The Fine-Scale Movements of Juvenile California Halibut in San Diego Bay: A Novel Approach Utilizing Acoustic Telemetry

A proposal submitted to the San Diego Unified Port District Environmental Committee

by

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Introduction

Since the late 1800's California halibut, *Paralichthys californicus*, has been one of the most highly prized fish caught by the recreational and commercial fisheries off central and southern California. While it has been found as far north as Washington State its common range extends from Morro Bay, California south to Magdalena Bay, Mexico (Eschmeyer et al., 1983; Fitch and Lavenberg, 1971). Adults occupy coastal waters less than 100 m deep but are more abundant in less than 30 m (Miller and Lea, 1972; Allen, 1982). California halibut spawn year round, primarily in February-March, with secondary spawning events occurring between July and October (Moser and Watson, 1990). Young-of-the-year and juveniles are commonly found in shallow nearshore coastal waters and in embayments (Kramer, 1990; Fodrie and Mendoza; 2006).

Because of its economic importance to California and dependence on shallow nearshore and embayment habitats as nursery grounds, which have been altered and reduced by human encroachment (Kramer 1990), it has been the focus of an increasing number of studies during the past 30 years. Studies in San Diego County have identified critical nursery habitat in the shallow waters (<8 m) along open coast and (<1 m) in embayments (Kramer, 1990). Juveniles are more abundant and prefer unvegetated, fine sandy, benthos over habitat with eelgrass (Drawbridge, 1990; Valle et al., 1999; Fodrie and Mendoza, 2006).

Recent studies aimed at identifying critical nursery habitat in San Diego County have quantified the available habitat and expected contribution of juveniles from these areas to the sub-adult population. Fodrie and Mendoza (2006) estimate that of the 33,174 ha (at low tide) of nursery habitat available to juvenile halibut within the San Diego County region, 13% (4174 ha) is present in San Diego Bay (SDB). This is about 81% of the embayment nursery habitat available to juvenile halibut in San Diego County. Additionally, Fodrie and Mendoza (2006) demonstrated that while 84% of the nursery habitat available in San Diego County is present in the shallow (<20 m) nearshore coastal waters, juvenile halibut from embayment nurseries have a greater annual recruitment, between 58 to 69%, to the older age classes. It has been estimated that San Diego Bay alone can account for over half of the juvenile halibut available to recruit annually to the adult population in San Diego County (Fodrie and Mendoza, 2006).

Tagging studies along the coast have shown that movements of young, sub-legal size (<58 cm in length), halibut are generally <10 km; months or even years after their release. Meanwhile larger fish (> 50 cm in length) tend to migrate farther and faster and can be found over several hundred kilometers from their release site (Tupen, 1990; Domeier and Chun, 1995; Posner and Lavenberg, 1999). Recently Fodrie and Levin (2008) investigated the connectivity of juvenile halibut nursery habitat in the embayments of San Diego County to the subadult (≤ 2 years in age) habitats along the coast. They found that juveniles emigrating from their nurseries in bays, including SDB, migrated < 10 km.

Given that in San Diego County 1) SDB has the largest embayment nursery habitat for halibut, 2) SDB can contribute to more than half of the annual juvenile recruitment to the adult population, 3) young halibut do not migrate great distances, makes SDB a critical resource in the County to ensure the long-term sustainability of the halibut fishery in the Bay and the adjacent coast.

Currently marine protected areas (MPAs) are being established in southern California as part of the Marine Life Protection Act. Several of the draft MPA maps that are currently being considered have identified the most southern or inner portion of San Diego Bay as an area that would be protected. However, a recent progress report by Merkel & Associates (2009) illustrates that the area of the SDB being considered in the MPA map proposals is largely eelgrass habitat. As mentioned earlier, juvenile California halibut are found in greater abundance and prefer unvegetated habitat. Fodrie and Mendoza (2006) determined that the optimal nursery habitat for juvenile halibut is located in the central and northern sections of SDB. Additionally, a 5-year study in SDB found that juvenile halibut were more abundant at stations outside of the most inner or southern region of the bay (Allen, 1999). Similar studies in other California embayments have also observed higher juvenile halibut abundances in the central and outer regions of embayments compared to innermost areas (i.e. farthest from the embayment opening) (Valle, 1999; Herzka, 2009). If the area closures that are currently being considered for SDB are implemented as part of the current MPA process, critical nursery habitat for California halibut in SDB would not be protected.

Most studies conducted to date have assessed juvenile halibut nursery habitat by sampling small areas of habitat during daylight hours over different sampling periods and tides (Allen, 1988; Allen, 1990; Kramer, 1990; Valle et al., 1999; Fodrie and Mendoza, 2006; Herzka, 2009). This sampling methodology only provides a "snapshot" of nursery habitat usage and does not address questions about fine-scale spatial and temporal movements that may be influenced by environmental factors such as seasonality, tides, lunar phase, as well as diel activities possibly associated with feeding. Drawbridge (1990) found that juvenile halibut feeding activity was greater in the late afternoon and during nights with full moons. Additionally, different juvenile halibut size classes prefer different sediment grain sizes (Drawbridge, 1990). Furthermore, some studies sampling juvenile halibut in embayments have had reduced catches of larger juveniles starting at around 140 mm standard length during the summer and fall months (Haaker, 1972; Allen and Herbinson, 1990; Kramer, 1990; Valle, 1999; Herzka, 2009). While not well understood, some suggested explanations have included sampling gear selectivity, size-selective mortality, and emigration. Emigration seems a plausible explanation as juveniles become piscivorous with increasing size (Allen, 1988; Drawbridge, 1990) and may find preferred larger prey in coastal waters. Investigators have also observed larger juveniles along the coast (Allen and Herbinson, 1989; Plummer et al., 1983; Kramer, 1990). For juvenile California halibut, understanding their short-term movements and their fundamental causes within SDB needs to be accounted for to successfully evaluate their nursery habitat. Habitat connectivity, associated with the ontogenetic emigration of juvenile halibut from their nursery habitat in SDB to the nearby coastal areas, should also be considered in conjunction with this nursery habitat.

The methodology employed in this study, acoustic telemetry, will attempt to identify site fidelity and movement patterns associated with environmental conditions and diel activity of juvenile California halibut in San Diego Bay. In addition patterns of habitat connectivity, associated with older juveniles emigrating to coastal waters, will also be investigated. Acoustic telemetry has been used effectively by scientists in fish to understand their fine-scale patterns of movement, site fidelity, and diel patterns of activity (Arendt et al., 2001; Humston et al., 2005; Topping et al.; 2006; Bellquist et al., 2008). The application of this technology to enhance our

understanding of their nursery habitat use in San Diego Bay will allow resource managers to effectively manage and protect this habitat.

Status of the fishery and enhancement

According to the California Department of Fish and Game records the largest commercial catch from state waters occurred in 1917 at about 1,600 tonnes. During the late 50's and early 70's commercial landings plummeted to record lows near 100 tonnes. Since 1980 annual commercial landings have been hovering around 500 tonnes, even after the usage of gill and trammel nets were prohibited within three miles of the coast. However, in 2007 commercial landings decreased to 200 tonnes and may reflect the implementation of new permit regulations and area closures. While commercial landings have fluctuated over the years (Figure 1), they appear to mimic larval abundances with natural population peaks about every 20 years (Moser and Watson, 1990; Barsky, 1990). However fishery effort is unknown during this time period and may account for the observed fluctuations. Recreational landings by commercial passenger fishing vessel's (CPFV's) reached a peak in 1960 at about 141,000 fish, but for the past 36 years annual landings have remained below 20,000 fish. Since 2004, CPFV's have landed less than 10,000 halibut annually.

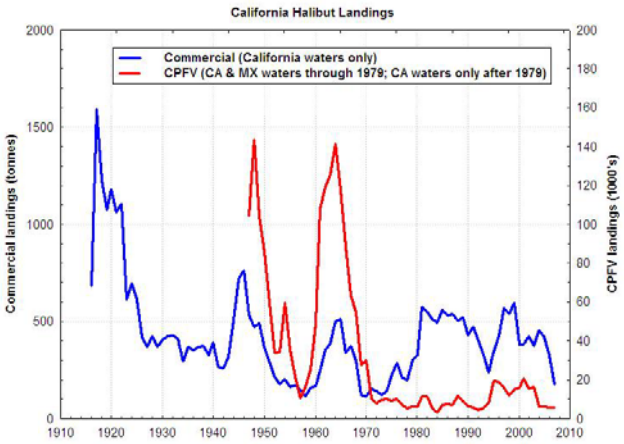

Figure 1. Commercial and recreational (CPFV) landings for California halibut 1916 – 2007.

With the loss of nursery habitat and a concomitant decline in fishery landings, resource managers need to incorporate multiple tools to help reduce or reverse the declines in landings. An often overlooked tool for resource managers that is gaining momentum globally as a proven approach is stock enhancement (Bell et al., 2008). In southern California stock enhancement of white seabass, a marine finfish, has occurred for the past 25 years. While white seabass has been the primary candidate, California halibut was previously considered by the California Department of Fish and Game as a species warranting enhancement due to embayment nursery habitat loss and declines in fishery landings. Currently the National Oceanic and Atmospheric Administration (NOAA) is committed to fostering the development of marine aquaculture as a tool for stock enhancement of important commercial and recreational fisheries. California halibut are presently being cultured by Hubbs-SeaWorld Research Institute with the intent of conducting pilot scale releases to enhance the local halibut population. In order to maximize their survival and eventual recruitment to the fishery, cultured fish should be similar to wild fish with respect to their life skills. With juvenile California halibut, a benthic ambush predator, this implies that they exhibit similar fine-scale movements and habitat usage as their wild conspecifics. The behavioral observations in this study, through the application of acoustic telemetry, will help to model expanded enhancement efforts in California.

In summary, identifying the fine-scale (in time and space) movements of juvenile California halibut within SDB will improve our understanding of how they use this critical nursery habitat and will provide resource managers with essential information that is vital to ensure the long-term health and protection of one of San Diego Bay's most valuable resources. Simultaneously stocking cultured California halibut and comparing their movements and habitat usage with their wild conspecifics will serve as a model for other national or international enhancement efforts that are considering identical or similar flatfish species.

Objectives

1) The primary objective of this project is to assess the fine-scale movements and habitat usage of juvenile California halibut in San Diego Bay using acoustic telemetry to support important management decisions such as the development of MPAs. This objective will be achieved by:

a. tracking movements over a greater time continuum will provide an increased level of precision with respect to their spatial and temporal patterns of movement that has not been achieved with previous investigations
b. combined active and passive tracking methods, including active tracking at night

2) A secondary goal of this project will be to compare differences in movement patterns between cultured and wild fish as a means of evaluating the feasibility of replenishing depleted halibut stocks in the future and/or using cultured fish as a surrogate for wild fish in studies such as this.

3) A tertiary goal is to establish a new network of acoustic receivers in SDB that can be utilized by other researchers with the advantage of being able to study smaller marine organisms with transmitters having a longer battery life.

Preliminary studies

With respect to the use of acoustic telemetry to study and observe fish movements, we have been using this technology in southern California since 2000. During this time we have conducted long-term tank studies looking at the effect of suture materials, healing and growth in white seabass and California halibut that have had transmitters surgically implanted into their peritoneal cavity. We have also conducted surgical implantation of transmitters in the field and have constructed a purpose-built portable surgical table. We have accomplished several studies on both of these species in different embayments in southern California where we have concurrently utilized both active tracking and passive monitoring (listening stations).

Methodology

Objective 1: To examine, with the use of acoustic telemetry, the fine-scale movement patterns and habitat usage of wild juvenile California halibut in San Diego Bay.

To accomplish this objective we will collect and release 25 wild juvenile halibut (<200 mm SL) in San Diego Bay with surgically implanted acoustic transmitters. To obtain live juvenile halibut, Sandy Grivetto, owner of Horizon Charters, has offered to donate live halibut that are caught as part of their marine science education program. If needed, we will use a small otter

trawl to collect juvenile halibut from the bay to supplement donated specimens. Acoustic transmitters will be surgically implanted following the protocols that we have already established and that have been approved by our Institutional Animal Care and Use Committee. Halibut with implanted transmitters will then be held in a small pen near the white seabass growout pen operated by the San Diego Oceans Foundation (SDOF). Fish will be held for several days to allow them to recover from the surgical procedure and they will be monitored by SDOF volunteers. All fish with transmitters will then be transported and released at the location where most of them were collected.

Because of the small size (weight) of juvenile halibut, VEMCO V7 transmitters will be used. The general "rule of thumb" when implanting transmitters into fish is to not have the weight of the transmitter, in water, exceed the weight of the fish, in air, by more than 2%. Because of the small size of transmitter needed in this study, VEMCO products were selected. The primary reason for this selection is that similar sized transmitters made by Sonotronics only have a battery life up to 21 days. The battery life of VEMCO transmitters can range from 26 to 432 days and is dependent upon the programming specified by the investigator when the transmitters are ordered. We plan to purchase transmitters that will have a battery life of at least 140 days which will facilitate both active tracking and passive monitoring.

Upon the release of the first group around October 2009, halibut will be actively tracked from a small vessel using a VEMCO VR28 tracking system. This system consists of a four channel ultrasonic receiver connected to a four element hydrophone that is mounted underwater attached to the vessel. The hydrophone array provides 360 degrees of monitoring coverage and determines bearing to the fish with the implanted transmitter while the vessel is underway. The receiver is connected to a portable laptop computer along with a WAAS-enabled GPS. Transmitter detections received by the VR28 are stored in an electronic file along with the date, time, latitude and longitude coordinates from the GPS unit. During the first two weeks after they are released, daily excursions will be made to actively reacquire individuals. Additional active tracking will be conducted at night during different moon phases after each release. After the initial two weeks of intensive daily active tracking, the frequency of daily excursions will be decreased and will depend on our ability to reacquire halibut until the next release of individuals. This active tracking protocol will be repeated again with a second release in the spring of 2010. Water temperature, dissolved oxygen, salinity, and pH will be collected, using a portable YSI 556 multi-probe meter, at the surface and at depth in locations where halibut are actively tracked.

A broadly dispersed array of 22 VEMCO VR2 underwater hydrophones (listening stations) will be deployed in San Diego Bay to supplement the data collected by active tracking (Figure 2). Prior to deployment range tests will be conducted to determine the detection range of the hydrophones. Our previous range tests indicate that water depth and benthic habitat type are the main factors that will determine the detection range. We anticipate, depending on the hydrophone location, that the circular area of bottom habitat where fish will be detected around the hydrophone will vary from about 31,000 to 785,000 m^2. On a monthly basis SCUBA will be used to replace and download data from the hydrophones. Currently we have made inquiries to the US Navy (LCDR Damon Dixon), US Coast Guard (LCDR Mike Dolan) and the San Diego Bay Harbor Patrol (Lt. Ken Franke) with regards to placement of hydrophones and SCUBA diving in the Bay. Currently the Harbor Patrol has approved the diving that would be conducted as part of this study and the USCG has requested to be notified of hydrophone placement and diving activities should this project get funded. Hydrophones will be deployed in SDB for the duration of the study.

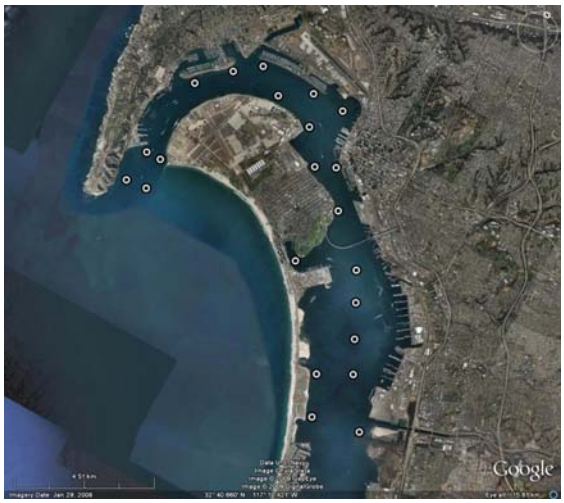

Figure 2. Tentative locations of 22 hydrophones (⊙) deployed underwater in San Diego Bay.

Because sediment grain size can determine habitat preference by juvenile halibut we will also collect benthic sediment samples in locations where halibut are released and actively tracked. Sediment samples will be collected with a 0.025 m^2 Petite Ponar grab. A 125 ml subsample will be collected from the top 2.0 cm of the sediment in the grab and placed in a polyethylene specimen container. Sediment grain size, including silts and clays, will be determined back at our facility according to the methods of Buchanan (1984). Additional sediment samples will also be collected from around the area where hydrophones are deployed.

Objective 2: To compare, through the application of acoustic telemetry, the fine-scale movement patterns and habitat usage of hatchery-reared juvenile California halibut in San Diego Bay and to determine if they exhibit similar behavior to their wild conspecifics.

Hatchery-reared halibut (<200 mm SL) will be grown at Hubbs-SeaWorld Research Institute's Mission Bay facility. Twenty-five individuals will be selected and VEMCO transmitters, similar in size and battery life as mentioned above, will be surgically implanted into their peritoneal cavity. After transmitters have been implanted and 2 weeks prior to their release, halibut will be held in a submerged system next to the SDOF white seabass growout pen in SDB. SDOF volunteers will monitor halibut in this system and feed them during this two week acclimation period. This containment system will also have sandy sediments on the bottom approximately 2 cm in depth. Louie (2005) determined that cultured California halibut can match background colors within one day but after one week they still differed from their wild conspecifics in their ability to bury in sediments. With the two week acclimation period we hope to reduce or eliminate any differences in this behavior. After this acclimation period the cultured halibut will

be released along with their wild, transmitter implanted, conspecifics discussed above. Active tracking and passive monitoring, as discussed above, will be implemented to detect their movements.

Data from the active tracking and passive hydrophone array for both the wild and cultured halibut will be imported into an Access database. Movements of individuals will be analyzed to determine if statistically significant trends, using parametric tests, are associated with the abiotic factors (water temperature, salinity, sediment grain size, tidal cycle, etc.) and biotic (emigration, diel activity). Comparisons between wild and cultured halibut with respect to their patterns of movement will also be investigated to determine similarity. Telemetry detections of halibut will be placed into GIS format so that the areas that they are utilizing in the bay can be overlaid with other GIS themes of San Diego Bay such as, bathymetry, eelgrass and non-vegetated habitat.

Objective 3. To establish a new network of acoustic receivers in SDB that can be utilized by other researchers with the advantage of being able to study smaller marine organisms with transmitters having a longer battery life.

With initial funding from the Port to deploy the acoustic receivers associated with this pilot study we will continue to seek additional funding to not only support the continued deployment of the array but to also investigate additional organisms. We will also seek to inform other potential investigators about this array and welcome their collaboration with additional studies.

Benefits to the Bay

This project, while beyond compliance and mitigation, will provide a valuable outcome to the residents and recreational fishing community who utilize San Diego Bay and the nearby coastal areas. Because California halibut is an economically important target species in the San Diego recreational fishery, a greater understanding of their nursery habitat utilization in SDB will provide for its active management and conservation in particular areas of the bay that may not be consider important. This should result in an increase in juvenile halibut survivorship and concomitant increase in the local abundance of adult halibut. This will ultimately provide greater fishing opportunities for recreational anglers and their families in San Diego.

This study will also provide for the environmental education and enrichment of various individuals and groups. Research assistants working for HSWRI generally have undergraduate degrees and are often seeking advanced degrees. The research assistants working on this project will receive valuable training and skills that will help to facilitate and shape their future direction in environmental research. Additionally, high school student interns at HSWRI will be used to assist with the marine sediment analysis and other components of this study. Their participation in this project will provide a unique opportunity to learn "hands-on" skills and to foster their scientific development. The information obtained from this study will be presented in public outreach to various organizations providing them with a greater understanding and appreciation for San Diego Bay and its resources.

Tasks and Milestones: The proposed project will have a 12 month duration starting with ordering transmitters in July 2009 and removing equipment from the bay by June 2010; conditional upon future funding. Upon the completion of the study a final report would be submitted by October 2010.

Tasks	2009 - 2010 J A S O N D J F M A M J
Order acoustic transmitters	X
Deploy acoustic hydrophones	X
Release 1st batch of 50 fish	X
Active tracking	X X X X
Release 2nd batch of 50 fish	X
Active tracking	X X X X X
Last transmitters battery life expire	X
Remove acoustic hydrophones	X

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II. Qualifying experience and previous related work

Michael Shane has over 20 years experience studying the marine ecosystems in southern California. He has conducted several studies similar to the proposed project. With regards to surgical procedures in fish he conducted several studies investigating the effects of surgical procedures and suture type associated with the implantation of transmitters and how they affect healing, survival and growth in white seabass and California halibut. He has presented this information at the Annual Meetings of the American Fisheries Society, Southern California Academy of Sciences, World Aquaculture Society, and the 3rd International Conference on Stock Enhancement. Michael has also given seminars during the past five years to veterinary students from UC Davis on fish surgery techniques. Recent field-related studies where he has used acoustic telemetry to study fish movement include:

- Movements of cultured juvenile white seabass released into Mission Bay. (June – October 2004). The Boeing Company Contact: Kevin Ober (714) 762-4192.
- Movements of cultured juvenile white seabass released into Agua Hedionda Lagoon. (November 2004 – June 2005). Partially funded by the San Diego County Fish and Wildlife Commission. Contact: Dawn Nielsen (858) 565-7046.
- Movements of cultured subadult California halibut released into Mission Bay. (July – December 2005). Funding support through private donations to HSWRI. Contact: Donald Kent (619) 226-3870.

This information has also been presented as part of his local outreach to the San Diego Rod & Reel Club, San Diego Freedivers, Marine Technology Society, and the Sportfishing Association of Southern California. Michael is also a certified diving instructor with the National Association of Underwater Instructors and is the Diving Safety Officer for Hubbs-SeaWorld Research Institute.

Mark Drawbridge has over 20 years experience studying the marine ecosystems in southern California and he investigated the feeding relationships, feeding activity and substrate preference of juvenile California halibut in coastal and bay habitats for his Master's Thesis at San Diego State University. He is adjunct faculty and lecturer in aquaculture at the University of San Diego. Mark has served as a graduate student advisor at the University of San Diego, California State University at San Marcos and Fullerton, and Autonomous University of Baja California, Mexico. He currently the President of the California Aquaculture Association. His current research focus is on fisheries enhancement for marine finfish, including California halibut, and offshore aquaculture.

III. Cost proposal

DESCRIPTION	REQUESTED	MATCHING	PROJECT TOTAL
A. PERSONNEL			
Mark Drawbridge		$ 4,000	$ 4,000
Michael Shane	$ 24,000		$ 24,000
Research Assistants	$ 36,000		$ 36,000
SUB-TOTAL SALARIES:	$ 60,000	$ 4,000	$ 64,000
B. FRINGE BENEFITS (35%)	$ 21,000	$ 1,680	$ 22,680
C. SUPPLIES			
Acoustic transmitters	$ 32,500	$ -	$ 32,500
Hydrophone batteries and deployment hardware	$ 2,500	$ -	$ 2,500
Misc supplies & dive support	$ 3,000	$ -	$ 3,000
TOTAL SUPPLIES:	$ 38,000	$ -	$ 38,000
D. TRAVEL			
Vessel Rental	$ 9,000	$ 9,000	$ 18,000
Vessel Fuel	$ 2,000	$ -	$ 2,000
Field Per Diem	$ 3,600	$ -	$ 3,600
Vehicle mileage for sampling effort (10m RT SDBay 40m R	$ 1,100	$ -	$ 1,100
TOTAL TRAVEL:	$ 15,700	$ 9,000	$ 24,700
E. EQUIPMENT			
Underwater acoustic hydrophones	$ -	$ 30,000	$ 30,000
VR28 Active tracking equipment	$ -	$ 15,700	$ 15,700
Handheld diver operated receiver	$ -	$ 4,300	$ 4,300
Directional hydrophone	$ -	$ 1,200	$ 1,200
Garmin handheld GPS	$ -	$ 400	$ 400
YSI multimeter	$ -	$ 3,500	$ 3,500
Rototap sediment shaker & seives	$ -	$ 1,300	$ 1,300
TOTAL EQUIPMENT:	$ -	$ 56,400	$ 56,400
TOTAL DIRECT COSTS:	$ 134,700	$ 71,080	$ 205,780
INDIRECT Costs on requested funds (15% & 42%)	$ 20,205	$ 66,223	$ 86,428
TOTAL ALL COSTS:	**$ 154,905**	**$ 137,303**	**$ 292,208**

Salary:
The requested budget includes costs to cover 4 months salary for Co-PI Shane and research assistants for the 1-year project. Research assistants will assist with field related activities (tracking and dive support) as well as laboratory analysis of sediment grain size. Co-PI Drawbridge will provide 0.5 month of his time as a match for this project. Fringe benefits for HSWRI are 35% and include employee benefits and applicable merit increases as warranted.

Supplies:
Funds requested for supplies include the purchase of 100 VEMCO V7 transmitters to be used in this study. The current hydrophones have expired lithium batteries and additional hardware, used in the deployment of the hydrophones, will be needed to support the tentative array of 22 hydrophones. Project associated miscellaneous supplies include laboratory supplies for the

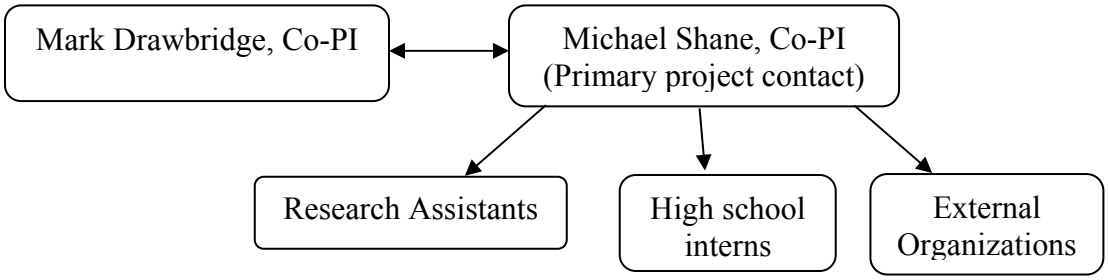
sediment analysis and YSI probe calibration. Diving costs include physicals, training, and purchasing of gear needed to safely conduct the dive operations of this study.

Travel:
Vessel rental fees requested will be used for the maintenance and upkeep of the 120 days of vessel usage estimated for this project. HSWRI has also matched 50% of these costs. The fuel consumption for vessel usage in this project is estimated at 500 gallons. A $4/gallon rate has been used to cover higher rates of gasoline charged by on-the-water services as well as unforeseen increases in fuel costs that may occur during this project. Field per diem will be used to cover costs associated food and liquids, to prevent dehydration, during the field related activities required to support this project. Vehicle usage estimated to support this project is 2,000 miles and is charge at the federal rate of $0.55 per mile. This includes an estimated 25 round trips (40 miles/trip) to the launch ramp in South Bay and 100 round trips (10 miles/trip) to the launch ramp at Shelter Island.

Equipment:
No equipment purchase is being requested associated with this project. There is over $56,000 of contributed equipment that will be used during this study.

Volunteer support, while not included as a match for this project, will come from various sources. The San Diego Oceans Foundation volunteers will help to monitor halibut temporarily help next to their white seabass growout pen. Horizon Charters has offered to provide juvenile halibut that they collect in conjunction with their routine marine educational program. High school student interns will assist with analyzing sediments for grain size and other aspects of the project as needed.

IV. Personnel
Both Mark Drawbridge and Michael Shane will work collaboratively as the principal investigators on this project. Michael Shane will be the primary contact for this project: Hubbs-SeaWorld Research Institute (HSWRI), 2595 Ingraham Street, San Diego, CA 92109. Phone: 619.226.3870 email: mshane@hswri.org. Michael Shane will organize the field related activities and coordinate the efforts of the research assistants at HSWRI. He will also coordinate with external organizations (San Diego Oceans Foundation and Horizon Charters) to support various aspects of this project. Horizon Charters has offered to donate live juvenile California halibut and San Diego Oceans Foundation has offered the support of their volunteers.



V. Subconsultants
None

VI. Non-Profit Status
Hubbs-SeaWorld Research Institute is a 501(c) (3) nonprofit corporation. Proof of non-profit status is provided under additional information.

VII. Applicant Disclosure
No citations for environmental violations have been issued to the applicant within the last five years.

VIII. Agreement
Hubbs-SeaWorld Research Institute (HSWRI) generally finds the insurance clause acceptable with the following exceptions:

1) HSWRI's current Commercial General Liability is $1,000,000
2) HSWRI's Commercial Automobile Liability is $1,000,000

If this project is funded and the increased limits are mandatory, then HSWRI would add the increase in premium to the requested budget for this proposal.

IX. Conflict of Interest
The applicant is not performing services of any kind that would conflict with the services provided by this agreement.

X. Additional Information
Animal Care and Use
The animal care and use policies of Hubbs-Sea World Research Institute (H-SWRI) are guided by the "U.S. Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training" developed by the Interagency Research Animal Committee. The Institute maintains a current Animal Welfare Assurance (#A3512-01) on file with the PHS/NIH Office of Laboratory Animal Welfare, and is registered with the USDA/APHIS as a Research Facility (Reg. No. 93-R-163). All research on live animals must be reviewed and approved by the H-SWRI Institutional Animal Care and Use Committee (IACUC) prior to beginning the research. Any change to an approved protocol that directly pertains to the use of animals requires submission of a revised Animal Protocol Form for review and approval before the proposed change may be implemented. Approved animal research projects are reviewed on an annual basis, and occasionally more frequently at the discretion of the IACUC.

Scientific Collecting
Michael Shane has a current Scientific Collector's Permit (#801228-05) that has been issued by the California Department of Fish and Game that allows him to collect fish, including California halibut, of the size and numbers required to conduct this study. This permit also allows him to employ a variety of methods, including otter trawls, which he can utilize to collect specimens.

Science Literacy

We actively seek the involvement of students from socioeconomic groups traditionally underrepresented in science and technology programs. Our scientists participate in programs designed to encourage and foster an interest in science and engineering among young women in middle school. We are also participants in the Harvey-Mudd College Upward Bound Program. For the past 30 years, this program has brought low-income, potential first-generation college-bound students from the San Gabriel Valley to San Diego, where they participate in a summer residential program. Hubbs-SeaWorld Research Institute has committed to providing annual internship opportunities at our Mission Bay and/or Carlsbad (California) laboratories under this program. This year's interns will be given the opportunity to participate in this project and other marine ecosystem health programs in the Southern California Bight.

Biographical Sketch
MICHAEL A. SHANE

Research Scientist
Hubbs-SeaWorld Research Institute
San Diego, CA 92109-7902
(619) 226-3946 mshane@hswri.org

A. Education:

San Diego State University	Biology	B.S. 1988
San Diego State University	Biology	M.S. 1997

B. Appointments:

1999-Present: **Research Scientist**. Hubbs-SeaWorld Research Institute, San Diego, CA
1995-2000: **Technical Post-graduate**. Edison International, Rosemead, CA
1988-2002: **Program Coordinator**. San Diego State University Foundation, San Diego, CA.

C. Publications:

Allen, L.G., D.J. Pondella II, and M.A. Shane. 2007. Fisheries independent assessment of a returning fishery: Abundance of juvenile white seabass (Atractoscion nobilis) in the shallow nearshore waters of Southern California Bight, 1995-2005. Fish. Res. 88:24-32.

D. Synergistic Activities:

Summer Mentor Harvey-Mudd College Upward Bound Program 2003-2006

E. Recent Collaborators:

Dr. Larry Allen (CSUN); Dr. Daniel Pondella (Occidental College); Dr. Richard Ford (SDSU, emeritus)

F. **Major Grants Awarded (last 5 years)**

Nearshore gillnet sampling for white seabass (Age I-IV), 2007-2008. California Department of Fish and Game. $159,000

Nearshore gillnet sampling for white seabass (Age I-IV), 2006-2007. California Department of Fish and Game. $86,000

Nearshore gillnet sampling for white seabass (Age I-IV), 2005-2006. California Department of Fish and Game. $99,870

Development of an acoustic monitoring array in Agua Hedionda Lagoon to track the movements of cultured juvenile white seabass and other marine fishes. 2004. San Diego County Fish and Game Commission. $21,300

Development of an acoustic monitoring array in Mission Bay to track the movements of cultured juvenile white seabass. 2002. The Boeing Company. $20,000

G. Additional Information

Awards and Fellowships:
Southern California Academy of Sciences annual meeting student paper award winner, 1997
American Sportfishing Association's A. J. Boehm Fellowship, 1994-1995

Professional memberships:
American Fisheries Society
American Society of Ichthyologists and Herpetologists
Southern California Academy of Sciences
American Academy of Underwater Sciences
National Association of Underwater Instructors (Instructor)
Divers Alert Network

Presentations:
"Marine ecological studies at Crystal Cove State Park to determine impacts from a coastal development project." Presented at Southern California Academy of Sciences Annual Meeting, CA, 2007.

"Movements of cultured white seabass, *Atractoscion nobilis*, released throughout the southern California bight." Presented at The 3rd International Stock Enhancement Conference, Seattle, WA, 2006.

"Developing surgical procedures for implanting transmitters in white seabass and application of VEMCO VR28 to small vessels." Presented at the American Fisheries Society Annual Meeting, Anchorage, Alaska, 2005.

"Acoustic tracking and monitoring of cultured juvenile white seabass released into southern California embayments." Presented at Southern California Academy of Sciences Annual Meeting, CA, 2005.

Recent technical reports:
Ford, R.F. and M.A. Shane. 2007. Nearshore gill net sampling program for white seabass (age I-IV): OREHP field sampling progress report for the contract period July 1, 2006 to June 30, 2007. Final report submitted to the California Department of Fish and Game and the Ocean Resources Enhancement and Hatchery Program Advisory Panel. 8pp.

Ford, R.F., B.B. Hemmingsen, M.A. Shane, and E. Strecker. 2007. Water quality and marine ecological monitoring studies for the Crystal Cove project. 1999-2006. Final Report Submitted to the Irvine Community Development Company, Newport Beach, April 2007.

Ford, R.F. and M.A. Shane. 2006. Nearshore gill net sampling program for white seabass (age I-IV): OREHP field sampling progress report for the contract period July 1, 2005 to June 30, 2006. Final report submitted to the California Department of Fish and Game and the Ocean Resources Enhancement and Hatchery Program Advisory Panel. 10pp.

Biographical Sketch
Mark Andrew Drawbridge

Work Address

Hubbs-SeaWorld Research Institute
2595 Ingraham Street
San Diego, CA 92109

619-226-3943 (Voice)
619-226-3944 (FAX)
mdrawbridge@hswri.org

Education

B.A. Gettysburg College, Gettysburg, PA. 1985 (Biology)
M.S. San Diego State University, San Diego, CA. 1990 (Marine Ecology)

Positions and Work Experience

1999-present Senior Research Scientist and Director of Aquaculture Program, Hubbs-SeaWorld Research Institute, San Diego, CA.
1996-present Adjunct Faculty, University of San Diego, San Diego, CA.
1989-1999 Research Biologist, Hubbs-SeaWorld Research Institute, San Diego, CA.

Current Committee and Society Affiliations

California Aquaculture Association, President; World Aquaculture Society, member; American Fisheries Society, member; Western Regional Aquaculture Center Technical Committee, member; Chairman of California Farm Bureau Aquaculture Commodity Advisory Committee; Advisory Panel member US- Japan Natural Resources Aquaculture Panel.

Recent Research Activities

- **Ocean Resources Enhancement and Hatchery Program (Program Manager and Co-Principal Investigator, 1993-present).**

  Evaluating the feasibility of restoring depleted white seabass (*Atractoscion nobilis*) populations through stock replenishment. Optimizing fish hatchery production and post-release survival through investigations of proper husbandry, enhanced system design, and assurance of genetic quality. Field studies of distribution and abundance of target species to determine preferred habitats, impacts of releases of cultured fish, and optimum release strategy. This program utilizes a primary hatchery for white seabass in Carlsbad, CA and a network of 14 satellite growout facilities throughout southern California. It is the largest, most comprehensive stock replenishment program for marine finfish in the United States.

- **Groundfish Replenishment Research Program (Co-Principal, 2002-present).**

  Evaluating the feasibility of restoring depleted groundfishes, including rockfishes of the genus *Sebastes*, through stock replenishment. This project has successfully led to the capture and breeding of native rockfishes and groundfishes from California, including the successful capture of rare adult cowcod from 100 m of water using portable hyperbaric chambers. Other species in culture include cabezon and halibut. This project has achieved many "firsts" including the first time cowcod have been

held in captivity and the first time species like starry rockfish have ever been bred in captivity.

- **Grace Mariculture Program (Co-Principal, 2000 - 2007).**
  Evaluating the feasibility of using offshore oil platforms as a base of operations for marine finfish farming. This project has received national attention and support as a model for offshore farming opportunity. As part of this project, successful rearing techniques have been developed for California halibut and yellowtail, and striped bass.

- **Open Ocean Culture of California Yellowtail (Co-Principal, 2006 - 2009).**
  Demonstration of commercial feasibility for offshore culture of California yellowtail working – a multinational approach working with ocean farmers in Mexico. This project was the first to grow cultured striped bass and California yellowtail in offshore cages in the Eastern Pacific. The California yellowtail were spawned and bred by HSWRI researchers in San Diego, which maintains the only breeding population for this species in the northern Hemisphere. Both species represent top candidates for offshore aquaculture because of their known value in the marketplace.

Recent Publications

Aalbers, S.A., G.M. Stutzer and M.A. Drawbridge. 2004. The effects of catch-and-release angling on the growth and survival of juvenile white seabass captured on offset circle and J-type hooks. North American Journal of Fisheries Management 24:793-800.

Lopez, L.M., Torres, A.L., Durazo, E., Drawbridge, M.A. and D.P. Bureau**.** 2006**.** Effects of lipid on growth and feed utilization of white seabass (*Atractoscion nobilis*) fingerlings. *Aquaculture* 253:557-563.

Stickney, Robert R., Barry Costa-Pierce, Donald M. Baltz, Mark Drawbridge, Churchill Grimes, Stephen Phillips and D. LaDon Swann. 2006. Toward Sustainable Open Ocean Aquaculture in the United States. *Fisheries*, Volume 31, No. 12.

Smiley, J.E. and M.A. Drawbridge. 2007. Techniques for live capture of deepwater fishes with special emphasis on the design and application of a low-cost hyperbaric chamber. *Journal of Fish Biology* 70:867-878.

Jirsa, D., M. Drawbridge, and K. Stuart. 2007. Spawning of a Captive Population of California Sheephead, *Semicossyphus pulcher*. Journal of the World Aquaculture Society. 38(1): 122-128.

Aalbers, S.A., and M. Drawbridge. (2008). White seabass spawning behavior and sound production. North American Journal of Fisheries Management. 137:542–550

Smiley, J.E. and M. Drawbridge. (2008). A simple apparatus for maintaining gas supersaturated seawater in the laboratory for experimental purposes. North American Journal of Aquaculture. 70:61–67

Non-Profit status

Internal Revenue Service

District
Director

Department of the Treasury

P.O. Box 2350 Los Angeles, Calif. 90053

Person to Contact: Karen Winslow

Telephone Number: (213) 688-4152

Refer Reply to: EP/EO:G-2:D

Date: SEP 16 1980

Hubbs-Sea World Research Institute
1720 South Shores Road
San Diego, California 92109

Gentlemen:

Your application for exemption from Federal income tax as an organization described in section 501(c)(3) of the Internal Revenue Code has been considered.

Our records indicate that you were granted exempt status under section 501(c)(3) on December 27, 1963. Therefore, we consider your organization to be exempt, and no further action will be taken on your current application.

Very truly yours,

Karen Winslow

Karen Winslow
Tax Auditor