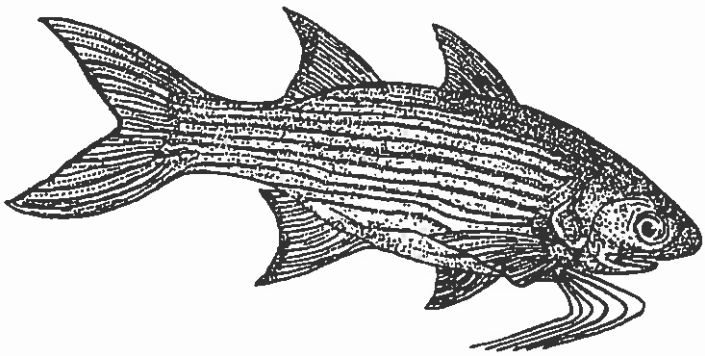
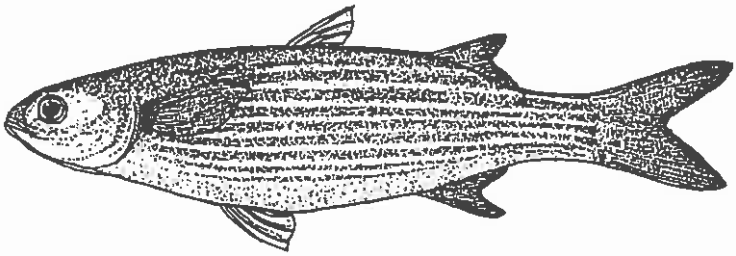
Prioritizing Marine Fishes for Stock Enhancement in Hawaii





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The Oceanic Institute

Prioritizing Marine Fishes for Stock Enhancement in Hawaii

by

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THE OCEANIC INSTITUTE

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Dr. Paul Bienfang
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Executive Summary

In 1988, The Oceanic Institute established a federally-funded, multi-year program titled "Stock Enhancement of Marine Fish in the State of Hawaii" (SEMFISH). The first phase of this project involved the selection of an appropriate species to focus stock enhancement research efforts. This report describes a formalized, semi-quantitative selection process which involved two workshops, a community survey, and the focused use of expert opinion.

A list of selection criteria for Hawaiian fish species was developed at the first workshop. The selection criteria were ranked, and each was assigned a numerical weight based on the number of "votes" it received from the 15 workshop participants. The participants included government fisheries experts and planners, economists, biologists, and representatives of commercial fishing interests.

On the recommendation of the panelists at the first workshop, a community survey was conducted to compile a list of potential species for stock enhancement. Almost 150 community surveys were sent to biologists, aquaculturists, state legislators, fisheries experts, ocean industry dealers, and representatives of commercial and recreational fishing interests. A species pool of 25 candidate species for stock enhancement research was produced.

Each of the 25 species was graded according to each of the 22 selection criteria compiled during the first workshop. Grading for each criterion was performed by experts in the field related to that criterion. Letter grades assigned by the experts were quantified, and the resulting numerical grades were multiplied by the weighting for each criterion. The resulting scores for each criterion reflect how well the species satisfied that criterion, and how important that criterion was in the selection process.

For each fish species, the scores for all 22 criteria were totaled to create an overall score. Thus, the species with the highest overall scores were those that most closely met the most important criteria. The two species that received the highest overall scores were moi (Pacific threadfin, *Polydactylus sexfilis*) and 'ama'ama (striped mullet, *Mugil cephalus*); kumu (goatfish, *Parupeneus porphyreus*) was ranked third.

At the second workshop, 16 panelists discussed the species selection process and the species rankings. Most discussion focused on the relative merit of the two top-ranked species, and many panelists favored moi as the priority species for stock enhancement research. However, other panel members suggested that field experiments should start with mullet because this was the only top-ranked species that could be mass-cultured. A general consensus emerged -- panelists agreed that work on both species should continue simultaneously.

The semi-quantitative, decision-making process focused discussions, stimulated questions, and quantified participants' responses. Panelists' strong endorsement of the ranking results and selection process demonstrated the potential for applying formal decision-making to other natural resource management issues.

Introduction

Nearshore fish populations in Hawaii have apparently suffered major reductions since the turn of the century (Shomura, 1987). The reasons for these declines are not known in many cases, but pollution, habitat destruction, and over-fishing could all have played a part. Recently, efforts have been made to reverse this trend.

In cases where over-fishing is a principal factor in fishery declines, fish populations can often be restored by improving juvenile recruitment. Recruitment can be increased by raising juvenile fish in the protective environment of a hatchery, then releasing them in appropriate wild habitats. Such "hatchery-release" programs have been used for many years to replenish fresh water fisheries. However, their effectiveness for nearshore marine species and their potential impacts on nearshore ecosystems are not as well documented.

In 1988, The Oceanic Institute (OI) received funds from the National Marine Fisheries Service (NMFS) to develop a stock enhancement research program for nearshore Hawaiian fish species. It became apparent that one of the most important elements of this program would be the selection and evaluation of appropriate indigenous species for stock enhancement research.

Before the scientific work could begin or the species could be selected, some difficult questions had to be answered. Many of these questions focused on the criteria to be used in selecting a species. For example, commercial and recreational demand are obviously important criteria, but should they take precedence over other factors?

Community input was sought to determine the answers to such questions. Two workshops were proposed -- the first to determine appropriate selection criteria, and the second to form a consensus on a species for stock enhancement research. To obtain as much information from the workshops as possible, OI researchers formulated a "grading" system which could be used to quantify the responses of the workshop participants.

It became apparent that one of the most important elements of this program would be the selection and evaluation of appropriate local species for stock enhancement research.

Ultimately, the selection process expanded to include not only the two workshops, but a community survey and interviews with experts in issues relating to Hawaiian fisheries. As it evolved, the selection process (Figure 1) proved to be efficient and enlightening.

This report describes in detail the process of eliciting community input and the numerical methods used to analyze the information obtained. It is hoped that this approach will prove useful in resolving other resource management conflicts, or at least in stimulating effective discussion of the issues.

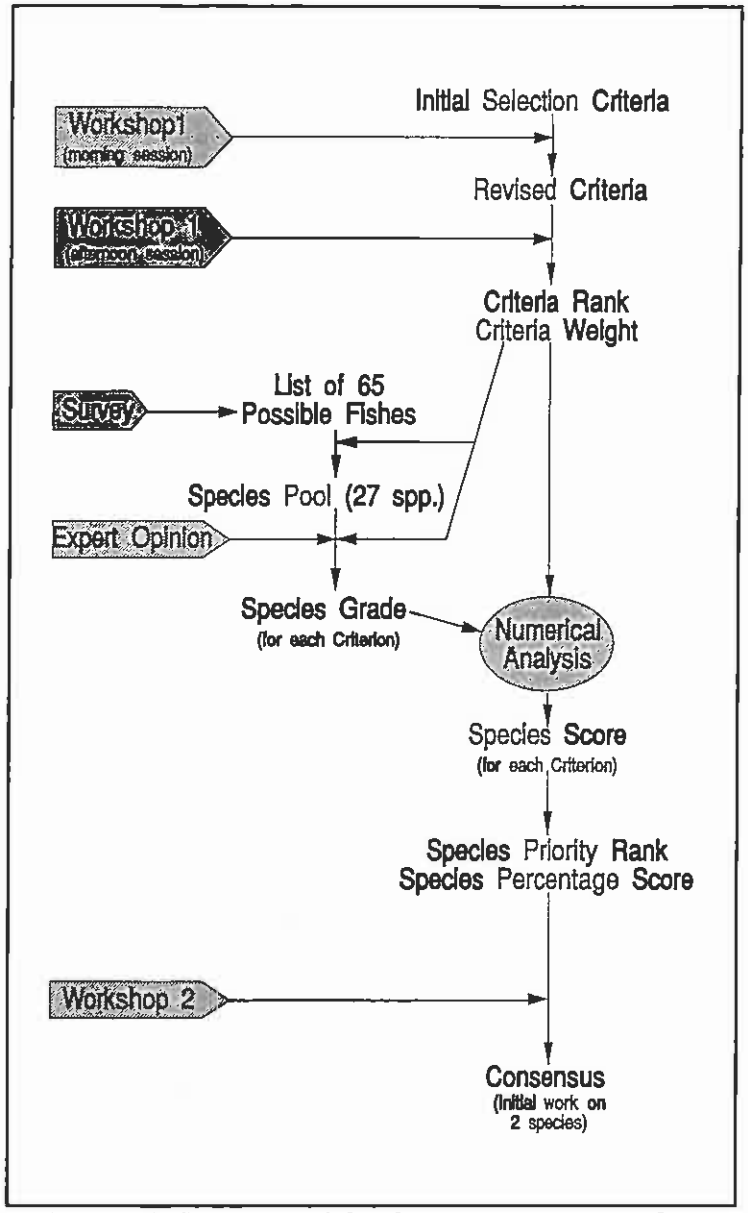

Figure 1. Summary of the decision process used to select a fish species for stock enhancement research.

Process Overview

The main stages in the species selection process are presented in Figure 1. Sources of community input are shown as boxes on the left side of the flow chart. These included:

- An initial workshop, where selection criteria were specified and ranked in order of importance.
- A community survey, which was used to solicit opinions on the selection criteria and to generate an initial list of possible species for stock enhancement research.
- Interviews with local experts to grade each candidate species with regard to each selection criterion.
- A second workshop, in which the results of the quantitative species selection process were discussed and a consensus was sought.

OI researchers compiled, analyzed, and summarized the community input in tables and lists of qualitative comments. Thus, each input yielded a written product that could be used at the next stage. A critical step in the numerical analysis process is shown as a shaded oval in Figure 1. At this stage, the degree to which each fish met each criterion was combined with the relative importance of that criterion. This produced a summary score for each species. The scores were ranked to determine those fish most appropriate for stock enhancement research.

Participants

Community input was solicited from diverse sectors of the marine fishery community in Hawaii. The types of agencies and the broad expertise of the individuals involved are summarized in Table 1.

Decision-making tools

In recent years, formal decision-making processes have been used effectively to prepare comprehensive plans for fisheries research (e.g. Bain, 1987). Mackett et al. (1983) discuss the implementation of an interactive management system for the Southwest Fisheries Center of the National Marine Fisheries Service (NMFS). Similar processes have been used recently for research on North Pacific pelagic fisheries, for strategic planning in Hawaii's skipjack tuna (aku) industry (Boggs and Pooley, 1987), and for a five-year scientific investigation of marine resources of the main Hawaiian Islands (Pooley, 1988).

For the workshops described below, a formal decision-making process, the "Interaction Method," was used. This method, also known as "Mastering Meetings for Results," was developed by Interaction Associates, a management consulting and human development firm based in San Francisco. The method emphasizes agenda planning, facilitative behaviors, collaborative problem solving, and follow-up. It is similar to the Delphi method, in which decisions are made through structured discussion, brainstorming, voting, and a search for consensus. The workshops were overseen by a trained facilitator (Jane Yamashiro of the University of Hawaii, Office of the Chancellor for Community Colleges).

Table 1. Affiliations and expertise of individuals consulted in the species selection process

Affiliations:

- federal agencies
- state agencies
- county agencies
- research laboratories
- University of Hawaii
- recreational fishing groups
- commercial fishermen
- fish wholesalers
- private citizens

Expertise:

- sport fishing
- commercial fishing
- fish marketing
- fishery economics
- fish ecology
- fish behavior
- fish diseases
- biometrics
- fishery management
- biology of Hawaiian fishes
- aquaculture
- aquaculture economics
- Hawaii aquaculture policy
- legal and institutional policies
- formal decision-making theory
- oceanography

Process Description

The following pages describe in detail each step of the species selection process shown in Figure 1.

Preliminary selection criteria

A preliminary list of selection criteria was prepared by OI staff. The criteria were divided into six broad categories:

- Biological and cultural considerations
- Knowledge available on species
- Enhancement considerations
- Release considerations
- Socioeconomic considerations
- Ecological considerations

Within these six categories, 15 specific criteria were submitted for review by participants in the first workshop. Several of these criteria had detailed "sub-criteria," including specific types of data that might be considered in the selection process.

First Workshop (April 27, 1988)

The goal of the first workshop was to establish the criteria for choosing and prioritizing species for stock enhancement research.

The workshop participants consisted of 15 individuals from a broad range of interests, disciplines, and backgrounds. The participants included representatives of commercial and recreational fishing organizations, state and federal ocean-related agencies, the University of Hawaii, and The Oceanic Institute (Table 2). These individuals were selected from an initial list of 80 to 100 names prepared with the help of a local consultant (Robert Iversen of Pacific Fisheries Consultants).

Prior to the workshop, all panelists were sent a copy of the preliminary criteria list and a letter explaining the exact nature of the decision-making process. The letter stressed that the preliminary criteria were presented simply as "food for thought," and were open to discussion and modification as necessary.

The April 27 workshop was held at The Oceanic Institute. The workshop lasted seven hours and was divided into two sessions, morning and afternoon. The goal of the morning session was to develop and refine the list of criteria. During the afternoon session, the revised criteria were to be prioritized and ranked in order of importance.

First workshop – morning session

At the beginning of the workshop, the facilitator explained that her purpose was to maintain the pace of the discussion and to take a neutral stance in the discussions. She also conducted a brief exercise to familiarize panel members with one another.

As an initial statement of consensus, the panel agreed to focus the discussions during the morning session on an approach to stock enhancement which replenishes or supplements adult population size by rearing and releasing juvenile marine finfish.

After a discussion about generating a new list of criteria for consistency with the workshop objective, the panel determined that the preliminary list mailed to panel members was a good starting point. The consensus was that the preliminary list of criteria "looked good," and that reordering the criteria under a different format was unnecessary. The following two and one-half hours of discussion centered on modifications to the preliminary criteria, and on new criteria to be added to the list. The panel decided to add a seventh broad category, "infrastructure considerations," to the six categories on the preliminary list.

At the end of the morning session, the facilitator sought an evaluation of the first half of the workshop. The panel concluded there had been some good discussion and the pace had been faster than normal for this kind of meeting. On the panel's recommendation, a revised list of criteria was printed before the afternoon session to reflect additions and modifications. This helped maintain pace and continuity for the afternoon session.

First workshop – afternoon session

The afternoon session began with combining of similar criteria and inclusion of new criteria to the "revised list of criteria." The panel promoted some sub-criteria to criteria level within the revised outline. The resulting list of criteria (including marked revisions) is presented in Figure 2.

Table 2. Organizations and individuals participating in the first species selection workshop

U.S. National Marine Fisheries Service (NMFS) - Honolulu Laboratory
Chris Boggs, Ph.D.: Fisheries Biologist
Jeff Polovina, Ph.D.: Mathematical Statistician

NMFS Western Pacific Regional Fishery Management Council
Justin Rutka: Economist
John Sproul, Ph.D.: Economist/Biologist

U.S. Fish and Wildlife Service
Hawaii Cooperative Fisheries Research Unit (HCFRU)
James Parrish, Ph.D.: Director

Hawaii State Dept. of Land and Natural Resources (DLNR)
Division of Aquatic Resources (DAR)
Alvin Katekaru: Program Manager

Hawaii State Dept. of Land and Natural Resources (DLNR)
Anuenue Fisheries Research Center (AFRC)
Mike Fujimoto: Section Chief

University of Hawaii - Sea Grant Program
Richard Brock, Ph.D.: Fishery Specialist

Hawaii State Dept. of Business and Economic Development (DBED)
Ocean Resources Branch (ORB)
Craig MacDonald, Ph.D.: Branch Chief

The Oceanic Institute
Cheng-Shang Lee, Ph.D.: Program Manager
Kenneth M. Leber, Ph.D.: Program Manager
Charles Brownell, Ph.D.: Research Scientist

Fisherman's Co-op; Hawaii Fishing Coalition
Gertrude Nishihara

Malama Na I'a
Gene Witham: Vice President (also: NMFS Senior Resident Agent)

Sea Life Park
Steve Kaiser: Curator (also: Commercial Fisherman)

Facilitator
Jane Yamashiro (University of Hawaii)

A. BIOLOGICAL AND CULTURAL CONSIDERATIONS

1. Availability of Viable Spawn
   a) broodstock (local) availability
   b) ease of broodstock maintenance
   c) ease of captive spawning
   d) age at maturity
   e) fecundity and spawning frequency
2. Ease of Larval Rearing
   a) tolerance to rearing conditions
   b) nutrition
3. Ease of Juvenile Rearing
   a) age/size at release
   b) tolerance to high density culture
   c) resistance to disease and parasites
   d) degree of cannibalism/aggressive behavior
   e) nutrition

B. KNOWLEDGE AVAILABLE ON SPECIES

1. Extent of recruitment limitation (knowledge of recruitment)
2. Size [at] capture
3. Reproduces locally in a habitat that has been degraded or is limited
4. Is mortality/growth ratio relatively low

C. ENHANCEMENT CONSIDERATIONS

1. Will release of mass quantities of juveniles increase adult population size
   a) to what measurable degree
   b) techniques
      i) put, take
      ii) put, grow, take
      iii) put, grow, reproduce, take
2. Ability to succeed... [likelihood of rapid success without additional research given current state of knowledge]
3. How conducive to experimental manipulation... [combined with C4]
4. Ease of monitoring impact on fishery / fish population
   a) does it lend to a small experimental and pilot scale project
      i) degree to which a rigorous experimental design can be deployed to gather needed information for larger scale projects
5. Inshore seasonal availability (will they stick around)
6. Ease of protection until reasonable market size
   a) difficulty or ease
   b) other enhancement techniques
   c) market size/age and utilization
7. Non-consumptive uses

D. RELEASE CONSIDERATIONS

1. Ease of transport and distribution
   a) target
   b) broadcast
2. Ease of identifying released species... [Combined with C4]
   a) procedure conducive to monitoring
   b) alternatives to tagging
      i. ease of identifying released species
      ii. identifying recovered
      iii. movement patterns
         a. residential vs. migratory
         b. dispersal (random)
      iv. special considerations
         a. seasonality
         b. environmental factors

E. SOCIOECONOMIC CONSIDERATIONS

1. Commercial and recreational demand
2. Multiple demands for same species... [Combined with E1]
3. Cost-Effectiveness
   a) technology
   b) unit culture cost
   c) distribution
      i. inshore vs. pelagic
4. Socioeconomic attractiveness
   a) profile
5. Fishing mortality
   a) degree of fishing pressure
6. Mitigation issues
   a) pollution
7. Cost of monitoring the effect

F. ECOLOGICAL CONSIDERATIONS

1. Documented decline - Catch Per Unit Effort (CPUE)
2. Availability of food
3. Availability of habitat
   a) knowledge of post-hatchery habitat
4. Impact on resident biota
   a) predation on desired species

G. INFRASTRUCTURE CONSIDERATIONS

1. Facilities
2. Hatchery cost...[Combined with E3]
   a) unit cost production vs. economic return
3. Cost of monitoring impact...[Combined with E7]

Figure 2. Final list of species selection criteria from the first workshop, held on April 27, 1988. Changes made after the lunch break are shown in brackets [ ]. Arabic numbers designate criteria; capitalized headings designate categories; other levels are sub-categories.

After a discussion of ranking protocols, the panel used formalized "Interaction Method" ranking procedures to "vote" on the criteria. Each panel member selected what he or she determined to be the 11 most important criteria (the top one-third). Each criterion was then ranked from 1 (least important) to 11 (most important). Ranking levels could be assigned only once.

By general consensus, the panel agreed that the results of this ranking process (criterion scores, based upon total votes a criterion received) could be used not only to determine which criteria were most important, but also to weight individual criteria for subsequent analyses. These weights were used to quantitatively compare the importance of each criterion, as determined by the workshop participants.

The results were tabulated during the afternoon workshop session. An important outcome was the panel's determination that one criterion, "commercial and/or recreational demand," was of primary importance, and that no species should be selected unless it met this minimum criterion. Thus, species for which there was little or no demand would not be considered for stock enhancement.

The panel decided a community survey should be conducted to establish a list of potential species (a "species pool") for stock enhancement research. Such a survey would provide input from a broad selection of affected and concerned individuals and user groups. The panel agreed that each species from the pool would be evaluated with regard to the selection criteria, based on consultations with various local specialists. OI staff agreed to coordinate this process and keep panelists informed of the results.

Comments from participants in first workshop:

"The ranking process accomplished the goals of both ranking and weighting."

"This process was an effective tool."

"I liked the cross-section of interests represented by panel members."

"I liked the workshop because it was structured but flexible; the sense of a deadline was maintained, but new departures and modifications were possible."

"I agree, and I felt that the process was very successful."

"The meeting's objective was to identify goals (criteria) which apply to species; the overall process (of prioritizing species) needs additional steps."

"Additional steps exist; once the species pool is generated, species will be scored by selected experts, and a meeting to seek consensus on the results will be held. So there is an opportunity for more input from panel members."

First workshop - results

The panelists' votes on selection criteria were tallied in two ways (Table 3). For each criterion, the total number of responses (the number of participants who included that criterion in their list of the top 11 criteria) were totaled. In addition, a "weighting factor" was obtained for each criterion by summing the numerical rank given by each

Table 3. Results of ranking process for species selection criteria (first workshop)

Criterion	No. of Responses	Overall Weight	Weight as % of total	Priority Rank
Commercial/Recreational demand (necessary criterion)	11	108	12.63	1
Availability of viable spawn	12	104	12.16	2
Juvenile release will increase adult population	11	90	10.53	3
Ease of larval rearing	12	83	9.71	4
Cost-effectiveness	11	64	7.49	5
Ease of juvenile rearing	12	61	7.13	6
Ease of monitoring impact/experimental design	11	58	6.78	7
Extent of recruitment limitation	9	51	5.96	8.5
Likelihood of rapid success	8	51	5.96	8.5
Impact on resident biota	5	29	3.39	10
Low ratio of mortality:growth	4	24	2.81	11
Documented historical decline	4	23	2.69	12
Availability of habitat	5	19	2.22	13.5
Movement patterns (residential vs. migratory)	5	19	2.22	13.5
Socioeconomic attractiveness (profile)	5	14	1.64	15
Inshore seasonal availability (stick around)	2	13	1.52	16
Fishing mortality (fishing pressure)	2	12	1.40	17
Facilities	3	11	1.29	18
Ease of protection until market size	3	8	0.94	19
Local reproduction - degraded/limited habitat	2	4	0.47	20
Availability of food	1	2	0.23	21.5
Ease of transport and distribution	2	2	0.23	21.5
Size at capture	0	1	0.12	25
Non-consumptive uses	0	1	0.12	25
Seasonality/environmental factors	0	1	0.12	25
Mitigation issues (pollution)	0	1	0.12	25
Cost of monitoring effort	0	1	0.12	25
Summary of results by broad categories				
Socioeconomic considerations (necessary)			23.39	1
Biological and culture considerations			29.01	2
Enhancement considerations			25.84	3
Fishery knowledge			9.36	4
Ecological considerations			8.54	5
Release considerations			2.57	6
Infrastructure considerations			1.29	7

participant. Thus, if all 15 panelists had agreed that a single criterion was the most important (a rank of 11), that criterion would have been weighted at 165 (11 x 15) which is the maximum possible. The weighting factors (rather than the number of responses) were used in all subsequent numerical analyses.

As shown in Table 3, two criteria -- "commercial/recreational demand" and "availability of viable spawn" -- received the highest weights (108 and 104, respectively). Of the top five criteria, two fall into the category of biological and culture considerations, and two into socioeconomic considerations. Five of the criteria received no responses (they were not included on any panelists' list of the top 11 criteria). However, since they had been previously agreed upon as acceptable criteria, they were retained for future discussion, and were arbitrarily assigned one response each.

Community survey

As recommended at the first workshop, the next step in the selection process involved a community survey. The purpose of this survey was to generate a species pool and to solicit comments on the species-selection criteria developed at the first workshop.

An initial survey mailing list was generated by Pacific Fisheries Consultants, and the survey was conducted by OI staff. Lists of names and addresses were also solicited from each of the 15 participants in the first workshop. The intent was to involve a broad spectrum of individuals who might be directly or indirectly affected by a stock enhancement program (Table 4).

Table 4. Generalized list of community survey recipients

- Aquatic biologists
- Aquaculturists
- Hawaii state legislators
- Administrators
- Fishery economists
- Representatives of commercial and recreational fishermen
- Ocean industry dealers and distributors
- Officers of private fishing associations
- Media representatives of public fishing interests

Survey questionnaires with stamped return envelopes were mailed to 147 individuals. The results of the criteria ranking process (Table 4) and a summary of the selection criteria (Table 5) were enclosed with the survey questionnaire.

Table 5. Summary of the 27 final species selection criteria

1) **COMMERCIAL / RECREATIONAL DEMAND** - There must be a recognized demand by commercial and/or sports fishing groups for the specific fish. This is a "make or break" criterion (only those fish which satisfy this criterion will be further considered).

2) **EASE OF MATURING AND SPAWNING** - The fish should have the potential to successfully mature and spawn in captivity.

3) **RELEASING JUVENILES SHOULD INCREASE FISH POPULATION** - Releasing juveniles should provide an otherwise unavailable supply of new recruits to the local fish population. (This is often the case when the number of reproducing adults has been sharply reduced by over-fishing.)

4) **EASE OF LARVAL REARING** - Larvae of the fish can be hatched from eggs produced by broodstock, and then raised to juvenile size, using existing culture techniques.

5) **COST-EFFECTIVENESS OF STOCK ENHANCEMENT PROCESS** - The value to society derived from increasing populations of this fish is likely to be great enough to justify the costs involved in raising juveniles for release and distributing them at release sites.

6) **EASE OF JUVENILE REARING** - Large numbers of fry can be reared and maintained in captivity until release.

7) **EASE OF EXPERIMENTAL DESIGN AND MONITORING IMPACT** - The fish should lend itself to release-recapture experiments and to monitoring programs set up to determine effectiveness of attempts to enhance the fish population.

8.5a) **EXTENT OF RECRUITMENT LIMITATION** - Recruitment of juveniles should be a primary limitation on growth of the existing fish population.

8.5b) **LIKELIHOOD OF RAPID SUCCESS** - The fish species should have the potential for a marked increase in fish population size and landings in the near future.

10) **IMPACT ON RESIDENT BIOTA** - Releasing juveniles should not interfere significantly with other sea life currently living in or near release sites.

11) **LOW MORTALITY : GROWTH RATIO** - Mortality rate should compare favorably with growth rate in wild populations (death rate before reaching maturity should be relatively small).

12) **DOCUMENTED DECLINE IN FISH STOCK OR FISH LANDINGS** - There should be fewer of these fish in the ocean now than in past years.

13.5a) **AVAILABILITY OF HABITAT** - Sufficient areas of the fish's preferred habitat should be available in Hawaiian coastal waters to support increased fish populations.

13.5b) **MOVEMENT PATTERNS (RESIDENTIAL VS. MIGRATORY)** - The released fish should remain in Hawaiian waters as adults rather than migrating elsewhere.

15) **SOCIOECONOMIC ATTRACTIVENESS** - Does the fish have a strong appeal to the general public?

16) **INSHORE SEASONAL AVAILABILITY** - The fish should be present in Hawaiian waters year-round rather than only at certain times of the year.

17) **FISHING MORTALITY (CURRENT FISHING PRESSURE)** - If there is currently a great deal of fishing pressure, minimal protective and enforcement measures should be required to insure successful stock enhancement.

18) **FACILITIES** - Hatchery and nursery facilities should be currently available for this fish.

19) **EASE OF PROTECTION UNTIL MARKET SIZE** - It should be possible to protect the released fish from capture until they are large enough for commercial or recreational fishing.

20) **HEARTY ENOUGH TO REPRODUCE IN DEGRADED/LIMITED HABITAT** - The fish should be able to survive in areas of damaged or destroyed habitat.

21.5a) **AVAILABILITY OF FOOD** - Adequate food resources should exist in the wild to support the released fish.

21.5b) **EASE OF TRANSPORT AND DISTRIBUTION** - Juveniles should be relatively easy to transport from the hatchery to release sites.

25a) **COST OF MONITORING EFFECT** - Costs of tagging and recovery should not be excessive.

25b) **SEASONALITY / ENVIRONMENTAL FACTORS** - The fish population should not be strongly affected by changes in the weather or environmental disturbances.

25c) **MITIGATION ISSUES** - Enhancement should not require a reduction in current levels of pollution in order to be successful.

25d) **NON-CONSUMPTIVE USES** - Consider whether this species attracts divers and other observers.

25e) **SIZE AT CAPTURE** - Consider how large these fish have to be in order to be considered large enough to keep.

Survey questions

The community survey contained three questions:

- "Without restricting yourself to fish that satisfy certain of the attached criteria, please identify marine fishes you would like to see replenished or enhanced in Hawaiian coastal waters. List them in order of importance to you. (1 = highest importance)" [Six numbered spaces were provided for the response.]

- "In your opinion, on which marine fish are replenishment efforts likely to be most effective? List in order of highest impact. (1 = highest)" [Three numbered lines provided.]

- "If you have any comments about the attached species selection criteria, please state them below." [Seven blank lines provided.]

Survey results

A total of 87 questionnaires were returned (a 59 percent return rate). From these responses, a preliminary list of 65 types of fish (not all were distinct species) was compiled. An abbreviated version of this list is shown in Table 6.

In response to the first question, three distinct species, moi (Pacific threadfin, *Polydactylus sexfilis*), kumu (goatfish, *Parupeneus porphyreus*) and 'ama'ama (striped mullet, *Mugil cephalus*) received the greatest number of specific responses (Figure 3). However, one broad family of fish, the ulua (jacks, Carangidae), received 33 responses, which was less than kumu but more than

Table 6. Preliminary list of fishes for stock enhancement obtained from community survey

Fish	Habitat	Fish	Habitat
Moi (*Polydactylus sexfilis*)	C	**Blue Marlin** (*Makaira nigricans*)	P
Kumu (*Parupeneus porphyreus*)	C	**Taape** (*Lutjanus kasmira*)	S
Ulua (family Carangidae)	N	**Hapu'upu'u** (*Epinephelus quernus*)	S
'Ama'ama (*Mugil cephalus*)	C	**Awa awa** (*Elops hawaiiensis*)	C
Mahimahi (*Coryphaena hippurus*)	P	**To'au** (*Lutjanus fulvus*)	S
Akule (*Trachiurops crumenophthalus*)	N	**Roi** (*Cephalopholis argus*)	S
Opakapaka (*Pristipomoides microlepis*)	S	**Kala** (*Naso brevirostris*)	C
Opelu (*Decapterus pinnulatus*)	N	**Weke 'ula** (*Mulloidichthys pflugeri*)	C
White Ulua (*Caranx ignobilis*)	N	**Flounders** (general)	C
Omilu (*Caranx melampygus*)	N	**Nabeta** (*Hemipteronotus niveilatus*)	C
Nehu (*Stolephorus purpureus*)	C	**Broom-tailed filefish** (*Pervagor spilosoma*)	C
Uhu (*Scarus* spp.)	C	**Yellow-tailed goatfish** (*Parupuneus chryserydros*)	C
Menpachi (*Myripristis* spp.)	C	**Ehu** (*Etelis coruscans*)	S
Aholehole (*Kuhlia sandvicensis*)	C	**Groupers** (general)	S
Weke (generic - goatfish)	C	**Masked angelfish** (*Genicanthus personatus*)	C
Omaka (*Caranx mate*)	N	**Sharks** (general)	P
Moano (*Parupeneus* spp.)	C	**Black and white butterflyfish** (*Heniochus acuminatus*)	C
White Weke (*Mulloides flavolineatus*)	C	**Kole** (*Ctenochaetus strigosus*)	C
Red Weke (*Mulloides vanicolensis*)	C	**Uhu uli'uli** (*Scarus perspicillatus*)	C
Onaga (*Etelis carbunculus*)	S	**Kaku** (*Sphyraena barracuda*)	N
O'io (*Albula vulpes*)	C	**Mu** (*Monotaxis grandoculis*)	C
Uku (*Aprion virescens*)	S	**Maomao** (*Abudefduf abdominalis*)	C
Aweoweo (*Priacanthus* spp.)	C	**Weke pueo** (*Upeneus arge*)	C
Awa (*Chanos chanos*)	C	**6-banded Ulua** (*Caranx sexfasciatus*)	N
Ono (*Acanthocybium solandri*)	P	**Palani** (*Acanthurus dussumieri*)	C
Aku (*Katsuwonus pelamis*)	P	**Nenue** (*Kyphosus cinerascens*)	C
Ahi (*Thunnus albacares*)	P	**Kamanu** (*Elagatis bipinnulatus*)	N
Snappers (general)	S	**Tilapia** (*Oreochromis niloticus*)	C

Notes: 1) Fish listed in order of total number of responses;
2) Orginal list of 65 fish edited to reduce duplication and inaccuracies;
3) Habitats: C - coastal; N - neritic; S - slope; P - pelagic

striped mullet. Jacks were generally lumped by respondents into a single category, although this name includes several different species. Mahimahi (dolphin-fish, *Coryphaena hippurus*) and akule (*Trachiurops crumenophthalus*) were the next most commonly mentioned species.

Of the top six fishes, moi, kumu, and striped mullet prefer nearshore habitats, ulua and akule are neritic (found in deeper coastal areas), and mahimahi is pelagic (found in open ocean waters; Table 6). Overall, coastal fishes received the greatest number of responses (about 200), followed by neritic fishes (about 100), and slope and pelagic fishes (less than 40 each).

In response to the second question regarding which species were most likely to be effective for stock enhancement, the top five fish were moi, striped mullet, kumu, mahimahi, and ulua (Figure 3).

In response to the third question regarding selection criteria, there were no suggestions that any particular criterion needed modification. In general, the responses reflected either support of the criteria list or suggestions for additional criteria. However, there were no consistent trends in the suggestions that indicated a significant omission in the existing criteria list. The qualitative responses to this question were grouped by subject categories and are presented in Appendix A.

Creating a species pool

The preliminary list of 65 fishes was reduced to 27 through a three-step process. First, the species were graded by planners from the

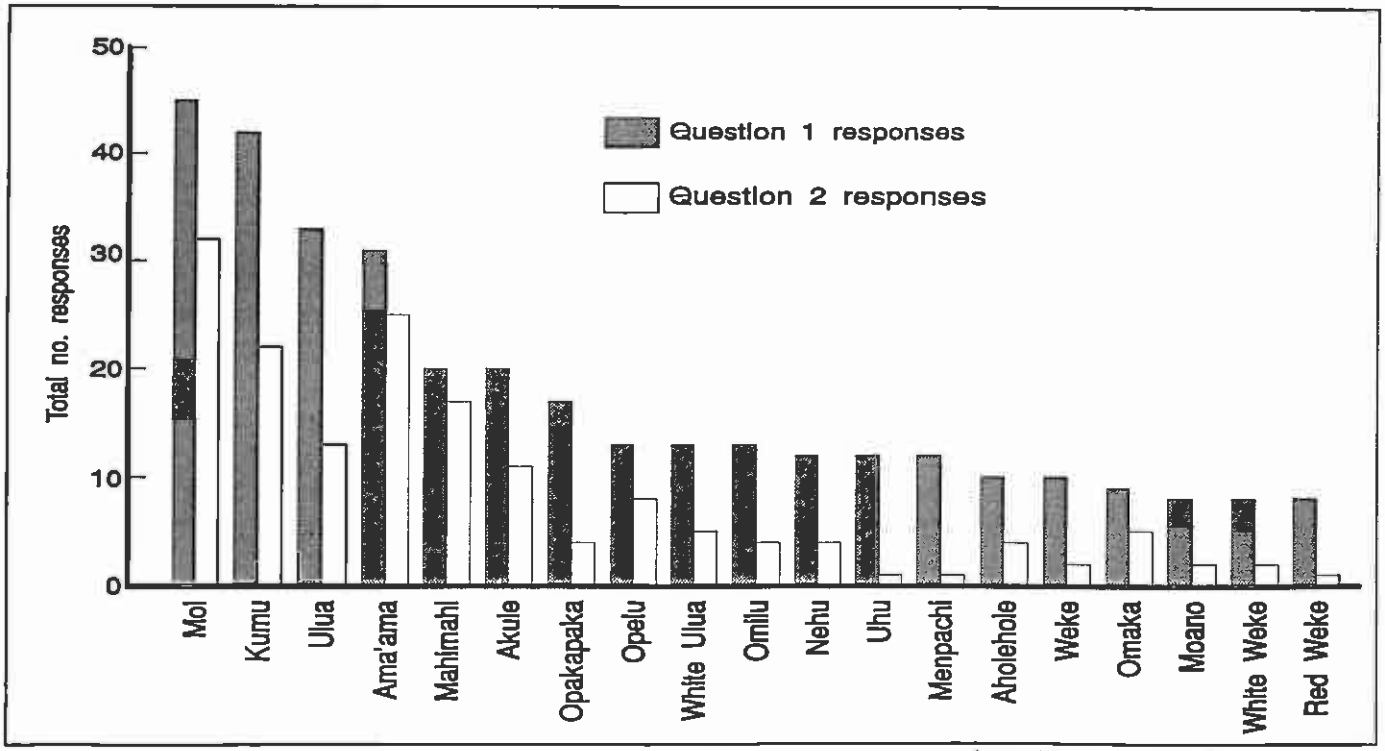

Figure 3. Responses to questions 1 and 2 of community survey (top 19 fishes only).

Hawaii State Department of Land and Natural Resources with respect to commercial and recreational demand. Those receiving grades of 2.0 or below were removed. Second, species that received less than 2 responses in the community survey were cut. Third, a single species (Ehu, *Etelis coruscans*), which received less than 2 responses but was rated excellent in commercial/recreational demand, was returned to the list.

Grading species

Use of expert opinion

To judge how well each of the 27 species satisfied each of the selection criteria, several groups of experts were consulted. They were asked to grade the species for specific criteria, based on their area of expertise. Specialists included representatives of Hawaii Department of Land and Natural Resources, the National Marine Fisheries Service, Hawaii Sea Grant, Hawaii Cooperative Fisheries Research Unit, and The Oceanic Institute (Table 7).

Each species (A through F) was graded according to how well it satisfied 22 of the criteria established during the first workshop (Table 8). The five least important criteria, which received arbitrary weights of "1", were not included in this or subsequent analyses. The letter grades were quantified using the following scale: F = 0, D = 1, C = 2, B = 3, A = 4, and A+ = 4.5.

Table 7. Sources of expert opinion used in grading fish species (for descriptions of criteria, see Table 5)

	Organization					
Criterion	OI	DAR	UH	HIMB	NMFS	Other
1		X				
2	X					
3		X				
4	X					
5	X					
6	X					
7	X	X			X	
8.5a		X				
8.5b	X	X				
10			X			
11		X			X	
12	X					
13.5a			X	X		
13.5b			X			
15	X	X				questionnaire
16	X		X			Bishop Museum
17		X			X	
18	X					
19		X				
20			X		X	
21.5a			X			
21.5b	X				X	
25a	X	X				
25b	X					Steve Kaiser
25c	X					
25d	X	X		X		
25e	X					

Key to Organizations:

OI - The Oceanic Institute (Ken Leber, Chris Kelly, Charles Brownell)

DAR - Hawaii State Dept. of Natural Resources, Division of Aquatic Resources (Director Henry Sakuda and staff at Honolulu Office and Anuenue Laboratory)

UH - University of Hawaii (Richard Brock, James Parrish, Ed Reese)

HIMB - Hawaii Institute of Marine Biology (Ken Holland)

NMFS - National Marine Fisheries Service (Chris Boggs)

Table 8. Species grades for each selection criterion (part 1)

CRITERIA		Moi	'Ama 'ama	Kumu	Red Weke	Moano	White Weke	Ahole-hole	Uhu	Men-pachi	O'io	Aweo-weo	Opelu	Akule
1	Comm./recr. demand	4.5	3.0	4.5	3.0	3.5	3.0	2.5	2.5	3.5	2.5	3.0	3.5	3.5
2	Available spawn	4.5	4.5	2.0	2.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0
3	Will increase no. of adults	3.5	2.0	2.5	2.5	2.5	2.0	2.0	2.5	3.5	2.5	2.5	2.0	2.5
4	Ease of larval rearing	3.0	4.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
5	Cost-effectiveness	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
6	Juvenile rearing	4.5	4.5	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
7	Impact monitoring	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0
8.5a	Recruitment limits	3.5	2.0	2.5	2.0	2.5	2.5	2.0	3.0	3.0	2.0	2.0	1.5	1.5
8.5b	Likelihood of rapid success	3.0	3.5	3.5	3.0	3.0	3.0	3.5	2.0	2.0	2.0	3.0	2.0	2.0
10	Impacts on local biota	3.0	3.5	3.5	4.0	4.0	4.5	4.0	3.5	3.0	3.0	2.0	2.5	2.0
11	Low mortality/ growth rate	2.5	2.5	2.5	2.5	2.5	3.5	2.5	2.0	3.5	2.0	1.5	3.0	3.0
12	Documented decline	4.5	3.0	4.5	4.0	4.0	4.0	2.0	2.5	3.5	4.0	3.5	2.0	3.0
13.5a	Available habitat	3.0	3.0	2.5	4.0	3.5	4.0	3.5	3.0	2.0	2.5	2.0	3.5	3.5
13.5b	Movement patterns	2.0	2.0	2.0	3.0	3.0	3.0	2.5	3.0	3.0	2.0	3.0	2.0	2.0
15	Socioecon. attractiveness	4.0	3.5	4.0	2.0	2.5	2.5	3.0	2.5	3.5	2.0	2.5	3.5	3.5
16	Inshore availability	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0
17	Fishing pressure	3.5	2.5	3.5	2.5	3.5	3.5	2.5	3.5	3.0	2.5	2.5	3.0	3.5
18	Availability of facilities	3.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
19	Ease of protection	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	1.0	4.0	1.0	1.0	4.0
20	Habitat for reproduction	2.0	3.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
21.5a	Availability of food	2.5	4.5	1.5	2.5	2.0	2.5	4.0	4.0	3.0	2.5	3.0	3.0	3.0
21.5b	Ease transp. & distribution	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.0	2.0

Table 8. Species grades for each selection criterion (part 2)

CRITERIA		White Ulua	Omaka	Omilu	Hapuu-puu	Uku	Opaka-paka	Ehu	Onaga	Taape	Mahi-mahi	Aku	Ono	Ahi	Blue Marlin
1	Comm./recr. demand	4.0	3.0	4.5	3.5	3.5	4.5	4.0	4.0	2.5	4.0	4.0	4.0	4.0	4.0
2	Available spawn	2.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	4.0	3.0	2.0	2.0	2.0
3	Will increase no. of adults	3.5	2.5	3.0	2.0	2.0	2.5	2.5	2.0	1.5	1.0	1.0	1.0	1.0	1.5
4	Ease of larval rearing	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.5	3.0	1.5	2.0	2.0	2.0
5	Cost-effectiveness	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
6	Juvenile rearing	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0
7	Impact monitoring	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0
8.5a	Recruitment limits	3.0	2.5	2.5	2.0	2.0	2.5	2.5	2.0	1.0	1.0	1.0	1.0	1.0	1.5
8.5b	Likelihood of rapid success	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0
10	Impacts on local biota	0.5	2.0	1.0	1.5	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0
11	Low mortality/ growth rate	3.0	3.0	3.0	1.0	3.0	3.0	3.5	1.0	2.5	2.5	2.0	1.0	1.0	1.0
12	Documented decline	3.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	3.0	1.0	1.0	2.0
13.5a	Available habitat	3.0	2.0	3.0	3.0	3.5	3.0	3.5	3.5	2.5	4.0	4.0	4.0	4.0	4.0
13.5b	Movement patterns	1.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0
15	Socioecon. attractiveness	4.0	3.0	4.0	3.0	3.5	4.0	3.5	4.0	2.0	4.0	4.0	4.0	4.0	4.0
16	Inshore availability	4.0	4.0	4.0	4.0	3.0	4.0	4.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0
17	Fishing pressure	3.5	2.5	3.0	3.0	3.5	3.5	3.5	2.5	2.5	2.5	1.5	2.0	2.5	2.0
18	Availability of facilities	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
19	Ease of protection	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0	1.0	1.0
20	Habitat for reproduction	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0
21.5a	Availability of food	1.0	3.0	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.5	1.5	1.5	1.5	1.5
21.5b	Ease transp. & distribution	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	3.0	2.0	1.0	1.0	1.0	1.0

Where insufficient information was available to grade a species with regard to a particular criterion, that species was arbitrarily assigned a grade of "C" for that criterion. For example, a "C" (2.0) grade was given to all species for criterion 5 ("cost effectiveness of the stock enhancement process"), since no detailed cost-effectiveness studies had been performed. This grading process was somewhat subjective; however, it did provide a semi-quantitative approach to prioritizing species and reduced the effect of individual bias on the results.

Numerical analysis

Following the grading process, species were "scored" with respect to each criterion. Scores for each species and criterion were calculated by multiplying the numerical grade (assigned by the experts) by the criterion weight (established during the first workshop). For example, moi received a grade of 4.5 with respect to commercial/ recreational demand, and this criterion was weighted at 108. Thus, moi scored 486 (4.5 x 108) for this criterion (Table 9).

For each species, the scores for all 22 criteria were totaled to calculate its overall ranking. A theoretical "excellent" score (3272) was calculated by multiplying each of the 22 criterion weights by the "A" grade of 4.0, then summing these values (for criterion 5, only "C" grades were given, so for all species the criterion weight of 64 was multiplied by the arbitrary grade of 2.0). A percentage score was calculated for each species by dividing the overall score for that species by the theoretical excellent score. For example, moi had an overall score of 3005.5; this yielded a percentage score of 91.9% (3005.5÷3272).

Numerical analysis results

Moi, striped mullet, and kumu were the three top-ranked fishes based on the numerical analysis described above. Relative to the theoretical "excellent" score of 3272, these species rated 91.9 percent, 84.5 percent, and 74.8 percent, respectively (see Table 9 and Figure 4). The remaining species among the top 11 received scores between 66 and 70.5 percent. There were clear breaks in the percentage scores between striped mullet and kumu, and between the bulk of the species and those receiving the four lowest scores: aku, *Katsuwonus pelamis*; ono, *Acanthocybium solandri*; ahi, *Thunnus albacares*; and blue marlin, *Makaira nigricans*, which received scores near 50 percent.

Table 9. Species scores based on species grades and selection criteria weightings (part 1)

CRITERIA		"A" score	Moi	'Ama 'ama	Kumu	Red Weke	Moano	White Weke	Ahole-hole	Uhu	Men-pachi	O'io	Aweo-weo	Opelu	Akule
1	Comm./recr. demand	432	486	324	486	324	378	324	270	270	378	270	324	378	378
2	Available spawn	416	468	468	208	208	208	208	312	208	208.	208	208.	208	208
3	Will increase no. of adults	360	315	180	225	225	225	180	180	225	315	225	225	180	225
4	Ease of larval rearing	332	249	373.5	166	166	166	166	166	166	166	166.	166	166	166.
5	Cost-effectiveness	128	128	128	128	128	128	128	128	128	128	128	128	128	128
6	Juvenile rearing	244	274.5	274.5	183	122	122	122	122	122	122	122	122	122	122
7	Impact monitoring	232	174	174	174	174	174	174	174	174	174	174	174	116	174
8.5a	Recruitment limits	204	178.5	102	127.5	102	127.5	127.5	102	153	153	102	102	76.5	76.5
8.5b	Likelihood of rapid success	204	153	178.5	178.5	153	153	153	178.5	102	102	102	153	102	102
10	Impacts on local biota	116	87	101.5	101.5	116	116	130.5	116	101.5	87	87	58	72.5	58
11	Low mortality/ growth rate	96	60	60	60	60	60	84	60	48	84	48	36	72	72
12	Documented decline	92	103	69	103.5	92	92	92	46	57.5	80.5	92	80.5	46	69
13.5a	Available habitat	76	57	57	47.5	76	66.5	76	66.5	57	38	47.5	38	66.5	66.5
13.5b	Movement patterns	76	38	38	38	57	57	57	47	57	57	38	57	38	38
15	Socioecon. attractiveness	56	56	49	56	28	35	35	42	35	49	28	35	49	49
16	Inshore availability	52	52	52	52	52	52	52	52	52	52	52	52	39	39
17	Fishing pressure	48	42	30	42	30	42	42	30	42	36	30	30	36	42
18	Availability of facilities	44	33	44	22	22	22	22	22	22	22	22	22	22	22
19	Ease of protection	32	32	32	32	32	32	32	32	32	8	32	8	8	32
20	Habitat for reproduction	16	8	14	8	8	8	8	8	8	8	8	8	8	8
21.5a	Availability of food	8	5	9	3	5	4	5	8	8	6	5	6	6	6
21.5b	Ease transp. & distribution	8	6	6	6	6	6	6	6	6	6	6	6	2	4
Overall Total		3272	3005.5	2764.0	2447.5	2186	2274	2224	2168.5	2074	2279.5	1992.5	2038.5	1941.5	2085
% of "A" score		100	91.9	84.5	74.8	66.8	69.5	68.0	66.3	63.4	69.7	60.9	62.3	59.3	63.7
Overall Rank			1	2	3	10	6	8	11	15	5	19	16	22	14

Table 9. Species scores based on species grades and selection criteria weightings (part 2)

CRITERIA		White Ulua	Omaka	Omilu	Hapuu-puu	Uku	Opaka-paka	Ehu	Onaga	Taape	Mahi-mahi	Aku	Ono	Ahi	Blue Marlin
1	Comm./recr. demand	432	324	486	378	378	486	432	432	270	432	432	432	432	432
2	Available spawn	208	312	208	208	208	208	208	208	416	416	312	208	208	208
3	Will increase no. of adults	315	225	270	180	180	225	225	180	135	90	90	90	90	135
4	Ease of larval rearing	166	166	166	166	166	166	166	166	207.5	249	124.5	166	166	166
5	Cost-effectiveness	128	128	128	128	128	128	128	128	128	128	128	128	128	128
6	Juvenile rearing	122	122	122	122	122	122	122	122	122	183	122	122	122	122
7	Impact monitoring	174	174	174	174	174	174	174	174	116	116	116	116	116	116
8.5a	Recruitment limits	153	127.5	127.5	102	102	127.5	127.5	102	51	51	51	51	51	76.5
8.5b	Likelihood of rapid success	153	102	102	102	102	102	102	102	102	0	0	0	0	0
10	Impacts on local biota	14.5	58	29	43.5	58	58	58	58	29	29	29	29	29	29
11	Low mortality/ growth rate	72	72	72	24	72	72	84	24	60	60	48	24	24	24
12	Documented decline	69	69	69	46	46	46	46	46	46	23	69	23	23	46
13.5a	Available habitat	57	38	57	57	66.5	57	66.5	66.5	47.5	76	76	76	76	76
13.5b	Movement patterns	19	38	38	19	19	19	19	19	19	0	0	0	0	0
15	Socioecon. attractiveness	56	42	56	42	49	56	49	56	28	56	56	56	56	56
16	Inshore availability	52	52	52	52	39	52	52	52	52	0	0	0	0	0
17	Fishing pressure	42	30	36	36	42	42	42	30	30	30	18	24	30	24
18	Availability of facilities	22	22	22	22	22	22	22	22	22	22	22	22	22	22
19	Ease of protection	32	32	32	32	32	32	32	32	8	8	8	8	8	8
20	Habitat for reproduction	8	8	8	8	8	8	8	8	8	0	0	0	0	0
21.5a	Availability of food	2	6	1	1	1	1	1	1	2	3	3	3	3	3
21.5b	Ease transp. & distribution	4	4	4	2	2	2	2	2	6	4	2	2	2	2
Overall Total		2300.5	2151.5	2259.5	1944.5	2016.5	2205.5	2166	2030.5	1905	1976	1706.5	1580	1586	1673.5
% of "A" score		70.3	65.8	69.1	59.4	61.6	67.4	66.2	62.1	58.2	60.4	52.2	48.3	48.5	51.1
Overall Rank		4	13	7	21	18	9	12	17	23	20	24	27	26	25

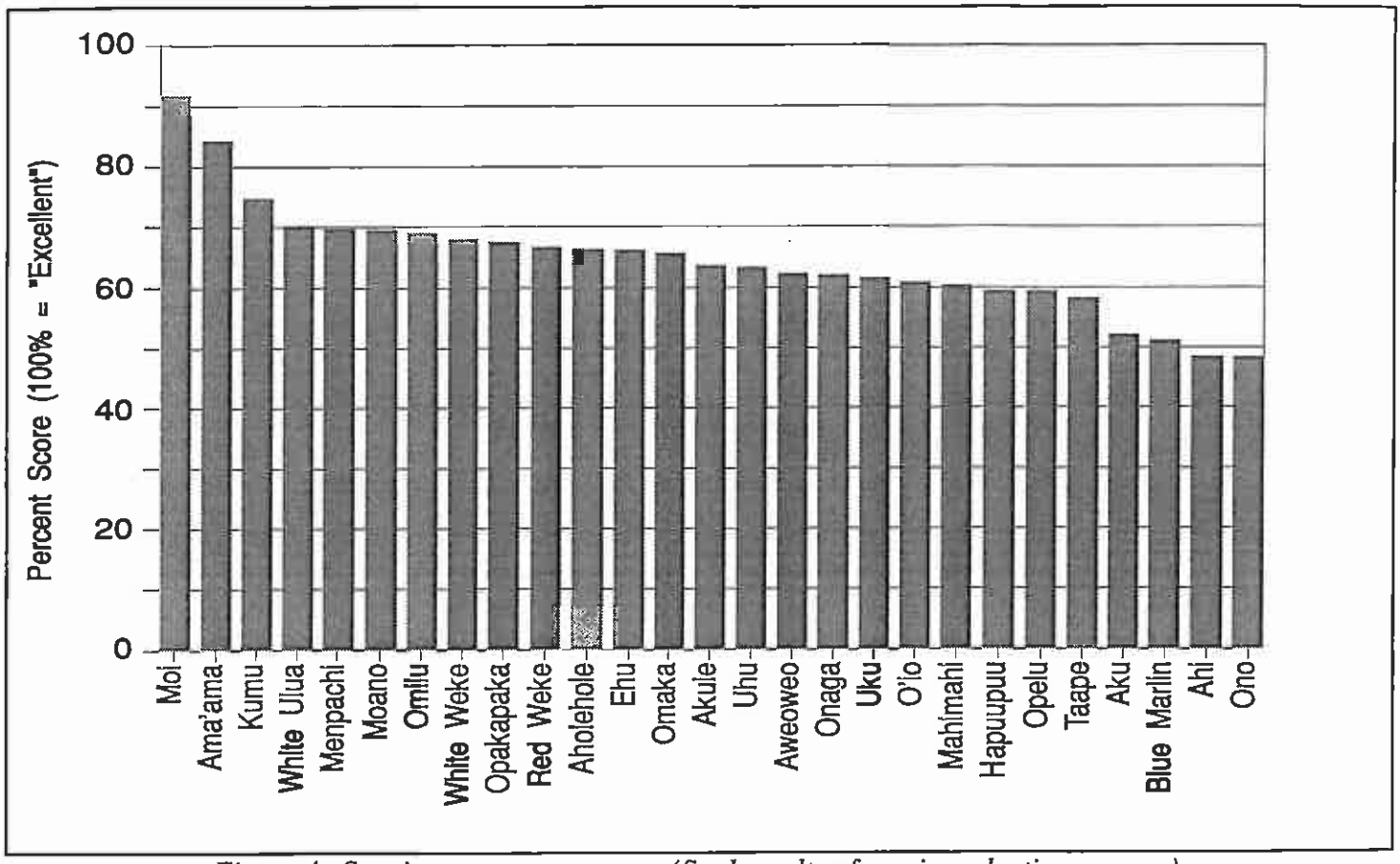

Figure 4. Species percentage scores (final results of species selection process).

Table 10. Organizations and individuals participating in the second species selection workshop

Panelists

U.S. National Marine Fisheries Service (NMFS) - Honolulu Laboratory
Sam Pooley Ph.D.: (Fisheries Economist)
Steve Ralston, Ph.D.: (Fisheries Biologist)

NMFS Western Pacific Regional Fishery Management Council
Paul Gates: (Biologist)

U.S. Fish and Wildlife Service
Hawaii Cooperative Fisheries Research Unit (HCFRU)
James Parrish, Ph.D.: Director

Hawaii State Dept. of Land and Natural Resources (DLNR)
Division of Aquatic Resources (DAR)
Alvin Katekaru: Program Manager

Hawaii State House of Representatives
Peter Apo: State Representative

University of Hawaii - Dept. of Oceanography
Richard Grigg, Ph.D.: Professor

The Oceanic Institute
Paul Bienfang, PhD.: Vice President
Cheng-Sheng Lee, Ph.D.: Program Manager
Kenneth M. Leber, Ph.D.: Program Manager

Tamashiro Market
Guy Tamashiro: Vice President

Star Market
Garrett Kitazaki: Fish Buyer

Sea Life Park
Steve Kaiser: Curator (also: Commercial Fisherman)

Malama Na I'a
Gene Witham: Vice President (also: Senior Resident Agent, NMFS)

United Fishing Agency
Brooks Takenaka: Manager

Independent commercial fisherman
Henry W. Pelekai

Observers

United Fishing Agency
Frank Goto

Pacific Fisheries Consultants
Robert Iversen

The Oceanic Institute
Robert F. Breeding: Technician
Linda A. Koch: Technician
Doreen M. Kealohanui: Secretary

Facilitator:
Jane Yamashiro (University of Hawaii)

Second Workshop (June 14, 1988)

Following the grading and scoring of species, a second workshop was held to seek consensus on the outcome of the species prioritization process. This workshop involved 16 panel members, five observers, and the trained facilitator, Jane Yamashiro (Table 10). Of the 16 panel members, six had also attended the first workshop.

The workshop, lasting three hours, was conducted at the Hawaii State Capitol Building in Honolulu. The objective of the workshop was to seek consensus on the species prioritization process, the criteria, and the results. A written summary of the species ranking process and results, along with supporting documents and data, were presented to each panel member.

After a brief introduction of the panel members, an overview of the species prioritization process was presented. The facilitator solicited questions and comments and clarified the project objectives and protocols.

Subsequent discussions focused on four areas:

- The species selection criteria
- The species prioritization process
- The results of the species prioritization process (the species rankings)
- The process of achieving consensus on the results

Discussion of the criteria

Panel members were asked first to focus their comments on the species selection criteria and the process by which these criteria were developed. Panel discussions began with questions regarding the relative importance of commercial versus recreational value in grading species for criteria one. In particular, the panelists noted that all the top ranked species were high in recreational rather than commercial value.

Most panelists agreed that, rather than specifying that a species must satisfy either one or the other value, the project should try to concentrate its efforts on the best fish from each category (commercial and recreational). Several panel members recommended that although stock enhancement efforts might initially focus on replenishing recreational species, it would be desirable eventually to target more commercially important species.

There were no recommendations for modifications, deletions, or additions to the list of criteria developed at the previous workshop. After lengthy discussions regarding the issue of commercial versus recreational value, the focus shifted to other criteria. Certain panel members showed strong support for incorporating criterion 5, "cost effectiveness," into the process. As one panelist put it, "...return on investment is the most important criterion to the legislature."

There was much discussion regarding the importance of species culture capability. Panel members were divided on this issue. Some representatives of government agencies felt the ability to culture the selected species should be a primary concern. Other participants felt that an additional species priority list should be generated without the criteria relating to culture capability.

A consensus emerged that more than one species should be chosen... for stock enhancement research.

Discussion of the ranking process

Some panel members proposed a multi-species approach to stock enhancement research, enabling a popular, "high-profile" species to be included in a future hatchery-release program. The point was raised that other states with marine stock enhancement programs had concentrated on high-profile species and became bogged down in culture research. Because these species could not be mass cultured, these states were not able to initiate field research on release and monitoring protocols. In the ensuing discussion, a consensus emerged that more than one species should be chosen from the species priority list for stock enhancement.

One panel member noted that the top three species were all nearshore fish and suggested that fish from other habitats might be chosen for later research if nearshore species produce negative results. Another participant felt that, although the selection process was elegant, it combined so many criteria that it could potentially mask important criteria or species that stand on their own merits. This panel member cautioned against getting locked into this selection process per se, advising the program to consider other methods of

Comments from participants in the second workshop regarding the use of moi and mullet in stockenhancement:

"The whole process has come up with moi, which is clearly a great fish."

"[There is] no problem with nearshore species like moi because: it has the number one position in the ranking; you could have more control over it through legislation like marine sanctuaries; it has high recreational appeal; if it were more abundant, it could have high commercial appeal as well; also you can monitor their habitats."

"My feeling is why wait until fish like ahi and mahi (etc.) are depleted before starting to replenish fish offshore? But getting mullet and moi going is a good step; moi is number one! You can't sell it or fish it because it's expensive and rare...We like moi, that's why there aren't many left. Right now its recreation and commercial potential is zero. It's a very good fish, very easy to catch. When I was young, my parents would take me down every season to catch moi and it was a lot of fun. Nowadays you don't have that and a lot of folks are disturbed...Maybe you have a point that we're not looking at it very objectively — where you're starting, with these [depleted] *species, might be the answer to get the program going; then eventually you could go into these other* [more commercially desirable] *species like nehu, akule, and opelu."*

"Another good thing about moi is that we already have protection on the books."

"You can't catch mullet with a pole and line unless you're an expert; moi and moi-lii [juvenile moi], *yes, but to catch mullet, you need nets. So what are we doing stocking mullet? It's hard to beat moi. From the commercial side, mullet are already imported and are cheap. So work with moi, ulua, papio. Besides, mullet habitats are all gone now...Keehi Lagoon, Kaneohe Bay, Pearl Harbor."*

"Moi is ranked number one, but it looks like you're starting with mullet here. What if you get nowhere with mullet?"

"...mullet is ranked number two solely because of its excellent culture potential." [Note: this is not the case; if mullet is scored an entire grade lower for every culture-related criterion, its overall score remains two percentage points greater than the fish ranked number three.]

"...the perception here is that work towards moi shouldn't suffer because of work going towards mullet."

selecting fish for later phases of a multi-species program.

Discussion of species ranking results

This panel discussion focused largely on the two top-ranked species, moi and striped mullet. The discussion included many positive responses to the concept of restocking moi (see sidebar). However, there was much less sympathy among the panel for mullet, perhaps due to a perception that relatively little commercial or recreational demand existed for this species.

Participants in the panel discussion suggested that it would be least risky to start stock enhancement efforts with species like moi and mullet, which scored high in the ranking process. The technology developed for moi and mullet could then be applied to other species.

Following this discussion, OI staff explained the rationale behind beginning stock enhancement field research using striped mullet. They argued that moi could not yet be mass cultured throughout the entire life cycle, and that large numbers of juveniles would be necessary for field research. They reminded the panel of the point raised earlier regarding other marine stocking programs, which were not able to pursue field research because of inadequate culture techniques. They also pointed out that mullet was the only species within the upper half of the rankings for which reliable mass culture techniques were available.

In this context, the selection of mullet was seen as a necessity to get the field research component going. Specifically, mullet

would be needed to develop the release and recapture protocols. Such standardized procedures would have to be developed before the marine stock enhancement concept as a whole could be tested.

Finally, OI staff emphasized that their plans did not call for "...sacrificing research on moi to work with mullet." Rather, they planned to push hard with research on moi culture and field studies using mullet.

Miscellaneous issues

Several key points were raised regarding the results of the species prioritization process. These included: 1) the importance of looking at other issues, such as habitat requirements; 2) the need to protect released fish from fishing pressure, including enforcement of fishing regulations; and 3) public education to promote self-enforcement of regulations. It was suggested that stock enhancement could be viewed as a possible tool for future fisheries management in Hawaii. The big question is: will it work? The consensus was that reasonable approaches with significant potential benefits should be investigated.

Discussion of consensus regarding results

Following this extensive discussion, the facilitator asked the panel whether they agreed with the results of the species prioritization process. See sidebar at right for panelists' comments. Closing comments were made and the workshop was adjourned.

Comments from participants in second workshop regarding the overall stock enhancement process:

"I don't think we need to feel that everything is settled today...it's good to come up with these one or two fish now, maybe three, but somewhere down the line the commercial guys ought to be part of the game."

"I don't think we can reach consensus that species for stock enhancement in Hawaii is settled and over and done with, because there are going to be new species coming on line in the future. Mahi is an example, and the strategy of stocking salt water ponds should be considered."

"I think that there's a consensus that we ought to start with something."

"If we don't start, we won't get over the hill."

"I'm impressed with some of the points made here; let's do what's doable, and let's do fish we can catch."

"Let's assume that, say, further on we'll get a higher profile fish that we can culture, but we're going to start with mullet, which may be habitat limited...but when we get there, what's the long term objective?

"The object here is to develop technology for stock enhancement. If it works, there's a new opportunity for the state to consider."

"Instead of even trying to get consensus on these rankings, which I'm not opposed to saying we have, just view this as input, ...you've got input on what's right with some, what's wrong with others. You're going to go ahead and work on what you can work on. If things don't work out, you've got input on what to choose next. That might be a different way of viewing it."

"Just say that no one dissented."

Discussion

The selection process

The need to prioritize species for research through a formal decision-making process was evident at the outset of the Stock Enhancement Program. What began as two workshops with a small panel of experts evolved into a more extensive process, incorporating the input of a broad selection of affected individuals and user groups. This cooperative approach ensured that all perspectives were heard, and it produced a strong consensus on the species prioritization process. Incorporating input from various experts during this early phase of the SEMFISH program prompted ongoing collaboration and interaction between several of the involved groups and OI.

The grading system developed by OI researchers helped quantify responses and focus the panelists on developing and ranking the species selection criteria as the initial step in the overall process. The grading system discouraged discussion of particular species at this early stage in the selection process. Although the grading process was somewhat subjective, it did reduce the effect of individual bias on the results. The presence of a trained facilitator was critical to steering the discussions, thus ensuring that the process was as productive as possible.

Strong endorsement of the criteria and ranking results by panelists at the second workshop confirmed the success of the quantitative approach. However, certain important criteria, such as habitat availability, can become obscured by a relatively low ranking. Thus, users of the quantitative approach are cautioned against total reliance on the numerical results.

The objective of the second workshop was to seek consensus on the species prioritization process, the criteria, and the results. The process and criteria were strongly endorsed, and most of the discussion then centered on the species ranking results. Once particular species were identified, individual agendas became apparent, obscuring the focus of the discussion. The success of a formalized decision-making process appears to depend on maintaining an objective approach as long as possible.

An important outcome of the second workshop was the recognition of political issues as possible determining factors in the selection of species for stock enhancement. For example, one panelist observed that demonstration of the cost-effectiveness of a stock enhancement program is imperative for successful marketing to legislators, and must be incorporated into the project design.

The results

Despite extensive debate, several questions remain about the relative importance of commercial and recreational demand, and their combination as one criterion for the purpose of this ranking process. These questions should be considered prior to conducting a full-scale stock enhancement program, although the resolution of these questions was beyond the scope of this study.

The species ranking results reflect the higher scores given to inshore omnivores and mid-level predators with fairly restricted habitat requirements. As expected, pelagic

predators emerged as a low priority for stock enhancement efforts. Species falling into this category have not been over-fished to the same extent as nearshore species. Also, pelagic predators are high in the food chain and therefore exert a significant impact on prey species. Furthermore, there is insufficient information on the dispersal patterns of pelagic species.

Panelists' strong support of personal favorites had no basis in the formalized rankings of species and criteria. Discussion of the relative merits of moi and mullet, the two top-ranked ranked species, at the second workshop revealed that most panelists favored moi as the target species for stock enhancement research, despite the fact that considerable funds would be needed to develop aquaculture techniques before test releases could begin. The perception existed that because mullet had less recreational appeal, its use for stock enhancement research would only be a result of aquacultural considerations. In fact, mullet was ranked second based on the full range of criteria established in the first workshop. In comparison, given the same grades that mullet received for the culture criteria, none of the pelagic species would have received an overall score as high as that for mullet.

Panelists' strong support of personal favorites had no basis in the formalized rankings of species and criteria.

Conclusion

This semi-quantitative decision-making process was successful in focusing discussions, stimulating questions, and quantifying the participants' responses during the species selection process. The inclusion of many different criteria necessitated a quantitative approach to the first stage, but feedback from the second workshop discouraged a rigid reliance solely on the rankings. The species prioritization process demonstrated the value of formal decision-making and its potential for application to other natural resource management issues.

Epilogue

Subsequent research to develop and test a marine stock enhancement capability in Hawaii has concentrated on striped mullet and moi, the two top-priority species identified in the selection process. As a follow-up to the workshop, OI researchers examined fry production potential for moi, striped mullet, and kumu, the third-ranked species. Moi and mullet showed good mass culture potential, but culture trials with kumu produced poor results. Because the mass culture technology existed for striped mullet, OI researchers decided to use this species as the initial species for stock enhancement pilot releases, while research continued on moi culture. To date, many of the bottlenecks to mass culture of moi have been resolved.

The Stock Enhancement Program has demonstrated that full-scale marine stock enhancement can be used as a mechanism for replenishing depleted mullet populations.

Because mullet is at the base of the fish food web, replenishing this species also allows natural predator communities to rebuild. The program is beginning to adapt the stock enhancement technology developed for mullet to moi. Unlike mullet, moi is a nearshore carnivore and is not closely tied to freshwater nursery habitats. Thus the stock enhancement technology developed for mullet can be applied to species occupying fundamentally different ecological niches.

Tagging technology

Tagging technology provides the basis for quantitatively assessing the success of a marine stock enhancement program. OI researchers have collaborated with biologists at the Washington Department of Fisheries (WDF) and Northwest Marine Technology, Inc. (NMT) to develop tags for striped mullet and moi. The internal coded wire tag, originally developed for salmonids (Isaksson and Bergman, 1978), has been successfully adapted to both mullet and moi. Tags are implanted in the snout area using an automatic injector with head molds designed specifically for each species. All mullet and moi fingerlings are tagged prior to release. Tag retention rates have been very high, averaging at least 97 percent for mullet and at least 95 percent for moi.

A visible implant tag is being developed for both mullet and moi as an external indicator of the internal coded wire tag. The visible implant tag will enable fishermen to identify adult hatchery fish, which will increase sample sizes. A fluorescent, orange-colored elastomer implanted in the peri-ocular tissue of mullet and moi shows the greatest potential to date.

Developing release strategies

The Stock Enhancement Program has taken a systematic approach to developing optimal release strategies, through a series of pilot release experiments and a rigorous test of the marine stock enhancement concept. The first pilot release of hatchery-raised striped mullet was conducted during SEMFISH Phase II in July, 1989. About 10,000 striped mullet fingerlings were released into Maunalua Bay, Oahu. Despite the small scale of the release, ten months of sampling showed a 1.7 percent impact of cultured mullet on the wild population in the bay.

In SEMFISH Phase III, intermediate-scale releases of hatchery-raised, tagged juvenile striped mullet in Maunalua Bay and Kaneohe Bay, Oahu demonstrated the importance of release habitat in determining fingerling survival. Kaneohe Bay, which has more freshwater input, was found to be a more suitable nursery site for mullet fingerlings. Phase III releases also showed that fish size-at-release is a critical variable in determining the survival rate of released fingerlings. Fish smaller than 70 mm total length made little or no contribution to wild populations. However, as part of a joint experiment with the Hawaii Division of Aquatic Resources (DAR), a similar release of hatchery-raised striped mullet was conducted in Hilo Bay, Hawaii, and size-at-release was found to have less effect on recapture rates. This suggests that size-at-release and release habitat have an interactive effect on fingerling survival.

SEMFISH Phase IV began in 1991. Its principle aim was to evaluate the interactive effects of release season and fish size-at-release on recruitment rates of cultured

striped mullet. Researchers discovered that release season, which controlled size-at-release impact, directly affected recruitment of hatchery-raised fingerlings. Greatest survival of the smallest fish occurred following spring releases, coinciding with peak recruitment of wild juveniles. In contrast, higher numbers of larger fish survived following summer releases.

Results of SEMFISH pilot releases emphasize the importance of conducting such pilot tests before initiating a full-scale stock enhancement program so that optimal, site-specific release strategies can be determined.

Evaluating stock enhancement

The completion of Phase IV research marked a milestone in the identification of optimal release protocols for a test of the marine stock enhancement concept. Phases V and VI, the test of the concept and its evaluation, are underway. The results to date indicate that hatchery-raised fish from two years of releases comprise 65 to 80 percent of the striped mullet in net samples from the primary nursery habitat in Kaneohe Bay.

Tagged, hatchery-raised fish released in Kaneohe Bay in 1990 and 1991 are now being recaptured by mullet fishermen. This demonstrates that released fish are surviving to adulthood and contributing to wild mullet populations.

OI researchers are also collaborating with the Hawaii Division of Aquatic Resources (DAR) to conduct a prototype demonstration of marine stock enhancement in Hawaii, and to transfer the newly developed SEMFISH technology to the State of Hawaii for eventual full-scale implementation. The prototype demonstration is being conducted in Waiakea Public Fishing Area (PFA) in Hilo Bay. Hatchery-raised fish released in 1990 and 1991 have already made a large contribution to the recreational fishery in the PFA -- one-sixth of the striped mullet caught in this fishery during 1992 and 1993 were of hatchery origin. This confirms the potential to restore depleted fisheries through releases of cultured fingerlings.

Tagged, hatchery-raised fish released into Kaneohe Bay in 1990 and 1991 are now being recaptured by mullet fishermen.

The success of OI's Stock Enhancement Program has received wide exposure. Invitations have been extended to SEMFISH researchers to describe the Hawaiian stock enhancement example, and to organize three symposia on marine stock enhancement at international meetings in Puerto Rico, Spain, and the mainland USA. Local media attention has also highlighted the program's successes.

The Stock Enhancement Program is now shifting its focus to moi, the top priority species for enhancement in Hawaii. This shift to moi will determine whether marine stock enhancement, successfully developed for striped mullet, can be achieved with an inshore fish occupying a niche not so closely tied to stream systems. The development of a stock enhancement capability for moi has progressed ahead of schedule. In 1993, the Stock Enhancement Program tagged and released approximately 20,000 juvenile moi

into prime surf-zone nursery habitats along the northeastern coast of Oahu. All released moi were marked with a visible implant elastomer behind the left eye, in addition to an internal coded wire tag. Pilot releases will continue in 1994 to examine the effects of size at release and habitat on the survival of released fingerlings.

SEMFISH research has illustrated the positive impact of hatchery releases on wild populations of striped mullet in Hawaii. The hatchery releases of moi are also expected to have a positive impact. Expanding the technology developed at The Oceanic Institute to marine species occupying different ecological niches will demonstrate the potential of marine stock enhancement as a third fisheries management tool, to be used in concert with habitat protection and fishery regulations.

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Appendix A: Community survey comments on species selection criteria

Culturing and rearing

- Success in culturing these species is not known and it will have to be tried.
- Feasibility of the hatchery approach is the critical consideration. You should focus on the species which are most feasible, then select those that also have recreational or commercial demand.
- It is nearly impossible to predict how easy some species will be to rear in captivity.

Species-specific responses

- Akule is an important species, but may be too difficult to spawn; however, ulua might work.
- Good commercial/recreational species for a cost-effective program include opelu and akule, though rearing could be expensive due to pelagic requirements of the larvae. They would provide increased landings and forage for other species.
- Top carnivores are not feasible due to feeding costs.
- Goatfishes serve two purposes: food demand and baitfish (for ulua).
- A good candidate is the giant trevally because it grows very fast.
- Taape that dwell in most of our good fishing areas are creating havoc by devouring the fingerlings in those areas. Their reproductive rate is also much higher than other species.
- Mahimahi restocking studies have begun at the Waikiki Aquarium.
- Mullet and aholehole would be most effective to replenish for two reasons: part of the life cycle is spent in an estuary so they adapt to various salinities and temperatures, and the technology for rearing is known.
- Important species for recreational interests include aku, ahi, akule, and opelu. These species also have a very high fecundity, and are fast-growing.
- Much work has already been done on the reproduction of mahimahi and blue marlin. Any new work could build on this research.
- Moi is never seen in markets any more.

- Perhaps you should consider introducing an exotic species such as red drum which has been used in experiments on the Gulf Coast. Its red color would make it popular here and perhaps it would remove some of the fishing pressures on other species.
- Habitat enhancement is needed.
- Fishery Aggregation Devices (FAD's) or artificial reefs are needed to focus attention on site-specific enhancement projects. These would lead to a proliferation of a variety of species.
- Regarding the availability of habitat, are target species enhanced by artificial reefs, substrates, etc.?
- Can this program be organized around ecosystems rather than individual species?
- More artificial reefs are needed.

Habitat concerns

- Habitat restoration is the key to any effort. If the habitat is available, replenishment should occur naturally. Actual stocking needs to be carefully planned.
- Thorough assessments need to be done before stocking to ensure that food, habitat and water requirements are met.
- Current fish populations have been affected by fishing pressure and changed environmental conditions.
- More emphasis on ecological considerations is necessary (e.g.. impact on resident biota, availability of habitat, likelihood of rapid success).
- It is crucial to determine the causes of the decline and to determine if stocking is the appropriate strategy for stock enhancement. Other strategies include habitat restoration and more restrictive fishery regulations.
- Important aspects include habitat improvement, restriction of gill netting, and restriction of exotic species introductions.

Species life history

- The critical aspect of a successful hatchery-and-release program is the complete understanding of the species' early life history.
- More research is needed on the life history of pelagic and deep-water fishes.

Demand

- I disagree that #1 is a make or break issue. It is more important to satisfy #2 and especially #3. Reducing fishing pressure would result in more reproducing adults.
- More weight should be given to shoreline recreational fisheries demand over nearshore or commercial demand.
- Fishing pressure and recruitment limitation
- Reversing the decline of our coastal resources will come by limiting commercial fishing and outlawing all nets.
- Fishing efforts need to be reduced. Restrictions are needed to prohibit gill netting by "recreational" fishermen, especially in estuaries and at night.
- Over-fishing has seriously depleted stocks.
- More restrictions are needed to control fishing.

Regulations

- Stricter regulations!
- All the above stocks are declining. We need effective enforcement efforts by state officials to protect fisheries and minimize over-fishing.
- Forage for other species
- Releasing species that are lower in the food chain will have a positive impact on those higher- up in the chain.
- Increasing the food supply for larger fishes is important.

Specific criteria

- Priority #3 should be ranked #1; also, #13.5a, #13.5b and #21.5a would be paramount.
- Criteria look good.
- #3 and #8.5 are the same and are as critical as #1. It is very important to know that the species is recruitment-limited or if recruitment is related to parent stock. #2, #4, and #6 are obviously important. #13.5 should be given more weight. Other criteria seem comparatively trivial.

- Criteria seem appropriate.
- The major criteria are: 1) public demand; 2) cost/benefit ratio using economic and value terms; and 3) measurable results and impacts.
- Criteria look fine.
- Related types of criteria should have been combined to lessen the number of individual criteria.
- Criteria #1, #2, #4, #7, #8.5, #10, #11, #12, #20, #21.5 are biological in nature. These objectives would be difficult to achieve.
- I agree with the results.
- Criteria ranking should be #1, #3, #10, #13.5b, #25c.
- No data is available to apply the criteria. How will it be resolved, by guessing or by an objective process?
- Criteria are fairly complete, well thought out.
- Criteria #1 through #6 appear to be adequately ranked on the prioritization scale.
- The criteria are extensive and well thought out.

Other organizations

- There is no criterion for funding priorities. Who will do the work: state, federal, county, private?
- Work should be done in cooperation with MHI-MRI (Main Hawaiian Islands-Marine Resource Investigation).
- More pressure needs to be put on the legislature and DLNR to establish more preserves in the Hawaiian islands.
- A problem exists where juveniles of a species like awa may be taken by the aku boats to be used as bait -- juvenile protection is needed.
- Mullet fingerlings are being caught by the tuna fleet for use as baitfish.

Miscellaneous

- Due to the decline of tuna boats, there seem to be more fishes in Kaneohe Bay.
- Larger fish are definitely in greater demand and shorter supply.

- Is it possible to replenish and enhance marine fishes in coastal waters by releasing juveniles?
- More thought needs to be devoted to the subject of enhancement before work is started on any species.
- Monitoring impact is obviously crucial; "reliable" data must be secured from recreational catch statistics.
- Monitoring could be assisted by clubs.
- Any enhancement program must include a viable resources management scheme.
- Criteria are good. I believe fishermen should select fish we need to work on.

Appendix B: SEMFISH Presentations

Leber, K. M. 1990. Species Prioritization for Stock Enhancement of Marine Fish in Hawaii. Oral presentation, Annual Meeting of the World Aquaculture Society. Halifax, Canada. June 1990.

Leber, K. M. 1990. Species Prioritization for Stock Enhancement of Marine Fish in Hawaii. Oral presentation, 120th Annual Meeting of the American Fisheries Society. Pittsburgh, Pennsylvania. August 1990.

Leber, K. M. 1990. Can Hatcheries Enhance Marine Fish Stocks? Oral presentation, 17th Annual Pacific Science Congress. Honolulu, Hawaii. May 1991.

Leber, K. M. 1991. Organizer and Moderator of the Special Session: Enhancement of Natural Fisheries Through Aquaculture. Annual Meeting of the World Aquaculture Society. San Juan, Puerto Rico. June 1991.

Leber, K. M. 1991. Can Hatcheries Enhance Marine Fish Stocks? Initial Evidence from Release-Recapture Experiments in Hawaii. Invited symposium paper, Special Session: Enhancement of Natural Fisheries Through Aquaculture. San Juan, Puerto Rico. June 1991.

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Leber, K. M., D. A. Sterritt, S. M. Arce, N. P. Brennan. 1992. Impact of Release Season on Survival of Cultured Striped Mullet (*Mugil cephalus*) Fingerlings Released into Two Nursery Habitats in Kaneohe Bay, Hawaii. Oral presentation, Annual Meeting of the World Aquaculture Society. Orlando, Florida. May 1992.

Leber, K. M., D. A. Sterritt, R. T. Nishimoto. 1992. Comparison of Dispersal, Growth and Survival of Cultured and Wild Juvenile Striped Mullet, *Mugil cephalus*, Released in a Hawaiian Estuary. Oral presentation, Annual Meeting of the World Aquaculture Society. Orlando, Florida. May 1992.

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