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Mugilids in the Muliwai: a Tale of Two Mullets

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Abstract

The *'ama'ama* or striped mullet, *Mugil cephalus*, is circumglobal in tropical and warm temperate seas. This species is common in estuaries, inland lagoons, and rivers. There are only two species of native mullet in Hawai'i. The *uouoa* or sharpnose mullet, *Neomyxus leuciscus*, is a small species and common along the rocky coastline. The striped mullet is an estuarine inhabitant as larvae and juveniles; the adults are found in deeper waters, usually where there is significant freshwater outflow, as stream surface flow or by groundwater intrusion. The *'ama'ama* is a significant species in traditional Hawai'i. This fish was coveted by royalty, and there are numerous words in the Hawaiian language describing the life stages and migration pattern. The species was once cultured in Hawaiian fish ponds but now is more significant as a recreational fishery species. Because of the general decline in coastal fish species, the Hawai'i Division of Aquatic Resources partnered with the Oceanic Institute to develop a prototype marine stock augmentation program for the *'ama'ama* fishery. A centralized hatchery spawned adults, reared the larvae, tagged young fingerlings with coded wire tags, and released them into juvenile habitats, such as Wailoa River estuary and Waiākea Pond in Hilo. The release of 20,000 hatchery fingerlings/year had no negative effect on the native mullet stocks, but made a significant contribution to the fishery. The size, location, and season at release of hatchery mullet fingerlings were critical to the success of the effort. The alien mullet, *Valamugil engeli* (*kanda*), accidentally released on O'ahu from 1955–1958, are reported to occur in great numbers in many estuaries in the main Hawaiian Islands. *Kanda* are very common in Hilo Bay, Wailoa, River and Waiākea Pond, a significant juvenile fish habitat for coastal marine species. The effort to protect the decline of the native mullet by classical fishery management rules has inadvertently provided greater protection for the alien mullet. The impact of the alien on the native mullet is now being studied, and, concomitantly, novel approaches are being discussed to control this invasion.

Introduction

Mullets comprise one of the more speciose and characteristic fish families (Mugilidae) in tropical and warm temperate coastal waters, estuaries, and lagoons. This family is made up of 80 species belonging to 17 genera (FishBase 2000). These schooling fish are highly euryhaline or diadromous (McDowall, 1988), iliophagous, and are generally found in mostly protected, soft-bottom habitats. Their marine phase is short and consists mostly of spawning individuals and the early larval stages. Mullets, especially *Mugil cephalus*, are an important food fish worldwide and have been the subject of numerous fishery studies and research on the aquaculture of the species. The striped mullet is the best-studied species, but its life cycle is poorly understood (McDowall, 1988).

Hawai'i, with its depauperate fish fauna, has only two indigenous species of mullets; the sharpnose mullet, *Neomyxus leuciscus,* and the circumglobal *M. cephalus*. The sharpnose mullet, locally known as *uouoa*, rarely exceeds 30 cm, occurs in small schools close to shore, and is rarely, if ever, observed in estuaries. The striped mullet or *'ama'ama*, is a much larger fish, reported to reach 90 cm; however, the average size is more like 50 cm (Randall, 1996). The striped mullet is known to penetrate low gradient streams, such as certain streams on Kaua'i, but is more common in protected habitats, especially in estuaries (*muliwai*). There are three types of estuaries in Hawai'i (Juvik & Juvik, 1998). The two most common are at stream mouths or where surface flow is absent but with significant groundwater discharge, such as Hilo Harbor. The other type is the more classical large embayment, such as Pearl Harbor on O'ahu.

Figure 1. Makoa and the Mullet, print by Dietrich Varez. Note live mullet in hand being carried from Waiākea Pond in Hilo to the young King Kamehameha in Kawaihae, south Kohala. Used here with permission from the artist via Volcano Art Center, Volcano, Hawai‘i.

In Hawai‘i the *‘ama‘ama* reach sexual maturity at about 28 cm, at about 3 years old, and migrates offshore during the winter months to spawn in the ocean. The pre-juveniles, averaging 20 mm standard length (SL), appear at intertidal estuarine habitats 30–45 days after hatching at sea (Major, 1978). The recruiting fingerlings use turbidity gradients as an orientation cue (Cyrus & Blaber, 1987) along with tidal transport as a mechanism to move into juvenile habitats. Pre-juveniles, averaging 17–35 mm SL, are very common in the shallow intertidal habitats in the spring but disappear by the end of June. Major (1978) reported that pre-juveniles inhabit shallow areas and tolerate highly fluctuating salinity and water temperatures as a pre-adaptation to avoid piscine predators. The fingerlings metamorphose into juveniles at 50 mm SL, abandon the extreme conditions in the shallows, and move into deeper waters. Concomitantly, there is a lengthening of the intestine and morphological changes to the teeth and lips, a feeding adaptation to benthic macrophagous omnivory (Blaber, 1987).

The *‘ama‘ama* has a long history in Hawai‘i. This species was revered by Hawaiian royalty as a food fish harvested from fishponds and later as a valuable commercial product in the early 1900s. In Hilo, there is a specialized hook-and-line recreational fishery targeting this species, and recently it was the subject of a very successful stock enhancement project to test the efficacy of marine stock augmentation by releasing hatchery-raised fingerlings.

In this report we will (1) provide, a brief background history of *‘ama‘ama*, in traditional Hawai‘i and as an important species in the fisheries; (2) summarize ongoing research on the use of stock enhancement in managing the recreational mullet fishery; and (3) document the invasion of *kanda*, an alien mullet introduced to the Hawaiian Islands from the South Pacific in 1955.

1. Background

‘Ama‘ama in traditional Hawai‘i

The mullet was prized as a food fish for royalty. Most were collected from coastal fishponds, constructed by placing a stonewall enclosing a small bay at a stream mouth. Recruiting fingerlings were

Table 1. Hawaiian language terminology describing the different size classes (A) and migratory behavior (B) of the native striped mullet, *Mugil cephalus,* on O‘ahu.

A

Hawaiian Name	Size Class
Pua ‘ama, Pua po‘ola	Finger size, new recruits
Kahaha, Pahaha	Hand length, juvenile stage
‘Ama‘ama	20 cm, estuary resident
‘Anae	30+ cm, reproductive adult

B

Behavioral Group	Migration Route	Behavioral Activity
‘Anae-holo	‘Ewa to Lā‘ie	Spawning migration, full-bodied
‘Anaepali	Lā‘ie to ‘Ewa	Return migration, skinny

passively collected by lifting the sluice gates during the rising tide and corralling the fish in the pond. The gate was lowered to keep fish from leaving but still allowed tidal circulation. During the reign of King Kamehameha I, it was common for some Hawaiian Chiefs to select the swiftest runner to collect the *‘ama‘ama* from their favorite fishpond so the fish would still be alive when they returned (Wyban, 1992). As a tribute to the swiftness of these runners, the present day Volcano Art Center's annual Kīlauea Volcano Runs trademark depicts the legendary runner *Makoa* (Fig. 1), who carried the *‘ama‘ama* from the fish ponds in Hilo, over the saddle road between the Mauna Kea and Mauna Loa volcanoes, and delivered the still wriggling fish to the young King in Kawaihae, north Kona (Desha, 2000). In 1939 King Kamehameha III introduced a code of law where every commoner had access to the fish resources. The exceptions were a few species that were solely reserved for royalty (Jordan & Evermann, 1902). The *‘ama‘ama* of Hulehia (Hulēia?), Anehola (Anahola?), and Hanalei, for example, were taboo to the general population and shows that the mullet was a highly prized fish during the Hawaiian Kingdom period.

The Hawaiian language recognizes the different size classes of the *‘ama‘ama* (Pukui & Ebert, 1986) (Table 1A) but most intriguing is recognizing the traditional migratory route between Ewa to Lā‘ie, O‘ahu (Table 1B). The terms describe the traditional spawning migration and their return (Wyban, 1992).

In the late 1800s, many coastal fishponds were not tended and fell into disrepair as the population migrated to the city or other crops, such as rice and taro, became more profitable. In 1900, there were only 99 documented fishponds, and Chinese immigrants operated most. A census at the Honolulu fish market in 1900 reported that 35.6% of the fishes sold were the *‘ama‘ama*, however, there was no differentiation between mullet taken from fishponds or the coastal seas (Cobb, 1905). Mullet were the most expensive fish at the market and sold for 25 cents/lb. The number of fishponds used to cultivate *‘ama‘ama* and other estuarine species continued declining into the next century. In 2000, there were only two fishponds in production in Hawai‘i. These fishponds collectively sold less than 1,000 lbs of *‘ama‘ama* in 2003 (Hawaii Division of Aquatic Resources, 2004).

‘Ama‘ama in the recreational fishery

Fishing for mullet by using local pole-and-line technique is a dying art if the popularity of this food fish is considered. This type of fishing, once easily recognized by the numerous, small wooden platforms, called stilt chairs, dotting the tidal flats (Hosaka, 1944) in Kāne‘ohe Bay and Ala Wai Canal, is gone. These wooden chairs were not set randomly; instead, the locations were carefully selected and placed close to the daily migratory path of the mullet (Rizzuto, 1985). Bread was used for chumming and as bait. These platforms are now prohibited because of environmental regulations, and more than likely, there is not much interest for perpetuating this fishing technique. Small skiffs now

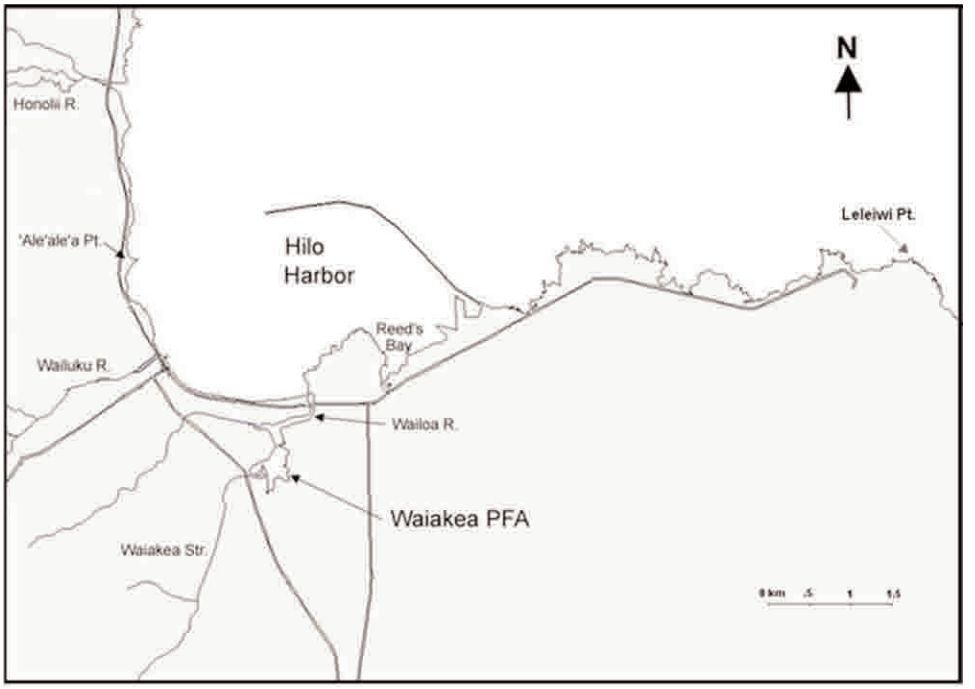

Figure 2. Map of Hilo Harbor, Wailoa River estuary, and Waiākea Pond.

replace such platforms. Hilo Harbor, especially the Waiākea Public Fishing Area (PFA), is one of the last strongholds of this type of mullet fishing. Fishers use a system of a delicately balanced bobber and tandem hooks baited with algae. Microscopic examination revealed that the bait is a wad of algae consisting almost exclusively of the chained diatom, *Melosira tropicalis* (Julius *et al.,* 2002). The catching of *ʻamaʻama* in Hilo is the only fishery in the world where diatoms are used as bait.

2. **Stock Enhancement in the Management of the Hilo Recreational Mullet Fishery**

History

Hawaiʻi coastal fishery stocks have seriously declined mostly due to anthropogenic impacts (Shomura, 1987). Observations by Okamoto (1994, pers. comm.), a seasoned fisher and Hawaii Fish & Game fishery biologist, noted that the average size of mullet caught in the 1940s averaged 3–4 lbs. He noticed a dramatic decline in average size over time and stated that mullet stocks are overfished and the brood stocks severely depleted. He hypothesized that the losses of shallow water nursery habitat and competition from the alien *kanda*, *Valamugil engeli*, have contributed to the decline.

The Hawaiʻi Fisheries Plan of 1990–1995 (Department of Land & Natural Resources, 1990) stated that the Division of Aquatic Resources (DAR) aims to restore to former abundance species whose numbers have become depleted, at least in part, because of loss or degradation of natural spawning and nursery areas. In 1990, DAR and the Oceanic Institute (OI) partnered to develop a collaborative project to help restore the declining coastal stocks by using marine stock enhancement technology. Initially, there was a series of public workshops to identify potential species that were candidates for stock enhancement. The two species that received the highest overall scores were the Pacific threadfin or *moi*, *Polydactylus sexfilis*, and the *ʻamaʻama*, *M. cephalus* (Leber, 1994). The latter species was selected because OI already had the technology to aquaculture the *ʻamaʻama* and there was a well-established recreational mullet fishery in Hilo, Hawaiʻi Island and a commercial net fishery in Kāneʻohe, Oʻahu Island.

Methods and study site

ʻAmaʻama fingerlings were cultured at a central hatchery on Oʻahu and shipped to the State Fisheries Research Station in Hilo for grow-out. Fingerlings of various sizes were batch tagged with internal Coded Wire Tags (CWT). Tagged fishes were kept for several days to allow recuperation from tagging stress. A total of 268,228 CWT mullet fingerlings were released at various locations in Hilo Bay from August 1990 to September 2000, except for 1996 when none were released. Hatchery release impact was assessed by creeling the recreational fisheries (starting in 1991) and by conducting bimonthly cast-net sampling (starting in 1990) at fixed stations in Waiākea Pond, Wailoa River, and Reeds Bay, all located within Hilo Harbor (Fig. 2). A 5-ft and 8-ft diameter cast nets with 3/8 inch stretch mesh, were used in combination to sample mullet fingerlings for the presence of CWT. A total of 15 throws were made at each station. The number of mullets was tallied by species, and the presence of CWT was detected with a magnetic tag detection unit. Fish with tags were collected and frozen. The CWT tags were excised, deciphered, and size, date, and release site information were recorded in a database. All native mullets were checked for tags and immediately returned to the wild if there were no tags. Creel census was conducted by interviewing mullet fishers in Hilo Harbor, but mostly in the Waiākea Public Fishing Area (PFA) where the fishery is concentrated.

Results and Discussion

The results were significant: 1. The prototype marine stock enhancement experiment demonstrated that even small-scale releases can have a significant impact on wild stock abundance (Leber *et al.*, 1995a); 2. The number of mullet entering the fishery was significant and was achieved annually; 3.The release of 20,000 fingerlings per year did not displace wild fish from the estuary (Leber *et al.*, 1995b); 4. The Wailoa River estuary, especially the boat launching ramp, was found to be an excellent release site; and 5. The most successful size at release was 70 mm total length (TL) and the optimum release period was during spring (Leber, 1995a; Leber *et al.*, 1997).

The number of CWT mullet in the fishers creel ranged from a low of 3.9% in 2003 to as high as 61.1% during 1999 (Fig. 3). The last batch of hatchery raised and tagged fish were released in 2000. The overall average increase on the recreational mullet fishery after 9 years of releasing hatchery-raised *ʻamaʻama* was 21.7%. Tagged mullet resided between 3 and 4 years in the Wailoa River estuary (Fig. 4). Most tagged mullet were caught during the second year after release and averaged 31 cm TL. The absence of 3–4 year (after tag and release) mullet from the Waiākea PFA fishery suggests that these fishes moved out of the estuary and presumably underwent an offshore spawning migration. There is no indication that these fish returned to the estuary; however, we have not conducted sampling or creel surveys outside of Hilo Harbor or along the coastal areas. Adult *M. cephalus* are often observed in smaller groups schooling along the coastal areas, and the larger individuals, around 55 cm, have been observed singly or in pairs, in deeper waters.

Hatchery mullet displayed a strong site fidelity to the Wailoa estuary. Most mullet tagged and released in the estuary resided there until they reached maturity. Small batches of CWT fingerlings released south (Leleiwi Point) and north (Honoliʻi Stream) of Hilo Harbor and a small neighboring estuary, Reeds Bay, returned and resided in Waiākea Pond PFA until undertaking the spawning migration.

The Hilo mullet project verified the potential of stock enhancement as an effective tool to replenish diminishing stocks. However, stock enhancement should always be used in conjunction with rather than instead of classical fishery management options (Blankenship & Leber, 1995), such as bag limit and area closure, since the goal of stock enhancement is to augment and not replace wild stocks.

Based on the results of this project, several management measures were implemented to further DAR's mission of replenishing and conserving native fish stocks:

A. Minimum catch size was increased from 7 to 11 inches (fork length, FL) (= 12.75 in TL) to allow mullet to 'escape' the fishery and emigrate offshore to spawn.

B. Closed season was extended for one more month, from December to March, because larger mullet caught in late February and March still had mature gonads.

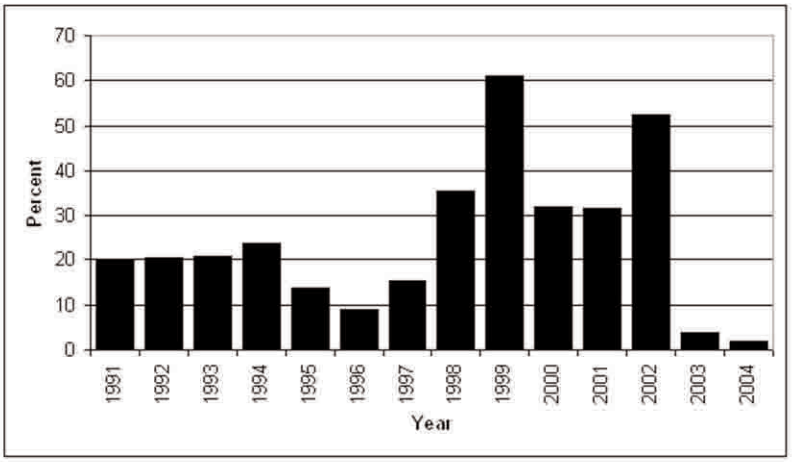

Figure 3. Percent tagged mullet in Hilo recreational fishery from 1991 to 2004 (n= 2,511).

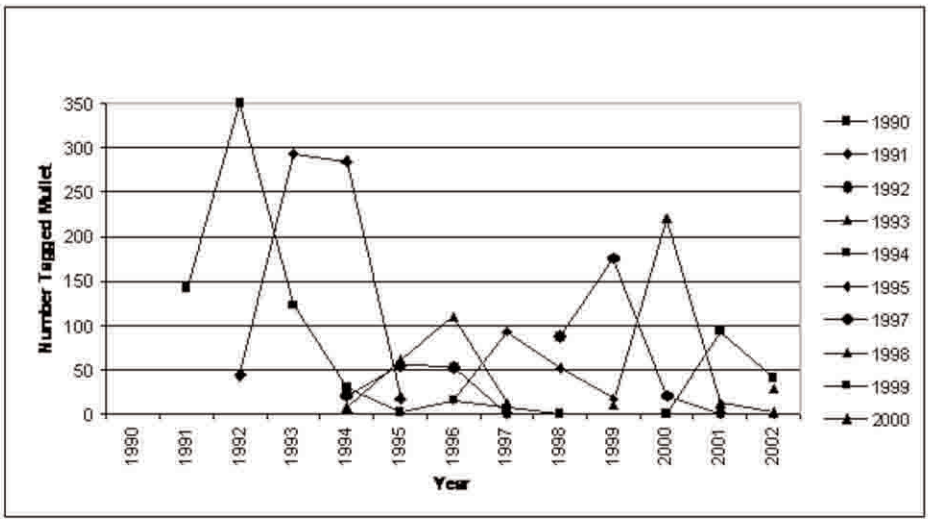

Figure 4. Residency time of tagged native mullet in Wailoa River estuary and Wai/a/*kea Pond from 1991 to 2002. Last release of tagged fish was in 2000.

C. The Waiākea PFA was extended seaward to include the Wailoa River estuary. Fishing gear was restricted to pole-and-line and the use of cast net and spearing was disallowed. The use of small mesh net to collect mullet fingerlings to stock private fishponds was not permitted. Wailoa River estuary was especially significant as a nursery habitat for newly recruited mullet fingerlings.

D. Bag limit was lowered to 10 fishes per day in Hilo Bay, Wailoa River estuary and Waiākea PFA.

E. Plans were developed to re-establish shoreline vegetation shoreline vegetation around the perimeter of Wailoa River and Waiākea has been thoroughly removed to accommodate

recreational park users for aesthetic reasons. We plan to reestablish shoreline vegetation to provide cover for juvenile fishes and crustaceans. Newly metamorphosed mullet seek shallow estuarine intertidal after recruiting into the estuary. Vegetative cover is essential to lessen the impact of avian and piscine predators (Majors, 1978).

3. Invasion of the Alien Mullet *V. engeli* into the Habitat of Native *M. cephalus*

Introduction

Hawai‘i has experienced waves of alien introductions starting in the early 1900’s. The first several waves were considered purposeful introduction, mostly as recreational game fish, for commercial harvesting, or to provide live bait for the tuna fishery. More recently, alien introductions are being viewed with great concerns and recent introductions now have been accidental releases, escapees, or animals inadvertently transported between islands or even introduced from other continents, such as Asia.

The alien *kanda*, locally as Summer or Marquesan mullet, was first introduced to O‘ahu between 1955–1958 (Randall & Kanayama, 1972, Hawaii Fish & Game fish introduction list). This fish was unknowingly mixed with several shipments totaling 143,800 Marquesan sardines *Sardinella marquesensis* (Maciolek, 1984), which were released at several sites on O‘ahu as supplemental bait for the live-bait skipjack tuna fishery (Murphy, 1960). The fishers were not enthusiastic about using Marquesan sardines because they were not as effective for attracting skipjack tuna as the native anchovy or *nehu*, *Encrasicholina purpurea*. The native anchovy is not very common now in Hilo Bay and was presumably out competed by the introduced sardine *S. marquesensis* (Okamoto, 1994 pers. comm.) or affected adversely by anthropogenic activity, such as sedimentation or the introduction of upland pollutants (U.S. Army Engineer District, 1980). The Marquesan sardine has been replaced by the introduced goldspot sardine, *Herklotsichthys quadrimaculatus.*

The population of the *kanda* exploded and invaded the native mullet habitat in many estuary and bays in the Hawaiian Islands. This alien mullet was reported to outnumber the native three to one on Kaua‘i from 1975–1978 (Maciolek, 1984) and made up nearly half of the catch in an O‘ahu estuary in 1981 (Maciolek & Timbol, 1981). In 2000, about a third of the mugilids sampled (n = 2806) on the south shore beaches of O‘ahu (Kapahulu Groin to the Diamond Head Lighthouse) were kanda (Iwai, 2004). Only 4 individuals of the native striped mullet were collected in this 14 month sampling program.

Methods and study site

CWT sample- Bimonthly cast-net sampling was started in 1990 at fixed stations in Waiākea Pond, Wailoa River and Reeds Bay to assess hatchery release impacts by noting the frequency of mullet with CWT. Sympatric species, especially the alien *kanda*, were counted and recorded. A 5 ft and an 8 ft diameter, 3/8 inch mesh cast nets were used in combination to sample juvenile and fingerling mullets. A total of fifteen throws were made at each station.

Alien mullet- Because of the increasing dominance of the alien mullet in the nursery habitat of the recreational mullet fishery, we started a monthly sampling program in May 2001 to gather baseline ecological and life history information the *kanda* mullet. We used a similar sampling protocol as in our standard sampling project except samples were collected monthly with only the 8-ft net. Three substations were established in each site in the estuary/pond (Wailoa River estuary and Waiākea PFA) and open bay (Hilo Bayfront).

Results and Discussion

CWT Sample

Long-term sampling data available from 1990 to 2005 clearly show decline of striped mullet in association with an apparent concurrent appearance of *kanda* around 1997 (Fig. 5). It seems that the disappearance of the native mullet is correlated with the proliferation of the alien mullet. However, both

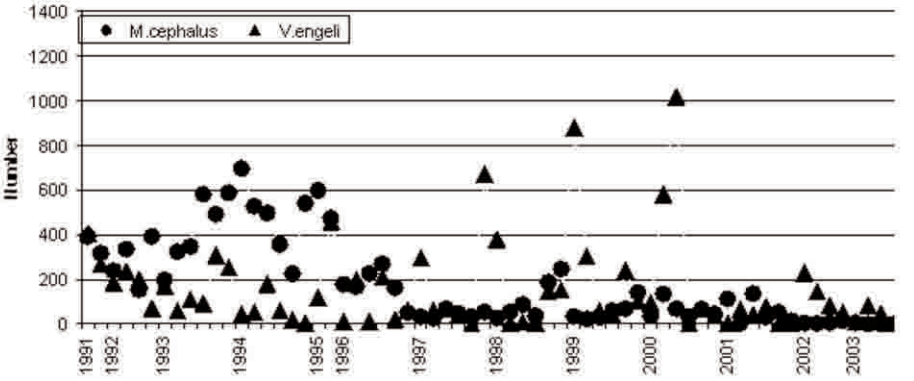

Figure 5. Total number of striped mullet and *kanda* in Wailoa River and Waiākea Pond from 1990 to 2005.

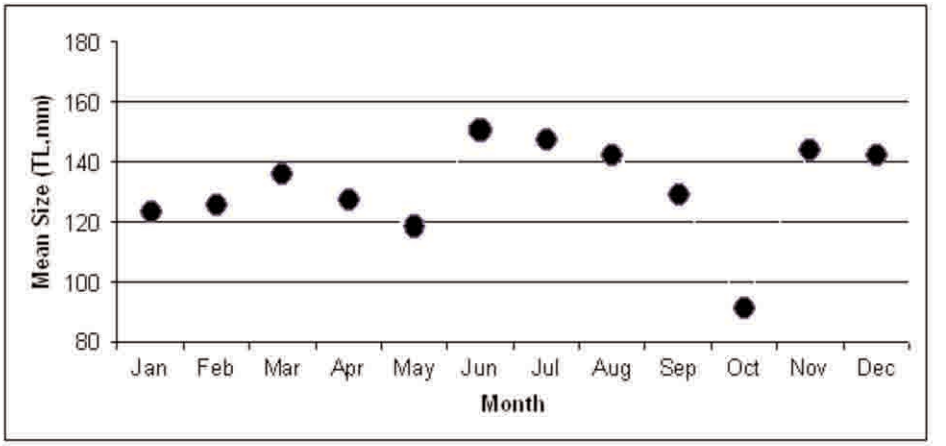

Figure 6. Combined average monthly mean size of *kanda* sampled in Wailoa River from 2001 to 2004. Note small mean size in October (n = 11,812).

mullets were apparently rare in 1997 and 2001. The pattern of *kanda* abundance does not seem to simply be the alien dominating the native. The alternative explanations can be: (1) the *kanda* is filling the niche opened by the decline of the striped mullet, either by years of poor recruitment or possibly due to years of over fishing; (2) the striped mullet is simply being out competed by the alien *kanda*; or (3) there is no competitive interaction between the species of mullet and the trends are coincidental.

Alien mullet, **Wailoa estuary**

Kanda were most abundant around the area where the Wailoa River Flood Canal empties into Waiākea Pond. Their size ranged from 28 mm to 250 mm TL, however, the average size was around 136 mm TL. There was a dramatic drop in average size during the months of October from 2001 to 2004 (Fig. 6). The drop in average size and an increase in numbers caught suggest the arrival of a batch of new recruits into the Wailoa River estuary. Like the native striped mullet in the estuary, the schooling behavior of *kanda* is very obvious. They graze on the bottom, jump out of the water when disturbed, and travel in large, well-defined schools. It is very difficult to discern the two species without some practice. Preliminary results suggest that *kanda* reach sexual maturity at around 140 mm TL, unlike the native mullet, which matures at a much larger size.

Table 2. **Number and frequency of fish species sampled in Hilo Bayfront from December 2002 to January 2005**. Mullet species emphasized in this study are in **boldface**.

Family	Species	Number	Percent
Mugilidae	***Valamugil engeli***	2947	68.5
Clupeidae	*Herklotsichthys quadrimaculatus*	306	7.1
Kuhlidae	*Kuhlia xenura*	298	6.9
Carangidae	*Caranx ignobilis*	199	4.6
Mugilidae	***Mugil cephalus***	143	3.3
Polynemidae	*Polydactylus sexfilis*	128	3.0
Carangidae	*Selar crumenopthalmus*	87	2.0
Carangidae	*Caranx sexfasciatus*	84	2.0
Mullidae	*Mulloides flavolineatus*	35	0.8
Carangidae	*Caranx melampygus*	20	0.5
Atherinidae	*Atherinomorus insularum*	18	0.4
Scombridae	*Scomberoides laysan*	11	0.3
Portunidae	*Portunus sanguinolentus*	6	0.1
Albulidae	*Albula vulpes*	4	0.1
Mullidae	*Upeneus arge*	3	0.1
Belonidae	*Platybelone argalus*	3	0.1
Mullidae	*Parupeneus porphyreus*	2	0.1
Palaemonidae	*Palaemon pacificus stimpsoni*	2	0.1
Hemiramphidae	*Hemiramphus depaupratus*	2	0.1
Acanthuridae	*Achanthurus triostegus*	1	0.0
Lutjanidae	*Lutjanus fulvus*	1	0.0
Poecilidae	*Poecillia sphenops*	1	0.0
Pomacentridae	*Abudefduf abdominalis*	1	0.0

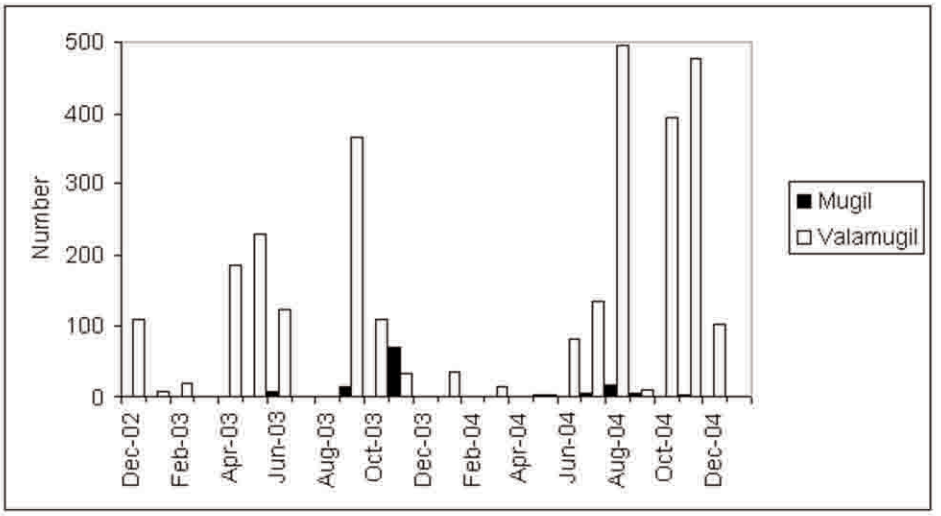

Figure 7. Number of striped mullet and *kanda* in Hilo Bayfront from December 2002 to December 2004.

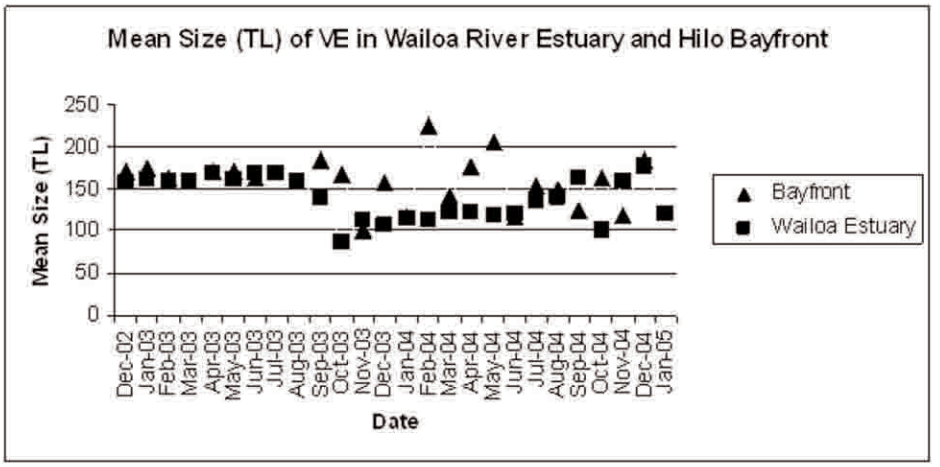

Figure 8. Mean size of *kanda* from Wailoa River Estuary and Hilo Bayfront from December 2002 to January 2005 (n = 3096).

Alien mullet, **Hilo Bay**

Mostly coastal marine species were collected in samples from the sandy bottom habitat along the Bayfront beach within the harbor. There was a total of 21 species from 15 families (Table 2). The most common family was the Carangidae, mostly piscivores, represented by 4 species. The goatfish family, Mullidae, had 3 species, and there were 2 species of mullet family. These fishes were mostly juveniles which represented species most targeted as adults by recreational fishers in the Hawaiian Islands.

The most numerically dominant species was the alien *kanda*, representing 68.6% of the total sample (n = 4294). Size ranged from 35 to 230 mm TL, but the overall average was 148.4 mm TL. A distant second was the goldspot sardine, *H. quadrimaculatus*, introduced to the Hawaiian Islands from the Marshall Islands in 1972. The *āholehole*, *Kuhlia xenura*, was the most common native

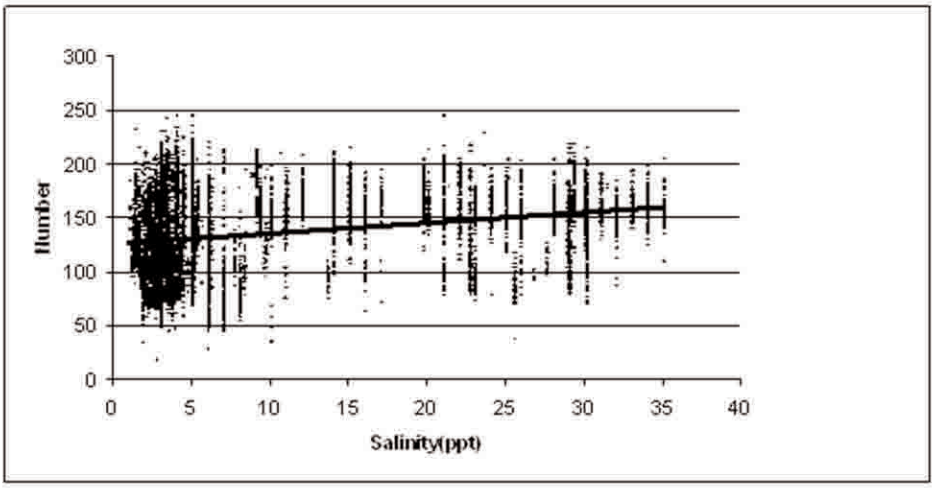

Figure 9. Correlation of number and salinity in the *kanda* in Wailoa River Estuary and Hilo Bayfront (n=16,097).

species at this site, and represented 6.9% of the total sample catch. The native striped mullet made up only 3.3% of the sample.

The number of *kanda* along the Hilo Bayfront far surpassed the number of native mullet (Fig. 7). The results are not surprising since the *'ama'ama* juveniles seem to prefer the more protected habitat in the estuary and pond. Generally, the smaller *kanda* are more common in the estuary and pond while the larger individuals prefer the marine conditions found in the harbor (Fig. 8). There is a significant correlation between size and salinity for *V. engeli (*Fig. 9), however, salinity may not dictate their preferred habitat. We believe that the alien *kanda*, like the native striped mullet, is euryhaline, and marine conditions may not be obligatory.

Mugilids in the Muliwai – lessons for management and restoration of Hawaii's coastal fisheries

The native Hawaiian culture, language, and legends are replete with knowledge of native plants and animals and their habitat. Much of this information probably was gathered by people who were closely bound to the land and the natural resources. Much of this knowledge appears in legends and proverbs. Hawaiian words depicting the different size classes of the mullet, from fingerlings to juveniles, and terms describing the traditional spawning migration route is proof of a broad knowledge of the life history of this prized species. Wai'anae and 'Anaeho'omalu, are places where the larger mullet probably congregated. Traditional fishponds were located at sites which more than likely attracted great number of fingerlings since the areas provided a protective habitat and optimal growing conditions. Even the placement of 'stilt chairs' on the reef flat marks the daily migratory route of the mullet and other species. These pieces of life history information, although disjointed, should be viewed as potential sites for restoration work or life history studies. For example, areas of traditional migratory routes could be identified and protected from overfishing. Bays with Hawaiian fishponds may be a potential nursery habitat that may need further protection. Gear restrictions at sites with potential brood stock populations should be considered. The wealth of information in the native culture is a valuable resource and should not be ignored because of its antiquity.

The project in Hilo Stock Enhancement of Marine Fish in Hawai'i provided the data essential

to implement new regulations for the mullet fisheries in Hilo. Release and recapture of tagged fish identified Wailoa River and Waiākea Pond as a significant nursery habitat. Increasing the minimum size allow young mullet time to reach reproductive size and "escape" the fishery. Extending the closed season and decreasing bag limit was added insurance to assure the continued contribution of mature fish to the wild brood stock population. From the start, fishing community participation was critical to the success of project.

Long term monitoring for tagged mullet highlighted the increasing dominance of the alien *kanda* in the nursery habitat for many of the major coastal fish species. The adults of many of these species are targeted by recreational fishers. The inadvertent release of a single alien fish species on one island demonstrates how quickly aliens can disperse because *kanda* now can be found statewide. Kanda are a smaller species than the native mullet. Thus, increasing the minimum net mesh size benefited the native but, unfortunately, the alien mullets as well

Denuding the nursery habitat of riparian vegetation provided greater opportunities for recreational fishing (especially the highly prized game fish, such as the piscivorous carangids) and appeased recreational park users who favored a more unobstructed and "pleasant" view. The loss of protective habitat among thickly vegetated banks of the river and pond likely made newly recruited mullet fingerlings more vulnerable to piscivorous fishes and bird and may have negatively impacted native mullet stocks in the Hilo mullet fishery. Reestablishing the vegetative belt of the shallow intertidal will be the beginning of restoring the nursery habitat of the native mullet.

The *muliwai*, or stream mouth/estuary, is an essential nursery habitat, especially for the native mullet. Unfortunately, it also is a preferred habitat for the alien *kanda*. Coastal areas in bays, such as Hilo Bay, provide habitat for many coastal marine fish species. Estuary as nursery habitat has long been ignored in Hawai'i. Most management efforts have focused on adult stages. The estuary connects two major habitats, the ocean and the forest, and inattention to the management and restoration of this critical bridge may contribute to the collapse of the watershed.

The establishment of alien fishes in Hawai'i has been repeatedly reported in the literature. Our focus now needs to move from documentation to management and ultimately, restoration.

Fishery management and restoration can best be accomplished if the effort is steeped in the marriage of native knowledge and scientific research, and they are more effectively implemented by empowering the fishing community.

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