

Significance of Fish Size-At-Release on Enhancement of Striped Mullet Fisheries in Hawaii

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Abstract

A tag-release-recapture study was conducted to evaluate size-at-release impacts upon recruitment of cultured, juvenile striped mullet, *Mugil cephalus* released in inshore habitats of Oahu, Hawaii, USA. In June and July 1990, 85,848 juvenile mullet were graded into five size groups (ranging from 45 to 120 mm in length), identified with binary-coded wire tags, and released into two estuaries (2×5 factorial design). Of the tagged fish, 42,822 were released into Kaneohe Bay on the east (windward) coast of Oahu; 43,026 were released into Maunalua Bay on Oahu's dryer south shore. The fish were released into both bays simultaneously. Releases were blocked in time across 5 release lots. To evaluate growth and survival rates of released mullet, both bay systems were sampled monthly with cast nets over a ten-month period after release. Overall, 733 tagged *M. cephalus* were recaptured, 277 from Kaneohe Bay and 456 from Maunalua Bay. Overall proportions of tagged fish in samples declined from 33.4% ($\pm 25.2\%$) of the total *M. cephalus* catch at week 5 to 1.88% ($\pm 0.95\%$) by week 23. From week 23 on, tagged fish averaged 2.09% ($\pm 0.23\%$) of the striped mullet in monthly samples. Within 9 wk after releases, recapture frequencies were clearly skewed in favor of fish that were larger at the time of release. Fish smaller than 70 mm when released were rare or absent in collections within 18 wk after release. This confirms results of a smaller-scale pilot study in Maunalua Bay and shows that fish size-at-release can have a major impact on the success of hatchery releases in marine habitats. Pilot studies to identify minimum fish size-at-release should be conducted at all sites targeted for full-scale marine hatchery releases.

The potential of hatchery releases to help replenish depleted marine fish stocks is being evaluated in Hawaii, where inshore and nearshore fish populations appear to have suffered major declines in abundance during this century. A series of pilot hatchery releases of native striped mullet *Mugil cephalus* are being conducted to examine the impacts of release protocols on growth and survival of cultured and released fingerlings (The Oceanic Institute 1990, 1991). These pilot experiments are identifying release parameters for a larger-scale test of the marine stock-enhancement concept in Hawaii.

Although full-scale hatchery releases are conducted in open marine habitats (e.g., Rutledge and Matlock 1986; Honma 1993), little direct information exists for evaluating the impacts of releases in marine systems on fish population size and on fishery yields. To design an effective test of the marine hatchery release concept, there are several key issues regarding release strategy that

need to be resolved. The importance of conserving genetic diversity among released fingerlings is a primary concern (Shaklee et al. 1993a, 1993b; Blankenship and Leber 1995). This study addresses a key question about the logistical success of releases: to what extent is post-release survival directly impacted by fish size at the time of release?

A pilot tag-release-recapture study in Maunalua Bay, on Oahu, Hawaii, revealed that cultured *M. cephalus* could survive and grow in a back-reef marine environment, but that fish size-at-release appeared to have a major impact upon recapture rates (and presumably survival) of tagged, juvenile striped mullet in their nursery habitats (The Oceanic Institute 1990). The smallest fish released were underrepresented in field collections made in Maunalua Bay; individuals less than 70 mm total length (TL) when released dropped completely out of field samples within 11 wk after release (The Oceanic Institute 1990).

Because of the importance of a minimum size requirement for survival of hatchery-released fish, corroboration is needed of the size-at-release impact observed in the initial Maunalua Bay study. This study examines if the impact of fish size-at-release on recapture rate is reproducible in Maunalua Bay, and whether size-at-release based differential mortality also occurs in more favorable striped-mullet nursery habitats located in Kaneohe Bay, Hawaii. A rigorous test of fish size-at-release impact was performed: 1) by releasing over five times the number of fish released in the initial study; 2) by releasing relatively high proportions of fish smaller than 70 mm TL (the critical size for survival in the initial study); and 3) by replicating the study in another mullet nursery habitat, Kaneohe Bay.

This study is part of a research program established to develop and test hatchery release strategies for replenishing depleted marine fisheries in Hawaiian coastal waters. The research program, titled "Stock Enhancement of Marine Fish in the State of Hawaii (SEMFIH)," is funded by the United States National Marine Fisheries Service.

Materials and Methods

Striped mullet *Mugil cephalus* were spawned at The Oceanic Institute, Oahu, Hawaii, and reared to fingerlings during winter and spring 1990. Batches of mullet eggs were hatched approximately every 6 wk over a 5-mo period. Larvae from each batch were cultured in 5,000-L tanks for approximately 40 d, and nursed for 2–6 mo in ponds and tanks at The Oceanic Institute and in ponds at the University of Hawaii Mariculture Research and Training Center in Kahaluu, Hawaii.

During the period 15 May through 19 July 1990, juvenile *M. cephalus*, ranging in size from 40 to 130 mm TL were harvested from nursery ponds and transported to 40,000-L holding tanks at the Institute. Fish were graded into five size groups; 90,406 were marked with internal binary coded wire tags

(Northwest Marine Technology, Inc., Olympia, Washington). Tags were implanted in the snout area using an automatic injector with head molds fabricated specifically for striped mullet by Washington Department of Fish and Wildlife biologists. Evaluation of target tissue and verification of the tag system for this species are dealt with elsewhere (Northwest Marine Technology, Inc. 1989; The Oceanic Institute 1990). All individuals released were tagged.

The tags identified fish size-at-release, release site and release date (lot). Batch codes were used to identify five size groups—45–60 mm TL; 60–70 mm; 70–85 mm; 85–110 mm; and 110–130 mm, and two bay systems—Maunalua Bay on Oahu's south shore, and Kaneohe Bay on Oahu's windward (eastern) coast. There was size variation in all batches of mullet reared for this study. However, the primary difference among fish size-at-release groupings was fish age.

Pilot studies have documented for *M. cephalus* a 97% tag-retention rate 12 mo after tagging (The Oceanic Institute 1990). To verify that tag-retention rates were that high in this study, at least 5% of the tagged fish from each release lot were randomly subsampled prior to each release. These subsamples, totaling 4,558 fish, were retained in tanks for up to 6 mo and periodically checked for tag retention. The subsampled fish were not released.

Tagged *M. cephalus* were released in five lots over a 2-mo period. In each release lot, all size groups were released into each bay system nearly simultaneously (however, fish above 110 mm TL were unavailable after lot 2). In the first lot, fish were released into Kaneohe Bay in the morning and into Maunalua Bay that afternoon (Fig. 1). Morning and afternoon releases were alternated during successive release lots.

Tagged *M. cephalus* were released into Maunalua Bay at Kawaikui Beach Park, a south-facing beach near the middle of the bay and the site of the previous releases. Salinities at Kawaikui were typically 25–35

ppt. In Kaneohe Bay, two of the five lots of fish released were stocked at Kahaluu Stream mouth in the north part of the bay. This is an east-facing shore. Salinities at the Kahaluu site ranged from 5–8 ppt during releases. This site is adjacent to Kahaluu lagoon, which is a principal nursery habitat for *M. cephalus* juveniles.

Because of a perceived increase in commercial bait fish collection activities near Kahaluu Stream after the first two experimental lots were released, the last three lots introduced into Kaneohe Bay were released from the Hawaii Institute of Marine Biology pier in the southern part of the bay. Salinities at pier ranged from 28 to 35 ppt during releases. All releases were made near the shoreline in water 0.5–1.5 m deep.

Beginning in June 1990 released and wild *Mugil cephalus* abundances were monitored monthly for 10 mo by sampling with cast nets. Recaptured tagged fish were removed from collections and returned to the laboratory for tag analysis. The first field collection began 4 wk after lot 1 was planted (1wk after lot 2). All release lots were in place prior to the second field collection.

Each field collection was conducted over approximately a 2-wk period. The monthly sampling design entailed collections at four stations within each bay system. Collections were made during the day over approximately an 8-h period at each station. Stations were established at *M. cephalus* nursery habitats, various tributaries located throughout each bay (The Oceanic Institute 1990). At each station, two substations were sampled, one established upstream, the other in the bay near the mouth of the tributary. Within substations, 15 cast net throws were made. To broaden the range of microhabitats and fish size-ranges sampled, two sizes of cast nets were employed. Ten of the 15 casts per substation were made with a 16-ft (4.9-m) diameter, $\frac{3}{8}$ -in (9.5-mm) mesh net, and five casts were made with a 10-ft (3-m) diameter, $\frac{1}{4}$ -in (6-mm) mesh net. Thus, 120 casts were made in each bay system during each sample month.

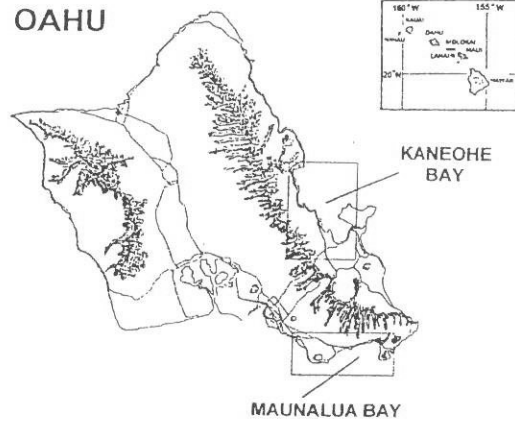


FIGURE 1. Map of Oahu illustrating location of study sites.

Placement of net samples was not random at sampling stations, but stratified over schools of mullet juveniles. Random sampling yielded few wild mullet, and very few tagged individuals. Mullet schooled in fairly low densities within these clear-water habitats, and our collections targeted these schools. Nevertheless, the data used to determine proportions of tagged versus untagged mullet were randomly distributed, because we had no indication that schools, once sighted, contained tagged individuals.

All mullet collected were measured and checked for tag presence using a portable tag detector (Northwest Marine Technology, Inc., Olympia, Washington). Tagged mullet were placed on ice and returned to the laboratory where they were thawed, weighed, and measured.

Treatment identifications were based on the tags retrieved from recaptured fish. Tags were extracted using a binary search to locate them within the snout region. Tags were decoded using a binocular microscope (40 \times). Around 4% of the tags from recaptured fish were lost during extraction. This error rate has declined to <1% in follow-up studies. Tags were first decoded at the Institute by SEMFISH biologists; following the initial decoding, the tags and code data were sent to Lee Blankenship at the Washington Department of Fish and Wildlife