NOAA/CRCP-DAR-CZM Coral Reef Cooperative Agreement
Final Report

Project Title: Spawning Seasons: Nearshore fisheries monitoring training, data collection, and data analysis.

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PI: Eva Schemmel, Conservation International Hawaii

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Award Period: May 15, 2016 through June 30, 2017

1. Executive Summary

This project provided technical assistance and support for local communities and State agencies to determine reproductive characteristics of targeted nearshore fish species to inform fisheries management and improve coral reef ecosystems in Hawaiʻi. We achieved this by conducting fish reproduction and spawning season training with fishing communities using standard monitoring protocols and through the collection and analysis of data for reproductive assessments. The biology of aholehole (*Kuhlia xenura*) and kanda mullet (*Moolgarda engeli*) was assessed in two locations (Hilo, Hawaii and Maunalua, Oahu). Kanda was found to grow fast, reproduce at a small size (140.1 mm) and young age (208 days), and spawn all year round. We did not find differences in growth, age, or reproduction between sampled locations. These characteristics make it a highly successful invasive species and likely to be more responsive to habitat and climate changes, possibly outcompeting native mullet species. Aholehole (*Kuhlia xenura*) was found to reach a large size at maturity, above the legal size limit (females 17.5cm (CI: 17.1-17.8cm) and males 15.9cm (CI: 15.4-16.4cm)), with a spawning season from October through May. The prior available information on *K. xenura* reproduction from Tester and Takata (1953) did not differentiate between the two species of flagtails that are present in Hawaii. This study provides the first ever reproductive biology for *K. xenura.* This information is essential for setting future management regulations for this species.

2. Brief Project Description

Gathering life history information at the scale needed for management can be achieved through collaborative efforts with local fishers. Working with fishers not only increases capacity to assess relevant biological metrics in multiple locations, but it also increases fishers involvement and understanding of the justification behind the fishery regulations imposed on them. Collaborative methods have been found to be successful in Hawaiʻi (Poepoe et al. 2007, Friedlander et al. 2013, Kittinger 2013, Vaughan and Vitousek 2013) and across the world (Johannes 2002, Cinner and Aswani 2007). Furthermore, when fishers are engaged in the management process, they have increased buy-in and compliance with rules and regulations (Wiber et al. 2004, Basurto and Coleman 2010).

Conservation International Hawaiʻi collaborated with local communities and the Division of Aquatic Resources to train and empower local communities to monitor their resources and support collaborative partnerships with regulatory state agencies (including DLNR-DAR and Coastal Zone Management [CZM] programs). This project worked to remove barriers to communication, build trust, and fill data gaps that have previously led to inadequate management and poor compliance with management alternatives, specifically aimed at protecting spawning fisheries regulations. This project furthered the capacity of communities to provide management alternatives aimed at protecting spawning populations in accordance with customary Hawaiian practices and conventional fisheries management strategies. Furthermore, the information developed from these community-based monitoring approaches provided valuable information to state management agencies (DLNR-DAR and CZM) to support effective management.

This project was comprised of two components. The *first* component developed and supported community-based monitoring and spawning season assessments in 4 communities, with the projected communities including Miloliʻi, Kīholo, and Kailapa on Hawaiʻi Island and Kahana on Oʻahu. This community based training in fisheries monitoring built local capacity to manage marine resources and supported local pono fishing practices. The *second* component gathered detailed location-specific information on reproductive biology, to inform state regulations and management. To achieve this second component of the project we partnered with the Department of Land and Natural Resources Division of Aquatic Resources (DLNR-DAR) and local communities focusing on the assessment of the reproductive biology of two fish species of management concern: native aholehole (*Kuhlia xenura)* and invasive mullet kanda (*Moolgarda engeli).* Aholehole is one of the priority food source species in Hawaiʻi and was reported as one of the top 10 targeted near shore fish species by local fishermen (Schemmel et al. 2016). Yet, little life history information existed for this species to set effective management regulations. Reproductive information for aholehole including size at maturity and spawning season is valuable to establishing future management regulations such as size limits, closed seasons, and/or bag limits. Additionally, we assessed the reproductive biology of the invasive mullet, kanda, to inform invasive species management as this species is of particular concern as a competitor of native mullet. Basic biology of mullet kanda was lacking, as assessments of the reproductive biology and life history of this species was not previously known in its native or introduced ranges. Through partnerships with the estuary team at DAR, we determine the life history of the invasive mullet. This information is being used to increase our understanding of its interactions with native mullet and assist in the development of mitigation and control strategies for this invasive species. Lastly, we compared the reproductive biology (spawning season and size at maturity) for both aholehole and kanda at two locations to determine the spatial variability in reproductive biology for each species. This information is critical to understanding the effectiveness of management regulations for sustaining local populations.

Objectives and tasks

1. Engage with and enlist community members from the following Project-identified communities that are interested in participating in community-based fishery monitoring practices:

a. Miloliʻi, Kīholo, Kailapa (Hawaiʻi Island) and

b. Kahana Bay (Oʻahu).

2. Conduct a minimum of one (1) workshop per Project-identified community to provide outreach and training in gonad sample collection and monitoring protocols to interested community members, utilizing monitoring methods developed for the "Hawai'i Moon Calendar Project."

a. Collect and conduct analyses for one year at minimum of two of the following project sites (Maunalua Bay, Hilo, and Kīholo) per fish species. Monitoring data and samples should be able to assess reproductive season and reproductive characteristics for the targeted reef species, including to include at a minimum:

b. Aholehole (*Kuhlia xenura*)

c. Mullet kanda (*Moolgarda engeli*).

3. Provide comparative analyses of spawning seasons and spawning time for aholehole and mullet kanda at a minimum of two out of three sites (Maunalua, Kiholo, and Hilo) and develop an interpretive summary of results for application into fishery management.

4. Utilize analysis results to collaborate with DLNR-DAR to develop a set of STATE approved recommendations and next steps to be taken to inform management actions for nearshore fisheries in support of healthy coral reef ecosystems.
5. Share results of the analyses and the STATE approved recommendations with participating communities to further inform sustainable fishing practices, including but not limited to, closed seasons and raised awareness on resource use and consumption.

3. Partners

- DLNR-DAR: Department of Aquatic Resources AIS team and Estuary Research Team, including Kim Peyton and Troy Sakihara.
- Fisheries Ecology Research Lab, University of Hawaiʻi at Mānoa.
- NOAA Fisheries Extension Agents (Matt Ramsey and Keith Kamikawa).

4. Approach

a. Detailed description of the work performed.

CI partnered with communities in the following locations: Miloliʻi, Kīholo, Kailapa, and Kahana Bay (Figure 1). Workshops were held in the fishing communities to train participating fishers on standardized methods of measuring, weighing, assessing gender, and collecting gonad samples from harvested species. Tools used to monitor spawning seasons and reproductive biology were provided to participating fishing communities and included: measuring tapes, fish scales (Rapala RMDS-25 25 lb/11.4kg, by 0.1kg), gonad scales (SWS100 100g by 0.01g), and lawaiʻa logbooks. The community monitoring methods that that were used were developed by Eva Schemmel, the PI for the "Hawaii Moon Calendar Project" (Schemmel et al 2016).

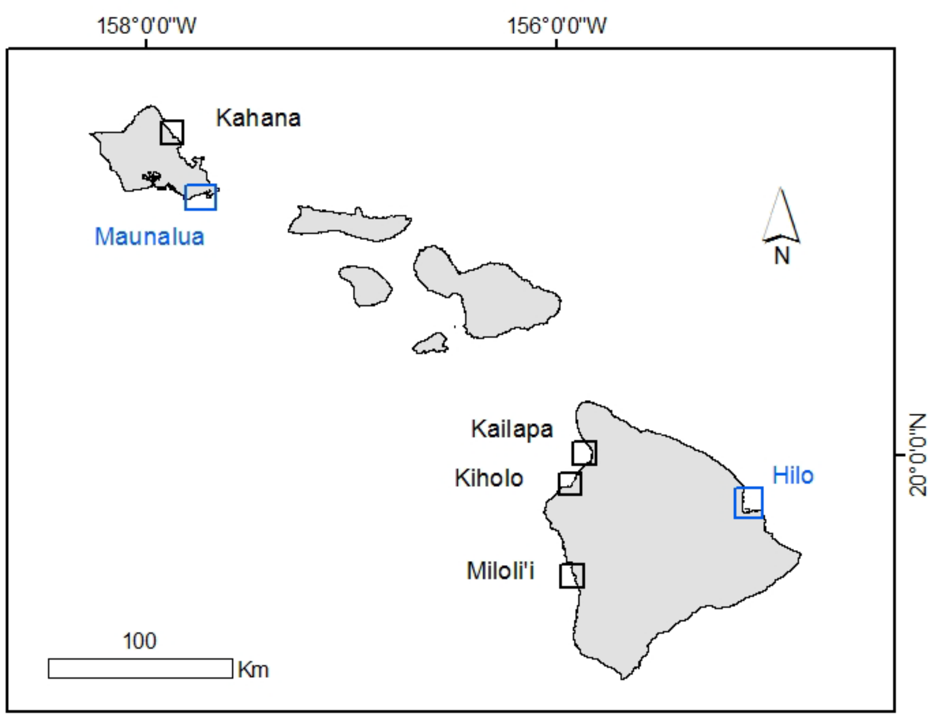

Figure. 1 Study locations showing the participating fishing communities (black) of Kahana, Kailapa, Miloliʻi, and Kīholo and the additional locations where fish reproductive assessments will take place (blue; Hilo and Maunalua Bay).

To gather information on spawning seasons and reproductive characteristics of aholehole (*Kuhlia xenera)* and mullet kanda (*Valamugil engeli*) we worked with DLNR-DAR partners and local fishers to collect gonad samples from two locations for each species. Aholehole (*Kuhlia xenera)* were collected from Maunalua Bay and Kīholo and mullet kanda (*Valamugil engeli*) were collected from Hilo and Maunalua Bay. Aholehole gonad samples have been collected from Maunalua Bay and Kīholo since January 2013 as part of the Hawaiian Moon Calendar Project. This data was incorporated into our assessment of aholehole from June 2016 through June 2017 in Maunalua Bay and a spatial comparison of size at maturity for aholehole from Kīholo and Maunalua Bay. To sample kanda we partnered with Kim Peyton and the DAR estuary team. Kanda were sampled monthly in Maunalua Bay between September 2015-December 2016 and monthly in Hilo Bay from December 2015 – December 2016. These samples were stored until analysis for this project during the project period from May 2016 through June 2017. Approximately 20 individuals were collected across the size range caught in the cast net (>100mm). Maunalua Bay samples were collected from Wailupe and Hilo samples were collected from Reeds Bay, Puhi Bay, and the Wailoa estuary. Sampling dates were randomly selected each month and sampling times took place during the morning from approximately 8 am - 12 pm.

We used gonadosomatic index (GSI) and standard histological techniques to determine spawning seasons (DeMartini and Fountain 1981; Schemmel and Friedlander et al 2016), size at maturity (Lowerre-Barbieri et al. 2009; Schemmel and Friedlander et al 2016), and additional reproductive characteristics. GSI is the relative percent mass of the fish gonad divided by the gonad free mass of the fish (GSI=gonad mass/gonad free fish mass*100). GSI data will be coupled with histological assessment of reproductive maturity and spawning seasons (Lowerre-Barbieri et al. 2009). GSI and frequency of reproductive phases provided a measure of reproductive output for each species at each sampling location. Together, this information was used to determine location specific spawning seasons and size at maturity for each species. This information was used in a comparative analysis for each species to determine if differences exist in size at maturity and spawning seasons between sampling locations. Likelihood ratio tests were done to compare size at maturity (L50) estimates for mullet kanda to determine if there are differences in size at maturity between genders (male or female) at each location and between locations (Schemmel & Friedlander 2016). No large (>7 cm) aholehole were found in North Kona communities. Aholehole were collected from fishponds and these ponds may have been a nursery ground for this species.

5. Community engagement and workshops

Workshops were held in each of the four communities to engage with and enlist community members from Miloliʻi, Kīholo, Kailapa, and Kahana Bay to monitor spawning seasons of harvested nearshore fish species.

Workshop Dates and Activities:

- July 1-2, 2016 - Kahana community gonad workshop.
    - Participants: 36
- June 15, 2016 - Visit with Miloliʻi community. Discussed fisheries management and ecological surveys.
    - Participants :14
- July 27, 2016 - Division of Aquatic Resources workshop and training of biologists in reproductive assessment of spawning seasons and size at maturity.
    - Participants: 6
- August 27, 2016 - Kahana Papio Fever fishing tournament. Workshop for participating fishers and reproductive data collected for fish captured in the tournament to assist the Kahana community in spawning season assessment for ulua species.
    - Participants: 45
- October 12, 2016 - Kailapa community gonad workshop at the Na Kilo Aina camp.
    - Participants: 60 children from elementary to high school levels.
- June 2, 2017 - Kīholo community workshop and results sharing. We reviewed the biology of aholehole assessed in the area and compared results with those for aholehole in Maunalua Bay.
    - Participants: 10
- June 3, 2017 - Miloliʻi community workshop on spawning and reproductive biology for harvested species. We reviewed results and known biology of species of interest with the community and provided them with a summary table of life history and biology of species of interest. We incorporated local knowledge on species biology into the table for their reference.
    - Participants: 8

Figure 2. Kailapa community workshop to teach young fishers and community members the importance of understanding fish biology, fishing impacts, and monitoring spawning seasons.

Figure 3. The Kahana Papio Fever fishing tournament. Participating fishers learned how to monitor spawning seasons and data was collected on papio and ulua (jacks) spawning and size at maturity for the Kahana community.

6. Biological Assessment for kanda (Moolgarda engeli) and aholehole (Kuhlia xenura)

Kanda (Moolgarda engeli)

Population Demographics

M. engeli sizes ranged from 30mm to 209mm (FL). Female and male size distributions did not differ between locations (χ^2 =0.37, p-value=0.54). Female *M. engeli* were found to be on average 23mm larger than males (t=7.19, p-value<0.01) (Figure 4). We found a 4:1 female to male sex ratio from *M. engeli* sampled from a 100 mm– 209 mm size distribution. There were 236 females and 84 males sampled from Maunalua Bay and 254 females and 37 males sampled from Hilo Bay.

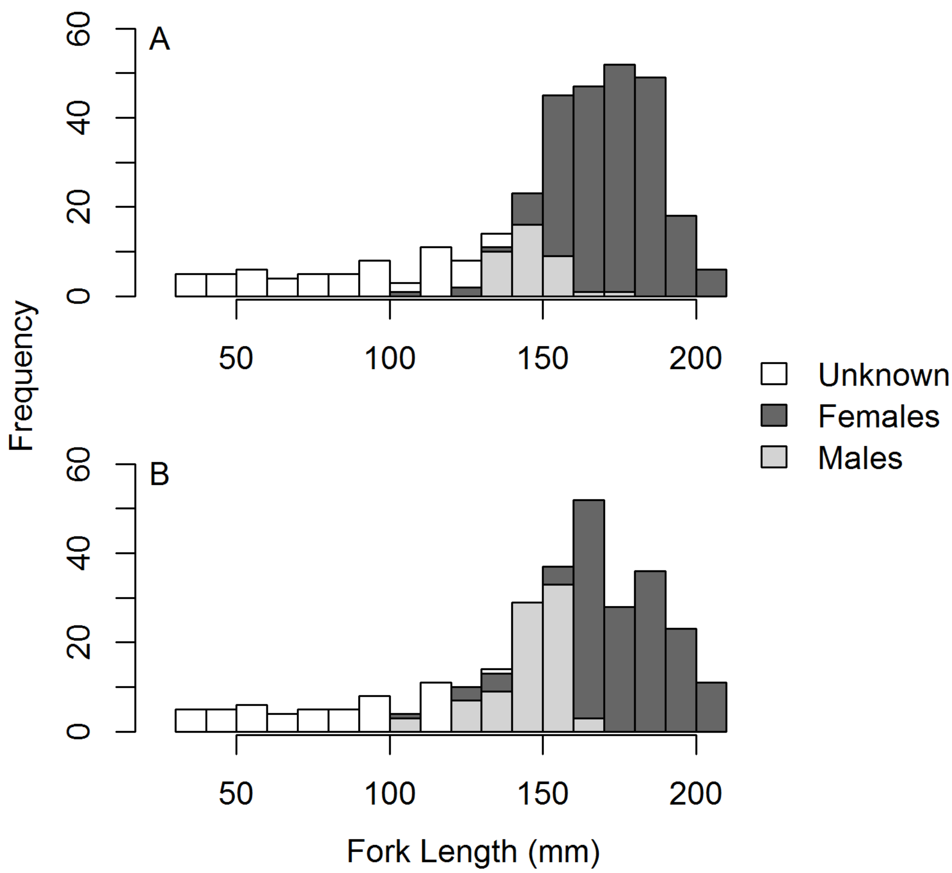

Figure 4. Length frequency distribution of *Moolgarda engeli* collected using cast nets and dip nets from A) Hilo Bay (Hawai'i) and B) Maunalua Bay (Oahu).

Sexual Maturity and Spawning Seasons

A total of 611 sampled *M. engeli* were included in the reproductive assessment. Female *M. engeli* size at maturity (L_{50}) and age at maturity (A_{50}) did not differ between locations (L_{50} : χ^2 =0.42, p-value=0.51; A_{50}: χ^2 =0.04, p-value=0.85). There was no difference in size (L_{50}) and age (A_{50}) of sexual maturity for females and males (L_{50}: χ^2 = 0.39, p-value =0.53; A_{50}: χ^2 =0.29, p-value=0.59). *M. engeli* reach sexual maturity at 140.1mm (CI: 139.5-141.6mm) and 208 days (CI: 204.2-220.9 days) (Figure 5).

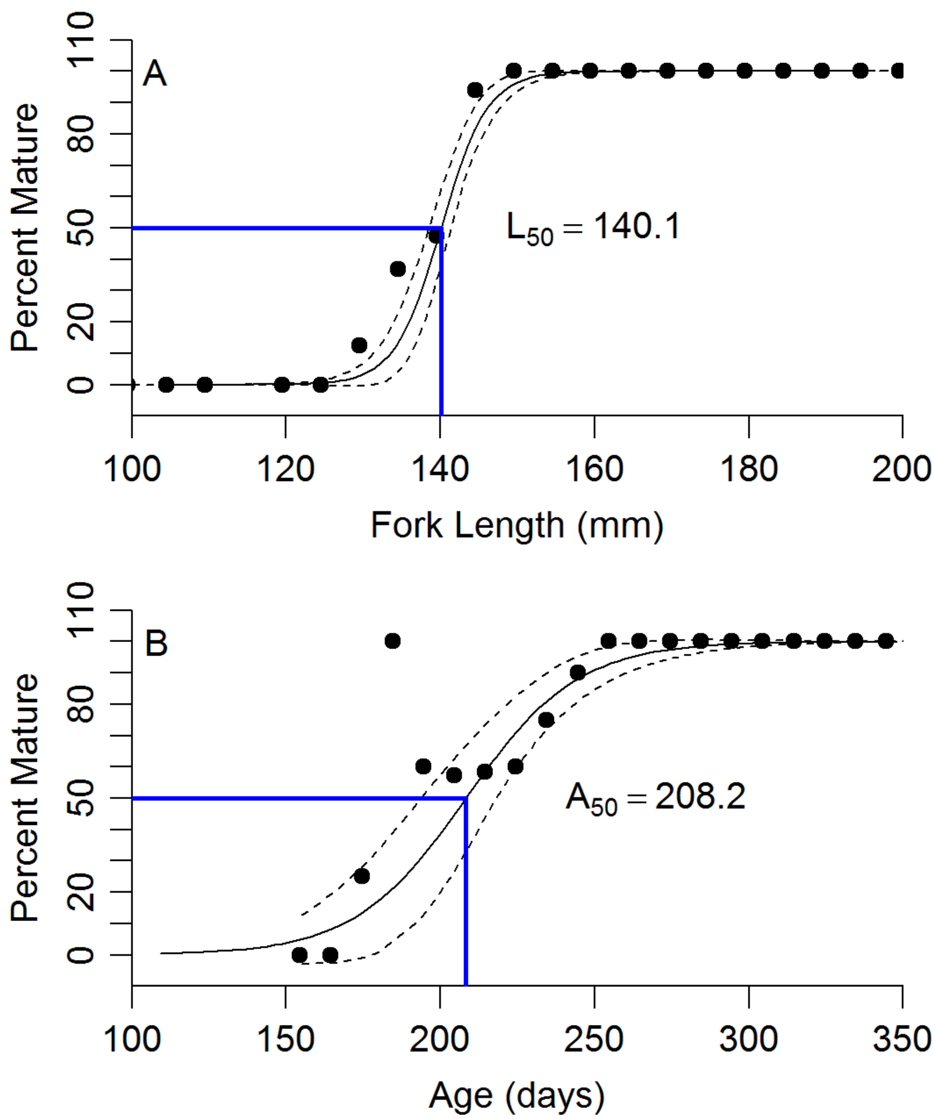

Figure 5. *Moolgarda engeli* size and age at maturity using 5mm fork length bins and 10 day age bins. A) L_{50} = 140.1mm (CI: 139.5-141.6mm) and B) A_{50} = 208 days (CI: 204.2-220.9 days).

Kanda exhibited group synchronous oocyte development, with batches of oocytes developing for each spawning event. *M. engeli* exhibited year round spawning with high gonadosomatic values and spawning capable females found throughout the year (Figure 6 & 7). Actively spawning females were found from April through December 2016.

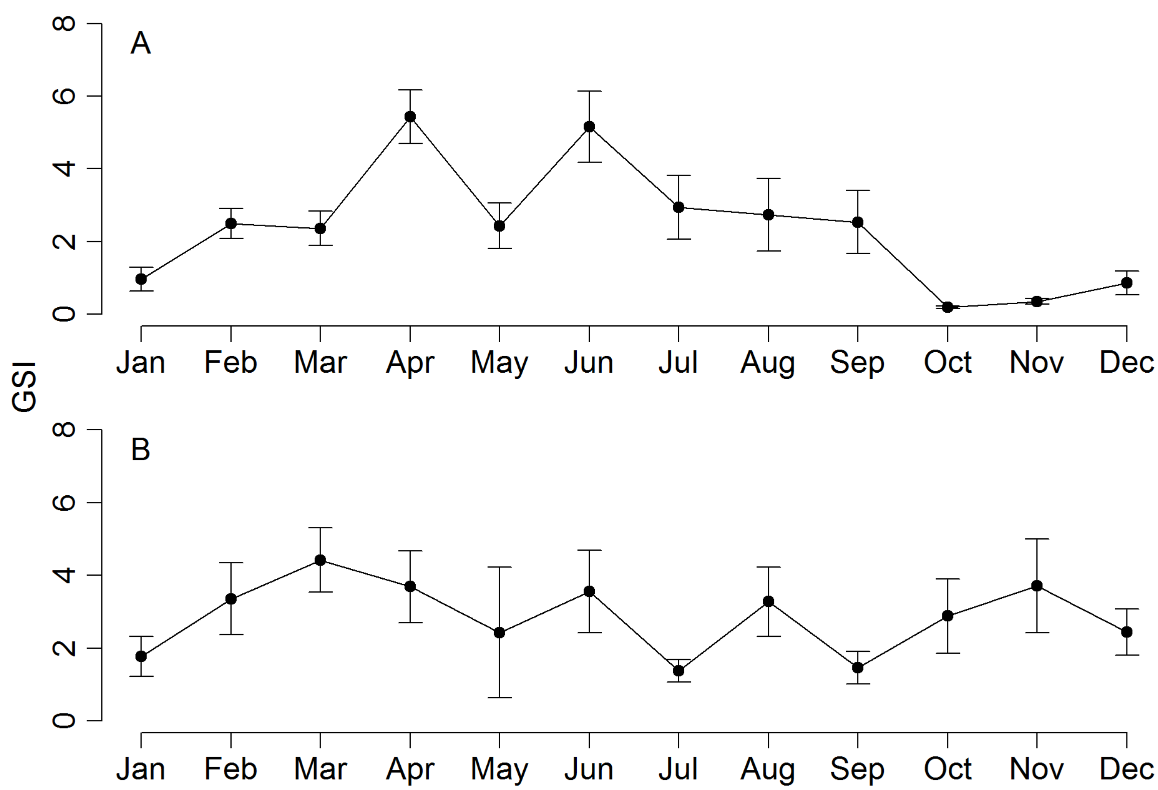

Figure 6. Mean monthly gonadosomatic index (GSI) for *Moolgarda engeli* from A) Hilo, Hawaii, and B) Maunalua, Oahu. Error bars represent standard error.

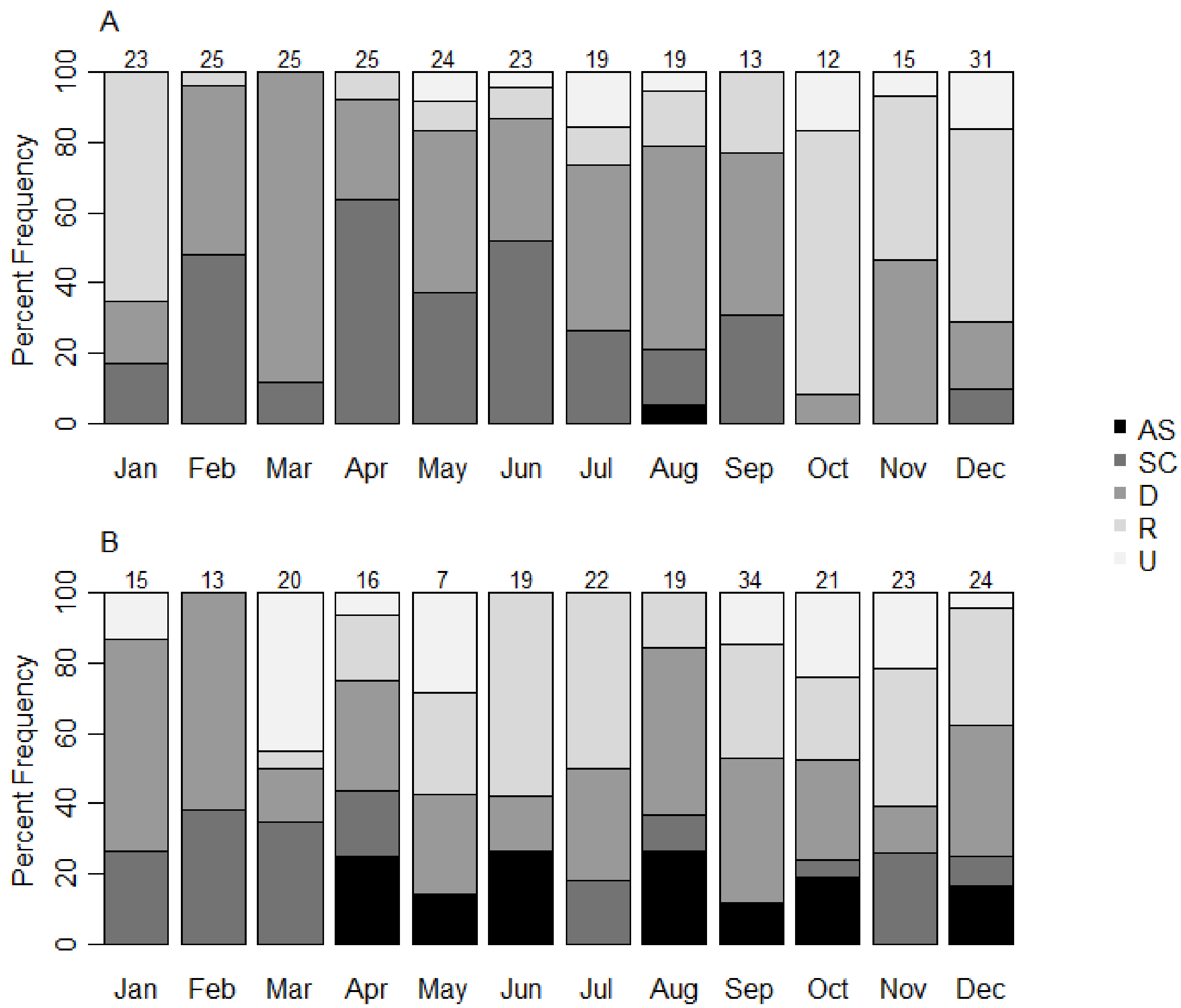

Figure 7. Reproductive state frequency of *Moolgarda engeli* in A)Hilo and B) Maunalua Bay. Refer to table # for descriptions. AS= Actively Spawning, SC= Spawning Capable, D= Developing, R= Resting, U=Undeveloped.

Age and Growth

A total of 227 *M. engeli* were measured for age (81 from Hilo and 146 from Maunalua Bay) spanning a size range from 30mm to 209mm. Ages ranged from 44 to 349 days (μ = 249.6 days ± 72.7 sd) for Hilo and 36 to 429 days (μ = 221.7 days ± 81.2 sd) for Maunalua Bay. The oldest fish was 429 days old (T_{max}) and 185mm FL. Generational turnover was estimated at 215 days or approximately 7 months.

M. enegli, individuals with unknown gender, males, and females were assessed together. The von Bertalanffy growth model (r^2=0.82) was the best fit model followed by power (ΔAIC=21.0, r^2=0.81) and linear (ΔAIC=38.8, r^2=0.79) growth models. *M. engeli* show asymptotic growth with growth rates slowing as fish reach maximum size ($FL = 278.71*(1-e^{(-0.0036(Age-19.7))}$, Figure 8). Females and males exhibited differential growth patterns (F=2.69, p-value<0.01), with males reaching smaller maximum sizes than females of a similar age (Figure 9).

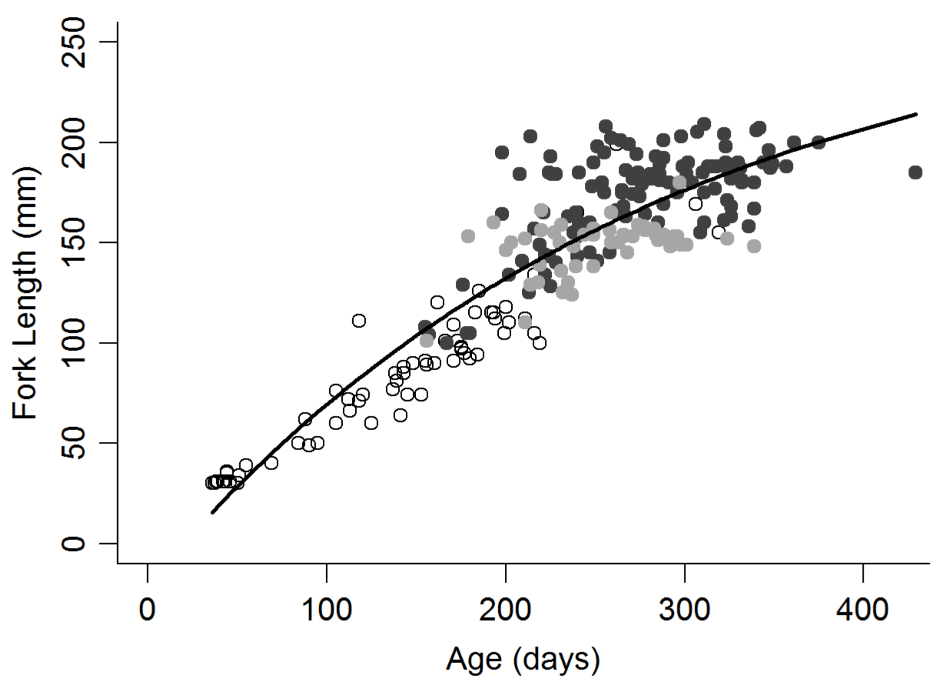

Figure 8. Von Bertalanffy growth curve ($FL=278.71*(1-e^{(-0.0036(Age-19.7))})$) for *Moolgarda engeli* (Males=gray circles, Females=dark gray circles, Unknown gender = open circles).

Aholehole (Kuhlia xenura)

A total of 73 aholehole were sampled from North Kona ranging from 10.7 cm to 20.2 cm (Table 1 and Figure 9). The majority of individuals were immature with only one mature female and eight mature males. There were no spawning capable or actively spawning females sampled from North Kona. This is interesting in terms of the role of fishponds as nursery habitat for aholehole. The majority of the aholehole sampled were from Maunalua Bay, Oahu. A total of 278 aholehole were sampled from Maunalua Bay (Table 1).

Table 1. Sample size by location and reproductive state for *Kuhlia xenura.*

Reproductive State	Maunalua Bay	North Kona
Total Females	187	47
Undeveloped	23	46
Developing	8	0
Spawning Capable	63	0
Actively Spawning	20	0
Resting	73	1
Total Males	91	24
Undeveloped	0	16
Mature	91	8

Size at maturity was slightly larger for females compared to males (Figure 9). Female size at maturity is 17.5 cm and male size at maturity is 16.4 cm. Size at maturity is larger than the minimum size limit of 5 inches.

Spawning season for aholehole from Maunalua Bay, Oahu was found to peak from October through May with a rest period during summer (Figure 10 & 11). Since there is no evidence of large spawning aggregations forming and given the long spawning season, closed seasons may not be the best approach for managing this species.

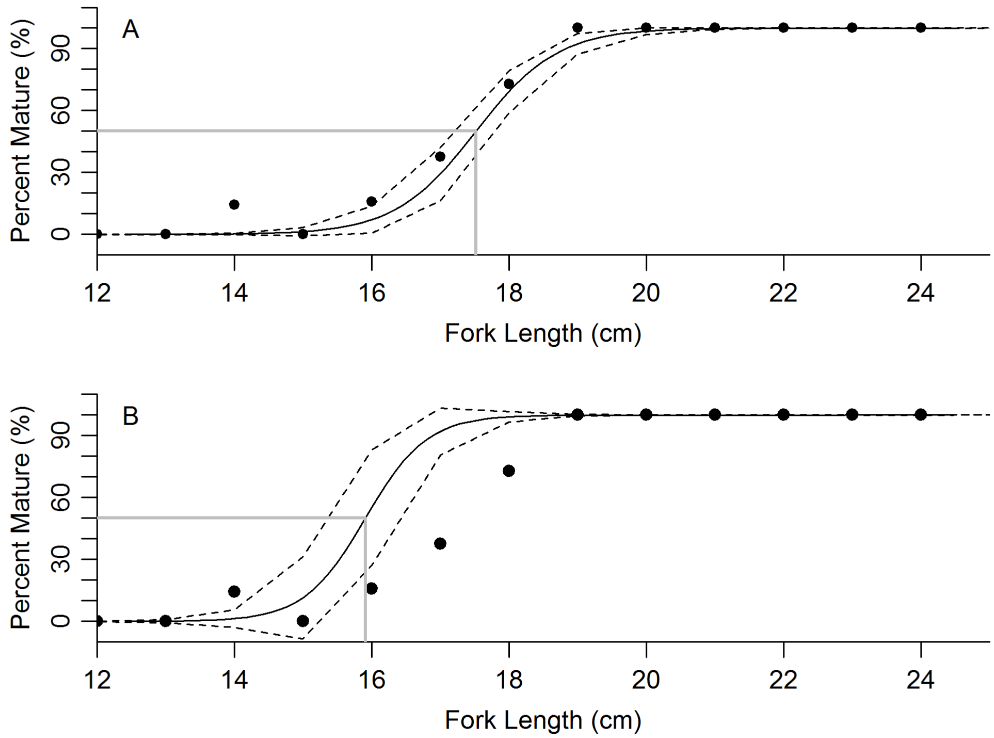

Figure 9. *Kuhlia xenura* size at reproductive maturity (L50). A. Females (17.5cm (CI:17.1-17.8cm), B. Males (15.9cm (CI:15.4-16.4cm))

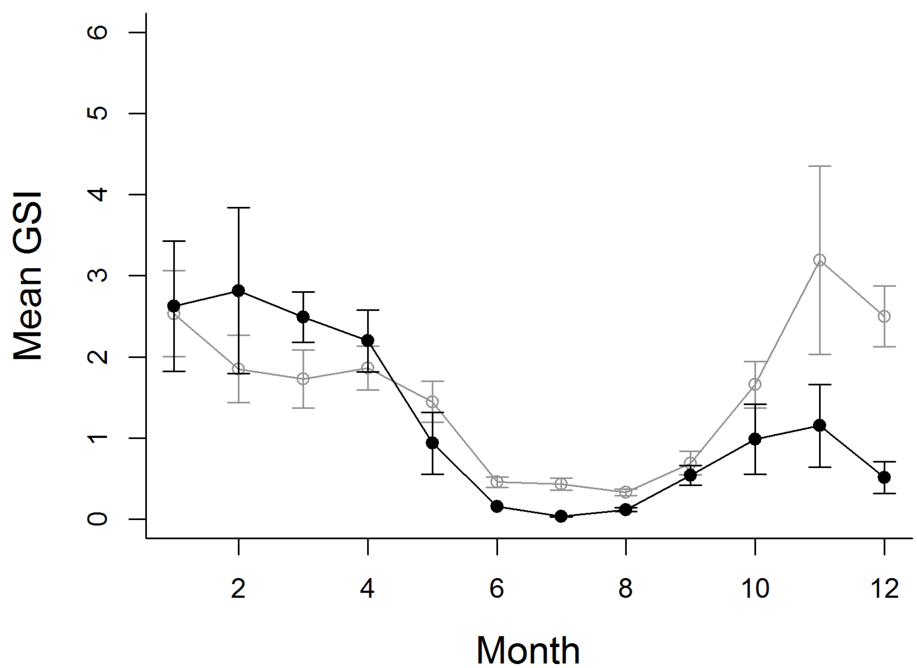

Figure 10. Mean gonadosomatic index per month for *Kuhlia xenura* reproductively mature females (gray) and males (black). Error bars are standard error.

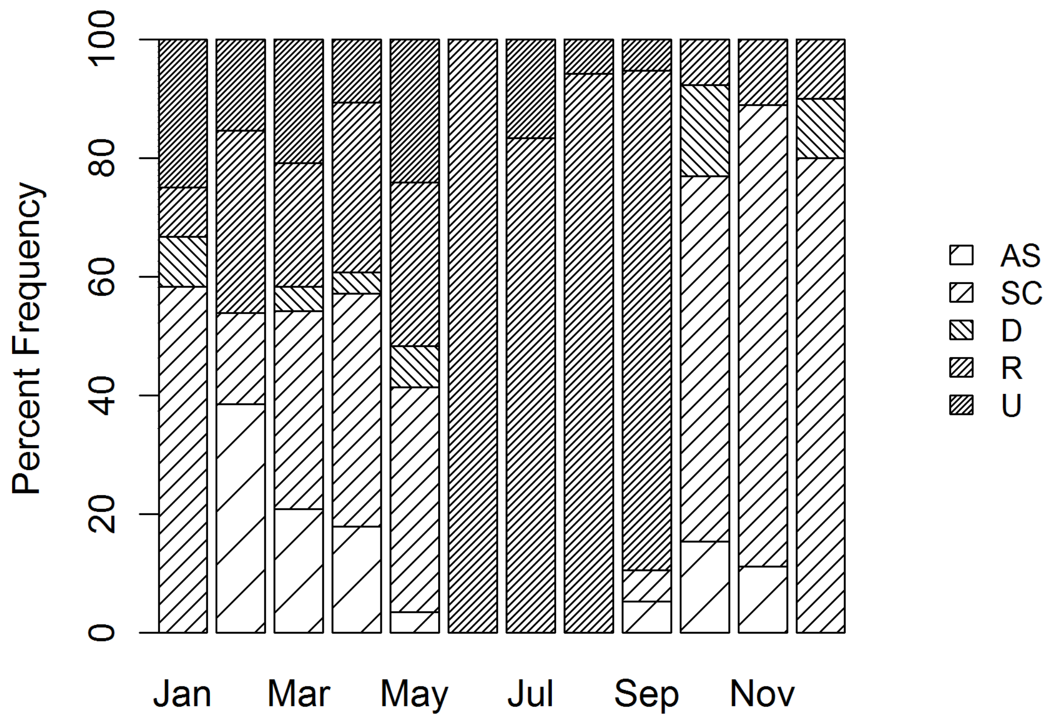

Figure 11. The frequency of reproductive stages of female *Kuhlia xenura* from Maunalua Bay, Oahu.

7. References

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8. Application of research

This project worked with DAR, local communities, and fishers to monitor their fishery to understand best practices such as harvest seasons and target harvest sizes. By incorporating fishers into local monitoring, they were able to understand the importance of size limits and closed seasons and therefore are more likely to comply with fishing regulations. Through these partnerships we were also able to gather reproductive information for several harvested reef fishes including but not limited to aholehole (*Kuhlia xenura)* and the invasive mullet, kanda (*Moolgarda engeli).* The biology of these species was shared with partners to better understand how to manage each species. The estuary team at DAR is utilizing the information on kanda to better understand the potential impacts of this invasive mullet on native mullet species and estuary ecosystems. The next step is to assess the biology of the native mullet (*Mugil cephalus* and *Neomyxus leuciscus)* and pair this with abundance and distribution assessments from the estuary research that DAR is conducting. The biology of *Kuhlia xenura* is the first ever biology for this species and serves as a baseline for establishing future management regulations. Despite the significant ecological, economic, and cultural importance of aholehole in Hawaii, prior to this study, little was known on their biology and life history. The prior available information on *K. xenura* reproduction from Tester and Takata (1953) did not differentiate between the two species of flagtails that are present in Hawaii. This study examined the reproductive biology of *K. xenura* to understand the biology of the endemic aholehole species. The next step is to understand the biology of *K. sandvicensis,* the other aholehole species in Hawaii.

9. Data Management: How information was shared and used by resource managers

Additional information from this research will be available within the next 6 months through published manuscripts and data will be available online. Results were shared through presentations to working groups, DAR, and communities. This research was shared at the May 4th, 2017 meeting for the Ocean Resource Management Plan at the office for Coastal Zone Management and on July 28th, 2017 for the Coral Reef Working Group.

Final Report Prepared by: ___Eva Schemmel_______________

Signature of Point of Contact: ____________