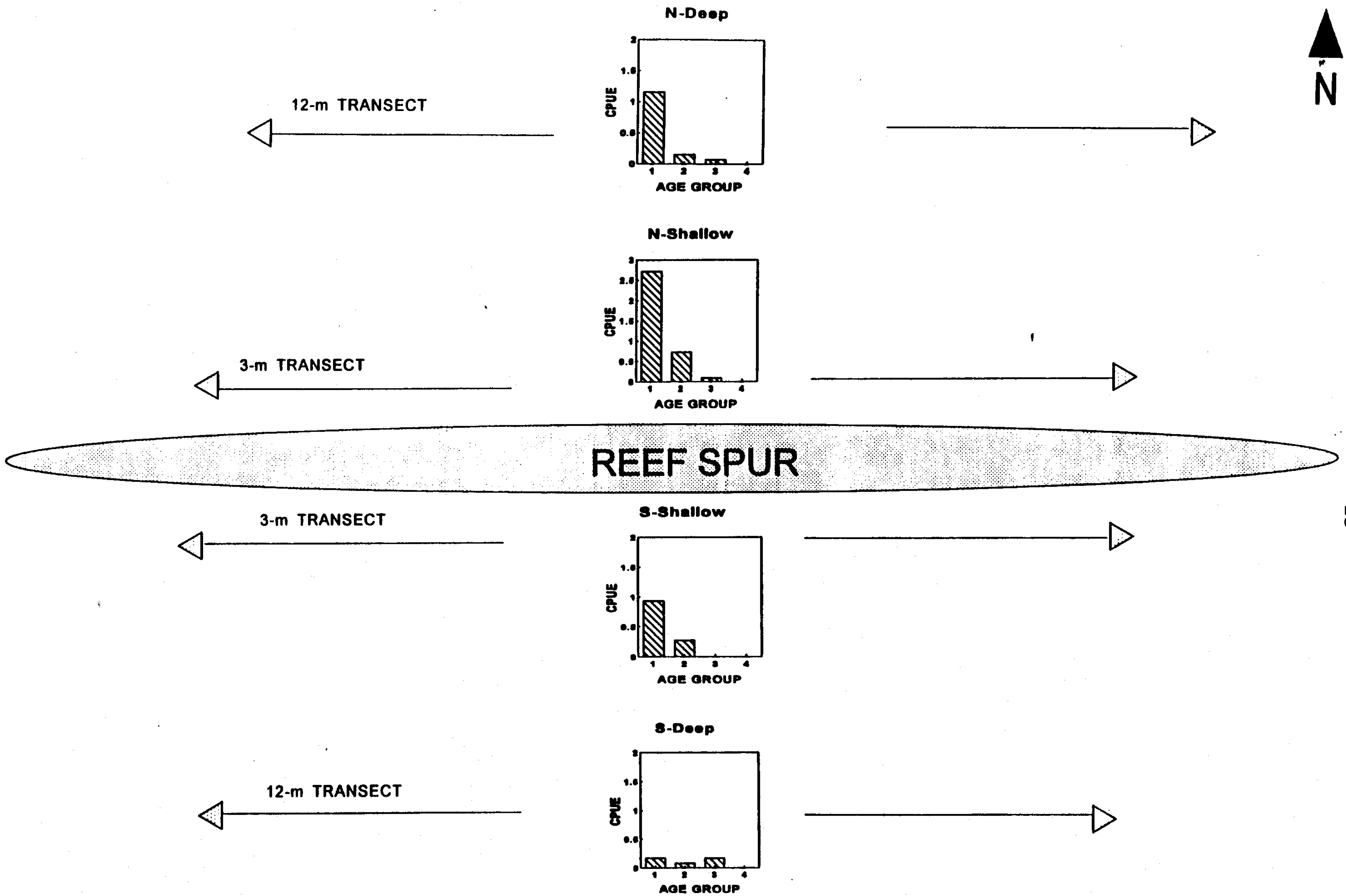


Figure 5. Research CPUE values at the northwestern reef spur, the area indicated by the arrow in Figure 4.

Northwestern Hawaiian Islands
Lobster

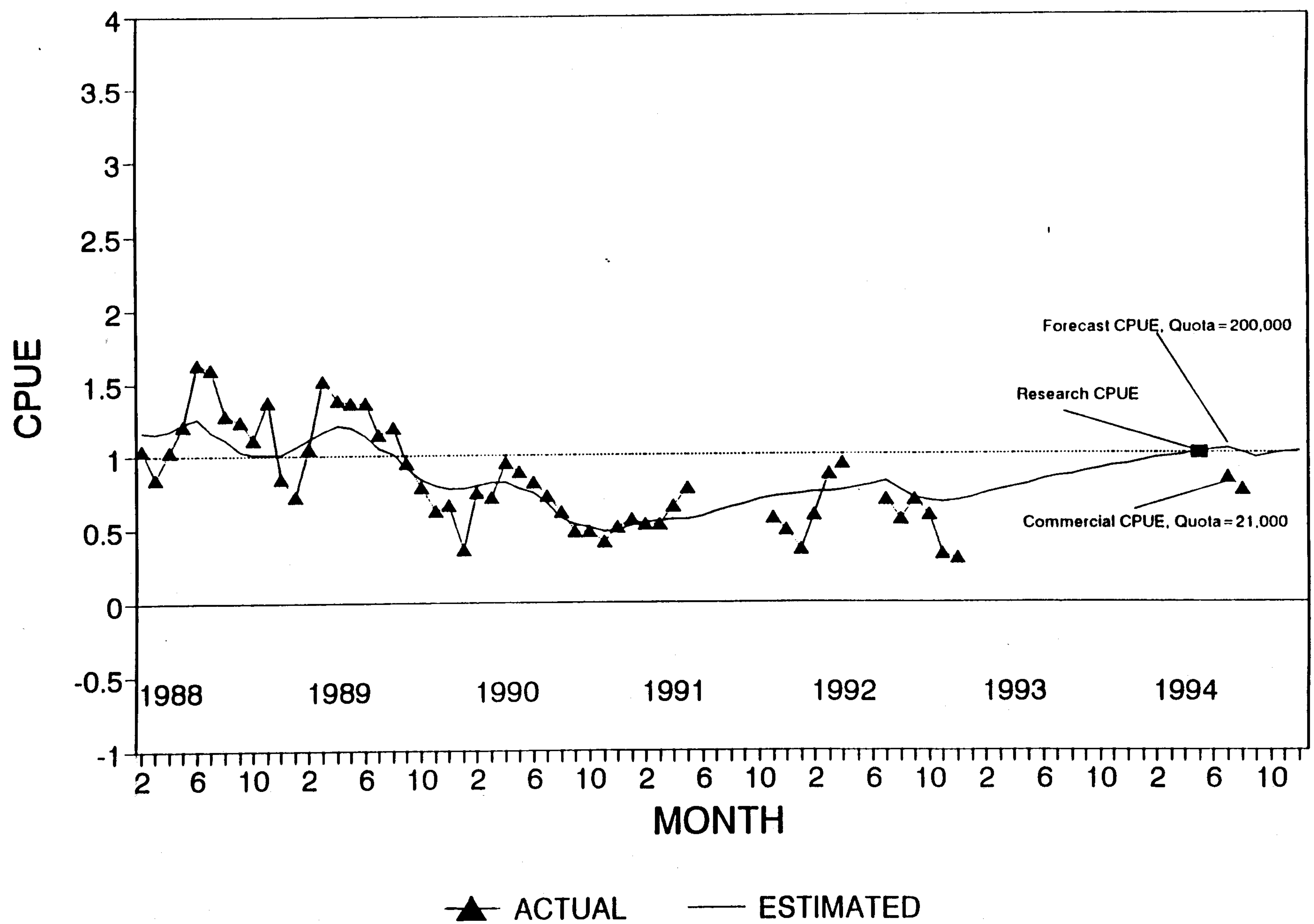


Figure 6. Monthly commercial CPUE and fit of the population model. The solid line projects the model fit through July 1994. [redacted]e s[redacted]squa[redacted] th[redacted]y 1[redacted]ese[redacted]CP[redacted]

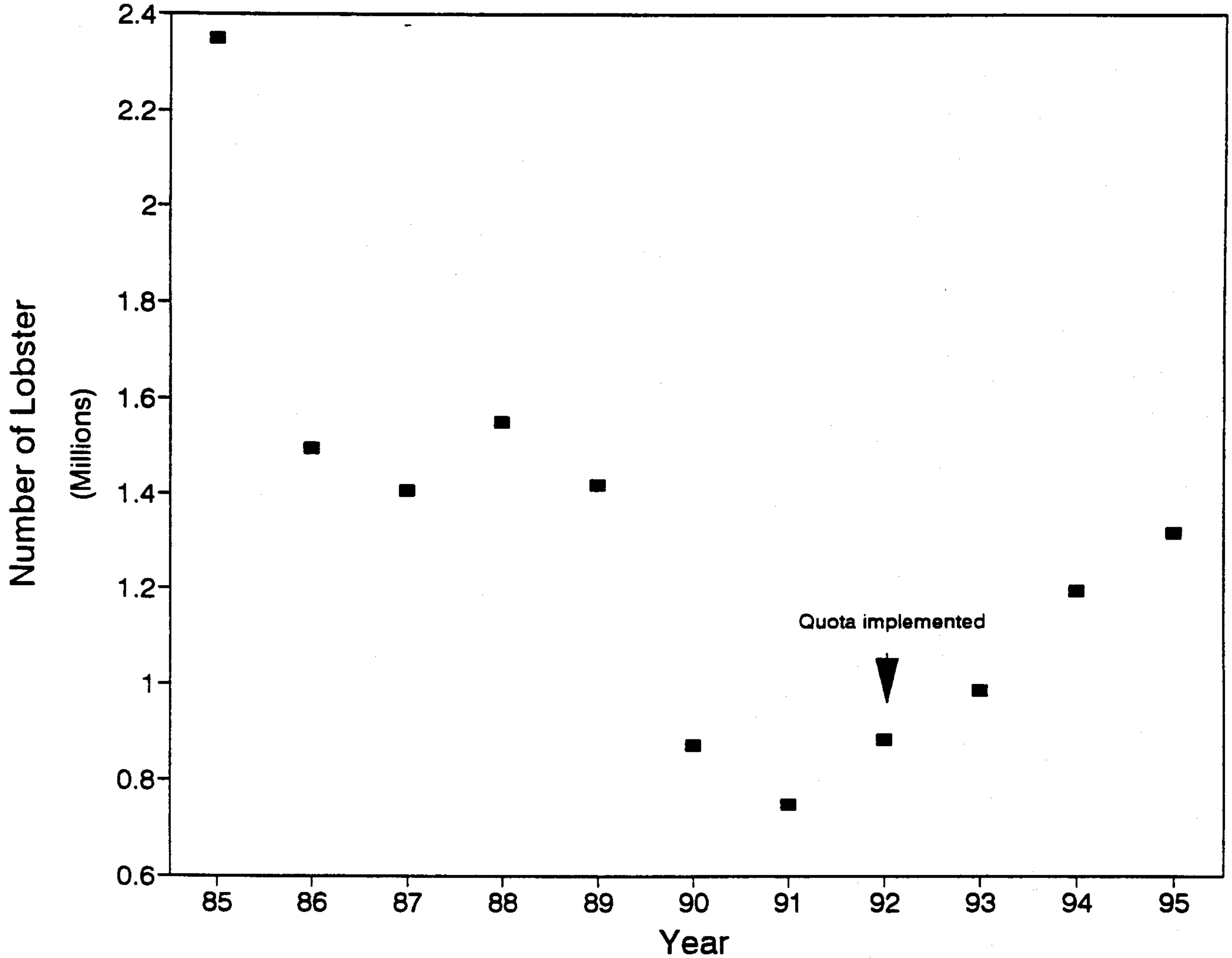


Figure 7. Estimate of the average annual exploitable NWHI lobster population (spiny and slipper lobsters combined) based on the population model.

Appendix 3

Wetherall, J.A., W.R. Haight and G.T. DiNardo, 1995
Computation of the preliminary 1995 catch quota for the Northwestern Hawaiian Islands lobster fishery
Honolulu Laboratory, Southwest Fisheries Science Center
National Marine Fisheries Service
Admin. Rept. H-95-04

Southwest Fisheries Science Center
Administrative Report H-95-4

COMPUTATION OF THE PRELIMINARY 1995 CATCH QUOTA FOR THE NORTHWESTERN HAWAIIAN ISLANDS LOBSTER FISHERY

Jerry A. Wetherall and Wayne R. Haight

Honolulu Laboratory
Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
2570 Dole Street, Honolulu, Hawaii 96822-2396

and

Gerard T. DiNardo

Marine Resource Dynamics and Assessment Program
Joint Institute for Marine and Atmospheric Research
University of Hawaii
1000 Pope Road
Honolulu, Hawaii 96822

March 1995

NOT FOR PUBLICATION

INTRODUCTION

The trap fishery for spiny lobsters (*Panulirus marginatus*) and slipper lobsters (*Scyllarides squammosus*) in the Northwestern Hawaiian Islands (NWHI) is managed by NMFS under the Crustaceans Fishery Management Plan (FMP) adopted in 1983 by the Western Pacific Regional Fishery Management Council (WPRFMC). The FMP defines a minimum legal size for harvested lobsters, requires the use of escape vents on traps, forbids the retention of berried females, and requires that vessel captains submit logbooks of daily catch and fishing effort. After logbook statistics in 1990 showed that the average catch per unit of effort (CPUE) had declined sharply (Table 1), an emergency fishery closure was enforced for several months in 1991, and the FMP was amended to provide additional protection from overfishing. Amendment 7, implemented in 1992, limited entry to the fishery to 15 permitted vessels, established a January-June closure to protect gravid lobsters before their summer spawning, and defined procedures for an annual catch quota.

The catch quota depends on the estimated lobster abundance (both species combined) in July, at the beginning of the 6-month (July-December) fishing season, relative to a predetermined "optimum" population size. Associated with the optimum population size is an optimum catch level. If the population starts the season at the optimum level of abundance and a quota equal to the optimum catch is allowed, the population will rebuild to the optimum level of abundance by the beginning of the next fishing season. If the July lobster abundance exceeds the optimum population size, the Amendment 7 quota formula allows harvest of the optimum catch plus the expected "surplus" of lobsters. On the other hand, if the July lobster abundance is less than the optimum population size the allowable quota will be less than the optimum catch, and may be zero. Expressed mathematically, the quota formula is:

$$Q = C_{opt} + [N_{est} - N_{opt}] , \qquad (1)$$

where

Q = the number of lobsters that may be caught (the quota), legal-sized spiny and slipper lobsters combined,

C_{opt} = the optimum catch,

N_{est} = the estimated abundance of lobsters at the beginning of the fishing season (July 1),

and N_{opt} = the optimum population size.

Amendment 7 stipulates that the optimum population size and optimum catch be set to jointly satisfy the Council objectives of stabilizing the July population at a level well above the FMP's overfishing threshold and achieving an average CPUE of 1.0 lobsters per trap haul during the fishing season (Haight and Polovina, 1993).

Amendment 7 calls for NMFS to issue a "preliminary quota" in February of each year and a "final quota" by August 15, using the same quota formula. The difference between the two is that the preliminary quota uses a forecast of the July abundance derived from a mathematical model of lobster population dynamics, whereas the final quota is based on a direct estimate of the July abundance derived from July's fishery statistics. Accordingly, the preliminary quota is generally much less precise than the final quota. It is intended to assist the industry and NMFS in planning for the upcoming fishing season.

During 1992, the first year of its application, the quota procedure appeared to function well. A relatively large preliminary quota was computed. The final 1992 quota was considerably smaller (Table 2), but still sufficient to sustain the fleet for the duration of the fishing season; the total catch for the year was slightly less than the final quota. The next year, a revised population model predicted that the July 1993 lobster abundance would be too low to allow a 6-month fishery and still enable the stock to rebuild to the optimum level by July 1994. Therefore, a preliminary quota of zero was set and the fishery closed. In 1994 a preliminary quota of 200,000 lobsters was calculated and the fishery re-opened. But catch rates in July were lower than expected, with the result that a final 1994 quota of only 20,900 lobsters was computed. By the time the final quota was determined in August, the catch already had surpassed this level. NMFS then invoked an emergency closure of the fishery.

The 1994 experience was difficult for both NMFS and the fishing industry and revealed serious weaknesses in the Amendment 7 quota procedure. Among the method's flaws are its sensitivity to errors in the estimate of the July 1 population size. Under current conditions, for example, a population estimation error of only ±5% will be amplified almost 35-fold in the quota estimate. Thus, there is a high likelihood of suboptimal harvest. Further, even a slight difference between the preseason model-based population forecast and the July fishery-based population estimate can produce a large difference between the preliminary and final catch quotas and serious disruption of fishing industry operations and fishery management.

Following the 1994 fishing season, the Council convened a panel of experts to review the NWHI lobster quota management procedures and to recommend steps to improve them. The review focused on catch quota methods but also examined the history of research on NWHI lobster biology, stock assessment, and population modeling. The panel recommended that alternative quota procedures be developed that would achieve more stable and dependable harvest levels while protecting the spawning stock and minimizing the risk of recruitment overfishing.

Specifically, the panel recommended that we:

(1) Standardize the CPUE lobster abundance index using general linear modeling (GLM) procedures.

(2) Evaluate the hypothesis that recruitment declined by 50% in recent years (beginning in 1990) against alternative hypotheses that catchability decreased, natural mortality

increased, or that the trend in stock size has been biased by including both spiny and slipper lobsters in the CPUE index.

(3) Develop population models for spiny lobsters, which account for a majority of the catch, to monitor changes in that species and evaluate bias that may be associated with combining data from both species in stock assessments. Analyze both commercial and research vessel data on spiny lobsters.

(4) Develop and evaluate new quota procedures that incorporate uncertainty in the stock assessment and variability in population processes, with the goal of stabilizing catch and achieving other industry objectives while assuring a low risk of overfishing.

The panel suggested that items (1)-(3) and related work on population dynamics and stock assessment be done first, followed by the development and testing of new quota-setting procedures. It was recognized that the analytical work would be time consuming and that computations would have to be carefully checked before new quota procedures were adopted. Accordingly, our work is proceeding with a view to having a new quota procedure in place for the 1996 fishing season. The Amendment 7 quota procedure will be applied during the upcoming 1995 fishing season.

In this report, we document the computation of the preliminary quota for the 1995 season. We also present results of preliminary studies related to the panel's recommendations (1) and (2).

THE MODEL OF POPULATION DYNAMICS

The quota formula components C_{opt} and N_{opt} are determined by the magnitude of recruitment, natural mortality and catchability, as well as the target CPUE value. and are derived from a model of NWHI lobster population dynamics and catch rates published by Haight and Polovina (1993). This model states that the number of exploitable lobsters at the beginning of a month is equal to the number of lobsters at the start of the previous month, minus natural mortality and catch during the previous month, plus the month's recruitment:

$$\begin{aligned} N_{i+1} &= N_i - N_i(1-S) - C_i + R/12 \\ &= N_i S - C_i + R/12 , \end{aligned} \tag{2}$$

where N_i is the population size at the beginning of month i, S is the monthly survival rate in the absence of fishing, C_i is the catch during month i, and R is the annual recruitment to the exploitable stock. In addition, it is assumed that the average CPUE during a month is proportional to lobster abundance at the beginning of the month:

$$CPUE_i = qN_i , \tag{3}$$

where q is the catchability coefficient. Thus the model of population dynamics can be expressed in terms of CPUE as:

$$\frac{CPUE_{i+1}}{q} = \frac{CPUE_i}{q}S - C_i + R/12 \ . \tag{4}$$

As described by Haight and Polovina (1993), the model parameters (S, q, and R) are estimated by fitting this equation to monthly statistics on CPUE and catch using least-squares methods. Because of spatial and temporal variation in population and fishery dynamics, catches of both lobster species are combined and data are pooled over fishing areas to calculate a composite NWHI monthly average CPUE. As new catch and CPUE data are added to the historical data base the model is updated. Estimates of C_{opt} and N_{opt} are recomputed annually as information on the basic parameters is improved.

Assuming that S, q, and R were constant over time, Haight and Polovina (1993) fit the population model to commercial CPUE data from 1983 through 1992. They found that the model fit quite well through 1989, but tended to overestimate observed CPUE after 1989 (Fig. 1). Based on oceanographic and population studies by Polovina and Mitchum (1992), Haight and Polovina (1993) attributed the poor fit of the model after 1989 to a change in recruitment. They rejected alternative hypotheses that the catchability had declined or natural mortality had increased. Subsequently, they fit the model to the same CPUE data assuming a two-phase recruitment: a high value that prevailed through October 1989, and a lower value thereafter. The more elaborate model fit the data much better (Fig. 1).

DID RECRUITMENT DECLINE AFTER 1989?

As recommended by the review panel, we evaluated alternative hypotheses that might account for the drop in commercial CPUE in recent years. To do so, we fit the dynamic population model under three sets of conditions:

Hypothesis A - change in survival

R, q, are assumed to be fixed constants. The monthly survival rate is assumed to be at one level, $S_{(1)}$, through October 1989, and a second level, $S_{(2)}$, afterward.

With R = 1,673,949, q = 7.32×10^{-7}, and $S_{(1)}$ fixed at 0.963, the analysis estimated $S_{(2)}$ = 0.875; i.e., a 3.4-fold increase in the natural mortality rate of exploitable lobsters (Fig. 2). We have no evidence to substantiate a change in natural mortality of this magnitude. This hypothesis is considered to be unreasonable.

Hypothesis B - change in catchability

In this case, S and R are assumed to be fixed constants. Catchability is assumed to be at one level, $q_{(1)}$, through October 1989, and a second level, $q_{(2)}$, afterward.

With $S = 0.963$, $R = 1{,}673{,}949$, and $q_{(1)}$ fixed at 7.32×10^{-7}, $q_{(2)}$ was estimated at 3.143×10^{-7}, a 57% reduction in catchability (Fig. 3). We have found no evidence that such a drop in q could have been caused by changes in commercial fishing practices; fishing strategies and vessel efficiencies have remained fairly constant. Moreover, CPUE statistics from research vessel surveys, which have maintained standard gear and fishing protocols over the years, are highly correlated with commercial fishery CPUEs during the same months (Fig. 4). Thus, a 57% drop in commercial vessel catchability is unlikely.

Hypothesis C - change in recruitment

In this case, described above and shown in Fig. 1, S and q are considered fixed constants. Recruitment is assumed to be at one constant level, $R_{(1)}$, from 1983 through October 1989, and at a different level, $R_{(2)}$, from November 1990 onward.

With $S = 0.963$, $q = 7.32 \times 10^{-7}$, and $R_{(1)}$ fixed at 1,673,949, $R_{(2)}$ was estimated at 741,679. Thus, the reduced CPUE since 1990 is consistent with a 56% drop in recruitment of legal-size lobsters. Support for this hypothesis is provided by age composition changes at two major fishing areas, analyses of spawning biomass per recruit, and oceanographic studies. Most lobsters recruit at an age of 3 years. Age composition data from *Townsend Cromwell* research surveys at Maro Reef show that not only did CPUE decline in all age classes between 1988 and 1990 (no data are available for 1989), and remain at a reduced level through 1992, but the proportion of lobsters older than 3 yr increased; both of these changes in age composition are indicative of a decline in recruitment (Fig. 5a). At Necker Island, 670 km southeast of Maro Reef, a similar decline in the abundance of 3-yr-old lobsters was observed, but the overall abundance was relatively stable (Fig. 5b).

With respect to spawning biomass per recruit (SBR), analyses indicate that during 1985 and 1986 SBR was approximately 40% of its expected level in the absence of fishing, suggesting that spawning biomass was not fished down to a level that would cause poor recruitment to the fishery during 1989-90 (Haight and Polovina, 1993).

Reduced NWHI lobster recruitment after 1989 is also consistent with an apparent decline in central North Pacific biological productivity at various trophic levels, following a period of enhanced primary productivity in the early 1980s. As described by Polovina et al. (1994), the period of increased productivity, during which lobsters and other species were at higher levels of abundance, was associated with decadal climate changes over the North Pacific. The subsequent decline in primary productivity likely resulted in lower survival of lobster larvae and reduced recruitment. Similar links between climate events and recruitment have been demonstrated in western rock lobster (Pearce and Phillips, 1988). In addition to the influence of climate on ocean productivity, associated variations in ocean circulation can alter recruitment by affecting larval transport. Polovina and Mitchum (1992) found that lobster recruitment at Maro Reef was correlated with the difference between sea level measurements at French Frigate Shoals and Midway Island 4 years earlier. The sea level difference between French Frigate Shoals and Midway Island reflects the strength of the Subtropical Countercurrent, which is thought to affect transport and survival of late-stage larvae at Maro Reef. The sea level anomaly is not correlated with lobster recruitment at Necker Island, but this may be explained by differences in the ocean circulation patterns affecting larval transport to the two banks.

In summary, of the three alternatives, a drop in recruitment is the most reasonable explanation for the observed reduction in lobster CPUE between 1989 and 1990.

IMPROVING INDICES OF ABUNDANCE

Previously, monthly lobster abundance indices used in the dynamic population model had been computed as the observed arithmetic average CPUE, using catch and effort statistics summarized by month. As recommended by the review panel, we conducted a general linear model analysis of CPUE to determine the effects of various factors on monthly average CPUE and to derive indices of abundance adjusted for such effects. Preliminary linear models were explored with factors which might measure the degree of species targeting, within-month depletion, and vessel fishing power, but these analyses proved to be complicated and will require further study.

We also examined the effect of another factor, the area of fishing (bank). If average catch rates vary significantly between banks, temporal differences in the distribution of fishing effort could bias the aggregate CPUE index. An analysis of variance (ANOVA) was computed with the model:

$$y_{ijkl} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \gamma_k + \epsilon_{ijkl}\,, \tag{5}$$

where

y_{ijkl} = natural logarithm of average CPUE for the l-th vessel-day of fishing in the k-th fishing area during the j-th month of the i-th year;

μ = overall mean of the log-transformed CPUE's;

α_i = effect of the i-th year;

β_j = effect of the j-th month;

$(\alpha\beta)_{ij}$ = interaction effect of the i-th year and j-th month;

γ_k = effect of the k-th fishing area (bank);

ε_{ijkl} = random error term.

We log-transformed the CPUE data to normalize model error and stabilize error variance, as required by the ANOVA's F-tests. Using the GLM procedure of SAS (SAS Institute, Inc., 1990), we computed F statistics to test the null hypothesis that the bank effect was zero; i.e., that the average monthly CPUE did not vary by bank. This hypothesis was rejected; the F-test showed that the "bank effect" was highly significant (Table 3). This result was not unexpected, as summary statistics have indicated considerable CPUE variation between banks (Table 4). Accordingly, we computed from the GLM a series of monthly mean log (CPUE) values which were adjusted for monthly differences in effort distribution among banks (so-called "least-squares means"). Corresponding adjusted mean CPUE statistics, in the original arithmetic units, were computed by back-transformation, incorporating proper bias corrections. The adjusted monthly CPUEs are generally close to the unadjusted data (Fig. 6).

UPDATED POPULATION MODEL

The dynamic population model described above was fit to the bank-adjusted 1983-1994 commercial CPUE data to update estimates of the parameters $R_{(1)}$, $R_{(2)}$ and q. Note that the bank-adjusted CPUEs were computed by averaging individual vessel-day CPUE statistics. In previous cases (Figs. 1, 2 and 3) the average CPUEs were based on aggregated monthly catch and effort statistics.

With the value of S fixed at 0.963, the analysis estimated $R_{(1)} = 1{,}686{,}695$, $R_{(2)} = 756{,}471$ lobsters per year, and $q = 7.17 \times 10^{-7}$ per trap haul. For purposes of computing C_{opt} and N_{opt} (see below), we set $R = R_{(2)} = 756{,}471$ lobsters.

The fitted model was used to forecast the July 1995 exploitable lobster population at $N_{est} = 1{,}328{,}202$ lobsters (Fig. 7). The predicted July 1995 CPUE is 0.952 lobsters per trap haul.

COMPONENTS OF THE CATCH QUOTA AND RELATED ANALYSIS

In past years, estimates of C_{opt} and N_{opt} were derived by iterative numerical approximation using a spreadsheet simulation model of lobster population dynamics. In this procedure the estimates of R, S and q were inserted into the spreadsheet, along with initial approximations of C_{opt} and N_{opt}. The model was run and values of C_{opt} and N_{opt} modified until the joint constraints of a stable July 1 population size and average CPUE equal to 1.0 lobsters per trap-haul were satisfied.

This year we improved the computation of C_{opt} and N_{opt} by deriving exact analytical formulas for them (Appendix); these formulas replaced the spreadsheet procedure.

Further, using the exact expressions for C_{opt} and N_{opt} we derived analytically the exact formula for the catch quota, Q^*, consistent with Amendment 7 management objectives:

$$Q^* = C_{opt} + \beta [N_{est} - N_{opt}] , \qquad (6)$$

where ß is a coefficient between zero and one whose value depends on the natural mortality rate and the duration of the fishing season (Appendix). It is evident from this exact quota result that the Amendment 7 quota formula is an approximation, as it does not account for natural mortality. The closeness of the approximation depends on three factors: the natural mortality rate, as reflected in ß; the difference between N_{est} and N_{opt} as a fraction of N_{opt}; and C_{opt}/N_{opt}, the optimum harvest ratio. When N_{est} exceeds N_{opt} the approximation will exceed the exact quota result by no more than (1-ß)/ß percent. Given the current estimate of ß = 0.87, such a positive bias would be less than 15 percent. Underestimation of the exact quota by the Amendment 7 approximation when N_{est} is less than N_{opt} would be comparatively greater, particularly if the optimum harvest ratio is low. When the Amendment 7 quota procedures were adopted the exact analytical results were unknown. In retrospect, however, use of the exact quota formula instead of the Amendment 7 approximation would not have altered key NWHI lobster management decisions. Because the approximate quota formula is stipulated in Amendment 7 it was used below to compute the 1995 preliminary quota.

COMPUTATION OF THE 1995 PRELIMINARY QUOTA

The preliminary catch quota for the 1995 NWHI lobster fishing season was computed using the Amendment 7 quota formula, updated estimates of C_{opt} and N_{opt}, and an estimate of the July 1995 population size projected from the population model.

The parameter estimates were:

C_{opt} = 134,494 lobsters

N_{opt} = 1,424,183 lobsters

N_{est} = 1,328,202 lobsters

Therefore, the preliminary quota is:

$$Q = 134{,}494 + (1{,}328{,}202 - 1{,}424{,}183)$$

$$= 134{,}494 - 95{,}981$$

$$= 38{,}513 \text{ lobsters.}$$

The Amendment 7 quota determination procedures assume that the quota will be taken in equal monthly increments over the fishing season, from July through December. In practice, however, the quota could be taken at a faster rate. Amendment 7 procedures require that the fishery be closed when the quota is reached or on January 1, whichever occurs sooner.

FUTURE COURSE OF ACTION

The preliminary quota figure was submitted to the NMFS Southwest Region in January 1995, for evaluation and further action. Based on the preliminary quota level and other considerations, NMFS will determine the appropriate course of action with respect to the 1995 NWHI fishing season and publish its determination on a timely basis.

In the coming months we will continue research to improve the NWHI lobster fishery management procedures, taking into consideration recommendations of the review panel. The research will involve four interrelated projects:

(1) Data management

To ensure a comprehensive, identifiable database for population modeling and fishery management research, all lobster data collected from the NWHI commercial fishery and research cruises will be assembled and systematically documented.

(2) Abundance indexing

To derive the best index of lobster abundance, CPUE statistics will be analyzed using a variety of statistical procedures, including Generalized Linear Models (GLM), General Additive Models (GAM) and time series analysis. Indices will be developed that account for factors which may affect lobster catchability. The factors to be considered include changes in fleet composition and vessel fishing power, changes in species targeting, variation in within-month depletion rates, and changes in area of fishing. To the extent possible, separate abundance indices will be developed for each species and bank.

(3) Population dynamics and biological reference points

The current model of NWHI lobster population dynamics will be thoroughly reviewed and evaluated. Alternative models will be explored that provide a more accurate description of population changes (reduce systematic bias), given available fishery information and biological data. In particular, we will evaluate ways to relax the current assumptions of constant catchability and recruitment. Methods will be explored to combine data from commercial fishing logbooks and research vessel surveys. Methods will be investigated to improve forecasts of lobster abundance based on the model of population dynamics.

Given improved population models and updated estimates of biological parameters, estimates of the overfishing guidelines specified in the FMP for NWHI lobsters will be revised (50 CFR Part 602 Guidelines). These will include estimates of the maximum sustainable yield (MSY) under the current recruitment regime and the optimum spawning potential ratio (SPR). These statistics will be computed by species and bank, where sufficient data permit.

(4) New quota setting procedures

The principal research emphasis will be on devising and evaluating alternative procedures for setting the annual catch quota. As recommended by the review panel, new procedures will be developed that:

Assure greater stability and dependability in the annual catch quota, consistent with goals of the fishing industry;

Establish a catch quota well in advance of the season opening date to ease industry and NMFS planning;

Avoid unnecessary and problematic mid-season quota adjustments; and

Provide adequate protection of the population from recruitment overfishing.

In developing quota procedure options, we will evaluate the performance of alternative methods under a range of assumptions about NWHI lobster population dynamics. The study will employ the best available population model but take into account model misspecification, statistical uncertainty in parameter estimates, and random variation in population processes. Simulation methods, including Monte Carlo and bootstrap resampling, will be used to judge the performance of quota setting options.

We emphasize here that the technical analysis of the Amendment 7 quota formula reported in this document is not part of the study to develop alternative quota procedures, but was undertaken incidentally as part of ongoing work with the lobster population dynamics model. The exact quota formula derived in that analysis will not be among the new alternative quota procedures evaluated.

When a preliminary evaluation of alternative quota methods is completed. NMFS and Council staff will present the options to the Crustaceans Plan Team and the Crustaceans Advisory Panel for consideration and comment. Based on these reviews, the options will be refined and modified to satisfy industry objectives and meet NMFS management requirements. Council and NMFS staff will then draft appropriate documents to amend the Crustaceans FMP and expedite Council adoption and NMFS approval of new quota procedures.

ACKNOWLEDGMENTS

Graphics were produced using Generic Mapping Tools (v. 2.1.4) developed by Wessel and Smith (1991), a public domain software system, with the assistance of William Kwok.

REFERENCES

Haight, W. R., and J. J. Polovina.
1993. Status of lobster stocks in the Northwestern Hawaiian Islands, 1992. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-93-04, 23 p.

Polovina, J. J., and G. T. Mitchum.
1992. Variability in spiny lobster *Panulirus marginatus* recruitment and sea level in the Northwestern Hawaiian Islands. Fish. Bull., U.S., 90:483-493.

Polovina, J. J., G. T. Mitchum, N. E. Graham, M. P. Craig, E. E. DeMartini, and E. N. Flint.
1994. Physical and biological consequences of a climate event in the central North Pacific. Fish. Oceanogr. 3:1, 15-21.

Pearce, A. F., and B. F. Phillips.
1988. ENSO events, the Leeuwin Current, and larval recruitment of the western rock lobster. J. Cons. Int. Explor. Mer, 45:13-21.

SAS Institute, Inc.
1990. SAS/STAT user's guide, Vol. 2, Ver. 6, 4th Ed., SAS Institute, Inc., 1686 p.

Wessel, P., and W. H. F. Smith.
1991. Free software helps map and display data. EOS Trans. Geophys. U., 72:441, 445-446.

TABLES

Table 1.--Annual landings of spiny and slipper lobsters (1,000's), trapping effort (1,000 trap-hauls), and the percentage of spiny lobsters in the landings, 1983-94[a].

Year	Spiny lobsters	Slipper lobsters[b]	Total lobsters	Effort	CPUE	Percent spiny lobsters
1983[c]	158	18	176	64	2.75	90
1984	677	207	884	371	2.38	78
1985	1,022	900	1,902	1,041	1.83	57
1986	843	851	1,694	1,293	1.31	54
1987	393	352	745	806	0.92	57
1988	888	174	1,062	840	1.26	84
1989	944	222	1,166	1,069	1.09	81
1990	591	187	777	1,182	0.66	76
1991[d]	131	35	166	296	0.56	79
1992[e]	260	164	424	722	0.59	61
1994[f]	85	46	131	168	0.78	65

[a]Data are provided to the National Marine Fisheries Service as required by the Crustacean Fishery Management Plan of the WPRFMC and compiled by the Fishery Management Research Program, Honolulu Laboratory.

[b]Indicated slipper lobster landings for 1984-87 are 72% of reported landings. The adjustment was made to account for a minimum size change in 1987.

[c]April-December 1983.

[d]January-May and November-December 1991.

[e]January-April and July-December 1992.

[f]July-August 1994.

Table 2.--Synopsis of Northwwestern Hawaiian Islands lobster fishery catch quota management statistics.

Year	Population parameters[1]	N_{opt}	C_{opt}	Preliminary N_{est}	Preliminary quota	Final N_{est}	Final quota	Final catch	Outcome & management action
1992	S = 0.960 R = 1.460 q = 0.914	1,400,000	960,000	1,190,000	750,000	878,000	438,000	424,000	Quota procedure appeared to work well.
1993	S = 0.963 R = 0.838 q = 0.732	1,366,000	220,000	1,065,574	0	no data	0	0	Fishery closed.
1994	S = 0.963 R = 0.838 q = 0.732	1,420,700	200,000	1,420,700	200,000	1,241,600	20,900	131,000	Final quota exceeded; season aborted in August.
1995	S = 0.963 R = 0.756 q = 0.717	1,424,183	134,494	1,328,202	38,513	---	---	---	

[1]S is survival rate in absence of fishing (monthly)

R is recruitment (millions of lobsters per year)

q is catchability (per million trap hauls)

Table 3.--ANOVA statistics for evaluation of bank effect.

Source of variation	Degrees of freedom	Sum of squares	F value (F_{calc})	Prob{$F>F_{calc}$}
Model	115	2018.479	64.88	0.0001 **
Error	6554	1773.110		
Corrected Total	6669	3791.588		
Year	10	1379.963	510.08	0.0001 **
Month	11	188.175	63.23	0.0001 **
Year*Month	91	382.953	15.56	0.0001 **
Bank	3	67.387	83.03	0.0001 **

**Highly significant.

Table 4.--Aggregate annual catch and CPUE (spiny and slipper lobsters combined) for principal lobster fishing banks in the Northwestern Hawaiian Islands, 1983-94. Catch in number of lobsters; CPUE in number of lobsters per trap-haul.

	Necker Island		Maro Reef		Gardner Pinnacles		St. Rogatien Bank	
Year	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE
1983	117,486	2.80	[redacted]	[redacted]	[redacted]	[redacted]	----	----
1984	258,907	2.73	309,495	2.22	252,647	2.56	----	----
1985	290,781	1.57	721,120	1.88	247,244	1.65	296,438	1.68
1986	225,419	1.07	542,936	1.34	143,073	0.87	178,643	1.30
1987	157,745	0.84	286,808	1.14	64,201	0.58	33,281	0.50
1988	169,648	1.08	531,791	1.39	169,546	1.20	127,906	1.46
1989	349,329	1.11	417,354	1.25	271,497	1.00	84,446	0.95
1990	283,584	0.67	153,104	0.72	296,917	0.60	[redacted]	[redacted]
1991	59,428	0.55	[redacted]	[redacted]	[redacted]	[redacted]	----	----
1992	167,197	0.48	139,751	1.01	96,056	0.48	----	----
1993	----	----	----	----	----	----	----	----
1994	65,581	0.81	[redacted]	[redacted]	42,116	0.61	----	----

---- no fishing

[redacted] confidential data

FIGURES

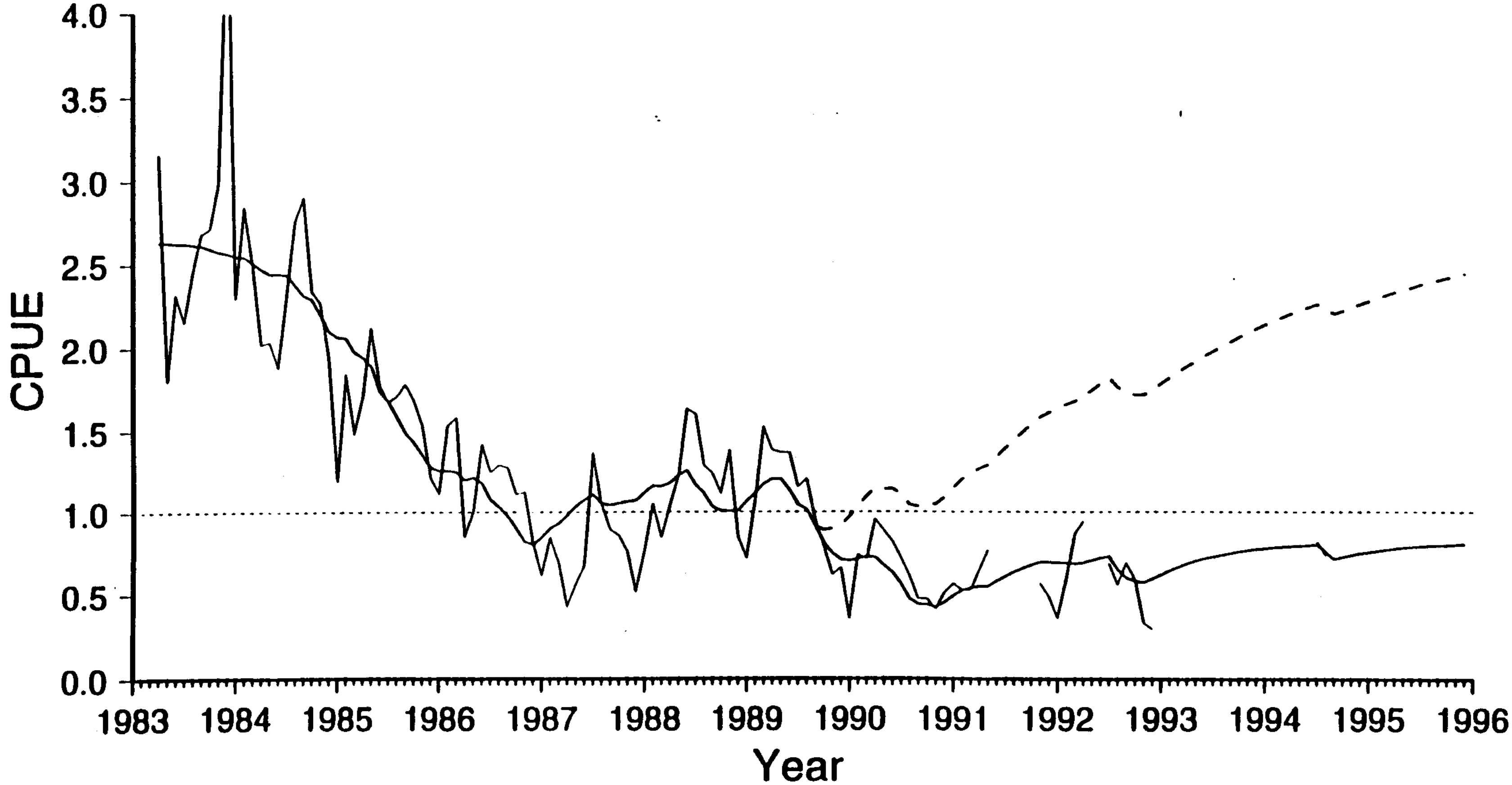


Figure 2.--Observed NWHI lobster CPUE (species combined, all banks) and fitted population models assuming a constant natural mortality rate (dashed line), and assuming an increase in natural mortality after October 1989 (solid line).

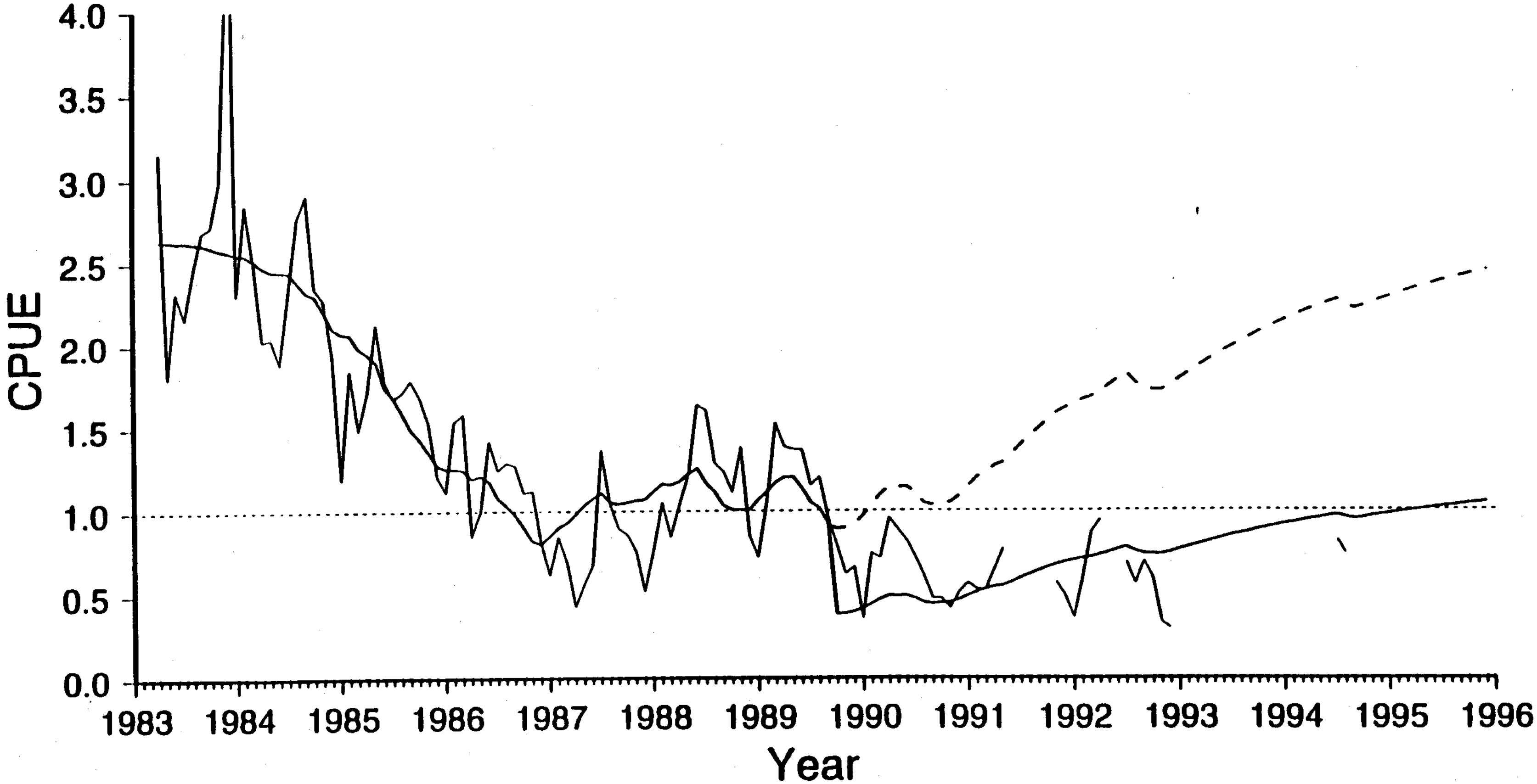


Figure 3.--Observed NWHI lobster CPUE (species combined, all banks) and fitted population models assuming a constant catchability (dashed line), and assuming an decrease in catchability after October 1989 (solid line).

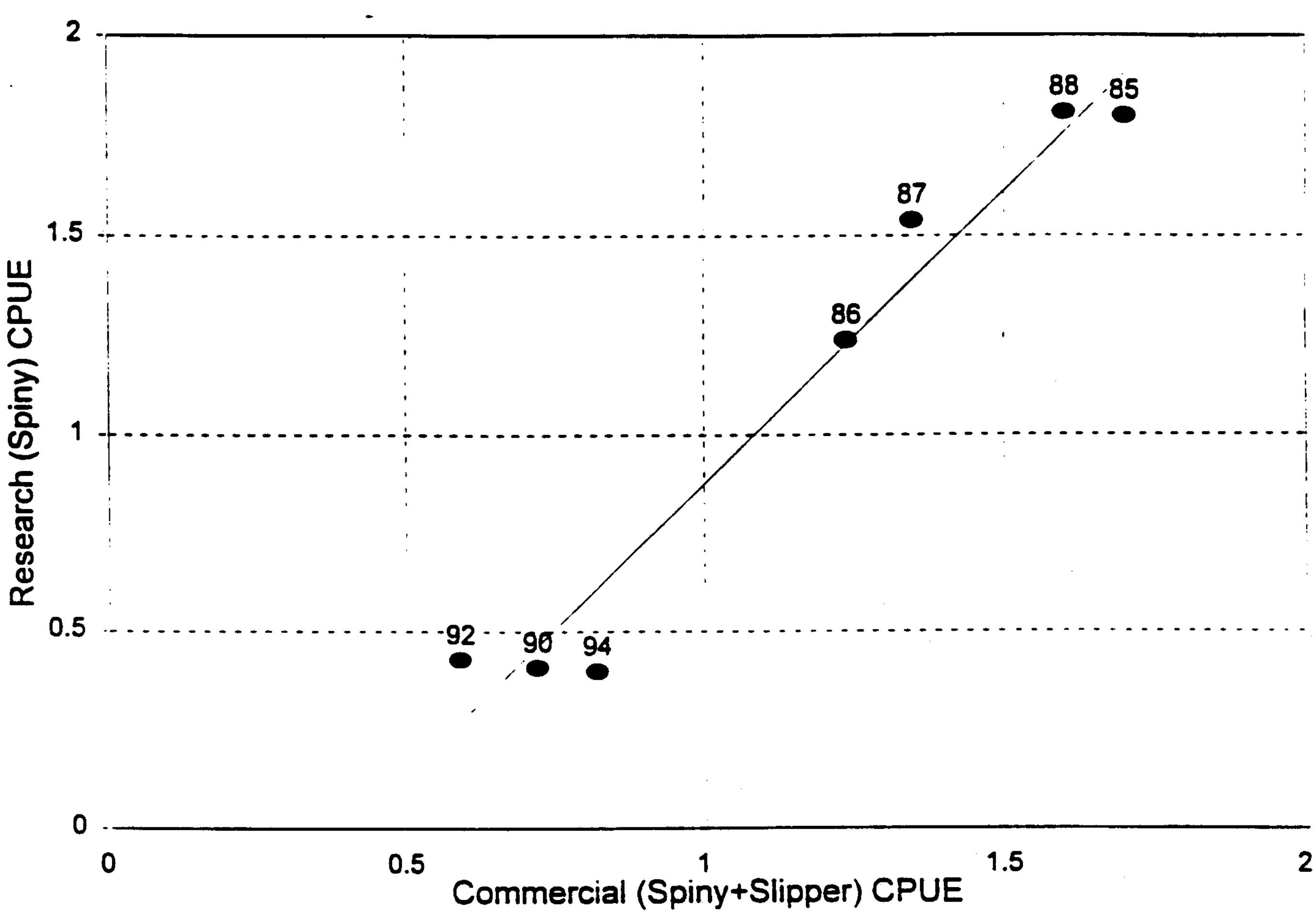


Figure 4.--Relationship between *Townsend Cromwell* (research) CPUE of spiny lobsters and commercial vessel CPUE of spiny and slipper lobsters in the same month, with year of fishing indicated.

(a) Maro Reef

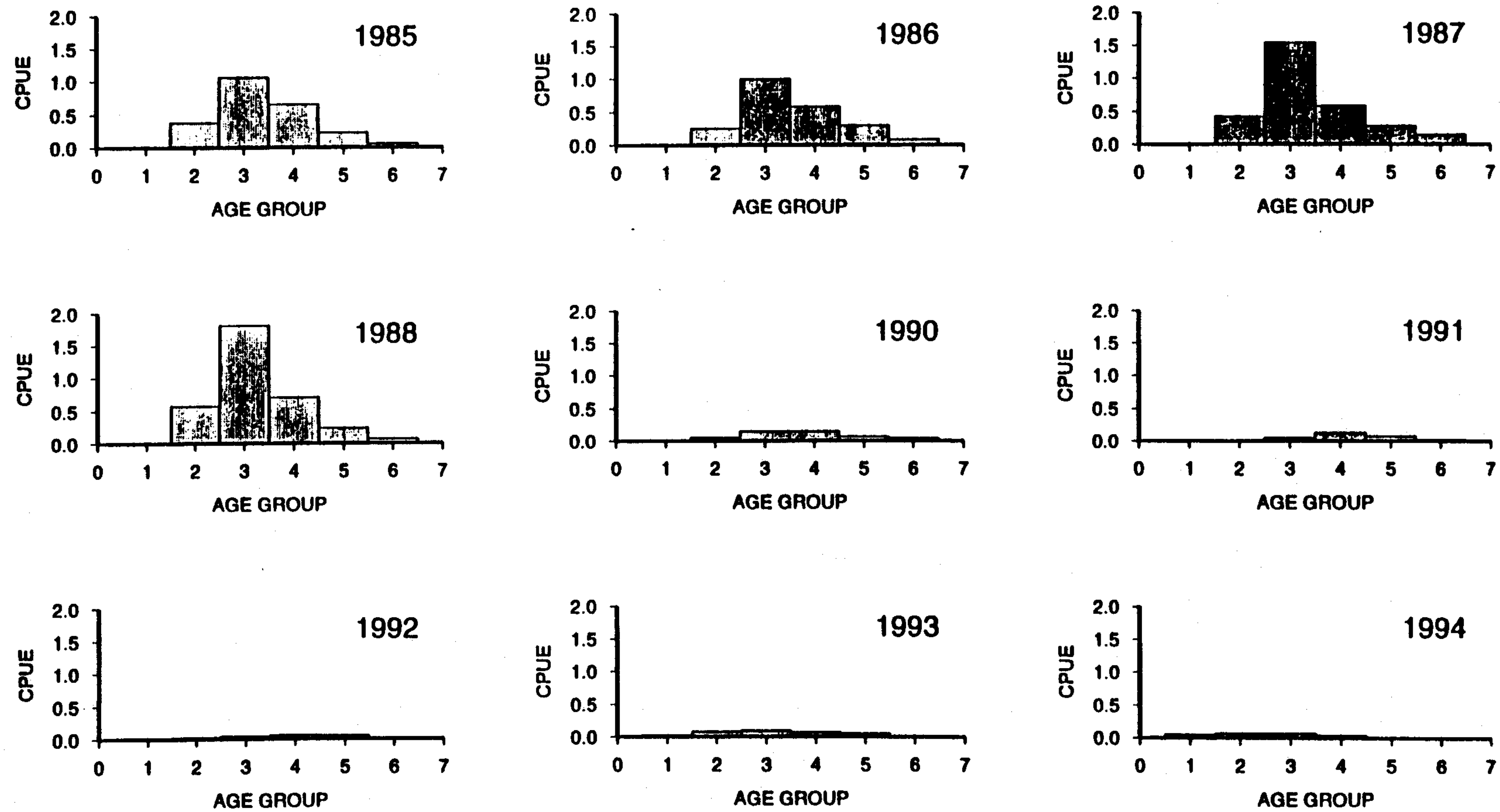


Figure 5.--Age-composition of spiny lobsters caught in the *Townsend Cromwell* research surveys. (a) Maro Reef.

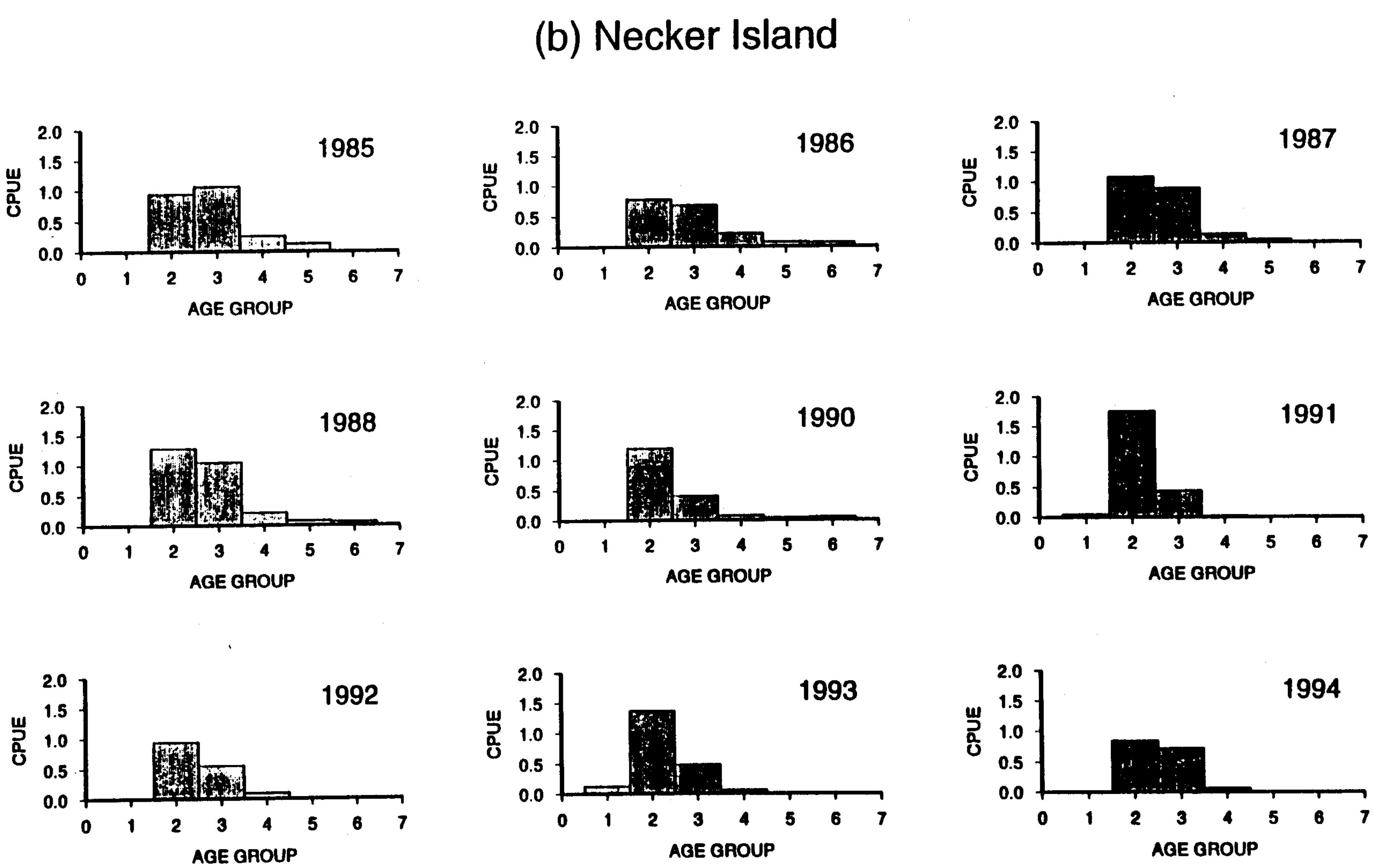


Figure 5.--Age-composition of spiny lobsters caught in the *Townsend Cromwell* research surveys. (b) Necker Island.

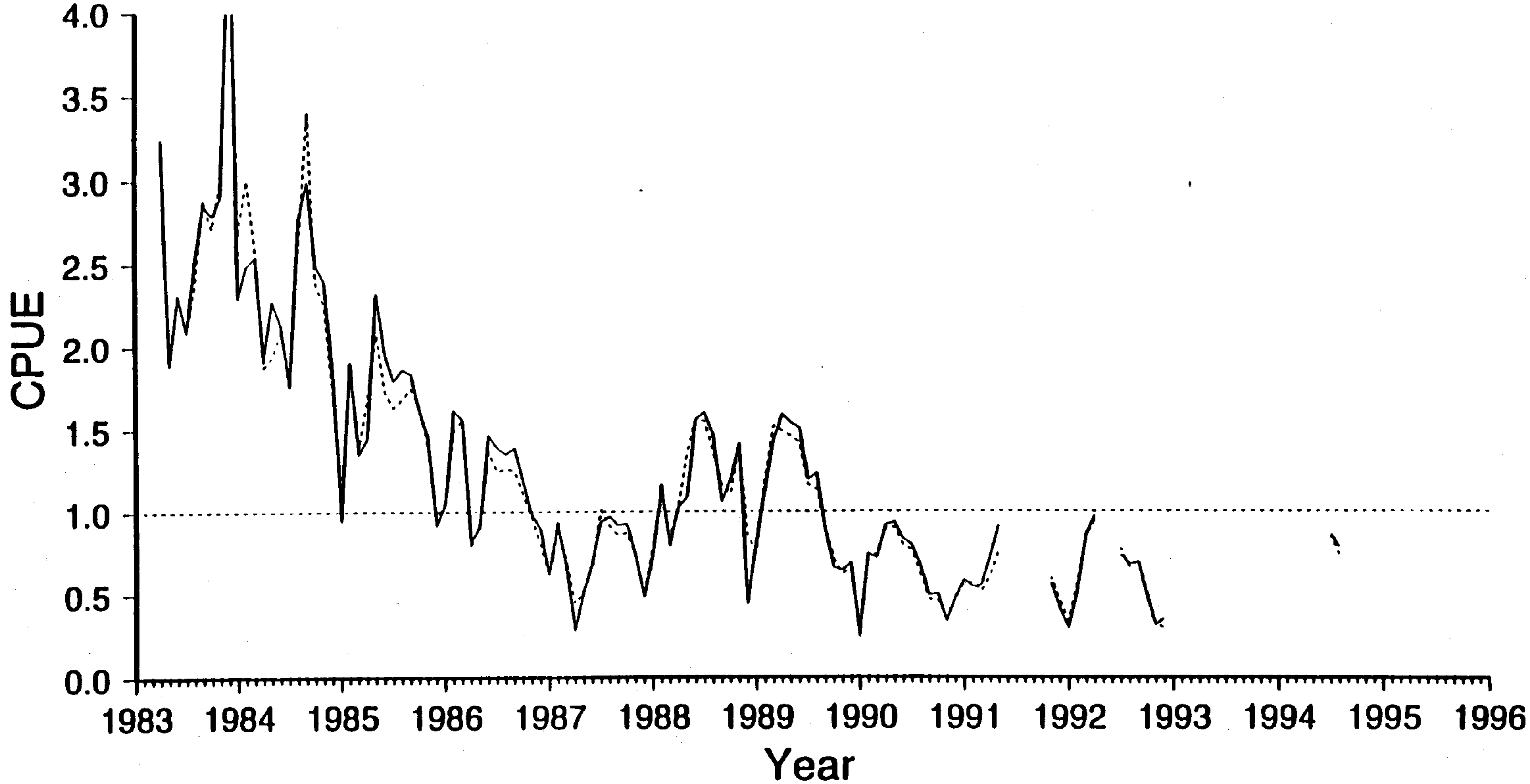


Figure 6.--Observed NWHI lobster CPUE (species combined, all banks) computed from vessel-day catch and effort statistics (dashed line) and corresponding "least squares means" average CPUEs adjusted for bank effects (solid line).

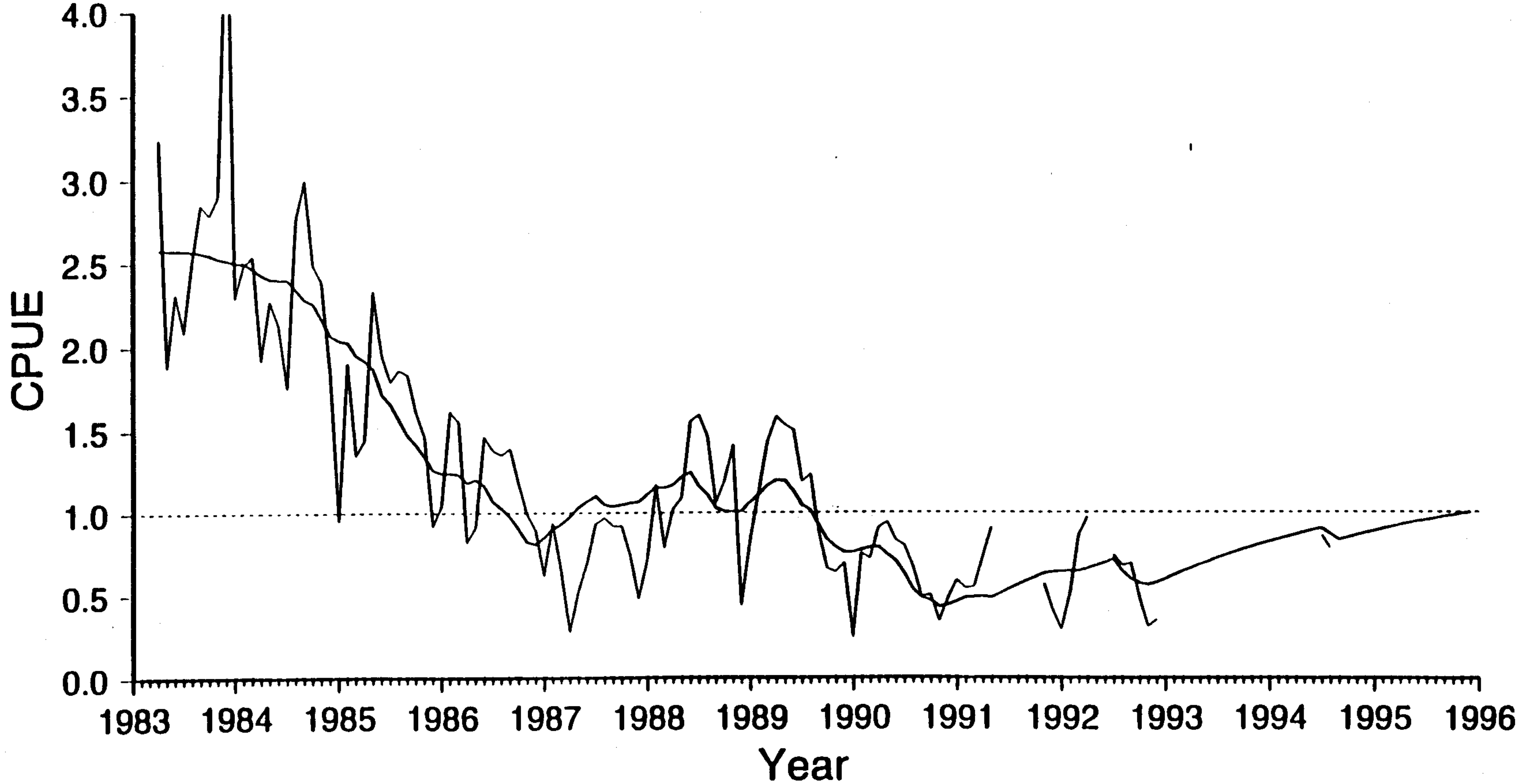


Figure 7.--Bank-adjusted average NWHI lobster CPUE (species combined, all banks) and fitted population model used to project July 1995 lobster population.

APPENDIX

APPENDIX

Discrete Model of Lobster Population and Harvest

This appendix describes the mathematical model of lobster population dynamics and harvest, and derivation of the optimum catch, optimum population size, and annual catch quota.

Definitions and Notation

N_i = Population size at the beginning of the i-th month (i = 1, 2, ... , 13).

C_i = Number of lobsters caught in the i-th month of an n-month fishing season (i = 1, 2, ... , n). We assume that all lobsters caught are killed, whether retained or returned to the sea.

C_{tot} = Total catch during the fishing season.

N_{opt} = Optimum population size at beginning of the fishing season. This is the initial population size large enough to allow the fleet to achieve a target average catch rate, Θ_{opt}, during the fishing season and to enable the stock to rebuild during the closed period to the same population size at the start of the following fishing season (a management goal).

N_{est} = Estimated population size at the beginning of the fishing season.

C_{opt} = Optimum catch. This is the catch that if taken from a population starting at N_{opt} will achieve the target Θ_{opt} and allow the population to rebuild to N_{opt} by the beginning of the following fishing season.

R_i = Number of lobsters recruiting to the harvestable stock during the i-th month (i = 1, 2, ... , 12).

R_{tot} = Total recruitment during the year.

M = Natural mortality coefficient (per month).

S = Natural monthly survival rate, defined as e^{-M}.

q = Catchability coefficient (per trap-haul).

n = Number of months in the fishing season.

$CPUE_i$ = Average number of lobsters caught per trap-haul during the i-th month of the fishing season,

= $q N_i$

Θ = Average number of lobsters caught per trap-haul during the entire fishing season,

= $(q/n) \{N_1 + N_2 + ... + N_n\}$

Θ_{opt} = Optimum value of Θ (a management goal).

Q^* = Annual catch quota derived from the population model (exact).

Q = Annual catch quota specified in Amendment 7 to the Crustaceans FMP (an approximation to Q^*).

β = A coefficient in the exact catch quota formula.

μ = Optimum harvest ratio.

δ = Relative discrepancy between the approximate and exact catch quotas.

Δ = Relative difference between the estimated July population size, N_{est}, and the optimum population size, N_{opt}.

Population Dynamics

The model of population dynamics assumes that natural mortality is proportional to the population size at the beginning of a month, whereas monthly recruitment occurs at a constant rate equal to $R_{tot}/12$. The population dynamics are described by the difference equation:

$$\begin{aligned} N_{i+1} &= N_i - N_i(1-S) - C_i + R_{tot}/12 \\ &= N_i S - C_i + R_{tot}/12 \ . \end{aligned} \tag{1}$$

In the absence of a fishery the population size at the start of each month will tend toward a constant, maximum size determined by the monthly recruitment and natural mortality rate:

$$N_{max} = \frac{R_{tot}/12}{(1-S)} \ . \tag{2}$$

Assume that fishing is allowed during the first n months of the year (in our context, the year begins on July 1), followed by a closed period of (12-n) months. Algebraic manipulation of Equation (1) yields a general expression for the population size at the beginning of the i-th month of the fishing season in terms of the population at the beginning of the year:

$$N_i = N_1 S^{i-1} + \frac{(1-S^{i-1})}{(1-S)} [R_{tot}/12 - C_{tot}/n] , \tag{3}$$

for i = 1, 2, ... , n

Similarly, the population size at the beginning of the j-th month after the fishery closes is:

$$N_{n+j} = N_1 S^{n+j-1} - \frac{S^{j-1}(1-S^n)}{(1-S)} C_{tot}/n + \frac{(1-S^{n+j-1})}{(1-S)} R_{tot}/12 , \tag{4}$$

for j = 1, 2, ... , (13-n)

In particular, Equation (4) can project the population size at the beginning of "month 13"; i.e., at the beginning of the next fishing season:

$$N_{13} = N_1 S^{12} - \frac{S^{12-n}(1-S^n)}{(1-S)} C_{tot}/n + \frac{(1-S^{12})}{(1-S)} R_{tot}/12 . \tag{5}$$

Optimum Population and Catch Levels

A key objective of the Council has been to maintain a constant population size at the beginning of each year, N_{con}. To find this equilibrium population size, set $N_{13} = N_1 = N_{con}$ in Equation (5) and solve for N_{con}:

$$N_{con} = N_{max} - \frac{S^{12-n} - S^{12})}{(1-S)(1-S^{12})} C_{tot}/n . \tag{6}$$

Clearly, N_{con} depends on C_{tot} and n, as well as S and R. Note that in the absence of a fishery, the population size at the beginning of every month is constant at a level of N_{max}. If a fishery is operating the population begins each fishing season at N_{con}, but otherwise is less than N_{con}, declining during the fishing season and rebuilding during the closed period.

In addition to stabilizing the population size, the Council has chosen to achieve a particular average CPUE during the fishing season, Θ. We can derive Θ using Equation (3) as:

$$\begin{aligned} \Theta &= \frac{q}{n} [N_1 + N_2 + ... + N_n] \\ &= \frac{q}{n(1-S)} [N_1(1-S^n) + (n - 1 - \frac{S(1-S^{n-1})}{(1-S)}) (R_{tot}/12 - C_{tot}/n)] . \end{aligned} \tag{7}$$

Combining the last two results, we can find the total annual catch, $C_{tot} = C_{opt}$, that will stabilize the population size at the beginning of each fishing season while also achieving an

Appendix 4

Alternative Harvest Guidelines for the Northwestern Hawaiian Islands Lobster Fishery

G.T. DiNardo
Honolulu Laboratory, National Marine Fisheries Service

*** * * DRAFT MANUSCRIPT * * ***

Introduction

Background to the Fishery

The Northwestern Hawaiian Island (NWHI) trap fishery for spiny lobster *(Panulirus marginatus)* and slipper lobster *(Scyllarides squammosus)* is managed by the National Marine Fisheries Service (NMFS) under the Crustaceans Fishery Management Plan (FMP) adopted in 1983 by the Western Pacific Regional Fishery Management Council. The FMP defines a minimum legal size for harvested lobsters, requires the use of escape vents on traps, forbids the retention of berried females, and requires that vessel captains submit logbooks of daily catch and fishing effort. In response to substantial declines in catch-per-unit-effort (CPUE) in 1991, the FMP was amended in 1992 to include an annual 6-month closed season (January-June), limited entry into the fishery, and establishment of an annual catch quota.

The annual quota is derived from a two-step process: (1) a preseason forecast quota is issued in February based on the results of commercial and research fishing in the previous year, and (2) an in-season (August) adjustment is made based on CPUE information from the first month (July) of commercial fishing (Fig. 1). A Constant Escapement strategy is used to compute the quota, allowing surplus production to be harvested if the population is above predetermined optimal escapement level. Optimal escapement is set at a level that provides an economically viable CPUE during July-December (1.0 lobster/trap-haul), while protecting spawning stock biomass from over-harvest. The quota methodology was first applied during the 1992 fishing season (Table 1). The 1993 preseason forecast indicated that the lobster stock size would be insufficient to permit a commercial fishery in 1993. Based on this information, the fishery remained closed from 1993 through June of 1994. The 1994 preseason forecast indicated that the population would rebuild to a level which would allow a fishery during the 1994 season, and the fishery was opened July 1, 1994. Commercial CPUE during the first month of fishing indicated that the population was smaller than predicted in January, and the fishery was subsequently closed. The 1995 preseason forecast indicated that a catch of approximately 38,000 lobsters could be allowed. Because of difficulties in managing a quota of this size, the NMFS Southwest Regional Office decided to close the 1995 commercial lobster fishery. An experimental fishery was allowed with a quota of 38,000 lobsters. The objective of the experimental fishery was to collect biological and fishery performance data for use in developing enhanced stock assessment and vessel tracking procedures.

Problem

In 1994, the Western Pacific Regional Fishery Management Council (Council) held a technical review of the stock assessment and catch quota setting procedure for the NWHI lobster fishery. The review was in response to concern among the fishing industry, the Council, and NMFS that the current quota setting procedure was overly sensitive to fluctuations in CPUE which resulted in highly variable quotas and which led to closures for all or part of recent fishing seasons. The review panel recommended that NMFS investigate revised quota-setting procedures, taking into account uncertainty in stock assessments and seeking to find a quota which results in low risk of overfishing the stock in any specified year.

The Council asked NMFS to also investigate the prospects of a retain-all fishery. In a retain-all fishery all lobsters caught and decked are harvested. Thus, minimum legal size for harvested lobsters is a function of the selectivity of the gear as defined in the FMP. When mortality resulting from the capture, decking, and discarding of sublegal and berried lobsters is high, there may be more benefit to the population if all decked lobsters are harvested. Because less fishing effort is applied to harvest the same quota in a retain-all fishery compared to a minimum-size fishery, mortality to sublegal and berried lobsters resulting from fishery interactions is less. If mortality to sublegal and berried lobsters resulting from fishery interactions is low, discarding may be more beneficial to the population.

Here we investigate alternative harvest strategies for the NWHI lobster trap fishery. Preferred strategies are those which assure minimal risk of reducing the lobster spawning potential ratio (SPR) below the established overfishing threshold. As defined in the FMP, overfishing occurs when the SPR is 20% or less. The SPR is a measure of the reproductive fitness of a stock. It is a measure of the extent to which fishing has reduced the potential reproductive output of an average recruit from that which would have existed in the absence of fishing.

Uncertainty associated with stock assessments, including fishery performance and population dynamics parameters, are expressed in terms of risk to the fishery. We define risk as the probability that the fishing mortality exerted in a given year for a specified level of allowable catch (harvest guideline) exceeds the fishing mortality associated with a 20% SPR. Computing allowable catches for a variety of risk levels results in the formation of risk curves describing the chances of not meeting the management objective (minimize the chance of overfishing) as a function of the allowable catch. The formation of risk curves conditional upon the overfishing reference point for a variety of catch levels provides a useful means of incorporating the uncertainty in stock assessments into management advice.

Methods

Harvest Strategies

Three harvest strategies were compared in a simulation of the management of NWHI lobsters (Table 2): Constant Catch, in which annual yield is constant; Constant Escapement (the current policy under Amendment 7), in which all individuals above an "optimum" population size, expressed as a target CPUE, are harvested; and constant harvest rate, in which the annual yield is proportional to population size. In implementing each strategy we assumed that the population size at the beginning of the fishing season was predicted in January. Thus, the current practice of a preseason population forecast and determination of the allowable catch level was maintained. However, there was no in-season adjustment of the allowable catch level.

Allowable catch levels (or harvest rate) were varied to assess their effect relative to the risk of overfishing. The harvest guideline options were examined under a range of assumptions regarding mortality of sublegal and berried lobsters caught and discarded. In particular, the effects of 0%, 25%, 50%, 75%, and 100% sublegal and berried lobster handling mortalities on choice of harvest strategy was tested. In addition, the effects of three fishing policies on choice of harvest strategy were also tested: the retention of all decked lobsters ≥50.0 mm tail width (TW) (the current policy under Amendment 7), the retention of all non-berried, decked lobsters ≥36.0 mm TW, and the retention of all decked lobsters ≥36.0 mm TW (a retain-all fishery).

Simulation Model

Model Characteristics

An age-structured auto-regressive computer model was developed to simulate population dynamics and test harvest policy alternatives. The model is intended to mimic the monthly dynamics of the stock, the assessment process upon which management recommendations are based, and dynamics of the fishery. The model computes the numerical abundance of lobsters in monthly age bins over a 20-year life span. The model allows for systematic (bias), process (recruitment), and measurement (catchability and size at maturity) error, as well as autocorrelation in monthly recruitment innovations. The model assumes a single species and lumps spiny and slipper lobsters together. In addition, the model implies no spatial structure and assumes a single fishing area, the NWHI. To ensure adequate evaluation of alternative harvest strategies the model computes population and fishing statistics over a 30-year time horizon with 500 Monte Carlo replicates. Results from a 10-year spin-up period are ignored. Using the remaining 20-year histories for each of the 500 replicates, population and fishery summary statistics are computed. These summary statistics were used to evaluate harvest strategy options. A more detailed schedule of events within the simulation model is outlined in Addendum A.

Model Assumptions

Although the NWHI lobster fishery targets spiny and slipper lobsters along isolated banks in the Hawaiian Archipelago, population dynamics parameters and fishery characteristics included in the model are specific to spiny lobster. Paucity of slipper lobster biological data, as well as sufficient bank-specific data, preclude development of species- and bank-specific models at this time. The consequences of this limitation on our choice of harvest strategy are unknown and will require further analysis. Recent research cruise and commercial fishery data suggest strong species- and bank-specific associations and possible changes in population dynamics parameters resulting from changes in lobster densities. Assumptions associated with the current model configuration follow.

1. Spiny and slipper lobster population parameters are similar.
2. Recruitment is constant and independent of stock size.
3. Size at maturity = 46.0 mm TW ± 10% error.
4. Minimum size caught by the gear = 36.0 mm TW.
5. There is no spatial targeting of lobsters.

A more detailed list of model assumptions can be found in Addendum B.

Evaluation Criteria

Risk of overfishing was used as the primary evaluation criterion. Other evaluation criteria include average annual catch, year-to-year variation of catch, and average annual CPUE. Average annual catch is a measure of the expected long-term (20-year) catch. Stability of catch is expressed as the average percent change in catch from one year to the next. Average annual CPUE is the long-term expected catch rate during the fishing season.

Results

The sensitivity of each harvest strategy to process (recruitment), measurement (catchability and size at maturity), and systematic forecast (bias) error was tested. However, since the goal of this study was to evaluate the performance of harvest strategies, taking into account uncertainty in stock assessment, only results from the more "conservative" model runs are presented for purposes of evaluation. These runs are associated with high parameter uncertainty and reflect worst-case scenarios. Strategies that perform well under these conditions are likely to perform well under most conditions. As the models are improved through further research harvest policy guidelines can be updated.

Applied levels of uncertainty associated with the conservative runs include an autocorrelation and coefficient of variation (CV) of the monthly random recruitment innovations equal to 0.99 and 0.50, respectively. The tested recruitment CV represents a fourfold increase over tentative estimates of recruitment variation. A positive 10% bias in population forecasting was assumed. The tested catchability CV was set at 1.0 and represents a doubling of tentative estimates of variation in catchability. Finally, we assumed size at maturity equal to 50.6 mm TW (Schedule B), which represents a positive 10% error in our best estimate of size at maturity. As previously stated, the combination of these values represents a conservative scenario.

Harvest Strategy Comparisons

Harvest strategy performance statistics assuming five levels of sublegal and berried lobster handling mortality are outlined in Table 3. Performance statistics for risk levels ranging from 0 to

10% were estimated for each strategy combination and allow for decisions regarding tradeoffs between risk of overfishing and fishing performance.

No harvest was below 10% risk for the Constant Escapement strategy. For those levels of risk tested, any fishing would put the population at risk of being overfished. Thus, no statistics for this strategy appear in Table 3. Allowable catches of approximately 294,000 lobsters were computed but at a 15% risk of overfishing.

For the Constant Catch (CC) and Constant Harvest Rate (CHR) strategy increases in average annual catch were associated with increased risk to overfishing regardless of fishing policy. The increase in risk and average annual catch was associated with decreased average annual CPUE and SPR. As more lobsters are removed through higher allowable catch levels average annual CPUE decreases. The reproductive potential of the population decreases with increased removals and the average annual SPR approaches the 20% SPR threshold. The decrease in average annual SPR is accompanied by an increase in risk calculated relative to the SPR threshold. Despite the observed decrease in average annual SPR associated with increasing risk, the average SPRs under all fishing policies were well above the 20% SPR threshold.

Relationships between average annual catch and risk, SPR, and CPUE for each of the fishing policies are presented in Figures 2-4. Within strategies, higher average annual catches are generally associated with lower handling mortalities for the same level of risk. Differences in average annual catches between handling mortalities were greatest when the fishing policy was to harvest all decked lobsters ≥50.0 mm TW. These differences decreased significantly when the policy was to harvest all non-berried decked lobsters ≥36.0 mm TW. Between strategies, lower average annual catches were associated with the CC strategy for the same level of risk regardless of the fishing policy (Fig. 2).

Average annual SPR generally increased relative to decreasing handling mortalities for the same level of average annual catch within a strategy (Fig. 3). Again, differences in average annual SPRs between handling mortalities were greatest when the policy was to harvest all decked lobsters ≥50.0 mm TW and decreased significantly when all non-berried decked lobsters ≥36.0 mm TW were harvested. Lower average annual SPRs were associated with the CHR strategy regardless of the fishing policy. Although lowest average annual SPRs (≈40%) were associated with the CHR strategy, in particular a fishing policy that harvests all decked lobsters ≥50.0 mm TW, the average annual SPRs were well above the 20% SPR threshold. Between fishing policies, average annual SPRs were lowest for the policy that harvests all decked lobsters ≥50.0 mm TW and similar for policies that harvest all non-berried decked lobsters ≥36.0 mm TW and all decked lobsters ≥36.0 mm TW.

Average annual CPUEs were generally lower for the CHR strategy regardless of fishing policy (Fig. 4). Average annual CPUE generally increased relative to decreasing handling mortalities for the same level of catch within a strategy. Average annual CPUEs were lowest for the policy that harvests all decked lobsters ≥50.0 mm TW. Average annual CPUEs were similar and higher for policies that harvest all non-berried decked lobsters ≥36.0 mm TW and all decked lobsters ≥36.0 mm TW.

Fishing Policies

For the CC strategy, there was little measurable difference in catch variability between fishing policies, regardless of the magnitude of sublegal and berried lobster handling mortality (Table 3). Higher average annual catches, SPRs, and CPUEs were generally associated with fisheries that harvest lobsters ≥36.0 mm TW compared to a minimum legal-size fishery that harvests lobsters ≥50.0 mm TW (Figs. 3 and 4).

For the CHR strategy, higher average annual catches and SPRs were attained for fisheries that harvest lobsters ≥36.0 mm TW when sublegal and berried handling mortality in the minimum legal-size fishery (harvesting of lobsters ≥50.0 mm TW) is at least 25%. At sublegal and berried handling mortalities less than 25% average annual catches and SPRs are higher for the minimum-size fishery. Average annual CPUEs and SPRs were consistently higher in fisheries harvesting lobsters ≥36.0 mm TW regardless of the handling mortality rate (Figs. 3 and 4). There was little measurable difference in year-to-year catch variability between fishing policies (Table 3).

Discussion

Strategy Performance

This study approached the evaluation of NWHI lobster fishery harvest strategies relative to a set of conservative scenarios. Given the uncertainty in the assessment of lobsters, this approach seems justified. As the models are improved through further research, harvest policy guidelines can be updated. At a maturity size of 50.6 mm TW any fishing under the Constant Escapement strategy put the population at risk. Among this strategy's flaws are its sensitivity to errors in the estimate of the July 1 population size. As pointed out in Wetherall, et al. (1995), a population estimation error of only ±5% will be amplified almost 35-fold in the harvest guideline estimate. Thus, there is a high likelihood of suboptimal harvest which can be interpreted as overfishing when in fact overfishing is not occurring. This sensitivity is further amplified because our model runs are conservative, with relatively large levels of process, measurement, and systematic error. The sensitivity of this strategy to errors in the forecasted July 1 population size resulted in fishery closures due to a perceived risk to overfishing, when in fact the population was not at risk and could sustain fishing. In some instances this type of error accounted for 70% of the total number of years the fishery was closed. Because of its sensitivity, this strategy is not recommended.

The CC and CHR strategies were more robust to uncertainty in lobster assessments. Neither of these strategies violated the overfishing threshold for our suite of allowable levels of risk. An appraisal of the pros and cons of the tested harvest strategies are outlined in Table 4.

Sublegal and Berried Lobster Retention Fisheries

While there are benefits to a fishery in which sublegal and berried lobsters are retained, the extent of these benefits depends on the magnitude of sublegal and berried handling mortality. Because we do not have an estimate of sublegal and berried handling mortality, we are unable to accurately assess the benefits of such an approach. In a similar study, Kobayashi (1995) found that the reproductive potential of the population more than doubled and mean weight per individual increased by approximately 22% in a retain-all fishery if sublegal lobster handling mortality was 100%.

A potential consequence resulting from the adoption of a retain-all fishery is selective retention of certain size-classes (high-grading), particularly if the market for smaller lobsters is limited, or there are significant price differentials between small, berried, and legal-sized lobsters. While there appears to be an established market for small lobsters in Hawaii, a price differential based on size and condition of lobsters does exist. As a result, high-grading could be a potential problem. When high-grading occurs, the true catch is greater than the reported landings. This causes the actual SPR to be lower then predicted for a specified level of catch. This may place the population at risk of overfishing if the adopted catch level is already high, and the associated SPR close to the SPR threshold.

However, high-grading is not likely to be problematic in the NWHI lobster fishery because of the type of harvest guideline generated and the distant-water nature of this fishery. Presently a fishery wide quota is generated and fishing trips generally last for 4-8 weeks. Assuming that vessels operate independently, vessels do not know the catch of other participants, or how close the fleet's cumulative catch is to the harvest guideline. Under these conditions, a fishermen is likely to retain all lobsters to ensure a profit.

There are 15 permits. How many vessel owners are there?

If the potential for high-grading exists the CHR strategy is recommended. Additional safeguards can be achieved by using a conservative level of risk or handling mortality to set the harvest guideline, or a fishing policy that allows for high-grading. Under a CHR strategy, an annual assessment of lobster abundance is required to determine the harvest guideline. Significant shifts in population size resulting from high-grading would be detected during the assessment and accounted for when setting the next years' harvest guideline in the form of a reduced allowable catch. In essence, the CHR strategy is self regulating and can account for unpredictable removals of lobsters from the population either through natural or unnatural causes.

The risk of high-grading can also be mitigated by using the CHR strategy with a minimum legal-size policy (harvesting of lobsters ≥50.0 mm TW) to set the harvest guideline. This policy is in actuality a selective retention (high-grading) policy in that fishermen are required to discard all sublegal lobsters (≤50.0 mm TW). The allowable catches associated with this policy can be modified to account for various handling mortality scenarios associated with different levels of high-grading. Following the conservative approach, we could assume 100% mortality of all discarded sublegal and berried lobsters to set the harvest guideline. Even under this conservative approach a catch of 135,000 to 217,000 lobsters would be available (Table 3c).

The new program also provides two other mechanisms which should reduce the risk of high-grading, or offset the effects if high-grading occurs. First, the total catch will be monitored to determine when the harvest guideline has been reached and the fishery should be closed. If fishermen report catches of small and berried lobsters but do not retain them, the catch will still be counted against the harvest guideline. If fishermen do not record any small or berried lobsters in their catch, then landings packing slips that indicate sales of such lobsters will be evidence of non-compliance with the requirement to maintain accurate logbooks. Further, if there are no records on catch and/or sales of small and berried lobsters, there will be no data on these catches to enter into the database for use in calculating the next year's harvest guideline, which is based on total exploitable biomass, including small and berried lobster. This would have the effect of lowering the estimated exploitable biomass and, in turn, lowering the harvest guideline for the next year.

Recruitment Uncertainty

Little is known about the recruitment of spiny and slipper lobsters in the NWHI. We therefore estimate long-term yield expectations as if recruitment is constant and independent of stock size and simulate future populations using randomly re-sampled values from observed recruitment estimates. Any changes in annual recruitment to the population, either through large-scale perturbations or density dependence, would result in changes to the SPR-fishing mortality relationship and necessitate reevaluation of harvest policies.

Life History Parameters

The NWHI lobster fishery is a multi-species fishery, harvesting both spiny and slipper lobsters. However, parameters in the model were developed from data collected on spiny lobsters. This inadequacy will likely effect model output. Additional research will be required to address this issue.

Overfishing Threshold

The results of this study indicate that consistent catches can be allowed without violating the established overfishing threshold. While an SPR of 20% represents a threshold, it should not be viewed as a target. The overfishing threshold represents a value to avoid crossing and should be considered when setting policy. While there is a potential to violate the threshold with levels of risk greater than 0, our results show that average annual SPRs at even the maximum level of risk tested (10%) were well above the threshold. Transferring this success to the real world will require effective population and harvest guideline monitoring programs.

References

Kobayashi, D.R. 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 Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service.

Polovina, J.J., W.R. Haight, R.B. Moffitt and F.A. Parrish. 1995. The role of benthic habitat, oceanography, and fishing on the population dynamics of the spiny lobster, *Panulirus marginatus* (Decapoda, Palinuridae), in the Hawaiian archipelago. Crustaceana 68:203-212.

Wetherall, J.A., W.R. Haight, and G.T. DiNardo. 1995. Computation of the preliminary 1995 catch quota for the Northwestern Hawaiian Islands lobster fishery. Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service, Admin. Rept. H-95-04.

Table 1.
Synopsis of Northwestern Hawaiian Islands lobster fishery catch harvest guideline management statistics.

Year	Preliminary quota	Final quota	Final catch	Outcome & management action
1992	750,000	438,000	424,000	Quota procedure appeared to work well
1993	0	0	0	Fishery did not open
1994	200,000	20,900	131,000	Final quota exceeded; fishery closed in August
1995	38,513	---	---	Fishery did not open; experimental fishery allowed.

Table 2. Annual yield functions for the tested population harvest strategies.

Harvest Strategies

Harvest Strategy	Harvest Rate*
Constant Catch	a
Constant Harvest Rate	b N
Constant Escapement	$\begin{cases} 0 & \text{for } N < c \\ \infty & \text{for } N > c \end{cases}$

* a, b and c are constants that determine the intensity of harvesting.

Table 3a. Performance statistics for the Constant Catch strategy (minimum legal size = 50.0 mm tail width) with varying levels of discard mortality and risk to overfishing less than 10%. Size at maturity is equal to 50.6 mm tail width. Target level is expressed as number of lobsters.

Harvest Strategy	Discard Mortality (%)	Target Level	Performance Statistics: Projected Average Catch	CPUE	Risk (%)	Catch Variability (%)	SPR
Constant Catch	0	25,000	27,000	1.38	0.0	27.4	0.92
		50,000	54,000	1.32	1.0	28.6	0.87
		75,000	80,000	1.27	2.0	29.4	0.82
		125,000	131,000	1.17	3.0	30.4	0.74
		150,000	156,000	1.12	4.0	31.4	0.70
		175,000	180,000	1.07	5.0	32.8	0.66
		187,000	191,000	1.05	6.0	33.3	0.64
		200,000	203,000	1.02	7.0	34.2	0.62
		213,000	215,000	1.00	8.0	34.8	0.60
		237,000	236,000	0.96	9.0	36.8	0.57
		250,000	246,000	0.94	10.0	38.0	0.55
	25	25,000	27,000	1.37	0.0	27.3	0.91
		37,000	40,000	1.34	1.0	27.5	0.89
		75,000	80,000	1.25	2.0	29.9	0.81
		100,000	105,000	1.19	3.0	30.4	0.76
		125,000	130,000	1.14	4.0	31.3	0.71
		150,000	154,000	1.08	5.0	32.7	0.67
		163,000	166,000	1.05	6.0	33.6	0.64
		175,000	177,000	1.03	7.0	34.8	0.62
		187,000	188,000	1.00	8.0	36.5	0.60
		200,000	199,000	0.97	9.0	37.4	0.58
		213,000	210,000	0.95	10.0	38.9	0.56
	50	20,000	22,000	1.38	0.0	27.3	0.92
		37,000	40,000	1.34	1.0	27.8	0.88
		50,000	54,000	1.30	2.0	28.6	0.85
		75,000	80,000	1.24	3.0	30.0	0.80
		112,000	116,000	1.14	4.0	31.5	0.72
		125,000	129,000	1.11	5.0	32.0	0.69
		150,000	152,000	1.05	6.0	34.3	0.64
		156,000	158,000	1.03	7.0	35.0	0.63
		163,000	164,000	1.02	8.0	36.1	0.61
		175,000	174,000	0.99	9.0	38.1	0.59
		192,000	188,000	0.94	10.0	40.6	0.56

Table 3a continued.

Harvest Strategy	Discard Mortality (%)	Target Level	Performance Statistics: Projected Average Catch	CPUE	Risk (%)	Catch Variability (%)	SPR
Constant Catch	75	20,000	22,000	1.37	0.0	27.3	0.92
		30,000	32,000	1.35	1.0	27.6	0.89
		50,000	54,000	1.29	2.0	29.3	0.84
		75,000	79,000	1.22	3.0	31.1	0.78
		100,000	104,000	1.15	4.0	32.8	0.72
		125,000	128,000	1.08	5.0	34.0	0.67
		137,000	139,000	1.05	6.0	36.3	0.64
		143,000	144,000	1.03	7.0	37.0	0.63
		150,000	151,000	1.01	8.0	38.4	0.61
		163,000	162,000	0.98	9.0	40.4	0.58
		175,000	171,000	0.94	10.0	42.5	0.56
	100	15,000	16,000	1.39	0.0	27.4	0.93
		25,000	27,000	1.36	1.0	27.6	0.90
		50,000	53,000	1.28	2.0	29.9	0.83
		75,000	79,000	1.20	3.0	32.0	0.77
		100,000	103,000	1.13	4.0	33.7	0.71
		110,000	113,000	1.10	5.0	34.6	0.68
		125,000	127,000	1.05	6.0	36.3	0.64
		130,000	131,000	1.04	7.0	37.6	0.63
		137,000	138,000	1.02	8.0	39.5	0.61
		150,000	149,000	0.98	9.0	41.6	0.58
		155,000	153,000	0.96	10.0	42.5	0.57

Table 3b. Performance statistics for the Constant Catch strategy (minimum legal size = 36.0 mm tail width) with varying levels of discard mortality and risk to overfishing less than 10%. Size at maturity is equal to 50.6 mm tail width. Target level is expressed as number of lobsters.

Harvest Strategy	Discard Mortality (%)	Target Level	Performance Statistics: Projected Average Catch	CPUE	Risk (%)	Catch Variability (%)	SPR
Constant Catch	0	25,000	27,000	1.69	0.0	27.4	0.92
		50,000	54,000	1.64	1.0	27.5	0.88
		75,000	81,000	1.59	2.0	28.5	0.84
		100,000	107,000	1.54	3.0	30.1	0.79
		137,000	145,000	1.46	4.0	30.5	0.73
		163,000	171,000	1.41	5.0	30.9	0.69
		187,000	195,000	1.36	6.0	31.8	0.66
		200,000	208,000	1.34	7.0	32.5	0.64
		213,000	220,000	1.31	8.0	33.4	0.62
		233,000	239,000	1.28	9.0	34.6	0.59
		246,000	251,000	1.25	10.0	35.4	0.58
	25	25,000	27,000	1.69	0.0	27.7	0.92
		50,000	54,000	1.64	1.0	27.5	0.87
		75,000	81,000	1.59	2.0	28.7	0.83
		100,000	107,000	1.53	3.0	30.1	0.79
		137,000	145,000	1.46	4.0	30.6	0.73
		163,000	171,000	1.40	5.0	31.0	0.69
		175,000	183,000	1.38	6.0	31.4	0.67
		200,000	208,000	1.33	7.0	33.2	0.63
		213,000	220,000	1.31	8.0	34.1	0.61
		225,000	231,000	1.29	9.0	34.6	0.59
		241,000	247,000	1.26	10.0	35.6	0.57
	50	25,000	27,000	1.69	0.0	27.7	0.92
		50,000	54,000	1.64	1.0	27.5	0.87
		75,000	81,000	1.58	2.0	29.0	0.83
		100,000	107,000	1.53	3.0	30.2	0.78
		137,000	145,000	1.45	4.0	30.7	0.72
		163,000	171,000	1.40	5.0	31.3	0.68
		175,000	183,000	1.37	6.0	31.9	0.66
		187,000	195,000	1.35	7.0	32.8	0.64
		213,000	220,000	1.30	8.0	34.2	0.60
		225,000	231,000	1.28	9.0	34.8	0.59
		237,000	242,000	1.26	10.0	35.6	0.57

Table 3b continued.

Harvest Strategy	Discard Mortality (%)	Target Level	Performance Statistics: Projected Average Catch	CPUE	Risk (%)	Catch Variability (%)	SPR
Constant Catch	75	25,000	27,000	1.69	0.0	27.7	0.92
		50,000	54,000	1.63	1.0	27.5	0.87
		75,000	81,000	1.58	2.0	29.1	0.82
		100,000	107,000	1.53	3.0	30.2	0.78
		125,000	133,000	1.47	4.0	30.4	0.73
		163,000	171,000	1.39	5.0	31.7	0.67
		175,000	183,000	1.37	6.0	32.1	0.65
		187,000	195,000	1.35	7.0	33.0	0.63
		200,000	207,000	1.32	8.0	33.8	0.61
		213,000	220,000	1.30	9.0	34.4	0.60
		233,000	238,000	1.26	10.0	35.6	0.57
	100	25,000	27,000	1.69	0.0	27.8	0.92
		50,000	54,000	1.63	1.0	27.5	0.87
		75,000	81,000	1.58	2.0	29.3	0.82
		100,000	107,000	1.52	3.0	30.2	0.77
		125,000	133,000	1.47	4.0	30.4	0.73
		150,000	158,000	1.42	5.0	30.9	0.68
		175,000	183,000	1.37	6.0	32.2	0.65
		187,000	195,000	1.34	7.0	33.2	0.63
		200,000	207,000	1.32	8.0	34.0	0.61
		213,000	219,000	1.29	9.0	34.6	0.59
		225,000	231,000	1.27	10.0	35.2	0.57

Table 3c. Performance statistics for the Constant Harvest Rate strategy (minimum legal size = 50.0 mm tail width) with varying levels of discard mortality and risk to overfishing less than 10%. Size at maturity is equal to 50.6 mm tail width. Target level is expressed as percent of the exploitable lobster population.

Harvest Strategy	Discard Mortality (%)	Target Level	Performance Statistics: Projected Average Catch	CPUE	Risk (%)	Catch Variability (%)	SPR
Constant Harvest Rate	0	13.0	187,000	1.07	0.0	144.5	0.64
		15.0	212,000	1.02	1.0	144.4	0.60
		18.0	235,000	0.98	2.0	144.2	0.56
		20.0	257,000	0.93	3.0	145.0	0.53
		23.0	275,000	0.89	4.0	145.0	0.50
		25.0	293,000	0.86	5.0	145.2	0.48
		26.0	296,000	0.85	6.0	145.3	0.47
		27.0	302,000	0.84	7.0	144.9	0.46
		28.0	316,000	0.81	8.0	145.9	0.44
		29.0	319,000	0.80	9.0	146.4	0.43
		30.0	326,000	0.79	10.0	147.1	0.42
	25	13.0	169,000	1.07	0.0	145.4	0.64
		15.0	191,000	1.01	1.0	145.5	0.59
		18.0	211,000	0.96	2.0	145.4	0.56
		20.0	229,000	0.92	3.0	146.4	0.52
		23.0	245,000	0.88	4.0	146.8	0.49
		24.0	251,000	0.86	5.0	146.6	0.48
		26.0	262,000	0.83	6.0	147.1	0.45
		27.0	267,000	0.82	7.0	148.0	0.45
		28.0	271,000	0.80	8.0	148.3	0.44
		30.0	282,000	0.77	9.0	149.7	0.41
		31.0	285,000	0.76	10.0	150.4	0.40
	50	13.0	155,000	1.07	0.0	145.4	0.63
		15.0	176,000	1.01	1.0	146.6	0.59
		18.0	193,000	0.96	2.0	146.8	0.55
		20.0	209,000	0.91	3.0	147.1	0.51
		23.0	223,000	0.87	4.0	148.7	0.48
		24.0	229,000	0.85	5.0	149.2	0.47
		25.0	234,000	0.83	6.0	149.4	0.45
		26.0	240,000	0.81	7.0	149.9	0.44
		28.0	245,000	0.79	8.0	151.3	0.43
		29.0	250,000	0.77	9.0	151.7	0.42
		30.0	254,000	0.76	10.0	152.5	0.41

Table 3c continued.

Harvest Strategy	Discard Mortality (%)	Target Level	Performance Statistics: Projected Average Catch	CPUE	Risk (%)	Catch Variability (%)	SPR
Constant Harvest Rate	75	13.0	144,000	1.06	0.0	145.7	0.63
		15.0	163,000	1.00	1.0	147.4	0.58
		18.0	179,000	0.95	2.0	147.8	0.54
		20.0	193,000	0.91	3.0	148.6	0.51
		23.0	206,000	0.86	4.0	149.9	0.48
		24.0	211,000	0.84	5.0	150.3	0.46
		25.0	216,000	0.82	6.0	151.0	0.45
		26.0	221,000	0.80	7.0	152.1	0.44
		28.0	226,000	0.78	8.0	152.9	0.42
		29.0	230,000	0.76	9.0	153.9	0.41
		30.0	234,000	0.75	10.0	154.5	0.40
	100	13.0	135,000	1.06	0.0	146.2	0.63
		15.0	152,000	1.00	1.0	147.4	0.58
		18.0	167,000	0.95	2.0	148.7	0.54
		20.0	180,000	0.90	3.0	149.5	0.50
		23.0	192,000	0.86	4.0	150.9	0.47
		24.0	197,000	0.84	5.0	151.3	0.46
		25.0	201,000	0.82	6.0	152.3	0.44
		26.0	206,000	0.80	7.0	153.5	0.43
		28.0	210,000	0.78	8.0	154.7	0.42
		29.0	214,000	0.76	9.0	155.2	0.41
		30.0	217,000	0.74	10.0	155.9	0.39

Table 3d. Performance statistics for the Constant Harvest Rate strategy (minimum legal size = 36.0 mm tail width) with varying levels of discard mortality and risk to overfishing less than 10%. Size at maturity is equal to 50.6 mm tail width. Target level is expressed as percent of the exploitable lobster population.

Harvest Strategy	Discard Mortality (%)	Target Level	Performance Statistics				
			Projected Average Catch	CPUE	Risk (%)	Catch Variability (%)	SPR
Constant Harvest Rate	0	3.0	47,000	1.66	0.0	146.2	0.89
		6.0	110,000	1.55	1.0	145.9	0.79
		10.0	163,000	1.44	2.0	146.4	0.71
		13.0	194,000	1.38	3.0	147.0	0.66
		15.0	223,000	1.33	4.0	147.6	0.62
		16.0	236,000	1.30	5.0	147.9	0.60
		18.0	249,000	1.28	6.0	148.3	0.58
		19.0	262,000	1.25	7.0	148.7	0.56
		20.0	274,000	1.23	8.0	149.3	0.54
		21.0	286,000	1.21	9.0	149.7	0.52
		23.0	297,000	1.19	10.0	150.0	0.51
	25	3.0	46,000	1.66	0.0	146.2	0.89
		6.0	107,000	1.55	1.0	146.0	0.78
		10.0	159,000	1.45	2.0	146.3	0.70
		13.0	190,000	1.39	3.0	147.0	0.65
		15.0	219,000	1.33	4.0	147.7	0.61
		16.0	229,000	1.31	5.0	147.9	0.59
		18.0	245,000	1.28	6.0	148.4	0.57
		19.0	257,000	1.26	7.0	148.8	0.55
		20.0	269,000	1.23	8.0	149.3	0.54
		21.0	280,000	1.21	9.0	150.0	0.52
		23.0	291,000	1.19	10.0	150.2	0.50
	50	3.0	45,000	1.66	0.0	146.2	0.89
		6.0	105,000	1.55	1.0	146.0	0.78
		10.0	156,000	1.45	2.0	146.4	0.70
		13.0	186,000	1.39	3.0	147.0	0.65
		15.0	214,000	1.33	4.0	147.9	0.61
		16.0	225,000	1.31	5.0	148.1	0.59
		18.0	240,000	1.28	6.0	148.8	0.57
		19.0	252,000	1.26	7.0	149.4	0.55
		20.0	264,000	1.24	8.0	149.8	0.53
		21.0	275,000	1.21	9.0	150.4	0.52
		23.0	286,000	1.19	10.0	150.5	0.50

Table 3d continued.

Harvest Strategy	Discard Mortality (%)	Target Level	Performance Statistics				
			Projected Average Catch	CPUE	Risk (%)	Catch Variability (%)	SPR
Constant Harvest Rate	75	3.0	44,000	1.66	0.0	146.2	0.89
		6.0	103,000	1.55	1.0	146.0	0.78
		10.0	153,000	1.45	2.0	146.5	0.70
		13.0	183,000	1.39	3.0	147.1	0.65
		15.0	210,000	1.34	4.0	147.9	0.61
		16.0	220,000	1.31	5.0	148.3	0.59
		18.0	235,000	1.29	6.0	148.9	0.57
		19.0	247,000	1.26	7.0	149.3	0.55
		20.0	258,000	1.24	8.0	149.7	0.53
		21.0	270,000	1.22	9.0	150.2	0.51
		23.0	280,000	1.20	10.0	150.6	0.50
	100	3.0	44,000	1.66	0.0	146.2	0.88
		6.0	101,000	1.55	1.0	146.0	0.78
		10.0	150,000	1.45	2.0	146.6	0.69
		13.0	180,000	1.39	3.0	146.8	0.65
		15.0	207,000	1.34	4.0	148.0	0.60
		16.0	217,000	1.32	5.0	148.0	0.59
		18.0	232,000	1.29	6.0	148.9	0.56
		19.0	243,000	1.26	7.0	149.2	0.55
		20.0	254,000	1.24	8.0	149.8	0.53
		21.0	265,000	1.22	9.0	150.0	0.51
		23.0	276,000	1.20	10.0	150.6	0.50

Table 3e. Performance statistics for the Constant Catch and Constant Harvest Rate strategies assuming a retain-all fishery (minimum legal size = 36.0 mm tail width) and risk to overfishing less than 10%. Size at maturity is equal to 50.6 mm tail width. Target level is expressed as number of lobsters for the Constant Catch strategy and percent of the exploitable lobster population for the Constant Harvest Rate strategy.

Harvest Strategy	Discard Mortality (%)	Target Level	Performance Statistics				
			Projected Average Catch	CPUE	Risk (%)	Catch Variability (%)	SPR
Constant Catch	100	25,000	27,000	1.70	0.0	27.9	0.92
		50,000	54,000	1.64	1.0	27.7	0.87
		75,000	81,000	1.59	2.0	28.9	0.83
		100,000	107,000	1.54	3.0	30.4	0.78
		137,000	145,000	1.46	4.0	30.8	0.72
		163,000	172,000	1.41	5.0	31.6	0.68
		175,000	183,000	1.39	6.0	32.1	0.66
		187,000	195,000	1.36	7.0	32.9	0.64
		213,000	220,000	1.31	8.0	34.4	0.60
		225,000	232,000	1.29	9.0	35.0	0.59
		241,000	246,000	1.26	10.0	35.8	0.57
Constant Harvest Rate	100	3.0	46,000	1.66	0.0	147.1	0.89
		6.0	105,000	1.55	1.0	146.6	0.78
		10.0	157,000	1.45	2.0	146.7	0.70
		13.0	188,000	1.40	3.0	147.2	0.65
		15.0	216,000	1.34	4.0	148.3	0.61
		16.0	227,000	1.32	5.0	148.7	0.59
		18.0	242,000	1.29	6.0	149.4	0.57
		19.0	254,000	1.27	7.0	149.9	0.55
		20.0	266,000	1.25	8.0	150.4	0.53
		21.0	277,000	1.23	9.0	150.9	0.52
		22.0	288,000	1.20	10.0	151.0	0.50

Table 4. Summary table of harvest strategy pros and cons.

Constant Escapement		
Con:	a)	overly-sensitive to uncertainty
	b)	higher risks of overfishing
	c)	High incidence of closing the fishery unnecessarily
	d)	gives the appearance of an overfished stock
Pro:	a)	promotes "faster" rebuilding of stocks due to unnecessary closures of the fishery
	b)	low to moderate catch variability
Constant Catch		
Con:	a)	does not insure protection of the population during bust years nor does it reap benefits during boom years
Pro:	a)	robust to uncertainty
	b)	lowest overall catch variability
	c)	high allowable catch rates and highest CPUEs
	d)	highest average annual SPRs relative to tested levels of risk
Constant Harvest Rate		
Con:	a)	highest catch variability
	b)	lowest average annual SPRs relative to tested levels of risk
Pro:	a)	insures protection of the population during bust years and during boom years benefits are realized
	b)	highest allowable catches with moderate to high CPUEs
	c)	robust to uncertainty

Figure 1. Time line of steps to determine the annual harvest guideline for the NWHI lobster trap fishery. Arrows indicate the approximate timing of an event. Arrows above the time line refer to harvest guideline setting steps; arrows below the time line refer to fishing events, in particular the onset and cessation of the fishing season.

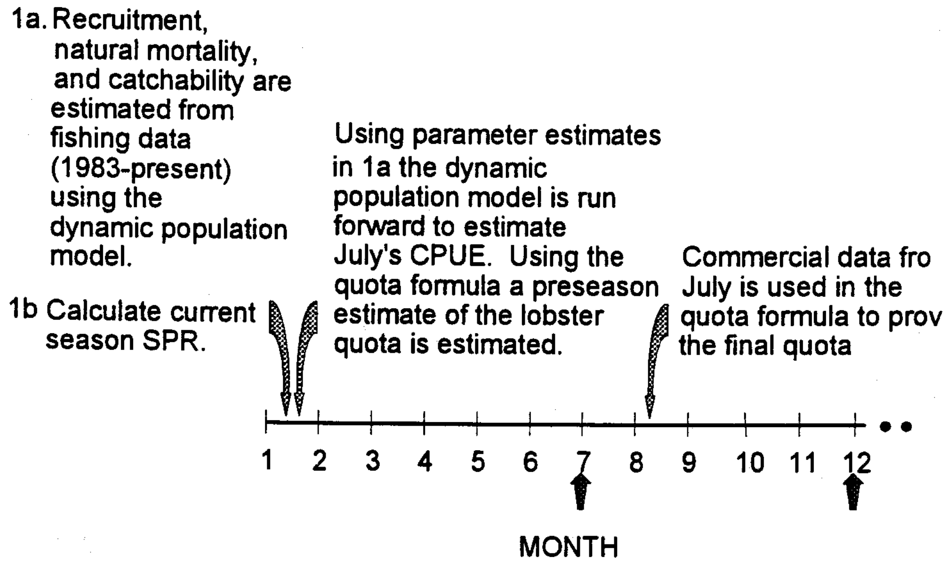


Figure 2. Comparison of risk curves by discard mortality rate for the Constant Catch (solid lines) and Constant Harvest Rate (dashed lines) harvest strategies for each fishing policy. Discard mortality rates from left to right are 0, 25, 50, 75 and 100%. Panel A represents the retention of all decked lobsters ≥ 50.0 mm TW, Panel B the retention of all decked non-berried lobsters ≥ 36.0 mm TW, and Panel C the retention of all decked lobsters ≥ 36.0 mm TW. The ordinate is the expected annual catch of lobsters in numbers.

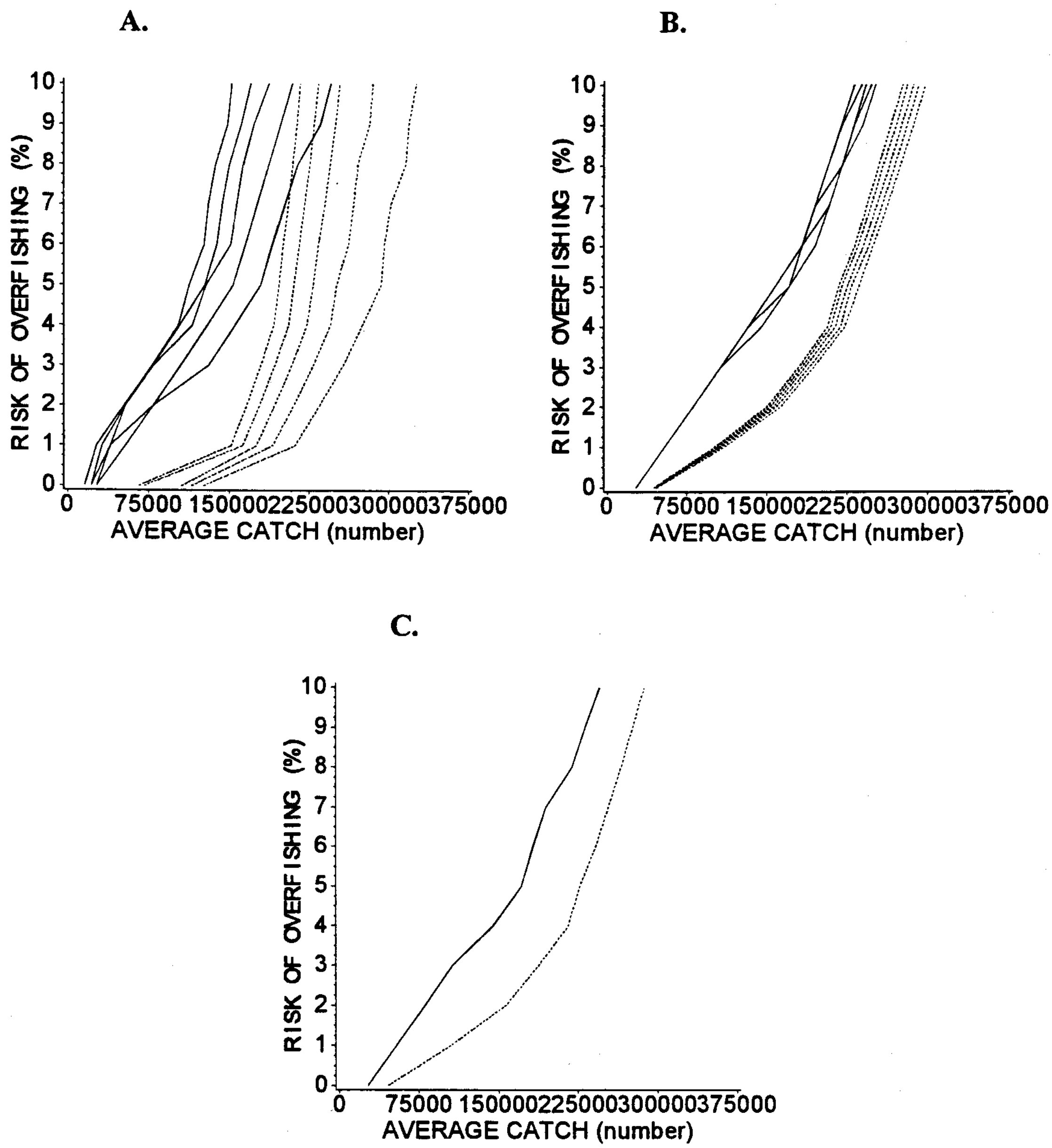


Figure 3. Expected spawning potential ratios by discard mortality rate for the Constant Catch (solid lines) and Constant Harvest Rate (dashed lines) harvest strategies for each fishing policy. Discard mortality rates from left to right are 0, 25, 50, 75 and 100%. Panel A represents the retention of all decked lobsters ≥ 50.0 mm TW, Panel B the retention of all decked non-berried lobsters ≥ 36.0 mm TW, and Panel C the retention of all decked lobsters ≥ 36.0 mm TW. The ordinate is the expected annual catch of lobsters in numbers. The horizontal dashed line at an SPR of 0.2 is for reference and represents the overfishing threshold.

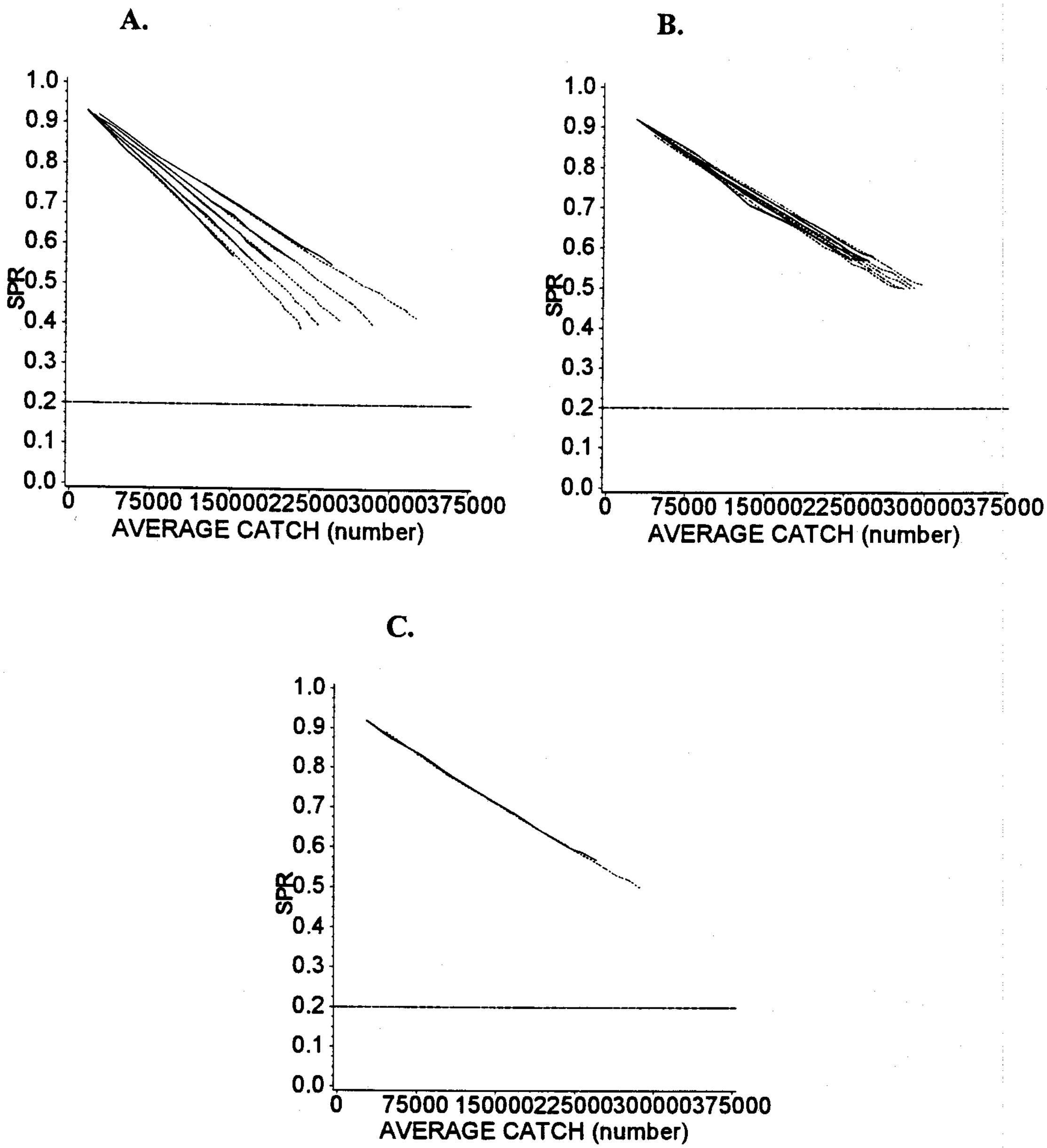
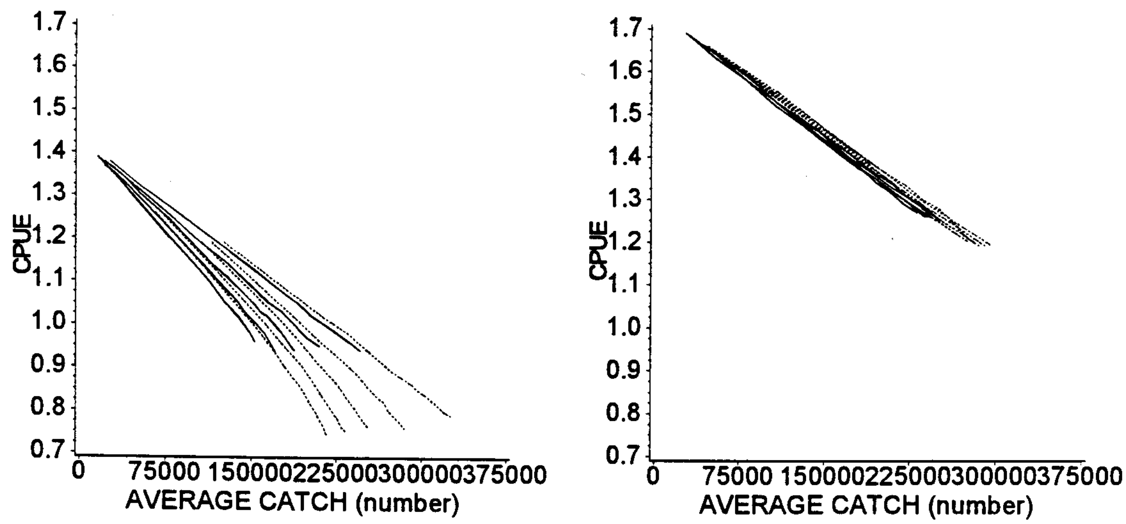
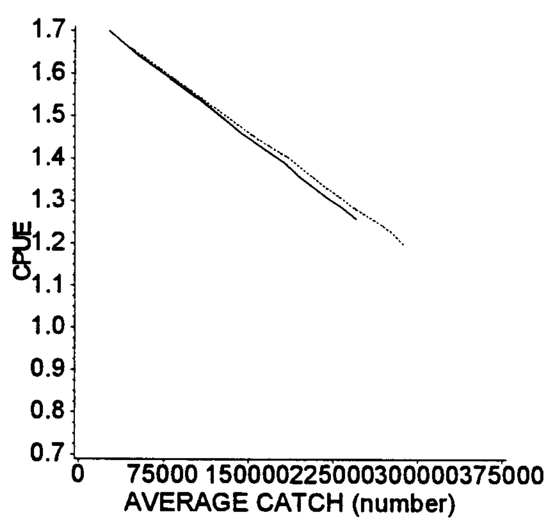


Figure 4. Expected catch per unit effort by discard mortality rate for the Constant Catch (solid lines) and Constant Harvest Rate (dashed lines) harvest strategies for each fishing policy. Discard mortality rates from left to right are 0, 25, 50, 75 and 100%. Panel A represents the retention of all decked lobsters ≥ 50.0 mm TW, Panel B the retention of all decked non-berried lobsters ≥ 36.0 mm TW, and Panel C the retention of all decked lobsters ≥ 36.0 mm TW. The ordinate is the expected annual catch of lobsters in numbers.

A. **B.**



C.



Addendum A. Model Event Schedule

The dynamics of lobsters in the NWHI were modeled using a modified version of the auto-regressive dynamics model of Polovina, et al. (1995). The numerical abundance of lobsters in monthly age bins over a 20-year life span are computed as:

$$N_{i,t+1} = N_{i,t}S - C_{i,t} + R_{i,t},$$

where $N_{i,t}$ is the number of lobsters of age i at the beginning of the i-th month, S is the monthly survival rate in the absence of fishing, $C_{i,t}$ is the number of lobsters of age i removed in month t, and $R_{i,t}$ is the number of lobsters recruiting to age i in month t. Age-dependent catch is based on a size-dependent selection give and the specified fishing policy (minimum legal-size or retention fishery).

The analysis was based on statistics from 500 Monte Carlo replicates, each simulating a 30-year period during which a specified set of model conditions and harvest policy parameters was in effect. In each case, a simulation run proceeded according to the following event schedule:

1. The vector of age-specific lobster abundance was initialized based on current conditions and initial population parameters computed (e.g., exploitable biomass, spawning biomass per recruit, etc.).

2. Under the specified set of input parameters (sublegal survival rate, sublegal retention rate, etc.) and each harvest guideline policy option, a 30-year history of population size, catch, and other variables was generated in monthly time steps.

3. Define the exploitable population as the population vulnerable to harvest (the sum of age-specific abundance weighted by age-specific selectivity). At the beginning of each simulated fishing season (1 July), the selected harvest policy (open or close the fishing season) was implemented as follows:

   - A "forecast" of the 1 July exploitable stock size, X_{est}, was generated as a function of the true 1 July exploitable stock size, X_{act}. The forecast incorporated specified levels of systematic (bias) and measurement (catchability) error. The forecast is intended to mimic the current 1 January forecast procedure.

   - Let F_{20} be the fishing mortality rate associated with an equilibrium SPR of 20%, and let U_{20} denote the associated exploitation (harvest) rate with respect to X_{act}. Based on the predicted stock size, X_{est}, and the harvest policy under study, a catch harvest guideline, Q, was determined subject to $Q < U_{20} * X_{est}$. The projected harvest rate, $U = Q/X_{act}$, determined a fishing mortality rate that was applied during the season.

   - The fishery generated a catch, C. The actual harvest rate over the course of the fishing season was computed as $U_{act} = C/X_{act}$. If $U_{act} > U_{20}$ a recruitment overfishing event was recorded.

4. During each month, catches of legal, sublegal (if retained), and berried females (if retained) lobsters were computed, population vector elements were updated, and spawning biomass and larval production were computed.

5. Results for a 10-year spin-up period were not used in the analysis. The initial years were disregarded because the model needed time to equilibrate. The model was based, however, on the current estimates of population size and structure. Results from years 11-30 were stored and summarized at the end of the run. Variables computed over the 20-year simulation included mean annual catch, mean year-to-year percentage change in catch, mean CPUE during the fishing season, mean SPR, mean annual fishing effort, and the risk of overfishing in any specified year.

Given the 20-year histories for each of the 500 replicates, mean annual catch, year-to-year variation in catch, mean CPUE, mean SPR, the risk of overfishing, and other statistics were computed. These summary statistics were used to evaluate harvest strategy options.

Addendum B. Model Assumptions

1. Natural mortality, catchability, and recruitment

The annual natural mortality coefficient (M), catchability coefficient (q), and annual recruitment to the exploitable population (R) were estimated by Wetherall, et al. (1995) using the statistical procedure developed by Polovina, et al. (1995). The parameter estimates, based on monthly catch and CPUE data from 1983 through 1994, were:

$M = 0.456/\text{yr}$
$q = 0.717$ per million trap hauls
$R = 0.756$ million lobsters per year

2. Length, weight, age conversions

The following relationships (W. Haight, unpublished data) were used in the model to convert specified values of tail width (TW, in mm) to estimates of body weight (WT, in kg) and age (t, in yrs):

$$WT = 0.0000043*(TW - 5.6)^{3.0}$$
$$t = -\ln[1 - (TW/83.0)]/0.30$$

3. Gear selectivity

Age-dependent gear selectivities were estimated by converting age to TW and interpolating linearly between specified points on a size-dependent selection give (W. Haight, NMFS Honolulu Lab, Unpubl.). The following points were specified:

Selectivity	TW
0.00	36.0
0.25	45.0
0.50	47.0
0.75	49.0
1.00	56.0

4. Maturation

Age-dependent probabilities of maturity were estimated assuming two maturity schedules by converting age to TW and interpolating linearly between specified points on a size-dependent maturation curve (W. Haight, unpublished data). The following points were specified:

	Tail Width	
Maturity	Schedule A	Schedule B
0.00	42.7	47.3
0.25	45.4	50.0
0.50	46.0	50.6
0.75	46.6	51.2
1.00	48.7	53.3

Schedule A assumes that the size at maturity (tail width at which 50% of the female lobsters in the sample were carrying eggs) is 46.0 mm TW and Schedule B assumes a size at maturity of 50.6 mm TW. Schedule A represents the current estimate of size at maturity and Schedule B assumes a +10% error in our assessment of size at maturity.

5. Spawning schedule

A monthly schedule of spawning activity was determined from logbook data on reported catch of berried female lobsters. The monthly spawning activity schedule is expressed as percent with the following distribution:

Month	Spawning Activity
1	1.2
2	0.2
3	0.6
4	0.8
5	18.1
6	28.6
7	30.9
8	12.8
9	1.6
10	1.9
11	1.6
12	1.7

6. Nominal effort schedule

A monthly schedule of nominal fishing effort was determined from logbook effort statistics reported by lobster vessels in recent years. The monthly schedule is used to apportion annual fishing effort into monthly fishing effort according to the following distribution:

Month	Percent Effort
1	0.0
2	0.0
3	0.0
4	0.0
5	0.0
6	0.0
7	30.0
8	30.0
9	16.0
10	15.0
11	8.0
12	1.1

Appendix 5

Simulated Effects of Discard Mortality on Spiny Lobster (*Panulirus marginatus*) Sustainable Yield and Spawning Stock Biomass per Recruit in the Northwestern Hawaiian Islands

D.R. Kobayashi
NMFS Honolulu Laboratory

*** * * DRAFT MANUSCRIPT * * ***

Introduction

Management regimes in many of the world's fisheries involves the use of a discard policy, whereby fishermen can legally retain only certain individuals of the managed species. These discard policies are usually related to animal size and/or reproductive condition. In the case of the Hawaiian spiny lobster (*Panulirus marginatus*) trap fishery in the Northwestern Hawaiian Islands, there is both a minimum size limit and a prohibition on retaining female lobsters that are carrying egg masses (henceforth termed "berried"). This management policy has been in effect since the start of the commercial fishery in 1976. Escapement vents on the lobster traps became mandatory in 1988 (Everson, et al., 1992), which allows some sublegal-sized individuals to escape. More recently, due to indications of a declining stock, an emergency 7-month closure of the fishery took place in May-November, 1991; and a limited-entry program, annual six-month closed season (January-June), and annual catch quota system have all been initiated starting in 1992 (amendment 7 to the Lobster Fishery Management Plan, 1992). Lack of detectable stock recovery prompted the emergency closure of the entire fishery for the 1993 season. In 1994, the fishery was opened with a relatively small annual quota of approximately 200,000 total individuals (combining several species of lobsters, Haight and Polovina, 1993b), which is only 11% of the peak catch of 1.8 million individuals in 1985 (Dollar, 1993). However, due to continued low catch rates, the fishery underwent another emergency closure in mid-1994.

The effectiveness of selective-retention management policies with regard to stock maintenance and/or recovery critically depends on the survival of discarded sublegal-sized and berried lobsters, particularly if there is "high-grading" in addition to management-related discards. High-grading is economically-driven selective discarding, whereby less valuable individuals are discarded in favor of retaining more valuable individuals. Given that there is a relatively small numeric catch harvest guideline, there could be substantial motivation for fishermen to high-grade, since larger lobsters generally sell at a higher price-per-pound than smaller lobsters (Dollar, 1993). There is qualitative evidence that many discarded lobsters may succumb to predation by sharks and large carangids as the discarded lobsters sink or swim to the bottom (Gooding, 1985; NMFS unpublished data). Other studies have shown that lobster eyes can be permanently damaged after brief exposure to ambient sunlight (Meyer-Rochow, 1994; Shelton, et al., 1985). Biochemical imbalances due to prolonged aerial exposure can also hinder survivability (Whiteley and Taylor, 1992), and thermal stress is an important factor in the lower latitudes (Brown and Caputi, 1983). Even if injured individuals successfully pass through the gauntlet of predators and do not succumb to their immediate injuries, mortality may be protracted due to an inability to compete successfully with conspecifics for food and/or shelter (Evans, et al., 1994).

This simulation study was done to investigate the effects of: 1) variable levels of discard mortality on sustainable fishery yield and spawning stock biomass per recruit, and 2) a hypothetical management regime where all captured lobsters are retained regardless of size or reproductive condition.

Materials and Methods

The effects of discard mortality were investigated with an age-structured computer simulation model. Fishing and discard mortality are modeled using a combination of three logistic curves (Q_1, Q_2, and Q_3). Each Q_i curve is parameterized as $Q_i = \frac{1}{1+e^{-c(CL-L50_i)}}$

where c is a shared curvature parameter, CL is carapace length in mm, and $L50_i$ is a location parameter representing the size at which Q_i is equal to 50%. Each Q_i has a unique $L50_i$, representing the sizes at which lobsters are vulnerable to the gear ($L50_1$=73 mm CL; NMFS unpublished data), can be legally retained ($L50_2$=77 mm CL; Uchida and Tagami, 1984), and become sexually mature ($L50_3$=51 mm CL; NMFS unpublished data), respectively. Q_1 is assumed to describe the selectivity of the lobster traps whereby individuals are subject to capture at an instantaneous fishing rate of Q_1F. This fishing rate is modified with a proportional multiplier P_D to describe the mortality of captured-and-discarded (henceforth termed "CAD") lobsters. For CAD sublegal sizes, P_D describes the fraction that do not survive. The mortality of CAD berried lobsters is dependent on P_D and another proportion P_B which describes the numeric proportion of berried females in the total mature population of males and females (P_B=0.167, NMFS unpublished data). For simplicity, fishing mortality is allocated to retention versus discard based on P_B. Possible changes in P_B due to successful releases are not considered, i.e., the population pool is assumed to be too large for sex-biased releases to alter the underlying sex ratio. For computational ease, fishing mortality is broken into two synchronous components. The first component is the mortality of CAD sublegal sizes and berried females, for which the relation $F_D=(Q_1-Q_2)P_DF+Q_2Q_3P_BP_DF$ is used to estimate the instantaneous mortality rate. Note that this first component refers only to population removal and is not tabulated as retained catch. The second component is the mortality of legally retained catch, which uses the relation $F_C=(1-Q_3P_B)Q_1Q_2F$ to estimate the instantaneous mortality rate. Note that when $P_D=1$, then the total fishing-related mortality to the population, $F_T=F_D+F_C$, asymptotically approaches F. When $P_D<1$, F_T asymptotically approaches $(P_BP_D+1-P_B)F$. Recruitment and the natural mortality rate, M=0.456 year^{-1} (Haight and Polovina, 1993b), remain constant in the model. The actual recruitment value is arbitrary for this analysis since the relevant calculations are scaled in terms of biomass per recruit. The model uses quarter-year time increments with numbers at age estimated with $N_t = N_{t-1} e^{-\frac{(M+F)}{4}}$. Length at age is characterized with a von Bertalanffy growth function $L_t = L_\infty(1-e^{K(t-t_0)})$, where L_∞=121 mm CL, K=0.31 year^{-1}, and t_0=0 years (Uchida and Tagami, 1984). Length to weight conversion is based on the relation $W_t = aL_t^b$, where a=9x10^{-7}, and b=2.9952 (Uchida and Tagami, 1984). The variance of length at age is approximated as $V_t=10(1-e^{-0.1t})$, and the logistic shape parameter c is set at 1.0 for the Q_1, Q_2, and Q_3 curves. The logistic curves and the population size structure are shown in Figure 1. Three values of the instantaneous fishing mortality rate, F, were used (0.2, 0.5, and 1.0). Estimated values of F for NWHI spiny lobster have ranged from 0.05 in 1983 (Haight and Polovina, 1993a) to as high as 1.2 in 1990 (Haight and Polovina, 1993a), although the 1990 F has also been estimated at 0.87 (Haight and Polovina, 1993a). The discard mortality multiplier, P_D, was varied from 0 to 1.0 by increments of 0.1 for each value of F used in the simulation. Percent changes in equilibrium yield per recruit (henceforth termed "YPR"; Beverton and Holt, 1957) and the spawning potential ratio (henceforth termed "SPR"; Goodyear, 1993) were calculated as a function of P_D. YPR is simply the fishery yield divided into the number of N_0 recruits. SPR is expressed as a percentage, comparing spawning stock biomass per recruit (henceforth termed "SSBR") in the currently fished population to SSBR in the virgin (unfished) population. Isopleths of equilibrium YPR and SPR were also estimated from the population model.

For each value of F and P_D, the hypothetical management regime of total retention was evaluated. This was done under the assumption that the total retention regime would allow the same overall weight yield of lobsters, including the take of sublegal-sized and berried individuals. A reduced-F (F') equilibrium fishery that had the same YPR as the initial condition was determined by iteratively varying F'. The percent change in SPR under the total retention regime was recorded, as well as the predicted change in mean weight per lobster in the catch.

Results and Discussion

Equilibrium YPR and SPR contours were mapped over a grid of $L50_1$ and F (Figure 2). This was done under the assumption of no discards (i.e., Q_2=1 for all sizes). Isopleths of YPR and SPR are approximately parallel over most of the grid; yet there were overall declines in SPR when following a YPR isopleth to an equilibrium fishery that can retain smaller individuals.

One consequence of non-zero P_D is that long term equilibrium yield, or YPR, will be lower at constant fishing effort than if P_D were zero (Figure 3). YPR is always lower in the presence of non-zero P_D, and when P_D=0.5 (where half of the CAD lobsters die), the percent changes (from P_D=0) are -6.6%, -13.3%, and -21.6% at F=0.2, 0.5, and 1.0, respectively. When P_D=1 (where all of the CAD lobsters die), the percent changes are -12.7%, -24.7%, and -38.2%, respectively (Figure 3).

Equilibrium SPR is also highly influenced by P_D (Figure 4); non-zero P_D always results in a lower SPR. When P_D=0.5, the percent changes (from P_D=0) are -4.6%, -8.1%, and -10.8% at F=0.2, 0.5, and 1.0, respectively. When P_D=1, the percent changes are -8.9%, -15.0%, and -19.3%, respectively (Figure 4).

The total retention, reduced-F' model estimated with the iterative search algorithm showed that SPR can either increase or decrease depending on the level of F and P_D (Figure 5). When $P_D=0$ at the lower values of F (0.2 and 0.5), then equilibrium SPR will decrease slightly with a total retention management plan. However, if P_D is nonzero, equilibrium SPR will probably increase with a total retention plan, regardless of the value of F. With certain values of $L50_1$, there may be two F' solutions for a given value of yield due to the "doming" of the YPR surface. In these situations, the smaller F' was used since presumably a relaxation of fishing effort would coincide with a total retention management plan. As mentioned earlier, there were increases in SPR with the total retention management plan except when P_D was near zero at low F. At $P_D=0.5$, there were SPR increases of 6.9%, 24.6%, and 71.2% at F=0.2, 0.5, and 1.0, respectively. If $P_D=1$, there were maximum SPR increases of 14.7%, 48.4%, and 119.3%, respectively (Figure 6). Although overall weight yield would remain the same, there would be changes in the mean weight per individual lobster in the catch (Figure 7). Mean weight would decrease at F=0.2 at all levels of P_D, and would increase at F=1.0 except when $P_D=0$. Mean weight would decrease at F=0.5 when $P_D<0.4$, and would increases when $P_D\geq0.4$. Over the range of F examined, mean weight changes ranged from a decrease of -5.3% (if initial F=0.5 and $P_D=0$) to an increase of 22.6% (if F=1.0 and $P_D=1.0$, Figure 7).

The discard of lobsters in the NWHI may have secondary effects on other fisheries as well. Since CAD lobsters may supplement the normal food source for sharks and large carangids, these predatory stocks may increase. Individuals may also acquire undesirable behavioral traits such as following fishing vessels. Sharks are already a major nuisance in the NWHI bottomfish fishery (Kobayashi and Kawamoto, in press), and large carangids can also damage/steal hooked fish and are of limited market value. It would appear that low survivability of CAD lobsters may also have potentially negative impacts on other non-lobster fisheries in the NWHI.

Conclusions

Clearly, the relative magnitude of discard mortality needs to be estimated before effective management can be undertaken. As the simulation results show, if all of the CAD lobsters are surviving, then a total retention management plan will have a negligible impact on the stock. However, if survival of the CAD lobsters is low, either due to immediate predation or protracted mortality from capture-related stress, then a total retention management plan will probably have a positive effect on the stock. The qualitative evidence to-date suggests that the second scenario of low CAD survivability is likely, favoring the adoption of a total retention management plan. Economic studies are needed to estimate the impact of a larger supply of smaller lobsters to the commercial market, given that there are already extreme fluctuations is size-related supply and demand (Dollar, 1993). Alternatively, more efficient means of discarding CAD lobsters to their habitat should be explored. A higher survival rate of CAD lobsters would benefit both the long term fishery yield and the SPR of the stock. The present impact of CAD lobsters on shark and large carangid stock size and behavior merits further research, since these predators have a negative influence on other non-lobster fisheries.

Acknowledgments

I thank Jeff Polovina for suggesting the direction of this study; Wayne Haight and Al Everson for providing some of the parameters, and Ed DeMartini and others for their constructive reviews of the manuscript.

References

Beverton, R.J.H., and S.J. Holt.
1957. On the Dynamics of Exploited Fish Populations. Chapman and Hall, New York, 533 pp.

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. Fish. Res. 2: 103-128.

Dollar, R.A.
1993. Annual report of the 1992 Western Pacific lobster fishery. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-93-09, 27 pp.

Evans, S.M., J.E. Hunter, _. Elizal, and R.I. Wahju.
1994. Composition and fate of the catch and bycatch in the Farne Deep (North Sea) *Nephrops* fishery. ICES J. Mar. Sci. 51: 155-168.

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. J. Fish. Man. 12(1): 161-171.

Gooding, R.M.
1985. Predation on released spiny lobster, *Panulirus marginatus*, during tests in the Northwestern Hawaiian Islands. Mar. Fish. Rev. 47(1): 27-35.

Goodyear, C.P.
1993. Spawning stock biomass per recruit in fisheries management: foundation and current use. In: S.J. Smith, J.J. Hunt, and D. Rivard (editors), Risk Evaluation and Biological Reference Points for Fisheries Management, Can. Spec. Publ. Fish. Aquat. Sci. 120, pp. 67-81.

Haight, W.R., and J.J. Polovina.
1993a. Status of lobster stocks in the Northwestern Hawaiian Islands, 1992. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-93-04, 23 pp.

Haight, W.R., and J.J. Polovina.
1993b. Status of lobster stocks in the Northwestern Hawaiian Islands, 1993. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-93-17, 13 pp.

Kobayashi, D.R., and K.E. Kawamoto.
In press. Evaluation of shark, dolphin, and monk seal interactions with Northwestern Hawaiian Island bottomfishing activity: A comparison of two time periods and an estimate of economic impacts. Fish. Res.

Meyer-Rochow, V.B.
1994. Light-induced damage to photoreceptors of spiny lobsters and other crustaceans. 67(1): 95-?.

Polovina, J.J.
1993. The lobster and shrimp fisheries in Hawaii. Mar. Fish. Rev. 55(2):28-33.

Shelton, P.M.J., E. Gates, and C.J. Chapman.
1985. Light and retinal damage in *Nephrops norvegicus* (L.) (Crustacea). Proc. R. Soc. Lond. B. 226: 217-236.

Uchida, R.N., and D.T. Tagami.
1984. Biology, distribution, population structure, and pre-exploitation abundance of spiny lobster, *Panulirus marginatus* (Quoy and Gaimard 1825), in the Northwestern Hawaiian Islands. In: R.W. Grigg and K.Y. Tanoue (editors), Proceedings of the Second Symposium on Resource Investigations in the Northwestern Hawaiian Islands, University of Hawaii Sea Grant, Honolulu, Hawaii, pp. 157-198.

Whiteley, N.M., and E.W. Taylor.
1992. Oxygen and acid-base disturbances in the hemolymph of the lobster *Homarus gammarus* during commercial transport and storage. J. Crust. Biol. 12(1): 19-30.

Figure 1. Sizes at entry to the commercial fishery, sexual maturity, and legal retention for Hawaiian spiny lobster *Panulirus marginatus* in the Northwestern Hawaiian Islands. Quarterly cohorts are shown for ages 1 year and older, as well as the cumulative population size frequency.

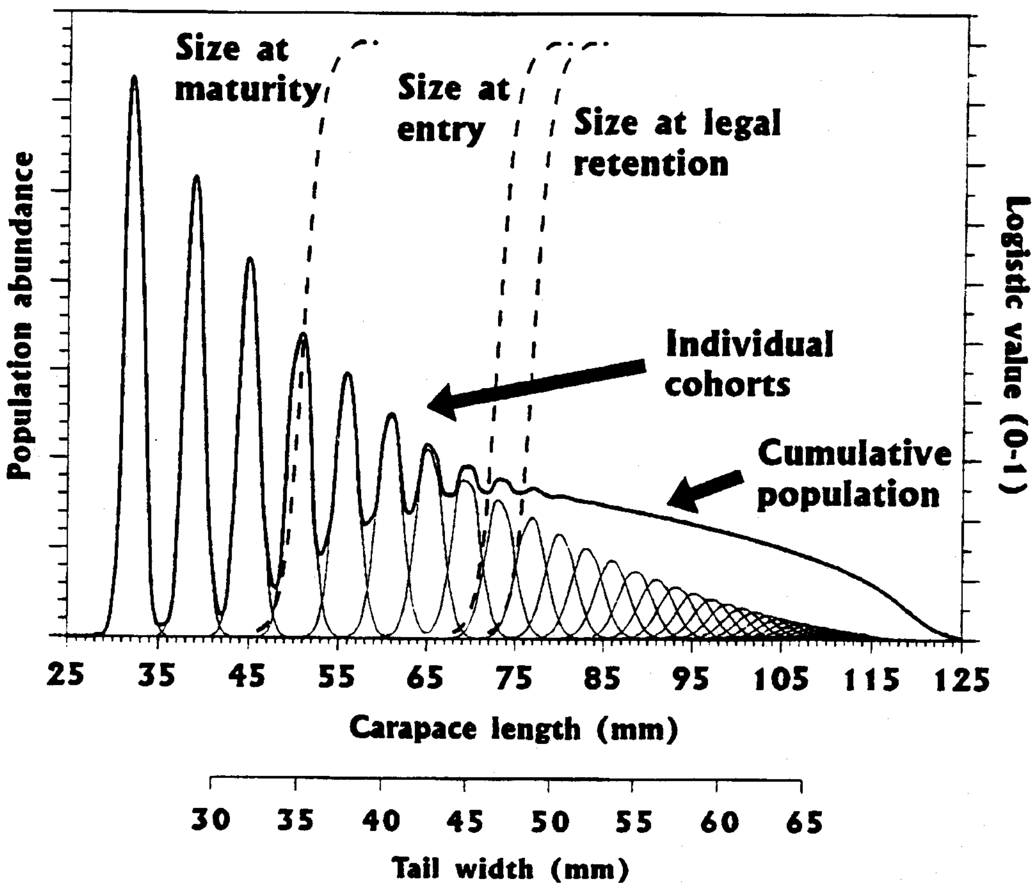


Figure 2. Contours of equilibrium YPR (A) and SPR (B) as a function of F and size at entry to the fishery. YPR is expressed as weight yield (kilograms) per one thousand recruits (N_0). SPR is expressed as a percentage, comparing the amount of spawning stock biomass currently in the population to the amount of spawning stock biomass in the unfished population.

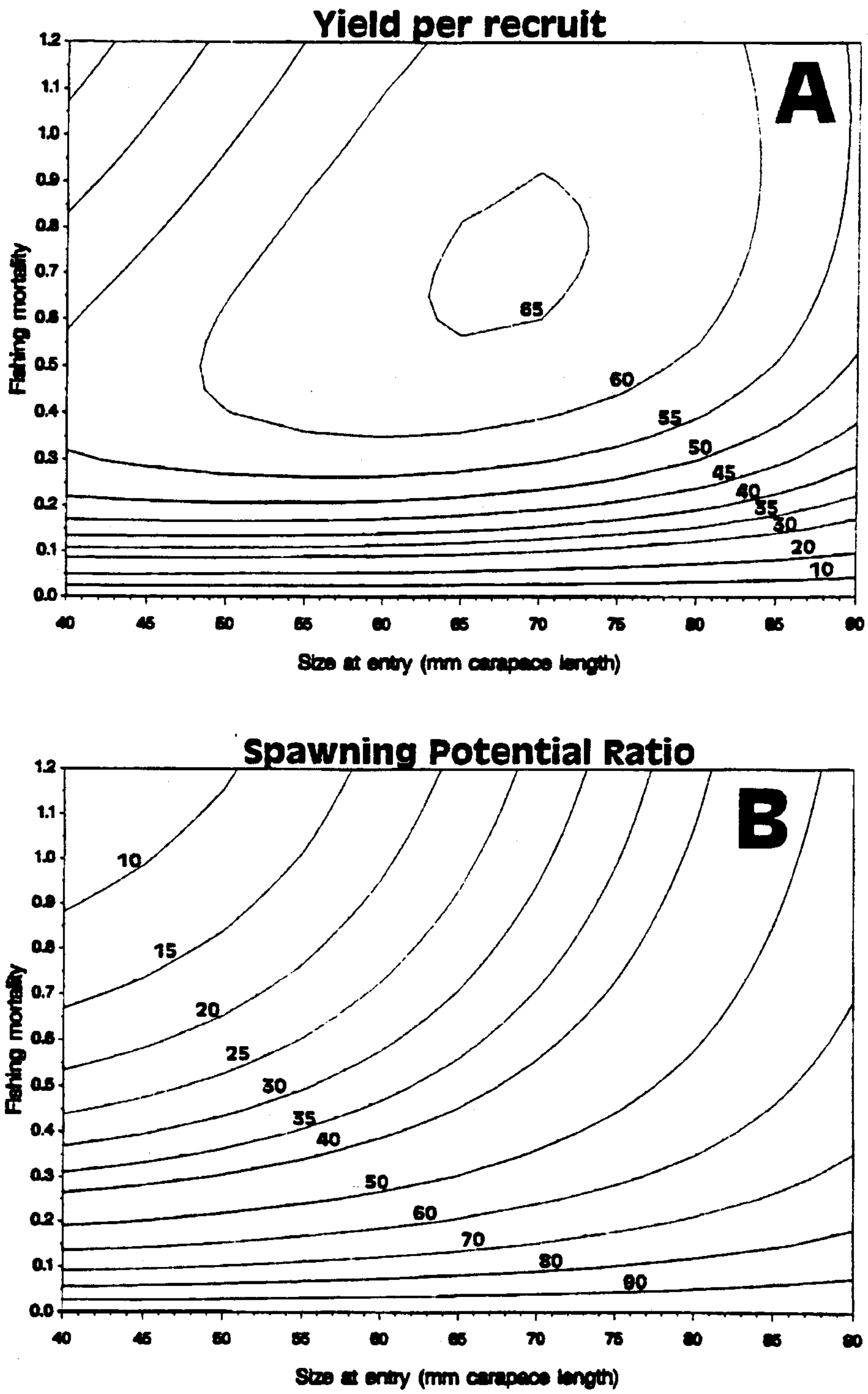


Figure 3. Values of equilibrium YPR at different levels of F and P_D (A), and the percent change from YPR at P_D=0 (B).

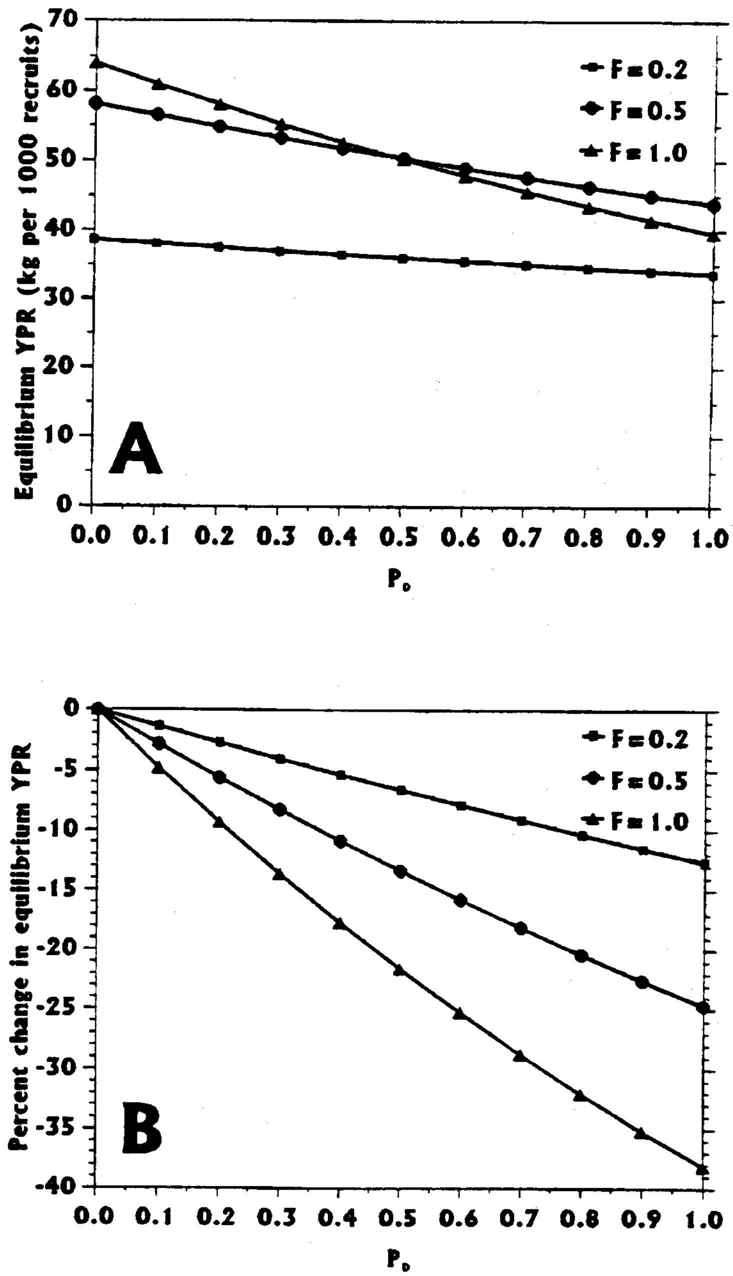
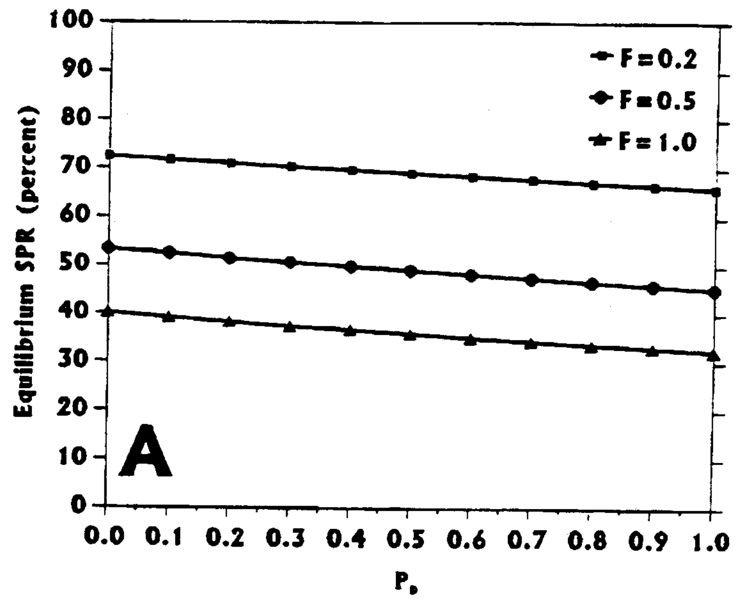


Figure 4. Values of equilibrium SPR at different levels of F and P_D (A), and the percent change from SPR at P_D=0 (B).



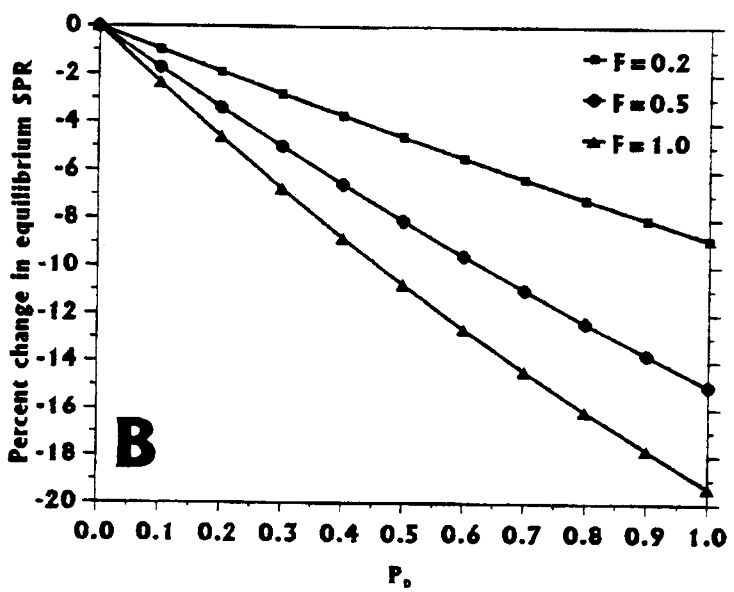


Figure 5. Values of equilibrium SPR at different levels of F and P_D. SPR1 refers to the SPR under present conditions where sublegal and berried lobsters are discarded. SPR2 refers to the SPR under a total retention management plan where all lobsters are retained with the same overall weight yield. Three values of F were used: 0.2 (A), 0.5 (B), and 1.0 (C).

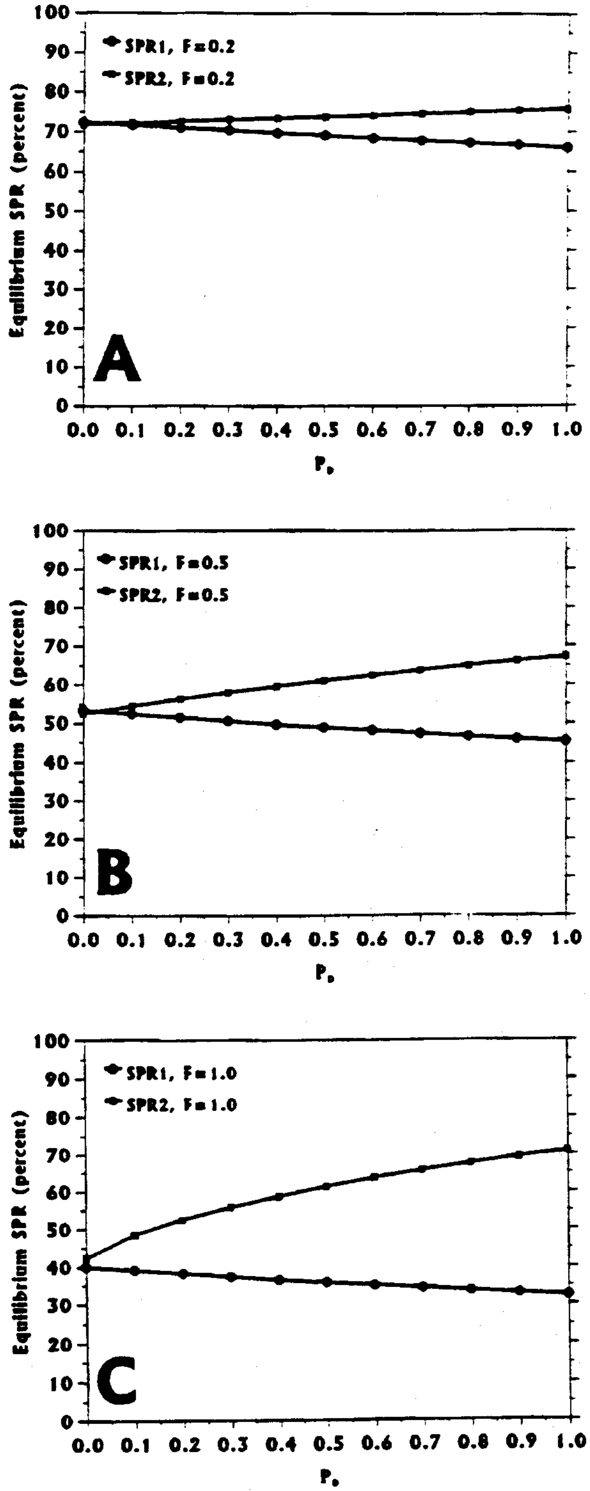


Figure 6. The percent change in SPR if a sublegal and berried discard management plan is changed to a total retention management plan.

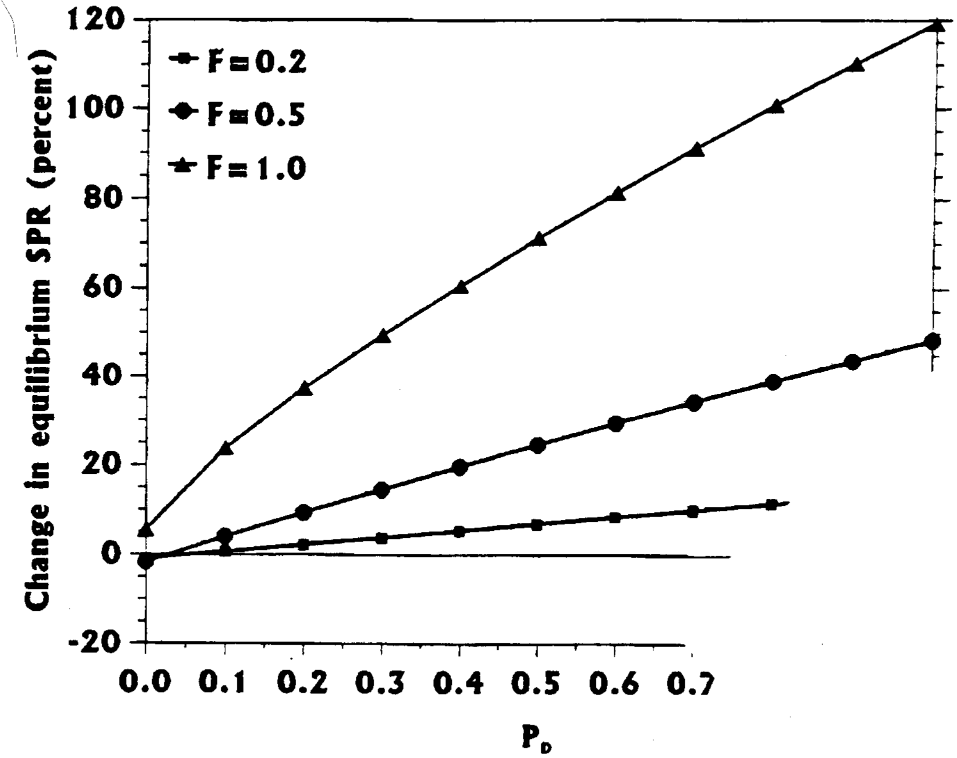
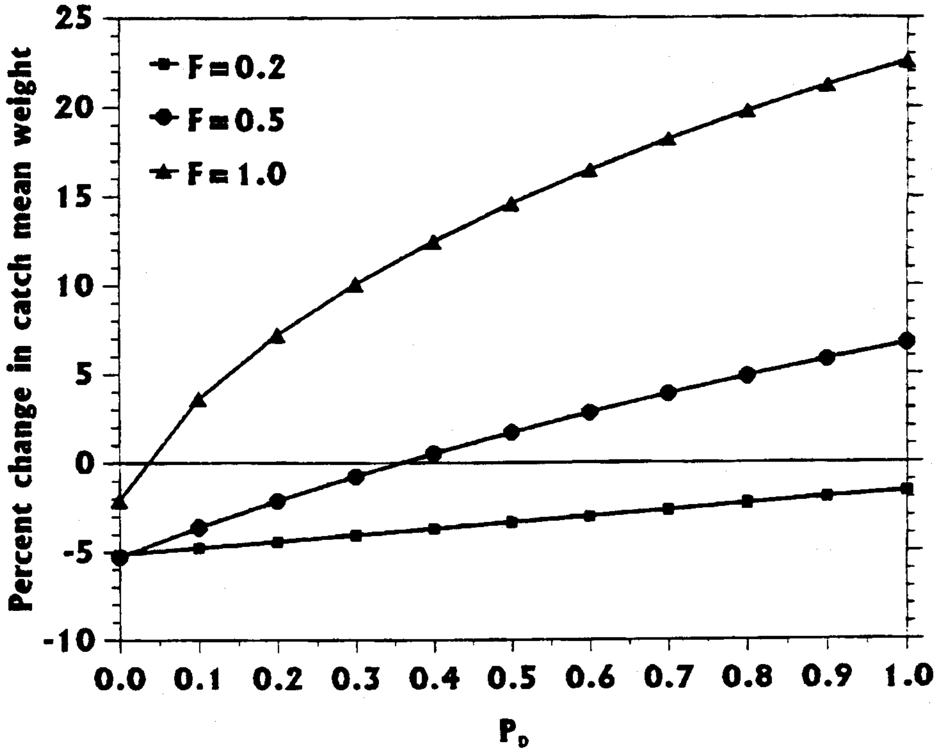


Figure 7. The percent change in mean weight per individual lobster in the retained catch if a sublegal and berried discard management plan is changed to a total retention management plan.



Appendix 6

Endangered Species Act Section 7 Consultation -- Biological Assessment

Proposed Action

Implementation of a new harvest guideline system for the Northwestern Hawaiian Islands (NWHI) crustaceans fishery.

Background

The NWHI lobster fishery is managed through regulations implementing the Fishery Management Plan for Crustacean Fisheries of the Western Pacific Region (FMP), which was prepared by the Western Pacific Fishery Management Council (Council). The regulations implementing the FMP currently include a number of conservation and management measures, including limited entry permits, notification and reporting requirements, an annual quota on harvest, size limits for spiny and slipper lobster, a requirement that undersized and egg-bearing female lobsters be discarded as quickly as practicable after trap retrieval and sorting, an open fishing season, and area closures. The Regional Director is authorized to place an observer aboard a permitted vessel. The regulations also provide the Regional Director with authority to close the fishery if he/she receives a report indicating mortality of a monk seal due to the fishery; and the FMP contains framework procedures for the Council to adopt new regulatory measures in case of reports of interactions between the fishery and monk seals. The FMP is intended to prevent overfishing by maintaining the spawning biomass at an optimum level and to maintain an economically healthy fishery through limited entry and significant freedom for individual permit holders to decide whether to fish. The FMP also is intended to ensure that Hawaiian monk seals and other protected resources are not harmed inadvertently by the fishery. §7 Cons.

Since implementation of the limited entry and quota system in 1992, the fishery has been marked by instability and unpredictability. The fishery was closed in 1993. In 1994, the initial quota was set at 200,000 lobsters and the fishery opened in July. The participating vessels experienced lower than expected catch rates, and the final quota was reduced to 20,000 lobsters after the data from the first month of fishing were added to the data base for use in the formula for deriving the final quota. By that time, the fishery already had taken over 100,000 lobsters, and NMFS immediately closed the fishery to minimize further take in excess of the quota. For 1995, the initial quota was derived as 38,500 lobsters. Due to concerns about being able to control the harvest and prevent exceeding the quota, NMFS established a zero quota for the commercial fishery and provided opportunity for one vessel to participate under an experimental fishing permit. That vessel has completed its trip, and the data are being analyzed.

Proposed New Lobster Fishery Management Program

The Council is completing and will soon submit for federal approval and implementation an amendment that will establish a new NWHI lobster harvest limitation program. It will maintain the limited entry system and will still be based on an annual assessment of the status of the stocks, with an annual determination of a harvest guideline. Under the new program, however, the harvest guideline would be derived using a constant harvest rate, whereas the current quota is derived using a constant escapement goal. The new program also includes an explicit level of "risk" of overfishing, that is, a level of probability that, in a given year, lobster stocks might be reduced below the level at which they are considered to be overfished for that year. That risk would be set at 10%. The new program also would make the fishery a retain-all fishery; the prohibitions on retaining small and egg-bearing female lobsters would be eliminated. This is because of concerns that the rate of mortality of lobsters that are captured and discarded is very high and the limits on retention result in waste. The retain-all policy effectively means that total fishing mortality would be reflected in the harvest guideline level. The fishery would be closed as closely as practicable to the date on which the harvest guideline is taken. The Regional Director would be authorized to close the fishery by notice to permit holders, with a notice to be published in the *Federal Register* as quickly as practicable. The amendment would include broad framework procedures to allow rapid regulatory response if new information demonstrates a need for action to protect lobster stocks or protected resources. Escape vents would allow all very small lobsters to escape. The fishery would be closed from 1 January through 30 June each year.

The new program will not change measures that were specifically instituted for lobster stock conservation and protection of Hawaiian monk seals. There would be no change in the size of trap openings (to prevent harm to Hawaiian monk seals) or the closure of waters around Laysan Island, less than 10 fm deep, and within atolls (to prevent interactions with monk seals and maintain some areas free of fishing). Permit holders would still be required to report any interactions with Hawaiian monk seals. The amendment includes framework procedures to facilitate rapid regulatory changes if new information demonstrates a need for action to protect monk seals, and the Regional Director has authority to close or limit the fishery in the event a death of a Hawaiian monk seal occurs that is due to the fishery or possibly due to the fishery. The Regional Director also would retain authority to place observers on lobster fishing vessels.

Status of Lobster Stocks

Lobster stocks are believed to be healthy and well above the level at which they would be defined as overfished. The most recent stock assessment (Haight and DiNardo, 1995) indicates that the exploitable population has increased every year since 1992. The spawning potential ratio (SPR, which is used to determine the status of stocks relative to the definition of overfishing) in early 1995 was 0.76 (contrasted with the 0.2 SPR that equates to overfishing) and has been increasing since 1992, although the increase is concentrated at Necker Island and has not been observed at Maro Reef.

It is noted that the productivity of lobster stocks appears to have substantially decreased from the level when the fishery began. Changes in environmental conditions are believed to have caused this decline. Whereas the stocks were thought to be capable of producing an annual harvest of about one million lobsters with an adult biomass of about 1.4 million lobsters, the current level of productivity is much lower. This is reflected in the projected harvest guideline levels derived in analyses conducted by the staff of the Honolulu Laboratory to assist the Council in making its decisions for the new system. Given the constant harvest rate associated with a retain-all policy and a risk level of 10%, the average harvest guideline would be about 280,000 lobsters per year rather than the earlier projection of about one million lobsters per year. The average SPR would be greater than 0.5, well above the 0.2 SPR at which the stock would be considered by definition to be overfished.

Lobster stock productivity appears to be linked to environmental changes rather than the fishery, and recent environmental changes have resulted in a lower level of stock productivity. Research indicates that lobster abundance at Laysan Island, which is closed to fishing, has decreased to the same degree as elsewhere in the NWHI. There has also been reduced productivity in other populations, e.g., reduced reproductive success of seabirds and Hawaiian monk seals.

Status of Hawaiian Monk Seals

The population of Hawaiian monk seals has been declining, assuming that beach counts (which show a 5% per year decline) are an accurate representation of the status of the population. The largest decline has been at French Frigate Shoals, the site of the largest population of monk seals. From 1989 to 1994, this population declined by at least 45%, and preliminary data for 1995 indicate the decline has not abated. At French Frigate Shoals, the primary problem has been a severe drop in juvenile survival, which has declined to as low as 30% of the last two cohorts from a survival rate of about 90% in the mid-1980s. The cause of the poor survival appears to be starvation. Shark predation, adult male aggression, disease, parasitism, poisoning (ciguatera) and human disturbance have all been ruled out as the primary cause of the high juvenile mortality. The starvation appears to be due to the lack of available prey.

The lack of prey may be due to one or a combination of the followinf reasons:
1. The seal population has reached carrying capacity and essentially reduced its own food supply;
2. Changes in environmental conditions may have reduced overall ecosystem productivity;
3. The availability of prey has been reduced by competition from humans.

It is known that monk seals feed on lobster, but the relative importance of lobster or other species (finfish, other crustaceans) in the diet is not known. While monk seals haul out mostly at areas that are not important fishing grounds, they are known to forage at the primary fishing areas (Necker Island, Maro Reef, Gardner Pinnacles). However, the relative importance of these areas for food is also not known.

Impacts of New Harvest Guideline Program

Impacts on Lobster Stocks - The models developed by the Honolulu Laboratory indicate that the stocks of spiny lobster will remain healthy over the long term under the new system, with an average SPR above 0.5, which is well above the 0.2 level at which the stocks would be considered overfished. The annual harvest guideline would vary in direct proportion to the estimated adult biomass, and would be higher when stocks were larger. The average harvest guideline would be about 280,000 lobsters per year, with all lobsters taken expected to be retained. The estimated average spawning biomass would be about 1.4 million lobsters, or roughly the target spawning biomass under the current program. The portion of the stocks in waters within 20 nm of Laysan and shallower than 10 fm around other islands would remain protected from fishing. This closes about 16% of total habitat and should further protect the stocks from overfishing as well as maintaining potential nursery areas for lobsters.

The retain-all approach is relatively untested in lobster fisheries. There are some unique attributes to this fishery that make the approach attractive. First, it is expected that there would be significant predation on discarded lobsters. The NWHI is far removed from population centers, and there is no commercial or recreational fishery that targets large fish that are predators on lobster, for example, sharks, jacks, monk seals and octopuses. A video produced by the Honolulu Laboratory documented that predation can occur, although the extent is not documented. Second, it is likely there is high mortality associated with the handling and discard of sublegal and egg-bearing lobsters. In some cases, lobsters may be exposed to sunlight and air for extended periods of time and suffer dehydration or blindness. Some lobsters may suffer the loss of one or more appendages. Such lobsters could have serious difficulty surviving even if they were not subject to predation by other animals. Unfortunately, there is no scientific evidence demonstrating the actual level of incidental mortality under the current regulations. However, the retain-all approach effectively incorporates what would have been incidental mortality into the overall harvest guideline and thus total fishing-induced mortality is used in the model used to project future harvest guidelines and SPR levels. This is important because sublegal and egg-bearing lobster may make up 50% or more of the total catch in some areas.

Impacts on the fishery - The amendment projects that net revenues are maximized with the retain-all strategy given the average harvest guidelines associated with the maximum risk level acceptable to the Council. The amendment also projects an overall catch-per-unit-effort (CPUE) rate of 1.2 lobsters per trap haul, so that total effort to take the average harvest guideline would be about 220,000 traps. In recent years, the average effort level per vessel was between 700 and 800 traps per night, so the average harvest guideline would be taken in about 300 days of fishing time. By comparison, the average number of trap hauls in the 1985-90 period was one million traps per year, which would have involved over 1,000 days of fishing. Thus, it is clear the level of effort will be substantially lower than effort levels in earlier years of the fishery.

It is projected that the fishery will experience positive net present value under the new program. It is noted that there is a market for small lobsters, but the price differential is not known and the impacts of the retain-all approach on costs and earnings cannot be determined with certainty at this time. Also, it is unlikely that all eligible permit holders will exercise their option to engage in the fishery in all years. At the average harvest guideline level, it is clear that all vessels could not be fully supported by the lobster fishery. It is likely that some will participate only in years in which the harvest guideline is greater than the average because of the cost associated with switching gear to be able to fish for lobster and the opportunity cost associated with not participating in other fisheries.

In deciding on the proposed retain-all approach, the Council considered the potential for "high grading" (retaining only the most valuable portions of the catch) by vessel operators. This is not expected to be a problem in most years when two or more vessels are expected to fish. Under such conditions, it would be in the interest of each vessel operator to maximize his or her share of the fixed harvest guideline by retaining all lobsters taken. The vessel operator will gain from not high grading by having to spend less time maximizing his or her share by sorting and discarding small or egg-bearing lobsters, although the benefits of keeping all the lobsters would be offset to some extent by the lower price generally paid for small lobster.

Impacts on Protected Species - The fishery as it would operate under the proposed new program is not expected to affect the status of Hawaiian monk seals or any other listed species or critical habitat. There are two potential types of effects: direct (i.e., interaction between monk seals and gear or fishermen) and indirect (fishing activity results in changes in behavior of monk seals or their health).

Direct Effects:

Except for one monk seal that became entangled in a trap bridle and drowned over a decade ago, there is no information to indicate that there have been direct interactions between the lobster fishery and monk seals. No reports of interaction have been submitted by permit holders. No reports have been received from NWHI field personnel of dead or live monk seals with scars or injuries that suggest interaction with lobster fishing gear. The best available information indicates there have been no direct interactions.

There has been little fishing in recent years. The fishery is projected to expand over recent levels under the proposed new management program, and this would increase the potential for direct interactions. However, the risk of interactions and associated harm to monk seals appears relatively low. The principal fishing areas have been Necker Island, Maro Reef, and Gardner Pinnacles. While monk seals have been observed at these areas, they are not the principal haul out areas (although Necker Island has a small population of monk seals) where populations are most abundant. Also, fishing is not permitted in waters shallower than 10 fm, which generally encompasses nearshore waters. It is reasonable to expect that the farther the fishery is removed from the shore, the less the likelihood of direct interaction or disturbance from fishing activities.

Indirect Effects:

It is not known with certainty whether the fishery will have indirect effects on monk seals. The productivity of the stocks of spiny and slipper lobster has declined since the early 1980s. A significant reduction in the catch per unit effort (CPUE) by research vessels was first observed at Maro Reef in 1990 and has persisted despite significant reductions in fishing at Maro Reef during 1991-92 and 1994, and a closure in 1993. A similar trend in research CPUE was observed at Laysan Island, where the fishery has been prohibited since the FMP went into effect. In contrast, recruitment of age-2 lobster to Necker Island remained fairly constant throughout the time series. Recruitment of spiny lobster at Maro Reef appears to correlate with the strength of the subtropical countercurrent, suggesting that mesoscale oceanographic features may impact the transport and survival of lobster larvae in their pelagic stage. The oceanographic processes that appear to affect recruitment occur in approximately decadal cycles.

The proposed new management program is intended to protect the long-term productivity of lobster stocks. Under the new harvest guideline formula, the projected average harvest guideline level would be significantly lower than the one million lobsters per year harvest level that the FMP originally estimated that the stocks could support. The average SPR (the measure of the health of the stocks) would be well above the level at which the stocks would be deemed overfished. To the extent the health of the lobster stocks is maintained, the availability of lobsters as forage for monk seals should be maintained. Lobster exoskeleton remains have been found in monk seal scats, but the relative importance of lobsters in the monk seal diet is unknown. If most fishing occurs in areas where the fishery has been most active in the past, then the populations of lobsters in waters in closest proximity to principal haul out areas will not likely be affected substantially by the fishery.

The relative importance of waters close to the principal haul out areas for Hawaiian monk seals and to waters most used by the fishery is not known. However, it appears that recruitment at Necker Island, one of the primary fishing areas, has remained relatively constant, while recruitment at Maro Reef has been reduced. This suggests that fishing has not been responsible for the decline of lobster populations. In fact, the Honolulu Laboratory, NMFS, has been unable to quantify a stock-recruitment relationship for spiny lobster.

While not known with certainty, there does not appear to be a substantial risk that the fishery will result in disturbance of seals or modification of their behavior. Fishing is prohibited in waters shallower than 10 fm and within 20 nm of Laysan Island. The fishery has not been active in waters in proximity to the primary haul out areas. There is no information to indicate that seals change their behavior due to the proximity of lobster fishing vessels.

It is noted again that the FMP, as amended, will contain broad frameworking procedures to facilitate rapid rulemaking if necessary to deal with problems identified after the amendment is in effect. This would include additional measures to protect monk seals. The Regional Director also has authority to close the fishery upon a report of fishery-related mortality of a monk seal and to require a vessel to carry an observer if necessary, including to determine or confirm whether interactions are occurring.

Impacts on Other Protected Species

There are no reports of interactions that would lead to an expectation that any other endangered or threatened species would be affected in any manner by the fishery as it would operate under the amendment.

Appendix 7

Draft Proposed Regulations

For the reasons set out in the preamble, 50 CFR 681 is proposed to be amended as follows:

PART 681--WESTERN PACIFIC CRUSTACEAN FISHERIES

1. The authority citation for part 681 continues to read as follows:

Authority: 16 USC 1801 et seq.

2. In § 681.2, the definitions of "Carapace length", "Final Quota", "Initial Quota", "Processing", "Processor", "Receiving vessel","Tail width of slipper lobster", "Tail width of spiny lobster", and "U.S.-harvested lobster" are removed, a new definition "Harvest guideline" is added, and the definition for "Slipper lobster" is revised to read as follows: Pro. Regs.

§ 681.2 Definitions.

* * * * *

Harvest guideline means a specified numerical harvest objective (that is not a quota). The fishery will cease as close as practicable to the attainment of the announced harvest guideline for a given season.

* * * * *

Risk means the probability that the fishing mortality for a specified harvest guideline for the spiny and slipper lobster stocks in Permit Area 1, in a given year, could exceed the fishing mortality that is associated with a spawning potential ratio of 0.2.

* * * * *

Slipper lobster means any crustacean of the family Scyllaridae.

* * * * *

3. In § 681.4 paragraphs (b)(2)(i)-(xx) are removed, and paragraphs (b)(2), (d), and (f) are revised to read as follows:

§ 681.4 Permits.

* * * * *

(b) Applications.

(1) * * *

(2) Each application must be submitted on a Southwest Region Federal Fisheries application form obtained from the Pacific Area Office containing all the necessary information, attachments, certification, signature, and fees.

* * *

(d) Change in application information. Any change in information on the permit application form submitted under paragraph (b)(2) of this section must be reported to the Pacific Area Office at least 10 days before the effective date of the change. Failure to report such changes may result in invalidation of the permit.

(e) * * *

(f) Expiration. Permits issued under this section will remain valid indefinitely unless transferred, revoked, suspended, or modified under 15 CFR part 904.

* * * * *

4. In § 681.5, paragraphs (b) and (d) are removed, paragraphs (c) and (e) are redesignated (b) and (d) respectively, and paragraphs (a) and (c) are revised to read as follows:

§ 681.5 Recordkeeping and reporting.

(a) Daily Lobster Catch Report. The operator of any vessel engaged in commercial fishing for lobster subject to this part must maintain onboard the fishing vessel, while fishing for lobster, an accurate and complete NMFS Daily Lobster Catch Report on a form provided by the Regional Director. All information specified on the form, which has been approved and validated under the Paperwork Reduction Act, must be recorded on the form within 24 hours after the completion of the fishing day. The Daily Lobster Catch Reports for a fishing trip must be submitted to the Regional Director within 72 hours of each landing of lobsters.

(b) Lobster Sales Report. The operator of any vessel engaged in commercial fishing for lobster subject to this part must submit to the Regional Director, within 72 hours of off-loading of lobster, an accurate and complete Lobster Sales Report on a form provided by the Regional Director and attach packing or weigh out slips provided to the operator by the first-level buyer(s), unless the packing/weigh out slips have not been provided in time by the buyer(s). The form, which has been approved and validated under the Paperwork Reduction Act, must be signed and dated by the vessel operator.

* * * * *

5. In § 681.7, paragraphs (a)(5), (b)(2), (b)(3), and (b)(4) are removed, paragraphs (b)(5) - (b)(14) are redesignated (b)(2) - (b)(11) respectively, and paragraphs (b)(1)(i) - (v), (b)(5) - (7), (b)(9) - (12), (b)(14), and (c)(1)(ii) are revised to read as follows:

§ 681.7 Prohibitions.

* * * * *

(b)* * *

(b)(1) * * *

(i) Without a limited access permit issued under Section 681.28;

(ii) By methods other than lobster traps or by hand for lobsters, as specified in Section 681.22;

(iii) From closed areas for lobsters, as specified in Section 681.21;

(iv) During a closed season, as specified in Section 681.27; or

(v) After the date announced by the Regional Director, as specified in Section 631.29(b)(3), and until the fishery opens again in the following calendar year.

(2) Fail to report before landing or off-loading, as specified in Section 681.23.

(3) Fail to comply with any protective measures promulgated under Section 681.24 or Section 681.25.

(4) When fishing for lobster is prohibited as specified in Sections 681.21, 681.22, 681.27, 681.28, or 681.29, possess on a fishing vessel any lobster trap.

(5) Fail to report catch and effort data, as specified Section 681.5.

(6) Leave a trap unattended in the Management Area except as provided in Section 681.22(f).

(7) Maintain on board the vessel or in the water, more than 1200 traps per fishing vessel, of which no more than 1100 can be assembled, as specified Section 681.22(e).

(8) Fail to mark legibly the vessel's official number on all traps and floats maintained on board the vessel or in the water, as specified in Section 681.22(g).

(9) Land lobsters taken in Permit Area 1 after the closure date announced by the Regional Director, as specified in Section 681.29 (b)(3), and until the fishery opens again in the following year.

(10) Fail to make a limited access permit available for inspection by an authorized officer upon request by that officer.

(11) Refuse to make available to an authorized officer and employee of NMFS designated by the Regional Director for inspection and copying any records that must be made available in accordance with section 681.11(a).

* * *

(c)(1) * * *

(c)(1)(i) * * *

(c)(1)(ii) In the months of May, June, July, and August, as specified in Section 681.43.

* * * * *

6. In § 681.10, paragraphs (a) and(b) are removed and the section is revised to read as follows:

§ 681.10 Observers.

All fishing vessels subject to this part must carry a scientific observer when requested to do so by the Regional Director.

7. In § 681.11, paragraph (a) is revised to read as follows:

§ 681.11 Availability of records for inspection.

(a) Upon request, any first-level buyer must immediately allow an authorized officer and any employee of NMFS designated by the Regional Director to access, inspect, and copy all records relating to the harvest, sale, or transfer of management unit species taken by vessels that have permits issued under this part or that are otherwise subject to this part, including, but not limited to information concerning:

(1) * * *

* * * * *

8. A new § 681.12 is added to Subpart A to read as follows:

§ 681.12 Framework procedures.

(a) Introduction. New management measures may be added, through rulemaking, if new information demonstrates that there are biological, social, or economic concerns in Permit Areas 1,2 and 3. The following framework process allows for measures that may affect operation of the fisheries, gear restrictions, harvest guidelines, or reductions or increases in catch and/or effort, if the information supports such a change.

(b) Annual report. (1) By June 30 of each year, the Council-appointed Crustaceans Plan Team will prepare an annual report on the fisheries in the management area, containing the following:

(i) Fishery performance data (e.g., landings, effort, value of landings, species composition);
(ii) Summary of recent research and survey results;
(iii) Habitat conditions and recent alterations;
(iv) Enforcement activities and problems;

(v) Administrative action (e.g., data collection and reporting, permits);

(vi) State and territorial management actions; and

(vii) Assessment of need for Council action (including biological, economic, social, enforcement, administrative, and state/federal needs, problems, and trends). Indications of potential problems warranting further investigation may be signaled by indicator criteria. These criteria could include, but are not limited to, important changes in: Mean size of the catch of any species; estimated ratio of fishing mortality to natural mortality for any species; decline in catch per unit effort by any sector; ex-vessel revenue of any sector; relative proportions of gear in and around the EEZ; turnover of limited entry permits in the fishery; species composition of the landings; research results; habitat or environmental conditions; or level of interactions between crustacean fishing operations and protected species in the EEZ or surrounding waters;

(viii) Recommendations for Council action; and

(ix) Estimated impacts of the recommended action.

(2) Recommendations for management action. The annual report shall specify any recommendations made by the Crustaceans Plan Team to the Council. Recommendations may cover actions suggested for federal regulations, state/territorial action, enforcement or administrative elements, and research and data collection. Recommendations will include an assessment of urgency and the effects of not taking action and will indicate whether changes involve existing measures, which may be changed under paragraph (c) of this section, or new measures, which may be implemented under paragraph (d) of this section.

(c) Procedure for changing established measures. (1) Established measures are those that are or have been in place via rulemaking procedures for the fisheries, including: the current harvest guideline model; logbooks and other reporting requirements; area closures; trap and other gear requirements; fishing season; and lobster size limits used in the model. The estimated and potential impacts of these measures have been evaluated in past FMP amendments and associated documents.

(2) The Council will identify problems that may warrant action through the annual report described in paragraph (b)(1) of this section, or a separate report from the Crustaceans Plan Team, the Advisory Subpanel, Scientific and Statistical Committee, lobster industry sector, enforcement officials, NMFS,

or other sources. Identified problems will be addressed as follows:

(i) At a Council meeting following completion or receipt of a report identifying a problem, the Council will discuss whether changes to established conservation and management measures would resolve the problem. Notice to the public and news media preceding the meeting will indicate that the Council intends to discuss and possibly recommend regulatory adjustments through the framework process for established measures to address the issue or problem. The notice must summarize the issue(s) and the basis for recommending the measures being reviewed and would refer interested parties to the document(s) pertaining to the issue.

(ii) Based on discussions at the meeting, which include participation by the Crustaceans Plan Team, Advisory Subpanel, Scientific and Statistical Committee, or other Council organizations, the Council will decide whether to recommend action by the Regional Director.

(iii) The Regional Director will be asked to indicate any special concerns or objections to the possible actions being considered under the framework process and, if there are any concerns or objections, will be asked for ways to resolve them.

(3) If the Council decides to proceed, a document will be prepared describing the problem and the proposed regulatory adjustment to resolve it. The document will demonstrate how the adjustment is consistent with the purposes of the established measure and that the impacts had been addressed in the document supporting the original imposition of the measure. The document will be submitted to the Regional Director with a recommendation for action. The Council may indicate its intent that the recommendations are to be approved or disapproved as a single action.

(4) If the Regional Director approves part or all of the Council's recommendation, the Secretary, in accordance with the Administrative Procedure Act, may implement the approved change in an established measure by publishing a final rule, waiving advance notice and comment. This does not preclude the Secretary from deciding to provide additional opportunity for advance notice and comment, but contemplates that the Council process will satisfy the requirements of the Magnuson Act and Administrative Procedure Act regarding prior notice and comment. Established measures are measures that have been evaluated and applied in the past, and adjustments under this framework must be

consistent with the original intent of the measure and within the scope of analysis in previous documents supporting the existing measure.

(d) Procedure for implementing new measures. (1) New measures are those that have not been used before in managing the fishery. New measures may have been previously considered but rejected in a past FMP amendment or document, but the specific impacts on the stocks and on permit holders have not been evaluated in the context of current conditions. Potential new measures include, but are not limited to: Species- or area-specific harvest guidelines; individual transferable quotas; fractional licensing; bycatch limits; or additional measures to protect Hawaiian monk seals and other protected species.

(2) A Crustaceans Plan Team report (annual report or in-season report), input from advisors, or input from NMFS or other agencies will first bring attention to a problem or issue that needs to be addressed at the next Council meeting. In its notice announcing the meeting, the Council will summarize the concern or issue raised, the party that has raised the problem, and the extent to which it is a new problem or a problem that may require new management measures. The Council will seek to identify all interested persons and organizations and solicit their involvement in discussion and resolution of this problem through the Council process, and the Council meeting notice in the Federal Register will emphasize that this problem will be discussed and that proposed actions may result.

(3) The document presenting the problem to the attention of the Council will be distributed to all advisory bodies of the Council who have not yet received it, with a request for comments. The document also will be distributed to the Council's mailing list associated with the FMP to solicit comments and to indicate the Council will take up action at the following meeting. The Council's chairperson may request the Council's Crustaceans Standing Committee to discuss the issue and review the comments (if any) of the Crustaceans Plan Team, Advisory Panel, or Scientific and Statistical Committee, and develop recommendations for Council action.

(4) At the meeting, the Council will consider the recommendations of its Crustaceans Standing Committee, if any, and other Council organizations and will take comments from the public concerning the possible course of action. If the Council

agrees to proceed with further action under the framework process, the issue will be placed on the agenda for the following meeting. A document describing the issue, alternative ways to resolve the issue, the preferred action, and the anticipated impacts of the preferred action, will be prepared and distributed to the public with a request for comments. A notice will be published in the Federal Register summarizing the Council's deliberations and preferred action and indicating the time and place for the Council meeting to take final action.

(5) In its notice for the following meeting, the Council will indicate that it may take final action on the possible adjustment to regulations under this section. At the meeting, the Council will consider the comments received as a result of its solicitation of comments and take public comments during the meeting on the issue or problem. The Council will consider any new information presented or collected and analyzed during the comment period. The Regional Director will be provided a specific opportunity to indicate any objections or concerns about any or all components of the measures being considered. The Council will then decide whether to recommend the establishment of new measure or measures under this section.

(6) If the Council decides to proceed, it will submit its proposal to the Regional Director for consideration, with supporting rationale and an analysis of the estimated biological, economic, and social impacts of the proposed actions. The Council may indicate its intent that all components of its recommendations be approved or disapproved as a single action.

(7) If the Regional Director concurs in whole or in part, the Secretary, in accordance with the Administrative Procedure Act, may implement the approved new measure by publishing a final rule, waiving advance notice and comment. Nothing in this procedure is intended to preclude the Secretary from deciding to provide additional opportunity for advance notice and comment in the Federal Register, but contemplates, that the Council process (which includes two Council meetings with opportunity for public comment at each) will satisfy that requirement.

(8) If a new action is approved and implemented, future adjustments may be made under the procedure for established measures.

(e) Nothing in this section limits the authority of the Secretary to take emergency action under section 305(c) of the Magnuson Act.

9. In Subpart B, §§ 681.21 and 681.22 are removed and §§ 681.23 - 681.30 are redesignated as 681.21 - 681.28, respectively.

10. In § 681.27, in paragraphs (b) and (g)(1), the words "He" and "he" are removed and the words "The Regional Director" and "the Regional Director" are added in their place respectively .

11. In § 681.28, in paragraphs (a), (b)(1), and (b)(3), the words "he" and "He" are removed and the words "the Regional Director" and "The Regional Director" are added in their place respectively.

12. In § 681.30, paragraph (c) is removed, paragraphs (d),(e), (f) are redesignated as paragraphs (c), (d) and (e), and paragraph (e) is revised to read as follows:

§ 681.30 Limited access management program.

* * * * *

(d) Replacement of a vessel covered by a limited access permit. A limited access permit issued under this section may, without limitation as to frequency, be transferred by the permit holder to a replacement vessel owned by that person.

* * * * *

13. In § 681.31, the section is redesignated as § 681.29, the section heading is revised, paragraph (c) is removed, paragraph (d) is redesignated as (c), and paragraphs (a), (b), and (d) are revised as follows:

§ 681.29 Harvest limitation program.

(a) General. A harvest guideline for Permit Area 1 will be set annually on a calendar year basis and shall: (1) apply to the total catch of spiny and slipper lobsters; and (2) be expressed in terms of numbers of lobsters.

(b) Harvest guideline. (1) The Regional Director shall use information in the daily lobster catch report and lobster sales report from previous years, and may use information from research sampling and other sources, to establish the annual harvest guideline in accordance with the FMP.

(2) NMFS shall publish a notice indicating the annual harvest guideline in the Federal Register by March 31 each year, and shall use other means to notify permit holders of the harvest guideline for the year.

(3) The Regional Director shall determine, on the basis of the information reported to NMFS during the open season by the operator of each vessel fishing, as required under paragraph (c) of this section and § 681.31 of this part, when the harvest guideline will be reached or exceeded. Notice of this determination, with a specification of the date after which fishing for lobster or further landings of lobster taken in Permit Area 1 is prohibited, will be announced to each permit holder and operator of each permitted vessel not less than 7 days prior to the effective date.

* * * * *

14. In Subpart B, § 681.32 is redesignated as § 681.30, the section is revised to read as follows:

§ 681.30 Five-year review.

After five years from the effective date of the rule implementing FMP Amendment 9, the Council, in cooperation with the NMFS, will conduct a review of the effectiveness and impacts of the NWHI management program, including biological, economic and social aspects of the fishery.

15. In Subpart C, § 681.43 is revised to read as follows:

§ 681.43 Closed season.

Spiny lobster fishing is not allowed in Permit Area 2 during the months of May, June, July and August.

Appendix 8

Regulatory Impact Review

A. DESCRIPTION OF FISHERY & IDENTIFICATION OF PROBLEM

The NWHI lobster fishery is managed by the Council and NMFS under the Crustaceans Fishery Management Plan (FMP), adopted in 1983. A summary of the FMP management objectives, governance, regulatory regimes along with the impacts of the proposed amendment are provided below.

After discovery in the mid 1970s, the lobster fishery grew rapidly with landings reaching a peak of 2.37 million pounds (combined spiny and slipper lobsters whole weight) in 1985. Ex-vessel revenue peaked at $6.2 million (not adjusted for inflation) in 1989 (Dollar, 1995). Commensurate with the growth in landings was an influx of participants in the fishery, to a peak of 16 vessels operating in 1985 and 1986. By 1986, however, economic analysis of the fleet suggested that above-normal profit opportunities were diminished, and open-access conditions appeared to prevail, thus dissipating (in aggregate) any resource rents to the primary producers (Clarke and Pooley, 1988). During this period, vessels typically fished year round (weather permitting) and focused on the production of frozen tails for US mainland and foreign markets. Most participating fishermen directed all of their efforts and resources toward lobster fishing. This era was typified by rather dynamic vessel participation (Clarke, et al., 1987), but the fleet numbers never exceeded 16 vessels an any year.

After the initial period of growth in 1982-86, the fishery declined, both in terms of ex-vessel revenue and landings. Subsequent analyses suggested that, from a purely economic perspective, the fishery was self-regulating, given the substantial costs associated with the initiation of lobster fishing in the NWHI and distortions in several factor markets, e.g., labor (Clarke, et al., 1994). Economic analyses also indicated that, aside from biological considerations, the lack of effort (input) constraints would lead to open-access equilibrium conditions, and sub-optimal economic performance would persist in the fishery.

In 1990, a substantial decrease in landings and catch-per-unit-effort (CPUE) was observed which continued through 1991. An analysis by the NMFS Honolulu Laboratory (Polovina, 1991) reported evidence to suggest recent recruitment to the fishery had been dramatically reduced and that fishery spawning stock biomass was estimated at 22% of pre-exploitation levels. A threshold overfishing level of 20% was previously established in Amendment 6 to the FMP. Based on this analysis the Council sought and obtained an emergency closure of the fishery from 8 May through 11 November 1991. In response to the substantial decline in CPUE, the FMP was amended in 1992 (Amendment 7) to include an annual 6-month closed season from January through June. The basic objectives of the regulatory regime as outlined in Amendment 7 were to protect the NWHI lobster stock from overfishing, ensure the maintenance of optimal spawning biomass, and allow the fishery to harvest surplus production in an economically viable manner. In addition, a limited entry program was introduced (with 15 vessels eligible for participation) and a system of annual catch quotas established. It should be noted the 15 vessels were capable of exerting effort levels well in excess of the most liberal predictions of sustainable yield from the fishery.

The catch quota procedure was based on a dynamic population model. It established quotas designed to result in a CPUE level which would provide what was deemed an economically viable CPUE (1.0 lobster /trap-haul) while protecting spawning stock biomass from over-harvest (Polovina, 1991). The quotas were based on an optimal biomass escapement approach, which allowed surplus production to be harvested if the population was above a threshold level.

During 1992, the first year of the application of a fleet wide quota, the procedure appeared to work reasonably well. A total of 12 vessels participated, landing 425,000 lobsters during an average of 74 fishing days per vessel. While the final in-season quota was considerably smaller than originally predicted, it appeared to have been sufficient to offset fleet costs associated with start-up and participation.

For 1993, the biological population model predicted that lobster abundance was insufficient to allow any harvest, and a complete closure was imposed on the NWHI lobster fishery. Commercial fishermen, lobster processors, wholesalers, and marketers were affected by the complete closure. Operators who were forced into other fisheries in 1992 to cover fixed costs on vessels, gear and associated equipment had to continue with other alternatives. Several operators left the state for other opportunities, but maintained their permits, while those remaining either entered or continued participation in the pelagic longline fishery, the NWHI bottomfish fishery, or the deep water shrimp fishery.

Markets established in the 1980s for NWHI lobster had, up to this period, been impacted by low landing volumes and the 1992 closure, but still maintained high levels of demand. However, with the complete cessation of any supply of product in 1993, a number of wholesalers and retail outlets (stores, restaurants, etc.) discontinued NWHI lobster marketing. In light of a reduced supply and the apparent future uncertainty of any product at all, active demand for NWHI lobster nearly disappeared.

In 1994, an initial quota was set at 200,000 lobsters, but the five participating vessels experienced slightly lower than expected catch rates in July. Because the quota-setting procedures were so sensitive to small changes in CPUE, the final quota was reduced to 20,000 lobsters. By the time of final quota determination, fishermen had already caught over 100,000 spiny and slipper lobsters. The fishery was closed by emergency measure on 24 August 1995. A total of 131,000 lobster were landed, 111,000 over the recommended final quota, but well under the initial quota (Dollar, 1995).

These events caused further alarm with permit holders (both participating and non-participating) and shoreside interests. Many fishermen felt the more conservative numerical quota (20,000 lobsters) should have been published to allow permit holders (potential participants) a better basis on which to make decisions. The drastic reduction in quota allowed few, if any, fishermen to offset what were considerable start up costs related to participation in the now-seasonal fishery. The total time allocated to lobster fishing was estimated to be between 90 and 120 days, considering the total time allocated to start up, preparation, traveling, fishing, off-loading and eventual conversion back to other fisheries. On average, the five vessels expended 40 fishing days each, compared to an average of 109 in 1990 (Dollar, 1995).

On the marketing side, vessel operators expected ex-vessel prices at $18-19/lb for premium sizes (4-8 oz) of spiny lobster given the strong price of traditional competitors (western Australian and Brazilian spiny lobster) and relative price differentials. However, given the abandonment of established marketing channels, ex-vessel prices averaged only $16.34/lb for spiny lobster tails. To obtain this price several operators had to consign product to brokers and in turn incurred additional costs of cold storage fees, insurance and delayed payments. While the situation for slipper lobster was less severe and ex-vessel prices remained fairly robust at $10.90, the relatively low volume (50,000 lb) was considered too small to warrant aggressive marketing efforts, especially in light of the substitutability of Brazilian scyallarid lobsters.

For 1995, the initial quota was calculated as 38,500 lobsters. Concerns about being able to control the harvest and prevent exceeding this minimal quota led the NMFS to establish a zero quota for the commercial fishery, but provided the opportunity for an experimental fishery (one vessel was selected) in an attempt to gain valuable biological data. If the entire experimental quota is reached, the total volume of lobster landed will be in the vicinity of 11-13,000 lb of processed frozen lobster tails. This small volume of lobster is not expected to stimulate much interest among local buyers, and will be sold at discounted prices (relative to traditional competitors and previous real lobster prices).

The quota system established in Amendment 7 is not achieving desired objectives. The management program for the NWHI lobster fishery is in need of modification to ensure the optimal utilization of the NWHI lobster resource.

B. MANAGEMENT OBJECTIVES

The FMP for the Crustacean Fisheries of the Western Pacific Region was developed by the Council in 1982, and the final rule implementing its regulations was published by the NMFS at 48 FR 5560 on 7 February 1983. The objectives set by the Council in the original FMP are:

- To assure the long term productivity of the stock and prevent overfishing;
- To promote the efficient contribution of the NWHI lobster resource to the United States economy;
- To collect and analyze biological and economic information about the spiny lobster fishery and improve the basis for conservation and management in the future;
- To prevent unfavorable impacts of the fishery on the Hawaiian monk seal and other endangered and threatened species.

The FMP has been amended eight times in response to changing conditions in the fishery. The FMP regulates fishing for crustaceans (mostly spiny and slipper lobsters) in waters of the NWHI (50 CFR 681 Subpart B). The FMP also regulates fishing in the EEZ of the main Hawaiian Islands (50 CFR 681 Subpart C), even though most lobster fishing in the main Hawaiian Islands occurs in state, not federal, waters. There are no federal regulations for EEZ waters around American Samoa and Guam because no substantial crustacean fisheries currently exist there. Regulations for these latter two areas may be developed at the first indications of any significant fishery.

The regulations for each stock are based on the principles of optimum yield, i.e., management based on maximum sustainable yield as modified by relevant ecological, social and economic considerations. In order to meet these objectives the current NWHI lobster fishery regulations include the following measures:

- To prevent overfishing (protect reproductive potential), minimum size limits, measured as tail width, are: spiny lobsters (*Panulirus marginatus*)--5.0 cm, and slipper lobsters (*Scyllarides sp.*)--5.6 cm. Lobsters below these sizes are referred to as sublegal lobsters.

- Recruitment overfishing is defined to be a level at which the spawning potential ratio, i.e., the spawning stock biomass produced on average by a post-larval recruit in adult biomass will not fall below about 1.4 million lobsters at the end of the year.

- To protect lobster spawning biomass, the NWHI lobster fishery is closed during the months of January through June, and egg-bearing lobsters (berried) cannot be retained at any time.

- To further support sustainable yields, the FMP established a quota system in 1992 under which NMFS determined annually a harvest quota (total allowable catch) that may be taken by the fleet. Once the quota is taken in a given year, the fishery is closed for the year.

- Commercial fishing gear is restricted to traps. To protect Hawaiian monk seals, the trap entrance must not exceed 6.5 inches in diameter. To facilitate the escape of sublegal lobsters, every trap must have two escape panels, each with four circular, 67-mm diameter holes.

- To minimize overcapitalization in the fishery, entry to the NWHI fishery is limited to 15 vessels, and no vessel may carry more than 1200 traps (1100 assembled).

- To protect lobster stocks and marine mammals in the NWHI, no commercial fishing is allowed (1) in waters shallower than 10 fm, (2) within lagoon waters, or (3) within 20 nm of Laysan Island. These refuges amount to about 16% of the total NWHI lobster habitat.

- To provide relevant and timely fishery information for management purposes, fishermen are required to have a federal lobster fishing permit and to supply catch and sales reports after each trip.

- To facilitate monitoring of catches and catch rates, determination of the final quota, and determination of the date the quota is reached so the fishery can be closed, the Regional Director establishes reporting requirements for permit holders.

C. IDENTIFICATION OF ALTERNATIVES

The Council considered three management strategies for estimating the acceptable biological take in the fishery, or "harvest guidelines". All strategies eliminate the in-season adjustment in the quota setting procedure, thereby reducing a major source of economic and administrative uncertainty and cost for fishermen and managers.

Strategy 1 (No Action) Constant Escapement -- the procedure used the existing policy under Amendment 7.

Strategy 2 Constant Catch -- a set number of lobsters allowed to be taken each year.

Strategy 3 Constant Harvest Rate -- the number of lobster allowed to be taken is proportional to stock abundance.

All three strategies were evaluated by the NMFS Honolulu Laboratory taking into account varying levels of risk (between 0 and 10%) regarding the current stock assessment procedure (DiNardo, In. Prep.). The modeling exercise and the input parameters focused on spiny lobster life history characteristics but utilized a combined spiny-slipper lobster approach. Allowable catch levels (or removal proportions) were varied to assess the effects of each harvest strategy. The biological model tested the probability (risk) of reducing the lobster spawning stock below the 0.2 SPR recruitment overfishing threshold level for any strategy using a number of fishing (retention) scenarios. Risk levels ranging from 0-10%, by 1% increments, were evaluated relative to the probability of exceeding the SPR overfishing threshold level. For each strategy, the three fishing scenarios were evaluated:

Scenario 1 Retain all non-berried lobsters caught, including those smaller than current minimum size.

Scenario 2 Retain only those non-berried lobsters larger than the current minimum legal size.

Scenario 3 Retain all lobsters caught, including berried females and those smaller than current minimum size.

All scenarios maintain other elements of the current regulations, including the use of 67-mm escape vents, with specific retention sizes detailed in Table 1.

Table 1. Lobster disposition according to fishing scenario.

	Minimum size	Legals	Sublegals	Berried Females
Scenario 1	> 36 mm*	Retain	Retain	Discard
Scenario 2	> 50 mm	Retain	Discard	Discard
Scenario 3	> 36 mm*	Retain	Retain	Retain

** estimated minimum size retained by fishing gear*

In addition, a measure of mortality upon post harvest discard was included at discrete levels of 0, 25, 50, 75 and 100 %. Finally, two measures of size at maturity were tested: a 46 mm tail width, the size biologists believe 50% of the spiny lobster populations matures, and a more conservative 50.6 mm tail width.

All combinations (3 strategies, 3 scenarios, 11 risk levels, 5 survival rates and 2 maturity estimates) were run over a 30-year time horizon, but averages of output information were provided for years 11-30. The initial years were disregarded in the calculation of the biological results based on the reasoning that the model needed time to equilibrate. However, the model was based on the current estimate of population size and structure.

Outputs from the biological simulation model included mean catch of lobsters taken by the fishery (years 11-30), variability in mean catch, mean fishing effort (number of traps), variability in mean fishing effort, mean number of sub-legal lobsters caught, and probability of SPR overfishing. In addition, population size, fishing effort, catch (legal and sub-legal lobsters) and recruitment to the population were computed.

D. ANALYSIS OF ALTERNATIVES

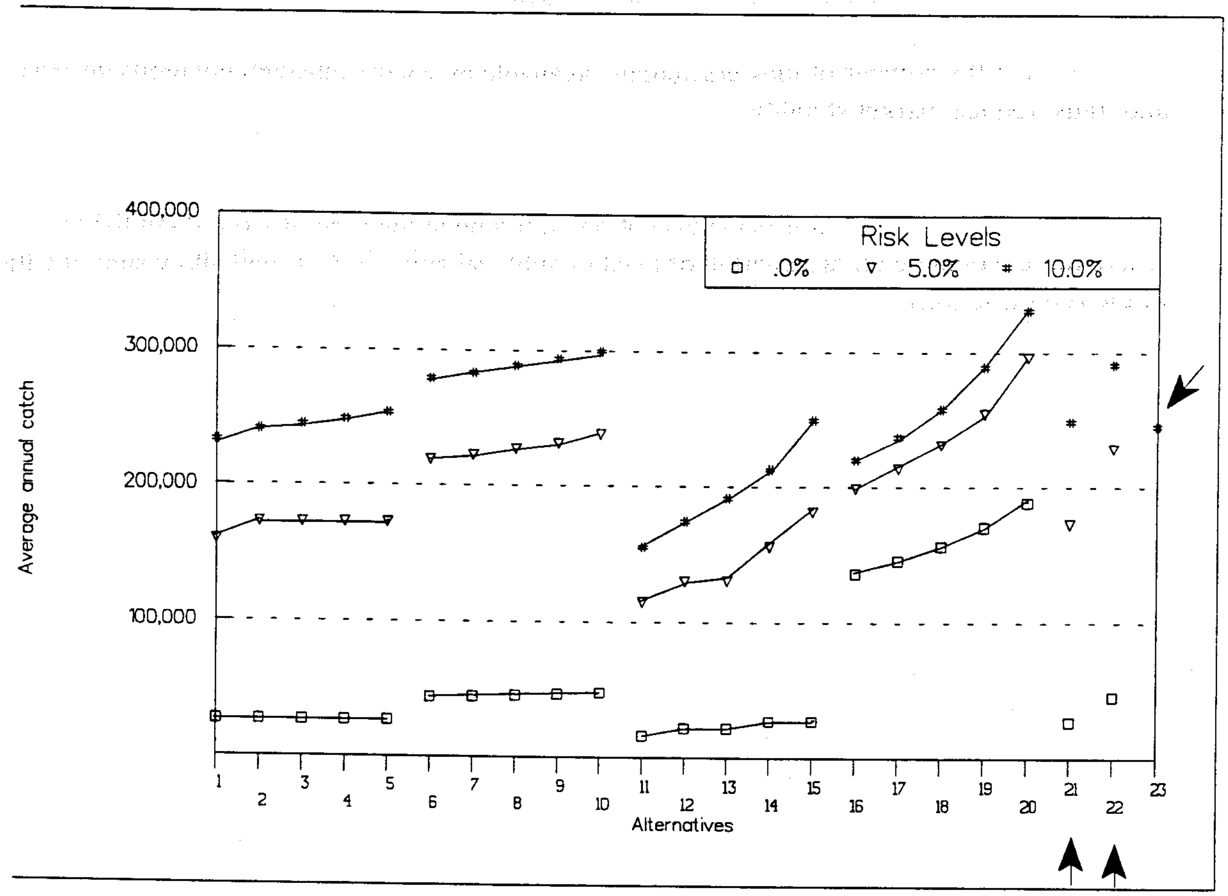
The results of the biological modeling experiment (see DiNardo, In prep.) revealed the poor performance of the current management regime (Strategy 1 - Constant Escapement). Strategy 1 was found to be extremely sensitive to small changes in realized CPUE and to errors in the estimate of population size, and was rated as overly sensitive to "worst case scenarios". Therefore it was not evaluated in as great a detail as Strategies 2 & 3. Additionally, the Council agreed to use the more conservative age of first maturity (50.6 mm) in evaluation of the proposed alternatives. (The 46 mm was evaluated and found to affect the economic results for each alternative only marginally.)

The first 22 alternatives detailed in Table 2 represent all three retention scenarios, under the five levels of survival for Strategies 2 and 3. The average annual numbers of lobsters predicted to be caught under each alternative are depicted in Fig. 1. This presentation depicts average catch for each assessment strategy. The Constant Escapement, or No Action, alternative (No. 23) represents an 8% risk level assuming a 50% post harvest survival rate. The biological model provides no estimates of exploitable surplus using a size at maturity estimate of 50.6 mm, therefore 46 mm was used, which interestingly also yields no exploitable surplus under 8% risk (see DiNardo, In prep.).

Table 2. Alternatives tested using Constant Catch and Constant Harvest Rate Strategies (2&3) under three scenarios, at various survival rates and 50.6 mm age of first maturity. (A retain-all scenario is implicitly a 0% survival rate.). The No Action alternative (No. 23) represents Constant Escapement (Strategy 1), retaining only legal lobsters at a 50% survival rate.

Alternative	Strategy		Scenario		% Survival
1	Constant Catch	2	No Berried	1	0
2	Constant Catch	2	No Berried	1	25
3	Constant Catch	2	No Berried	1	50
4	Constant Catch	2	No Berried	1	75
5	Constant Catch	2	No Berried	1	100
6	Constant Harvest Rate	3	No Berried	1	0
7	Constant Harvest Rate	3	No Berried	1	25
8	Constant Harvest Rate	3	No Berried	1	50
9	Constant Harvest Rate	3	No Berried	1	75
10	Constant Harvest Rate	3	No Berried	1	100
11	Constant Catch	2	Legal Only	2	0
12	Constant Catch	2	Legal Only	2	25
13	Constant Catch	2	Legal Only	2	50
14	Constant Catch	2	Legal Only	2	75
15	Constant Catch	2	Legal Only	2	100
16	Constant Harvest Rate	3	Legal Only	2	0
17	Constant Harvest Rate	3	Legal Only	2	25
18	Constant Harvest Rate	3	Legal Only	2	50
19	Constant Harvest Rate	3	Legal Only	2	75
20	Constant Harvest Rate	3	Legal Only	2	100
21	Constant Catch	2	Retain-All	3	0
22	Constant Harvest Rate	3	Retain-All	3	0
23	Constant Escapement	1	Legal Only	2	50

Figure 1. Lobster catch (numbers) from the NWHI fishery for each alternative considered under Amendment 9 (see Table 2 for definitions of alternatives). Data ordered by strategy and scenario, for five post-harvest survival rates, except for last three which represent the Retain-All (lower arrows) and No Action alternatives (upper arrow).



The Constant Catch strategy involves an approximately constant number of lobster be landed each year, under the various retention scenarios. This attempts to ensure fishermen of some level of lobster fishing (season) each year thereby precluding problems associated with frequent closed seasons and unpredictable annual variation in harvest levels. The same is basically true for the Constant Harvest Rate, except fishermen are allowed to harvest more lobster in years which stocks are particularly strong. Various survival rates are provided because of the unknown nature of post harvest mortalities of non-retained lobster.

The influence of various levels of risk for the preferred alternative (No. 22) is depicted in Fig. 2, while the relationship between catch and effort over a 30-yr time horizon for a 5% risk level is presented in Fig. 3 (note that the values of effort and catch will be higher under the proposed risk level 10%).

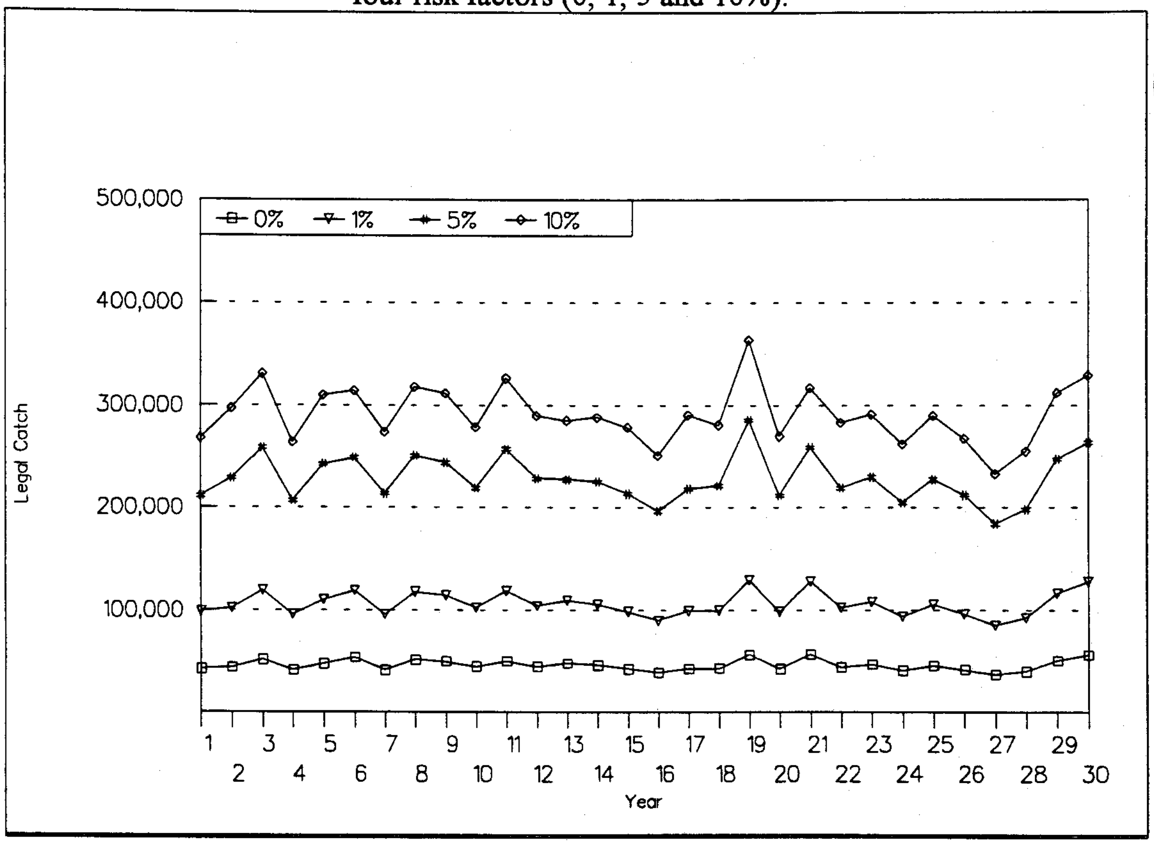
Each strategy is expected to have the same administrative burden with respect to research and management. However, the Retain-all scenario may be expected to lighten the regulatory burden on both the producers and NMFS enforcement agents. The no-berried retention scenario (1) is also expected to reduce this burden, but to a lesser degree than the retain-all scenario.

The Constant Catch and Constant Harvest Rate strategies are expected to considerably reduce the number of seasons the fishery is completely closed, allowing lobster processors and marketers a better opportunity to establish markets. Data from the biological model indicate, however, that the number of lobsters actually available may vary substantially between seasons and, thus, reduce market stability.

The impact of all alternatives on the reporting burden imposed on fishermen and processors is expected to be the same. A possible exception would be in the case of a retain-all fishery where there would be no designation of legal or sublegal animals; this will allow simplification of the reporting forms.

wouldn't NMFS still want the biological catch data as before?

Figure 2. Annual number of lobsters predicted to be caught under the preferred alternative for four risk factors (0, 1, 5 and 10%).

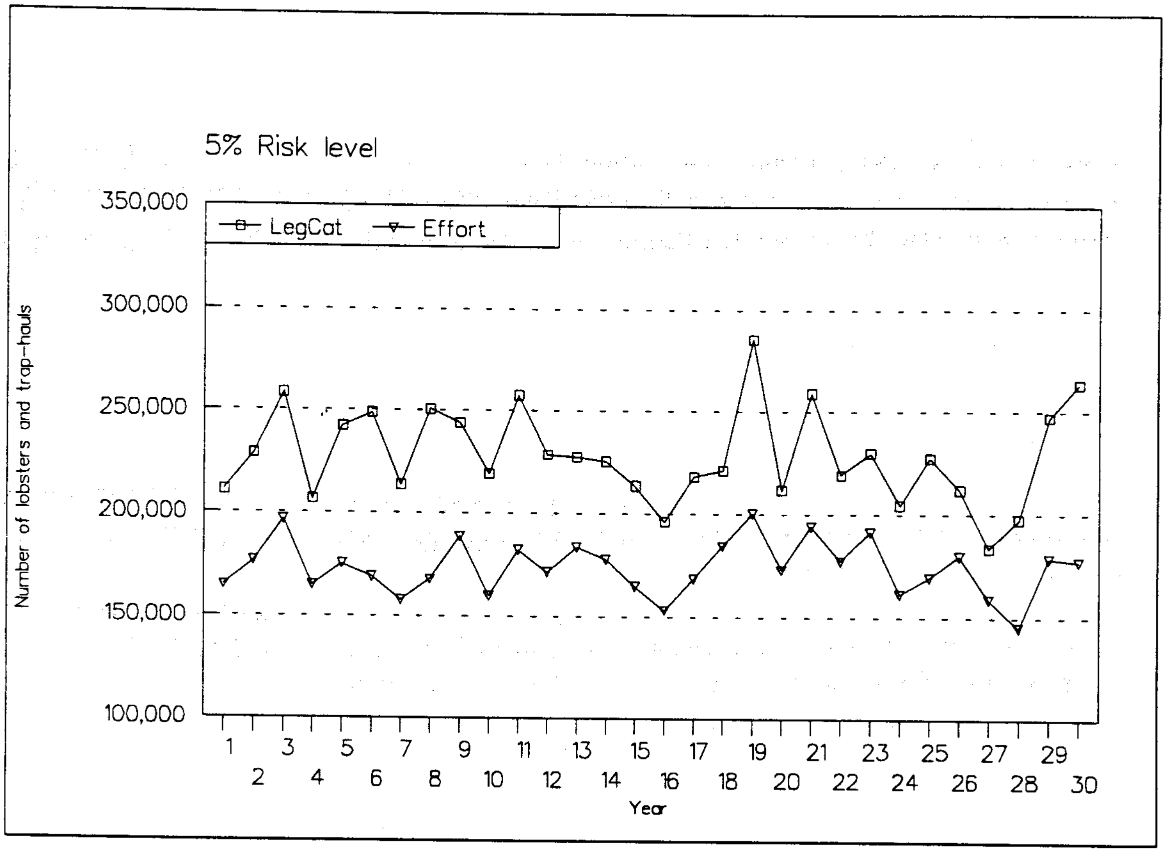


E. ANALYSIS OF BENEFITS AND COSTS

Economic Analysis Method

The economic analysis of the various alternatives presented is based on a benefit-cost analysis. Benefit-cost analysis is employed to determine the option (alternative) which either maximizes social welfare or minimizes costs. To conduct this analysis, the best available quantitative and qualitative data are employed. However, the analysis includes a number of important caveats which should be considered when judging the adequacy of the results and their potential impact on the decision process.

Figure 3. Yearly predicted catch (numbers of lobster) and effort (trap-hauls) for the preferred alterative (No. 22) at the 5% risk level. Values will be higher under the proposed risk level of 10.0%.



Methodological Considerations and Net Present Value of the Fishery

The Net Present Value (NPV) for the producing sector of the NWHI lobster fishery was calculated based on the catch and effort estimates as developed under the various alternatives shown in Table 2. The NPV calculates the stream of income (or costs) over a discrete time horizon, under the assumption that revenue received in later periods is not valued as much as revenue received in the current period. Comparing aggregate present values implicitly acknowledges that the sooner income is earned, the sooner it could be potentially reinvested (or spent on consumptive activities). From the perspective of industry participants (harvesters and marketers), net revenues which can be reinvested sooner create an incentive, or higher value, than revenue that is obtained in future periods. This incentive is counter balanced by the need to maintain the biological integrity of the stock and social preferences (economic and ecological) for its existence. For each alternative the NPV is calculated

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+r_t)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r_t)^t}$$

where B_t represents the benefits derived for period t, C_t is the cost in period t, n is the time horizon evaluated, r_t is the discount rate for period t. This analysis is slightly different from a strictly financial projection in that it attempt to approximate social welfare considerations, such as the marginal and opportunity costs of factor inputs.

Decision Criteria

If the NPV is greater than zero, the alternative creates real wealth. A second decision criterion can be to compare alternatives to determine which best maximizes wealth or net benefits. A third decision criterion would be to compare each alternative to the No Action alternative (No. 23).

Discount Rate

The choice of an appropriate discount rate (r) has, and will continue to be a subject of considerable philosophical and theoretical debate (Zerbe and Dively, 1994). That discussion need not be repeated here in that all alternatives are calculated using the same base discounting rate which is equal to the 1994 long-term Treasury Bond rate of 7.41% minus the current rate of inflation (GDP deflator of 2.5%). As demonstrated in the NPV equation above as long as the denominator is kept constant then alternatives can be ranked. Sensitivity analysis for the preferred alternative (No. 22) is presented in Table 9, with discount rates of 7%, as mandated by the Office of Management and Budget (OMB, 1992), and 1%. The time horizon used for the economic calculations is the same used in the biological model (30 years). It should be noted the predominant NPV effects of time occur over the first 20 years, therefore it is considered appropriate for aiding in choices between policy alternatives.

There are a number of additional theoretical considerations which should be addressed when doing B/C analysis. Of particular concern is that each proposed alternative should be quantitatively reviewed, at least initially, to estimate net national economic benefit without regard for the marginal social utility of income (using Kaldor-Hicks criteria) after which distributional affects may be considered. However, given the limited size of the NWHI lobster fishery, its associated markets, which can be categorized as classic 'price takers' (Clarke, et al., 1994), along with its limited geographic scope, all of the various alternatives are postulated to have trivial net national economic impact and therefore national impacts are ignored.

B/C analysis should also attempt a first-order approximation and estimate effects on both consumer and producer surplus. In theory, the alternative that maximizes the sum of the positive changes of producer and consumer surplus less management and enforcement costs should be the preferred alternative barring any overriding associated concern (national security, etc.). However, given the relatively small contribution of the NWHI lobster fishery to international and national, as well as local frozen lobster sales, and the substitutability of a number of other lobster types and species sold on what appear to be relatively competitive national and international markets, changes in consumer surplus are considered insignificant. Additionally, information does not exist on the measurement of consumer surplus regarding NWHI lobster. Finally, the time and expense required to obtain this type of information would be considerable. Therefore, the focus of the B/C analysis presented here is on producer surplus.

Sunk costs, at least those that cannot be avoided, should theoretically be excluded from B/C analysis. Here, all costs that producers incur that cannot be avoided are included in the analysis. But as shown below, costs are charged only if the opportunity cost of participating in the NWHI lobster fishery exceeds break-even levels or opportunities afforded in other fisheries.

Taxes are transfer payments which reflect a transfer of control over fiscal resources from one source to another and are excluded from the analysis. Externalities have not been considered, nor have leakages due to factors such as foreign ownership of vessel or on-shore processing and marketing companies.

Uncertainty is incorporated into these calculations in a number of ways beginning with the biological model: results are provided for risk levels between 0 and 10%. It should be noted that 10% would be considered relatively conservative for financial decisions but may be appropriate for decisions related to social welfare. Uncertainty is also considered by the range of results presented for various post harvest survival possibilities. Finally, sensitivity analysis is provided for significant parameters used in the NPV calculations, and a range of discount rates are tested.

A total of 23 NPVs were calculated using a spreadsheet incorporating cost and revenue data on vessel performance, as well as the biological model's outputs (Pooley, Unpubl.; Pooley and Hamilton, Unpub.) to estimate producer surplus. NPV of the fishery under a particular management alternative is directly estimated from catch and effort estimates (CPUE) generated from the biological model (DiNardo, In prep.). Although the biological model only reports outputs from years 11-30, NPV calculations require that benefits (or losses) from all 30 years are considered due to "value front loading", especially in years 1-10. Also, theoretically transition costs to the new regime must be implicitly evaluated.

Direct comparison with averages expressed in DiNardo (In prep.) was not possible. The biological model estimates lobster population and calculates how many lobsters can be harvested from that population while maintaining the overall population above the 20% SPR level at a certain risk level. In this, fishing (i.e., effort) is not directly relevant (except in the distribution of harvest within the fishing season) for the biological model or the estimation of the harvest guideline (quota). However, for the economic analysis, fishing effort is a significant determinant. The economic model takes the biological model's information and then adjusts fishing parameters as appropriate from an economic perspective. It should be noted the initial presentation of the biological model (DiNardo, In prep.) did not generate annual streams of catch and effort (since effort was not essential to the biological analysis). These effort streams were calculated after the fact by the NMFS Honolulu Lab's Stock Assessment Group, using CPUE proportional to the (recalculated) population estimates in each year. Thus, because of the method of generation (through the Monte Carlo simulation methods), there are slight differences in the biological and economic aggregate summaries. These are not significant for economic analyses (Pooley, Unpubl.).

While only three risk levels are reported here (0, 5 and 10%), the economic model calculates the risk of recruitment over-fishing for 11 levels (0 through 10%, one-percent steps), except for the Constant Escapement alternative.

No Action Alternative

The No Action alternative is the Constant Escapement strategy at an 8% risk level and assuming a 50% post harvest survival rate. The biological model estimates zero exploitable surplus using a size at maturity estimate of 50.6 mm, so 46 mm was used (see DiNardo, In prep.). No exploitable surplus is estimated to occur below 8% risk levels.

Fleet Costs

Financial or economic data for the NWHI lobster fishery have not been updated since originally collected in 1986 (Clarke and Pooley, 1988). At that time, vessels typically participated in the fishery throughout most of the year. Catch rates and the composition (species) of catch was considerably different than experienced between 1992-94. With the advent of limited entry, seasons, and catch quotas, full time participation in lobster fishing has become both a physical and economic impossibility. Lobster vessel operators have shifted to other fisheries for their primary source of income and those that do participate do so on a seasonal basis. Despite these differences, the only data available for analysis are forward "projections" of the economic relationships identified in that earlier work. The forward projection was done using the Honolulu Consumer Price Index (HCPI) to adjust per unit fishing vessel costs for an average vessels participating in the fishery in 1990 (see Pooley and Hamilton, Unpub.). The cost-earnings profile is based on full-year operations and does not account for start up costs or amortization of fixed costs over a limited number of months. Specifically, these costs represent lobster fishing activities of 4.2 trips/year with a total of 135 fishing days/vessel. The values were converted to per day costs and employed in the analysis conducted here.

For cases in which updated information existed (ex-vessel price, CPUE, traps per fishing day etc.), these values were adjusted accordingly, based on Dollar (1995).

The lack of updated information on the financial impact of vessel performance under the current management regime is a considerable limitation of this analysis. Despite these limitations, the data appear to represent the best approximation of the opportunity cost of capital and labor inputs when allocated on a per trap haul basis for vessels currently participating in the NWHI lobster fishery (Pooley, Unpubl.).

Another concern is a lack of the economic analysis on the truncated seasons, which is considered by some to be the most problematic of the current quota setting procedure (Pooley and Hamilton, Unpubl.). Until such times as the economic and performance data base on NWHI lobster vessels is updated, the use of adjusted historical data must suffice.

Table 3. Estimated 1994 Costs of a prototypical vessel participating in the NWHI lobster fishery: annualized operations. (Adapted from Clarke and Pooley, 1988)

Fixed Costs	Capital	113,743
	Annual Repair	45,213
	Insurance	65,689
	Administration	15,623
	Other	55,037
Total Fixed Costs		$295,305
Operating Costs	Fuel &Oil	54,918
	Bait	36,218
	Handling	25,800
	Provisions	20,121
	Gear & Supplies	27,933
	Other	8,167
	Crew Share	144,700
	Captain Bonus	10,800
Total Operating Costs		$328,756
TOTAL COSTS		$624,061

For determination of the net income streams (see below) it was assumed that fishermen base their decision whether or not to engage in the NWHI lobster fishery on the prospects of revenue exceeding current opportunity costs. For projected seasons (years) in which anticipated CPUE is expected to be low, eligible fishermen are expected to continue in their activity in other fisheries (longlining, bottomfishing, or fishing outside of the Hawaii) and forego the opportunity to engage in lobster fishing. However, under all the current and proposed management regimes, lobster fishing is expected to commence in July, a time that is considered marginal for pelagic longlining, the primary commercial fishing option for lobster vessels physically in Hawaii. Therefore, participation in the NWHI lobster fishery was constrained to zero when the predicted CPUE (as generated for each year for each alternative in the biological model) is less that the variable costs of fishing or

$$ \$ * (CPUE) < OC \therefore \text{ No Fishing. Aggregate fleet fishing costs and revenue for that year} = 0 $$

where $ is the anticipated price per lobster, CPUE is the anticipated catch per unit effort from the biological models and OC is the break-even operating costs for that scenario. The effect of this economic constraint is to reduce extraordinary economic losses which would occur when high effort levels are associated with low CPUEs as predicted by the biological model.

Previous studies revealed significant distortions in the availability of labor, which proved to be a significant input factor in lobster vessels cost structure (Clarke and Pooley, 1988; Clarke, et al., 1994). The potential effects of labor costs as adjusted by the HCPI in the current analysis were reviewed and compared to contemporary labor rates in other Hawaii based fisheries (Hamilton, NMFS Honolulu Lab, Unpub.). The results indicate the traditional crew share formula employed by the NWHI lobster fishery (a percentage of the gross receipts after trip costs) provided what was felt to be excessive renumeration to crew, therefore a fixed labor rate at the break-even level of fishing was employed to approximate social opportunity cost labor rates. Estimated CPUE was the only criterion constrained. Some fishermen will participate in the NWHI lobster fishery, even when very few lobsters are available, so it was deemed inappropriate to place similar constraints on the decision process based on the numbers of lobster available in a given year.

Estimated Ex-Vessel Revenue

Ex-vessel revenue was estimated using average combined lobster species ex-vessel price in 1994. Current information on the NWHI lobster fishery (Dollar, 1995) indicates that each landed lobster returned $6.39 ex-vessel. Twelve alternatives include retention scenarios that will in all likelihood result in the landing and marketing of lobsters currently precluded from landing and sale because of their smaller size or the presence of external eggs. Discussions on this matter have come up on this matter in a number of venues but few data exist on the relative economic or market value of these classes of lobster.

For simulation modeling purposes a 57% reduction (or 43% "discount") for the average price per lobster for small and berried lobsters was incorporated into the economic analysis. The weighted value (price per pound converted back to price per piece) was multiplied by the relative contribution of the various size classes of a hypothetical spiny and slipper lobster catch using commercial landings from 1994 and NMFS research data for these size classes below the currently defined legal limits (Clarke, NMFS Pacific Area Office, Unpub.). These results are based on a August 1995 survey of informed industry representatives and suggest a relatively greater discounting than originally employed by Pooley and Hamilton (Unpub.). Table 4 provides estimates for the price per lobster under each of the three scenarios.

Table 4. Price per lobster ($) for various retention scenarios. (Source: Dollar, 1995, and NMFS unpublished data)

	Scenario 1	Scenario 2	Scenario 3
Legal	6.39	6.39	6.39
Sublegal	2.75	n/a	2.75
Berried	n/a	n/a	2.75
Average	4.93	6.39	4.52
Discounted value, based on $6.39	30%	0%	35%

F. BREAK-EVEN ANALYSIS

Break-even catch rates (lobster per trap haul) independent of any "sunk" costs incurred by a truncated season, were calculated to adjust the biological model's catch and effort outputs for unrealistically low CPUEs (Table 5). Break-even CPUEs were initially compared to the constraint regarding participation (detailed above) and incorporated in the NPV calculation for each alterative presented. Forgone catches are not added back into the next years population or catch, which is considered the most conservative approach. Base line break-even catch rates are presented in Table 6.

Table 5. Summary of break-even catch rates and costs per trap haul for a prototypical NWHI lobster vessel operating in 1994. ( ) = negative dollars, i.e., losses.

Total Revenue	$576,807
Total Costs	$624,061
Total Operating Costs	$328,756
	($56,254)
Total Trap Hauls	114,308
Total Lobster (No.)	88,869
Lobsters per trap haul	0.78
$ per lobster	7.39
Total Cost per lobster	$7.02
Operating Cost per lobster	$3.70
Net Revenue (Profit) per lobster	($0.63)
Operating revenue per lobster	$2.69
Total Revenue per Trap Haul	$4.97
Total Cost per Trap Haul	$5.46
Operating Cost per Trap Haul	$2.88
Net Revenue per Trap Haul	($0.49)
Operating Revenue per Trap Haul	$2.09

Table 6. Break-even input parameters for NWHI Lobster vessel, based on annualized operations in 1994.

	Scenario		
	1 No Berrieds	2 Legal Only	3 Retain-All
Lobsters / Trap Haul	0.585	0.450	0.640
Total Lobsters / Vessel (No.)	66,870	51,439	72,586
Operating Cost / Lobster	4.93	6.39	4.52

F. RESULTS

Summary of Net Benefits

NPV for the 23 alternatives are presented in Table 7 and depicted in Fig. 4. The NPV for each alternative for the three levels of risk (0, 5, 10%) show considerable variation. This effect is depicted in Fig. 5, which displays the varying impacts differing levels of risk have on six representative alternatives. Economic and fishery production values for the preferred alternative (No. 22) for the relevant range of risk are provided in Table 8 and depicted in Fig. 6. These results emphasize the variability of the NPV's depending on factors such as risk level and CPUE.

Sensitivity of economic model to parameter values

The sensitivity of significant economic parameters was tested for the preferred alternative (alternative 22) and is presented in Table 9. Previous studies (Clarke and Pooley, 1988) have documented the significance of fluctuations in gross revenue on net profit for NWHI lobster operations. Of particular concern is the impact of discounting factor imposed (43%) on lobsters currently defined as sublegal and berried has on ex-vessel price and in turn gross revenues. This parameter is hypothesized to have significant implications and commensurate effect on NPV calculations. The impact on NPV under differing price discounting schemes, at a fixed intermediate risk level (5%) is presented in Table 10. While Fig. 7 presents a comparison of estimated NPV using the discounted value of sublegal and berried lobster tails and the current (1994) ex-vessel price at a fixed 5% intermediate level of risk.

Competitive Effects

The NWHI lobster fishery and the associated industry is composed entirely of small businesses and is expected to remain so. Given there are no large businesses involved in the fishery, no disproportional small vs. large business effects are expected as a result of adoption of any of the proposed alternatives.

Demographic Analysis

A demographic analysis was not conducted, however the social implications of the proposed action are discussed in Section 5.3.3 of the amendment.

Table 7. Net Present Value of Alternatives at a risk level of 0, 5 and 10%, using a 4.6% discount rate. ( ) = negative values.

Alternative	Strategy	Scenario	% Survival	0% Risk	5% Risk	10% Risk
1	2	1	0	743,365	2,882,151	2,633,933
2	2	1	25	743,757	2,956,886	2,598,318
3	2	1	50	745,108	2,988,841	2,612,324
4	2	1	75	745,756	3,023,296	2,629,812
5	2	1	100	746,093	3,057,844	2,647,288
6	3	1	0	1,171,602	2,708,727	1,422,854
7	3	1	25	1,192,216	2,729,754	1,399,603
8	3	1	50	1,217,121	2,749,215	1,357,270
9	3	1	75	1,240,734	2,765,420	1,313,942
10	3	1	100	1,267,957	2,773,198	1,258,520
11	2	2	0	654,253	2,727,181	1,957,311
12	2	2	25	858,012	2,944,580	1,899,904
13	2	2	50	862,955	3,233,186	2,105,857
14	2	2	75	1,068,600	3,565,519	2,423,058
15	2	2	100	1,076,749	3,955,536	2,589,544
16	3	2	0	2,971,166	(1,064,902)	(4,516,655)
17	3	2	25	3,178,647	(1,033,306)	(4,636,361)
18	3	2	50	3,371,457	(868,617)	(4,587,934)
19	3	2	75	3,599,159	(600,156)	(4,982,225)
20	3	2	100	3,909,127	(704,935)	(4,187,930)
21	2	3	0	567,656	1,950,720	1,100,897
22	3	3	0	925,219	1,425,133	(210,955)
23	1	2	0	n/a	n/a	(5,463,611)

Status quo (row 23)

Scenario 1 = No berrieds
2 = Legal Only
3 = Retain All

Strategy 1 = Constant Escapement
2 = Constant Catch
3 = Constant Harvest Rate

Figure 4. Net Present Value of alternatives at risk levels of 0, 5 and 10% (using a 4.6% discount rate), in thousands of dollars. Upper arrows delineate the retain-all options for both strategies (2 & 3) and the lower arrow shows the no-action alternative. (□ = 0% risk levels).

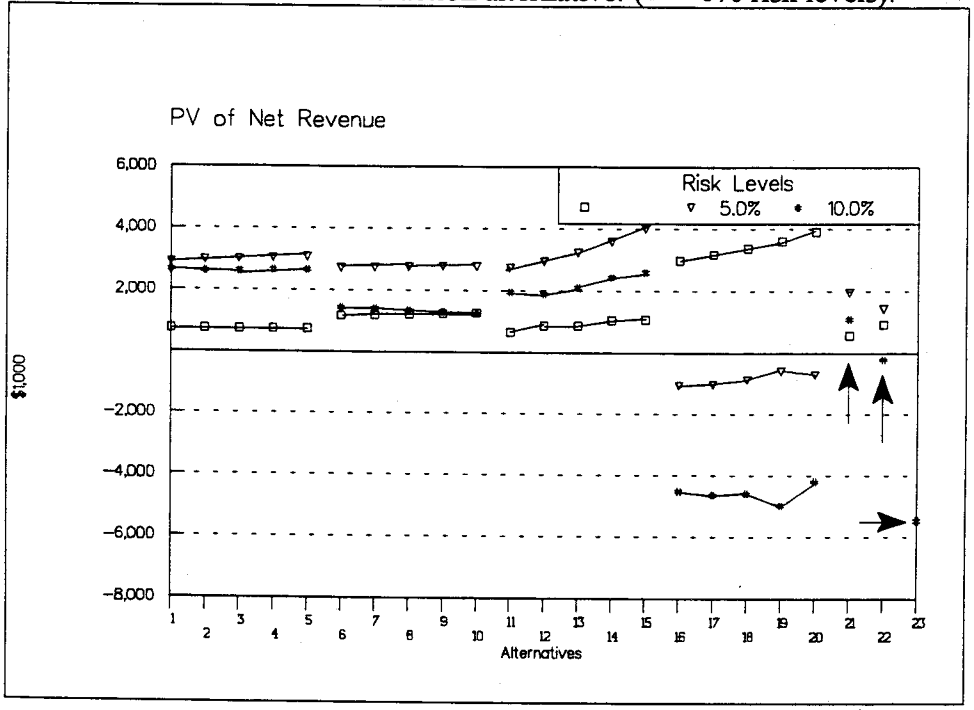


Figure 5. Impact of biological risk on the present value for six alternatives. (see Table 2 for definition of alternatives)

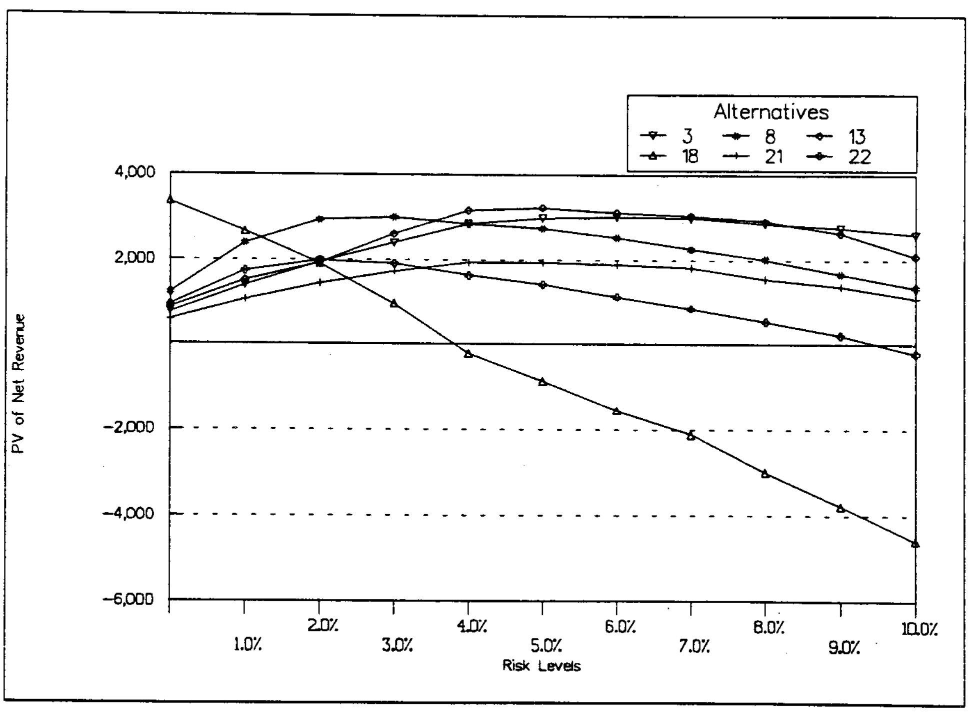


Table 8. Estimates of economic parameters at 11 levels of risk for the preferred alternative (No. 22).

Risk Level	Present Value ($) Net Revenue	Revenue	Total Cost	Annual Catch (No.)
0.0%	925,219	3,324,881	2,399,662	45,800
1.0%	1,739,880	7,708,338	5,968,458	106,110
2.0%	1,992,720	11,493,440	9,500,720	158,063
3.0%	1,915,984	13,743,802	11,827,819	188,980
4.0%	1,637,467	15,830,323	14,192,856	217,567
5.0%	1,425,133	16,633,799	15,208,666	228,467
6.0%	1,128,221	17,770,085	16,641,864	243,973
7.0%	849,991	18,678,622	17,828,631	256,367
8.0%	545,041	19,546,918	19,001,877	268,273
9.0%	217,907	20,401,818	20,183,911	279,940
10.0%	(210,955)	21,217,081	21,428,036	291,087

Figure 6. Net Present Values for various levels of risk (0-10%) for the preferred alternative (No. 22).

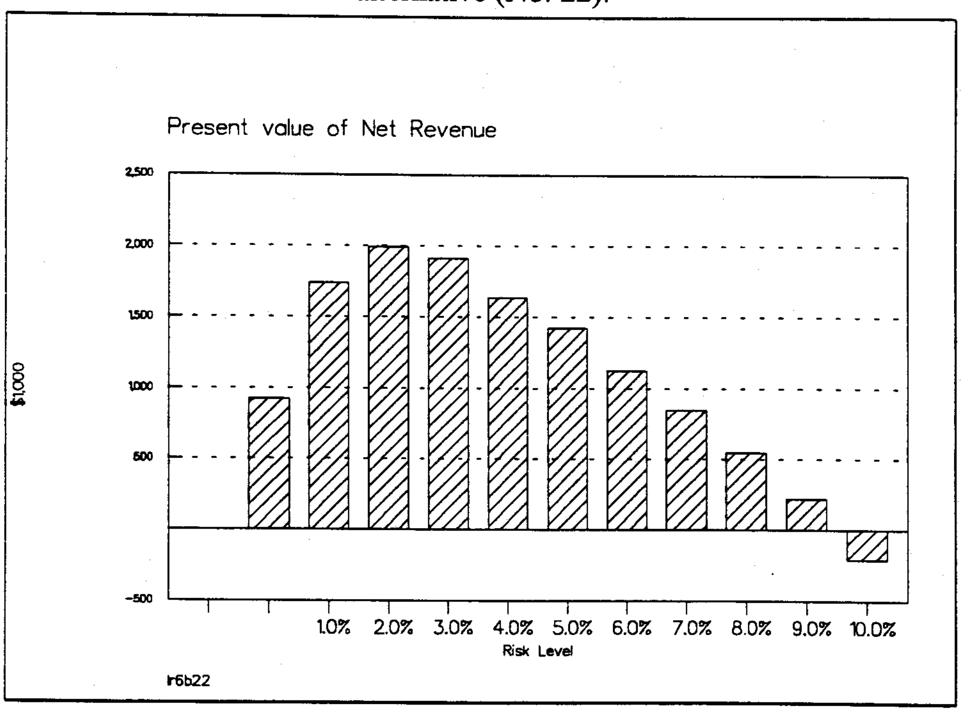


Table 9. Sensitivity of economic model to various parameters for the preferred alternative (No. 22).

Parameter	Present Value of Net Revenue* ($)
"Preferred alternative"**: Retain-all, Constant Harvest Rate	$1,425,000
Lobster base price = $7.02 (increased by 10%) {average price = $4.98}	$3,088,000
Small & berried lobster price = Lobster base price (no discounting ∴ average price = $6.39)	$8,290,000
Small & berried price discount = 53% {average price = $4.85}	$2,629,000
Total cost of effort = $4.91 (decreased by 10%)	$2,946,000
Net Present Value discount rate = 0%	$2,527,000
Net Present Value discount rate = 7%	$1,129,000

* *Net Present Value calculated over 30-yr time horizon at 4.6% discount rate (except for discount rate sensitivity tests).*

** *Preferred alternative parameters: maturity 50.6 mm, 5% biological risk level, 4.6% discount rate, $6.39 base lobster price ($4.52 average as adjusted for small & berried lobsters in Retain-all scenario @ 43% price discount. $5.46 total cost of effort (per trap haul).*

F. CONCLUSIONS

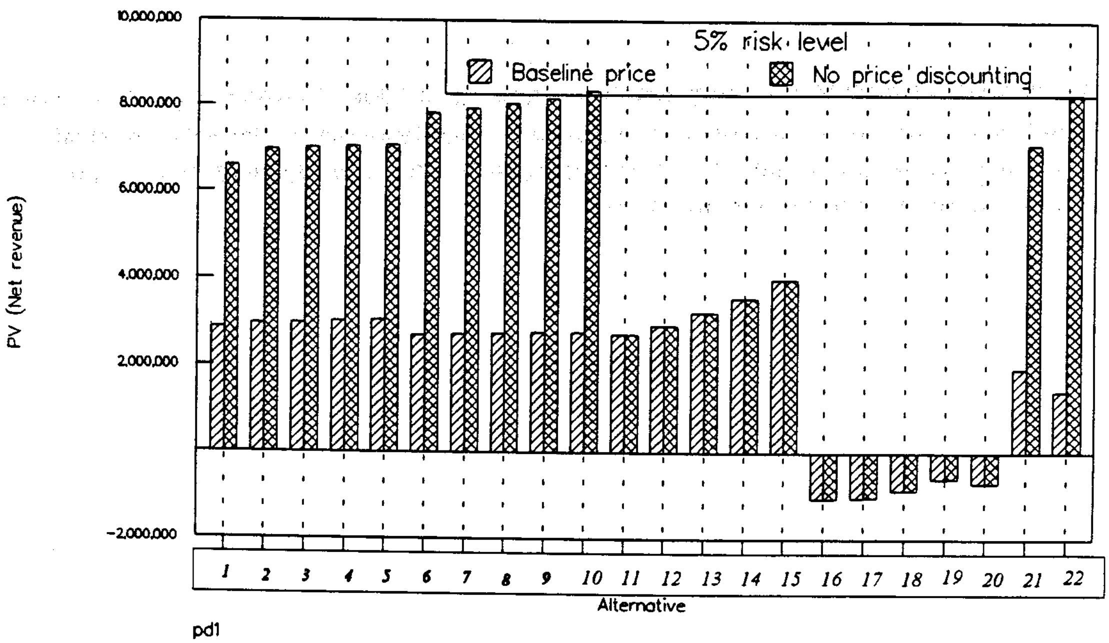
The break-even analysis revealed that under various scenarios fishermen are required to maintain substantially different CPUEs in order to maintain economic viability. The input parameters utilized here indicated that CPUEs would have to vary by as much as 30% to maintain break-even economic conditions under the different retention scenarios. The numbers of lobsters caught is generally higher under greater risk levels, with CPUEs being generally lower, sometimes substantially so.

The economic results suggest that NPV and net revenues correlate closely with CPUE for all alternatives. This underscores the fact that the biological model's predicted catch at the various risk levels is a major determinant in the economic results. This relationship results in several alternatives having higher NPV at low risk levels than at higher risk levels, while in most instances intermediate risk levels (5%) generally perform best from a purely economic perspective. This effect results in dome-shaped risk-to-NPV profiles for most alternatives.

Table 10. Sensitivity analysis of the impact on NPV of differing ex-vessel lobster prices at the 5% risk level for alternatives 1-23.

	Sensitivity Analysis: P (Net revenue, $)		
Alternative	Baseline Price Discounting	No Price Discounting	Partial Price Discounting
1	2,882,000	6,602,000	4,742,000
2	2,957,000	6,986,000	4,971,000
3	2,989,000	7,020,000	5,005,000
4	3,023,000	7,057,000	5,039,000
5	3,058,000	7,092,000	5,075,000
6	2,709,000	7,842,000	5,275,000
7	2,730,000	7,943,000	5,336,000
8	2,749,000	8,065,000	5,407,000
9	2,765,000	8,185,000	5,475,000
10	2,773,000	8,365,000	5,569,000
11	2,727,000	2,727,000	2,727,000
12	2,945,000	2,945,000	2,945,000
13	3,233,000	3,233,000	3,233,000
14	3,566,000	3,566,000	3,566,000
15	3,996,000	3,996,000	3,996,000
16	(1,065,000)	(1,065,000)	(1,065,000)
17	(1,033,000)	(1,033,000)	(1,033,000)
18	(869,000)	(869,000)	(869,000)
19	(600,000)	(600,000)	(600,000)
20	(705,000)	(705,000)	(705,000)
21	1,951,000	7,120,000	4,535,000
22	**1,425,000**	**8,290,000**	**4,857,000**
23	n/a	n/a	n/a

Figure 7. Sensitivity of NPV to lobster price at a fixed intermediate level of risk (5%).



Using the baseline economic assumptions presented, NPV is maximized at approximately $4 million under the Constant Catch (Strategy 2) while retaining legals only (Scenario 2) assuming a 100% post harvest survival rate and a 5% level of risk (alternative 15). However, alternative 20 (Constant Harvest Rate, legals only (Scenario 2 at 100% post harvest survival)) yielded a NPV with similar results.

The preferred alternative does not generate the highest NPV under baseline economic conditions. This finding is demonstrated, however, to be extremely sensitive to the predicted per unit ex-vessel price of lobsters. If the price discounting used in the baseline analysis is removed, such that all lobsters receive the same price, then the economic results change considerably (Tables 9 and 10, Fig. 7). The preferred alternative is considered to be economically viable, especially when compared to the No-Action alternative.

The economic performance of the No-Action alternative (No. 23) provides the greatest support for modifying the NWHI management regime. Under the basic economic assumptions presented here, the existing regime is costing society at least $5-6 million in forgone revenues.

These results suggest:

- The NPV of a NWHI lobster fishery in which retention scenarios are liberalized (Scenarios 1 & 3) will ultimately be determined by the ex-vessel price of lobsters currently defined as sublegal and berried.

- With the significant number of management alternatives yielding relatively low NPV's, a policy which minimizes additional management (including enforcement) and social costs is more appealing.

- While the discard mortality estimates for sublegal and berried lobsters, and the economic conditions in the fishery, are open to refinement, it appears that a management strategy that utilizes either a Constant Catch or Constant Harvest Rate strategy will maximize social welfare, or at least minimize losses.

- The adoption of either the Constant Catch or Catch Harvest Rate strategy, with elimination of the in-season adjustment procedure, is expected to provide increased social welfare over and above the current method of Constant Escapement.

G. REFERENCES

Clarke, R.P., P. Milone, H.E. Witham. 1987. Annual Report of the 1986 Western Pacific Lobster Fishery. Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service, Admin. Rept. H-87-6.

Clarke, R.P. and S.G. Pooley. 1988. An economic analysis of NWHI lobster fishing vessel performance. U.S. Dept. Commerce. NOAA-TM-NMFS-SWFC-106. 46 p.

Clarke, R.P., S.S. Yoshimoto and S.G. Pooley. 1994. A Bioeconomic Analysis of the NWHI Lobster Fishery. Mar. Res. Econ. 7: 115-140.

DiNardo, G.T. In prep. Alternative harvest guidelines for the Northwestern Hawaiian Islands lobster fishery. Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service.

Dollar, R.A.. 1995. Annual Report of the 1994 Western Pacific Lobster Fishery. Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service, Admin. Rept. H-95-06.

OMB (Office of Management and Budget). 1992. Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs. Circular No. A-94 (rev.). Transmittal Memorandum No. 64.

Pooley, S.G. Unpubl. Draft regulatory flexibility analysis (dated 13 Oct 95). Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service.

Pooley, S.G. and M. Hamilton. Unpubl. Simulated Economic Risk Assessment of Alternative Quota Strategies for the NWHI Lobster Fishery. Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service.

Polovina, J.J. 1991. Status of the Lobster Stocks in the NWHI, 1990. Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service, Admin. Rept. H-91-04.

Zerby, R.O. and D.D. Dively. 1994. Benefit-Cost Analysis. In: Theory and Practice. Harper-Collins.