HOOK-AND-LINE MORTALITY OF SAN FRANCISCO BAY HALIBUT

TRAVIS TANAKA
State Finfish Management Project
California Department of Fish and Game
20 Lower Ragsdale Drive, Suite 100
Monterey, CA 93940

INTRODUCTION

San Francisco Bay (Bay) is the location of an important California halibut (*Paralichthys californicus)*, fishery. The California halibut (halibut) fishery is managed by the California Department of Fish and Game (Department). The Bay, like other estuarine habitats, may serve as spawning habitat and nursery grounds for halibut. During the restricted 2006 Chinook salmon season and more recently the 2008/09 Chinook salmon closure, the recreational and commercial fishing public in central California directed more effort towards halibut. Based on California Recreational Fisheries Survey (CRFS) angler interviews and commercial landing records, the 2006 season saw a dramatic increase in direct effort toward Bay halibut. With the full closure of salmon in 2008, directed halibut effort increased further (Table 1).

Table 1. San Francisco Bay halibut relative recreational effort and commercial landings summary

YEAR	2004	2005	2006	2007	2008	2009
Recreational skiff anglers[1]	126	116	500	213	638	623
Commercial landings[2]	76	79	176	37	454	602

[1]Number of recreational anglers interviewed by CRFS samplers who were targeting halibut
[2]Number of landing receipts received showing halibut
Source: CRFS sample data and CDFG landing receipts

With the increase in effort, which resulted in an increase in harvest, concerns from the fishing public arose regarding 1) potential over-exploitation of the halibut resource and 2) increased mortality due to gut hooking of sublegal-sized (sublegal) halibut. Recreational anglers and some commercial hook-and-line fishermen expressed concern to the Department that the Bay halibut resource would not be able to sustain excessive fishing pressure and increased catch. Bay fishermen reported to the Department that, in their opinion, they were concerned about "fishing out" the resource with boats getting limits every day. Bay fishermen also expressed concern over the use of treble hooks in regards to gut-hooking sublegal halibut and their survival after release. Some recreational fishermen suggested increasing the minimum legal size from 22 to 26 inches; this would likely result in the release of a greater number of fish and possibly reducing take by the fishery. In 2008, the average recreationally caught halibut was 25.25 inches (640 mm). The average length of commercial hook-and-line caught halibut is not available. By releasing 22- to 26-inch halibut, the spawning biomass may increase, but only if the released fish survive.

Some halibut anglers interviewed by the Department's State Finfish Management Project (SFMP) staff used a "halibut trap rig". Halibut trap rigs entail the use of a single "J" hook and a treble (trap) hook tied in-line (Figure 1). The J hook is tied such that its position along the leader can be adjusted to the size of the bait used. The J hook is inserted through the lower and upper jaw, pinning the bait's mouth shut with the treble hook inserted near the tail. The chances of hooking fish with trap hook gear may be greater due to the secondary treble hook. Trap hook gear may be used with live, fresh-dead, or frozen bait. Single J, circle, or treble hooks are sometimes used for halibut, especially if live bait is available or if the bait is small. While fishing within the Bay, recreational anglers are restricted to one line with no more than two hooks. Commercial fishermen are restricted to no more than two hooks on four or six lines depending upon the amount of crew onboard. There are no other hook restrictions.

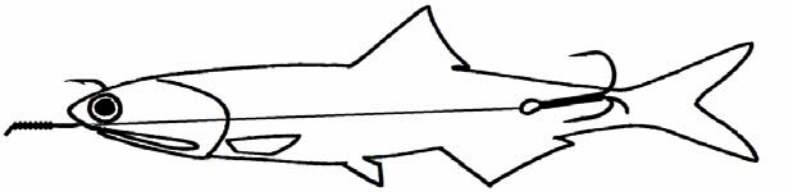

Figure 1: Halibut trap rig with anchovy bait. (Illustration: Ashok Sadrozinski, CDFG)

Both recreational and commercial halibut fisheries are managed by a minimum size limit. Minimum size regulations are a standard fishery management method used to ensure stable stock structure by requiring the release of sexually immature individuals, reducing total fishing mortality, and maintaining fishery yield despite angler pressure (Hoxmeirer and Wahl 2009; Webb 1991). Since 1971, the legal minimum recreational size for California halibut has been 22 inches total length (559 mm). In 1979, legislation established 22 inches total length as the minimum for commercial take. In addition to the minimum size, the recreational fishery is managed by a possession limit of three halibut per person north of Point Sur, Monterey County, and five halibut per person south of there. There are no specific regulations pertaining to the handling of halibut.

For fisheries managed by a minimum size, maximum size, or both (slot limit), a certain amount of hooking mortality is expected and factored into the management of that species. For most fisheries, hooking mortality over 20 percent is considered high and requires fishery management action (Muoneke and Childress 1994). Researched fisheries that have size regulations and "acceptable" hooking mortality levels include Pacific halibut (5-7 percent), white seabass (10 percent), and spotted seatrout (11 percent) (Aalbers et al. 2004; Stunz and McKee 2006; Meyer[1] 2007). Although size limits would result in a percentage of released fish that may experience post-release mortality, the spawning population would benefit through a reduction of total fishing mortality (Hoxmeirer and Wahl 2009).

[1] Meyer, Scott. 2007. Halibut Discard Mortality in Recreational Fisheries in IPHC Areas 2C and 3A. Discussion Paper. Alaska Department of Fish and Game-Division of Sport Fish, Homer, Alaska

The purpose of this study by the Department's SFMP was to investigate the potential impacts, including possible mortality rates, that hook-and-line fishing gear and handling methods have on sublegal sized halibut. The SFMP investigated the effects of fish handling and recorded the rate of gut hooking per hook type used in the Bay drift hook-and-line halibut fishery from June to September in 2008 and 2009. Troll methods were not investigated. No blood was taken to assess cortisol levels as an index of physical stress.

METHODS

June-September 2008
After identifying the types and sizes of fishing hooks used within the fishery, the study was conducted onboard the Department's 19-ft. skiff R/V *Ronquil*. Total fishing time for each survey day was between 4 and 6 hr and the number of lines fished varied from four to six.

Fishing locations within San Francisco Bay varied depending upon wind intensity/ direction, current speed, tide status, and fishing reports. The latter were reviewed prior to the fishing trip to establish a plan for that day. Locations fished included Alameda Rockwall, Berkeley flats, Oyster Point, Paradise Cay, San Pablo Bay, and Southampton Shoal (Appendix 1). Depth fished ranged from 3 to 30 ft. Most fishing activity occurred from 10 to 15 ft. Attempts were made to schedule trips during periods of incoming high tides and favorable weather forecasts.

Upon arrival to the fishing location, a drift was set and fishing gear deployed. Drifts were set to allow for movement of the vessel from deeper (25-30 ft.) to shallow water (5-10 ft.). During drifts exceeding 3 knots due to wind, the hooks and baits would pass through the water in a fashion similar to troll gear. A sea anchor was deployed to reduce this effect.

Various hook types were utilized with frozen anchovies (eight trips) and live anchovies (five trips). Hook types included commercially- and staff-tied halibut trap rigs consisting of a sliding #1/0 live bait J hook and a hard-tied #4 or #6 treble hook. Trap hook gear was used with large (greater than 4 in.) or frozen bait. Single hooks used included #4 to 1/0 live bait J hooks, #4 to 1/0 circle hooks, and #4 treble hooks. The size of hook used varied with bait size. Larger baits required larger hooks while small bait requires the smallest hook available. Matching the hook size to the bait prevented fish from taking the bait without being hooked (large baits) or the fish from seeing the hook before taking it (small bait). Single hooks were used primarily for live bait, but were also used with frozen baits.

Fishing rods consisted primarily of 7- 9-ft graphite and fiberglass blanks with bait casting and conventional reels consistent with gear used by the Bay recreational and commercial fleet. Fishing line test ranged from 10-25 lb. Sinker weight

amount varied between 1-4 oz, depending upon current and speed of drift, and was rigged with three-way swivels.

All fish were landed using a rubber mesh net. Net mesh size was 1.25 and 1.50 inches. After netting, each fish was gently restrained with wet hands to determine hooking location and the hook removed using needle nose pliers. If the fish was hooked post-pharyngeal, the leader was cut and the hook was left in place. Hook locations (Appendix 2) were classified as:

1. M: Mouth (includes lower jaw, maxillary, and corner)
2. PP: Post-Pharyngeal (gut or esophagus hooked) or if near the pharyngeal stricture
3. R: Roof or palate inside mouth
4. G: Gill
5. I: Isthmus (pharynx)
6. S: Snagged with location on body noted
7. T: Tongue
8. any combination such as R/G, R/T, G/I

It should be noted that the heart and gall bladder of halibut are located immediately posterior (beginning of esophagus) to the soft tissue of the pharyngeal stricture which may increase the intensity of a post-pharyngeal wound. Hooking location is considered a contributing factor in immediate or delayed mortality. Hooking in or near vital areas such as the esophagus or gills greatly increase the chance for mortal wounding. (Muoneke and Childress 1994).

After recording hooking location, the total length of the fish was measured. A condition code based on taxis and wounding was also assigned:

1. Condition 1: Considered best with no blood or significant wounding evident, very lively
2. Condition 2: Lively, blood present
3. Condition 3: Bleeding profusely, death likely
4. Condition 4: Fish is dead (immediate mortality)

Muoneke and Childress (1994) classify mortality as delayed or immediate. Fish condition may be a predictor of immediate or delayed mortality. For the purposes of this study delayed mortality would include those halibut that died while under observation. Immediate mortality would include any halibut landed dead or that had died before delivery to the Aquarium of the Bay. The primary criterion in determining condition was the presence and amount of blood (Malchoff et al 2002).

When possible, all halibut were tagged with a Floy T-bar FD-54 anchor tag for identification purposes. Non-halibut species were measured and the condition assessed before release. All fish were assigned a landing status: (K) kept, (R) released, (DO) drop off known, (DO?) drop off unknown. A drop off is defined as a

hooked fish that was not landed. The drop off unknown (DO?) status is defined as a fish that was hooked, but escaped before positive identification.

Fish held for observation were retained onboard in a 160-qt cooler. Fresh seawater was replaced regularly using a 5-gal bucket. Total processing time for halibut, from time of landing to release or placement into the holding tank, was less than 2 min out of water. At the end of the survey day, all retained halibut were transported by boat from the fishing area to the Aquarium of the Bay at Pier 39, San Francisco. Fish were housed in a 900-gal circular quarantine tank supplied by water pumped directly from the bay with all tank discharge flowing to the municipal sewer. Aquarium husbandry staff monitored and provided food for the captive halibut. Upon a captive halibut death, Aquarium staff notified a SFMP staff member to arrange a pickup. If SFMP staff was not available for pickup, the halibut was frozen and retrieved at a later date.

A necropsy was performed by SFMP staff to assess the amount of internal damage caused by hooking, bodily damage due to handling, subsequent infection (if any) and possible cause of death. The fish was measured, weighed, and exterior condition noted. With the blind side down, an incision was made from the ventral edge of the operculum to the isthmus, exposing the gills. Each gill arch was carefully removed and the lower jaw split from the isthmus to the tip, fully exposing the buccal cavity. All hook wounds were noted and photos taken. An incision near the anal vent to the dorsal pectoral fin exposed the viscera. Sex and internal condition were noted. All organs were removed individually but none were weighed. Presence of blood or evidence of wounding was noted. Otoliths were removed for ageing purposes.

Captive control halibut were not used for this study due to husbandry limitations and the lack of opportunity to collect halibut without hooking. No other methods of collection were available to the SFMP that would not cause exterior wounds or excessive stress. To demonstrate healthy viscera, mouth-hooked halibut in good condition were sacrificed as a control.

June-September 2009

Although the procedure in general for the second survey season was similar to the first, several changes were made. Total fishing time for each survey day was between 6 and 7 hr. A larger vessel, the Department's 32-ft R/V *Triakis,* was used. This vessel had more deck space to sample fish and to store a second 160-qt cooler. The second cooler was used as an additional live tank for bait or halibut. Two layers of indoor carpet were laid down on the deck as padding to prevent bruising of halibut in the event that a halibut became uncontrollable during its assessment. A submersible pump system was added to circulate Bay water to both tanks. The rubber landing net was reserved for incidental species, while a small-meshed (0.125 inch) knotless landing net was used for all halibut. The smaller meshed net was used to reduce or eliminate fin splitting.

For any halibut landed, the assessment process was the same as in 2008. Fishing locations included Berkeley Flats, Southampton Shoal, Oyster Point, Paradise Cay, and the barges near Treasure Island (Appendix 3).

Hook position and fish condition were recorded for all species. Single J, circle hooks, and trap hook gear were used. Frozen bait (all nine trips) was used if live bait was unavailable or when the bait expired before use. Live bait when available (four of nine trips) consisted of large (6-10 inch) sardines or small (3 inch) anchovies.

RESULTS

June-September 2008

The 2008 survey consisted of 13 fishing days. There were 63 halibut and seven incidental species caught (Table 2). Of the 63 halibut, 34 were sublegal, 38 were kept for observation, and 25 were tagged and immediately released.

Table 2. Species caught for 2008 survey

COMMON NAME	SPECIES	NUMBER CAUGHT	RELEASED BOAT SIDE	RETAINED
California halibut	*Paralichthys californicus*	63	25	38
brown smoothhound	*Mustelus henlei*	20	20	0
bat ray	*Myliobatis californica*	12	12	0
striped bass	*Morone saxatilis*	7	7	0
Pacific staghorn sculpin	*Leptocottus armatus*	2	2	0
leopard shark	*Triakis semifasciata*	2	2	0
grey smoothhound	*Mustelus californicus*	1	1	0
sevengill shark	*Notorynchus cepidianus*	1	1	0
	Total	108	70	38

Initially all halibut, including those that were mouth-hooked or foul-hooked, were kept for observation. Due to concerns of overcrowding the study tank and the on-board tank, on subsequent trips legal-sized, mouth-hooked halibut in good condition were released boat-side after being assessed, measured, and tagged. All post-pharyngeal-, gill-, and isthmus-hooked halibut, or halibut that sustained exterior wounds or bleeding, were kept for observation. While under observation, 10 halibut died, eight were sacrificed, and three died during the survey day or during delivery (same-day mortality) to the Aquarium. Captured halibut (61 of 63) ranged from 14.4 to 39.4 inches (365 to 1,000 mm) with an average size of 21.6 inches (548 mm). Two halibut were not measured. Necropsies were performed on all but one halibut of the 21 halibut that either died or were sacrificed to assess internal condition due to hook damage, infection and to postulate cause of death.

The un-necropsied halibut was in an advanced state of decomposition before Department staff was notified. Two of the eight sacrificed halibut were controls to provide examples of fish with healthy internal organs and external features showing little to no damage.

The three halibut that experienced same-day mortality were all mouth-hooked with single circle hooks. Two out of three were in excellent condition at capture with no visible bleeding. A necropsy on each fish uncovered bruised viscera including the liver. These fish may have been battered by the other halibut in the cooler causing fatal blows to vital organs.

For a better statistical comparison, attempts were made to catch an equal number of halibut per hook type. For example if more J hook caught fish were needed, then more rods and trips would be dedicated to using J hooks (Appendix 4).

The type of bait used also influenced species composition of the catch (Table 3). While using frozen anchovies, more bottom dwelling species such as bat rays and smoothhounds were caught. The use of live bait reduced the catch of these species and increased the probability of encountering halibut. Halibut will attack frozen bait; however, 12.8 percent more halibut were caught with live bait. This trend also occurred during the 2009 survey season.

Table 3. 2008-09 species catch relative to bait type

COMMON	SPECIES	FROZEN	LIVE
California halibut	*Paralichthys californicus*	41	47
brown smoothhound	*Mustelus henlei*	24	13
bat ray	*Myliobatis californica*	16	2
leopard shark	*Triakis semifasciata*	3	4
sevengill shark	*Notorynchus cepidianus*	3	-
striped bass	*Morone saxatilis*	2	7
Pacific staghorn sculpin	*Leptocottus armatus*	2	-
grey smoothhound	*Mustelus californicus*	1	2
soupfin shark	*Galeorhinus galeus*	-	1
spiny dogfish	*Squalus acanthias*	-	1
white croaker	*Genyonemus lineatus*	-	1
	Total Fish	92	78

Captive halibut expired at different intervals. The earliest observed mortality occurred within 24 hr of capture. This was a PP-hooked, 18.0-inch (458-mm) halibut. The fish swallowed the J hook of the trap rig; the treble hook was hanging free outside the mouth. During measuring, this fish had brief contact with the deck removing some exterior slime and increasing the amount of fin splitting. The second quickest mortality involved a mouth hooked (circle hook) 21.6-inch (549-mm) halibut that expired 2 days after capture. This halibut also had fin splitting in the caudal fin, but no deck contact. This fish was caught early in the survey day and may have been battered from other halibut in the tank. The other mortalities occurred within 2-4 weeks of capture. All fish had no stomach contents, showed signs of exterior bacterial infection, and had organs in a state of failure. Mortalities

that had a “PP” classification also had friable liver tissue and some also had internal bleeding.

All captured halibut had some fin splitting of the caudal fin caused by the large mesh size of the landing net. This splitting could have also been exacerbated by contact with the deck or the walls of the cooler. Scales and external “slime” were lost on a few fish after on-deck contact after landing. Fin splitting and scale loss may increase the likelihood of bacterial infection and may increase stress, especially during warm water conditions. The average Bay water temperature was 12.5 ˚C in June and continued to increase to 16.6 ˚C in September. Several fish had advanced fin rot on the caudal fin. For the other non-post pharyngeal mortalities, this external wounding and infection may have contributed to death.

Eight halibut were sacrificed during the first year of study. Two were sacrificed as a control, while the other six were sacrificed after living in captivity for several weeks. Five of these six were classified as post-pharyngeal and showed significant internal damage due to hooks. While these fish survived for up to eight weeks, due to initial and continual internal damage from the hook and the subsequent infection caused by hooking, expiration was likely. The sixth fish was hooked in the isthmus and had organs that were noted to be in excellent condition. The hook had missed the aorta upon initial hooking.

Most mortalities exhibited some amount of internal parasitic infestation; however, internal parasites are common in fishes and are not necessarily related to stress or other health problems. Most fish had nematodes within the viscera and connective tissue surrounding the digestive tract. Some halibut also had nematodes embedded in the liver. None had external parasites other than isopods (gill lice), but did exhibit erythematic signs of bacterial infection.

Fourteen captive halibut were released into the Bay with their attached tag. As of January 2011, none of these captive fish had been reported to the Department as recaptured. Of the 25 halibut released boat side, one was caught again approximately 28 days after initial capture by an angler who reported catching and releasing a tagged sub-legal halibut. The location of both captures was the same. The angler reported that the fish was in excellent condition when released.

June-September 2009

There were 9 survey days, conducted two-three times per month. Six lines, using single J hooks, circle hooks, and halibut trap gear were fished. Frozen anchovies were primarily used due to the sporadic availability of live anchovy and sardine most of the season. Fishing locations included Berkeley flats, Paradise Cay, Southampton Shoal, NE side of Treasure Island, and Oyster Point (Appendix 3). Due to wind and a slower vessel, fishing activity was conducted closer to the vessel’s marina to increase survey time. Based on fish reports, no single location was best for targeting halibut.

All gear types were fished equally in attempts to capture a proportional number of halibut relative to hook type (Appendix 5). Twenty-five halibut were caught along with nine other species (Table 4). The size range for 24 of 25 measured halibut was 18.5 to 35.7 inches (470 to 907 mm) with an average of 25.0 inches (634 mm). One halibut was not measured. Seven halibut were tagged and released boat-side. One legal-sized, tagged halibut was recaptured by a recreational angler fishing the Berkeley flats. This fish was recaptured after 28-30 days of liberty. This halibut was in the same area as initial capture.

Three of the 18 retained halibut had same-day mortalities; two of these died shortly after netting, the other before delivery. The first two were hooked through the gills with a treble hook and were bleeding profusely. Of the 15 captive halibut, four mouth-hooked halibut were opportunistically injected with Oxytetracycline for age validation purposes for a separate ageing study and transferred into the main display aquarium at Aquarium of the Bay. One of the four treated halibut died 22 days after treatment due to unknown causes. This fish was discovered by Aquarium staff during the Bay's warm water event. Upon examination by SFMP staff, a broken mandible was observed. The other 11 halibut died while under observation, but none before 50 days in captivity.

Table 4. Species caught for 2009 survey

COMMON NAME	SPECIES	NUMBER CAUGHT	RELEASED BOAT SIDE	RETAINED
California halibut	*Paralichthys californicus*	25	7	18
Brown smoothound	*Mustelus henlei*	17	17	
Bat ray	*Myliobatis californica*	6	6	
Leopard shark	*Triakis semifasciata*	5	5	
Grey smoothhound	*Mustelus californicus*	2	2	
Sevengill shark	*Notorynchus cepidianus*	2	2	
Striped bass	*Morone saxatilis*	2	2	
Soupfin shark	*Galeorhinus galeus*	1	1	
Spiny dogfish	*Squalus acanthias*	1	1	
White croaker	*Genyonemus lineatus*	1	1	
	Total Fish	62	44	18

The first mortality occurred 50 days after capture. This was a post-pharyngeal J-hooked halibut. The stomach was empty and showed signs of liver failure. This fish also experienced a heavy parasite infestation. The longest lived fish was trap-hooked, had swallowed the treble hook, and had the J hook lodged in the mouth. After 3 months, this fish expired in mid-August during cleaning of the quarantine tank. A dissection revealed inflamed tissue at the site where the treble hook set post-pharyngeal in the esophagus. There was clotted blood present in the cavity along with parasites on and in the organs. The blind side of the fish exhibited erythemia indicating possible internal bacterial infection.

All mortalities, regardless of hooking location, had similar parasite infestations, both externally and internally. As the Bay water temperature increased during its seasonal warming event, parasite load of captive halibut also increased. James et

al. (2007) and Malchoff et al. (2002), in independent hooking mortality studies, found water temperature to be a factor in mortality. Bay temperature averages were higher in 2009 compared with 2008. At the beginning of the survey the average Bay water temperature was 16.5˚C (61.7˚F) and peaked at 17.8˚C (64˚F) in August. Aquarium staff reported that many display and quarantine fish had increased parasite infestations during this warm water period. Most halibut also displayed signs of bacterial infection, including erythematic skin and fin rot. While these captive halibut lived for several months, the internal damage from hooking may have made them susceptible to the ensuing bacterial infection. Improved care and handling techniques likely reduced the immediate impacts from hooking; however death was still likely, especially when compounded with issues associated with captivity.

No captive halibut were released in 2009.

DISCUSSION

Statistical Validation

Despite the small sample size, limited statistical analysis was possible. Before any statistical tests were applied, all hooking data for retained halibut was consolidated into four groups (Table 5) relative to hook type (J or treble) and fish status (live or dead). In order to improve the sample size for analysis, halibut that were sacrificed were considered live. Dead halibut consisted of captive mortalities only. Since the purpose of this study was to test if there was a difference in hooking mortality between J and treble hooks, and that no halibut were caught the second season using circle hooks, hooking data for circle hooks was excluded from the analysis.

Table 5. Summary of hooking data based on total numbers of live or dead halibut relative to hook type

	Live	**Dead**
J hook	15	10
Treble hook	18	11
TOTAL	33	21

Using chi-square analysis to examine for any statistical difference between live or dead halibut by hook type (if $p>0.05$), the probabilities were 0.2794 for 2008 and 0.1469 for 2009. Since the probabilities are greater than 0.05, we must accept the null hypothesis that there is not a significant difference between the hook types as related to mortality.

Gear Impacts and Hooking Location

After catching 88 halibut of various sizes, there appear to be no significant impacts due to hooking among the different gear types (Appendices 4 and 5). Within the Bay drift hook-and-line fishery, all hooks fished with bait may have equal opportunity for gut hooking. However, based on SFMP angler interviews (Table 6) and observations obtained through this study, most halibut and incidental species

are mouth-hooked. For this informal angler survey, 1.9 percent of halibut were hooked post-pharyngeal. Study observations show a higher rate of gut hooking at 15.9 percent. Project staff does not believe this to be an issue notwithstanding the limited sample size.

Table 6. Summary of gear used by San Francisco Bay anglers

GEAR TYPE	ANGLERS INTERVIEWED	HALIBUT RETAINED	HALIBUT RELEASED	HALIBUT REPORTED GUT HOOKED
J hook only	147	176	97	4
Treble only	28	38	21	2
Circle hook only	18	17	9	0
J-treble trap	56	56	15	3
Unknown	13	33	11	0
Total	262	320	153	9

Source: 2008-09 SFMP angler interviews

While treble hooks may make release more difficult, study observations indicate that treble hooks tend to set in the mouth. In a comparison study of the effect of J hooks and treble hooks in an unrelated fishery, Matlock et al. (1993) found no significant difference in mortality between the hook types. They found that restricting gear would not reduce unintentional fishing mortality.

Location of the initial wound may be a significant contributing factor to immediate and delayed mortality. Wounds to the heart or associated vascular tissue and severe wounds to the gills would result in immediate death. Presence of large volumes of blood may be a good indicator of immediate or delayed mortality. (James et al. 2007)

In a hooking study involving summer flounder (*Paralichthys dentatus*), a species which experiences high levels of effort and comprises 60% of recreational catch for fishermen in mid-Atlantic states, estimated hooking mortality averaged 9.5%. Researchers found that while hook type and fish length are not significant factors, hooking location and bleeding do contribute to post-release mortality. Malchoff et al. (2002) also found that leader length and leaving hooks in deeply-hooked fish influence mortality rates as well.

Effects of Captivity and Increased Water Temperature

In our study, subsequent bacterial infection, susceptibility to increased parasite infestation, and in some cases, latent mortality, may be due to captivity and the effect of overcrowding. This may be the primary reason that all fish retained in the quarantine tank in 2009 survived at least 50 days but eventually died in captivity. While in the quarantine tank, Aquarium staff reported no observing feeding activity by captive halibut. All necropsied and dissected captive halibut had empty stomachs and no indication of ever feeding. Once the select few fish were placed into the larger main display, normal behavior returned as reported by Aquarium staff.

Aquaculturists will often use a larger holding facility than the 900-gallon one employed by this study. The large brood stock tank at the California Halibut Hatchery, Redondo Beach, CA, exceeds 39,000-gallons. Their small brood stock tank capacity exceeds 9,700 gallons (D.E Conklin et al. 2003). Space limitations may increase the likelihood of captive mortality.

While water temperature is an uncontrollable environmental factor, increased temperatures do influence mortality. Since this study occurred at the start of the Bay's warming trend, comparative captive halibut data are not available. Other hooking studies that examined hooked fish year-round (James et al. 2007) or during the summer only (Stunz and McKee, 2006) noted that hooking mortality is highest during warm water periods. This could be due to the additional stress of reduced dissolved oxygen and changing salinity.

Effects of Handling

This study indicated that onboard handling procedures and hand-held retrieval net type may be the greatest contributing factors to latent mortality of sublegal halibut. Handling includes hook removal technique. After switching to the soft knotless net and adding a padded deck surface in our study, external wounding was eliminated. By keeping the caudal fin and scale and slime layer intact, captive halibut did not appear to be as susceptible to bacterial and parasitic infections. Smaller halibut (<20 inches or 508 mm) seem to be more susceptible to mishandling and stress.

Recreational CPUE

While fishing effort and success were elevated in 2008-09 compared to previous years, based on CRFS angler interview data and charter vessel logbook data (Table 7), the public's perception on catch success may be exaggerated. Bay fishermen enjoyed above-average catch rates compared with historical values; however they were not as high as some claimed or believed. A large influx of sublegal halibut in 2007 may have contributed to the elevated catch in 2008 as these fish reached legal size.

Table 7. Observed San Francisco Bay average halibut catch per angler (number of fish)

FISHING MODE	2004	2005	2006	2007	2008	2009
RECREATIONAL SKIFF						
Average catch per angler	1.05	0.87	0.83	0.92	1.02	0.95
Average released per angler	0.20	0.24	0.49	0.96	0.75	0.39
CHARTER VESSELS						
Average catch per angler	0.34	0.34	0.42	0.36	0.96	0.75
Average released per angler	0.14	0.01	0.39	0.65	0.55	0.27

Source: California Recreational Fisheries Survey samples and CDFG charter boat logs.

Recommendations

Based on the limited findings, the SFMP does not recommend changing any gear regulations within San Francisco Bay. The SFMP does recommend anglers use a soft, knotless landing net and avoid laying the fish directly on any rough surface. Use care if measuring a halibut and keep fingers or pliers out of the gills. When

handling fish, never use a dry net or dry hands and support the fish by the head and tail. If the fish is sublegal, avoid netting or pulling the fish out of the water to release. Ease sublegal halibut back into the water; do not throw them. If gut-hooked, cut the leader and do not attempt to remove the hook. Attempts at hook removal may increase damage to vital tissues or increase the chance of death.

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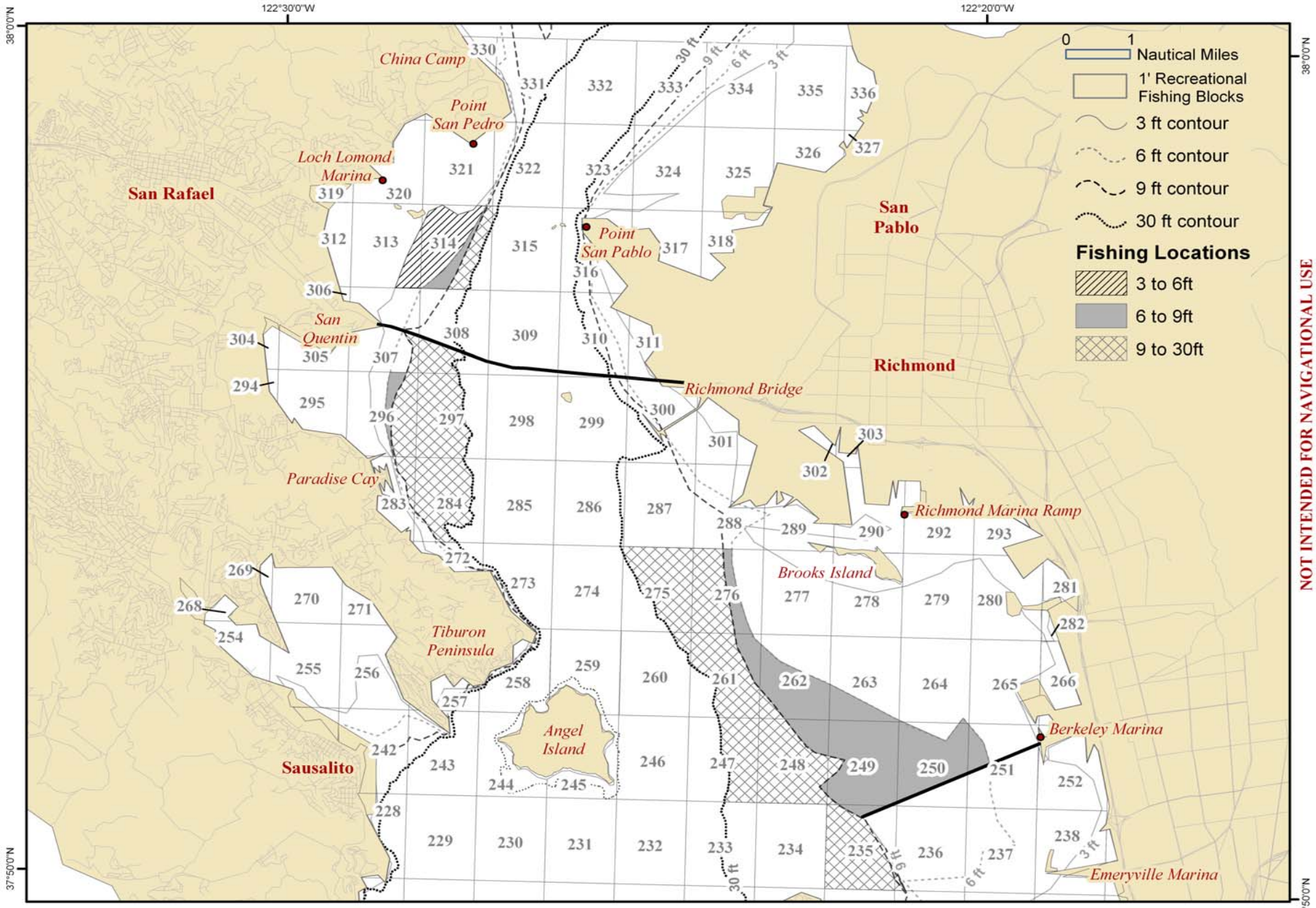
APPENDICES

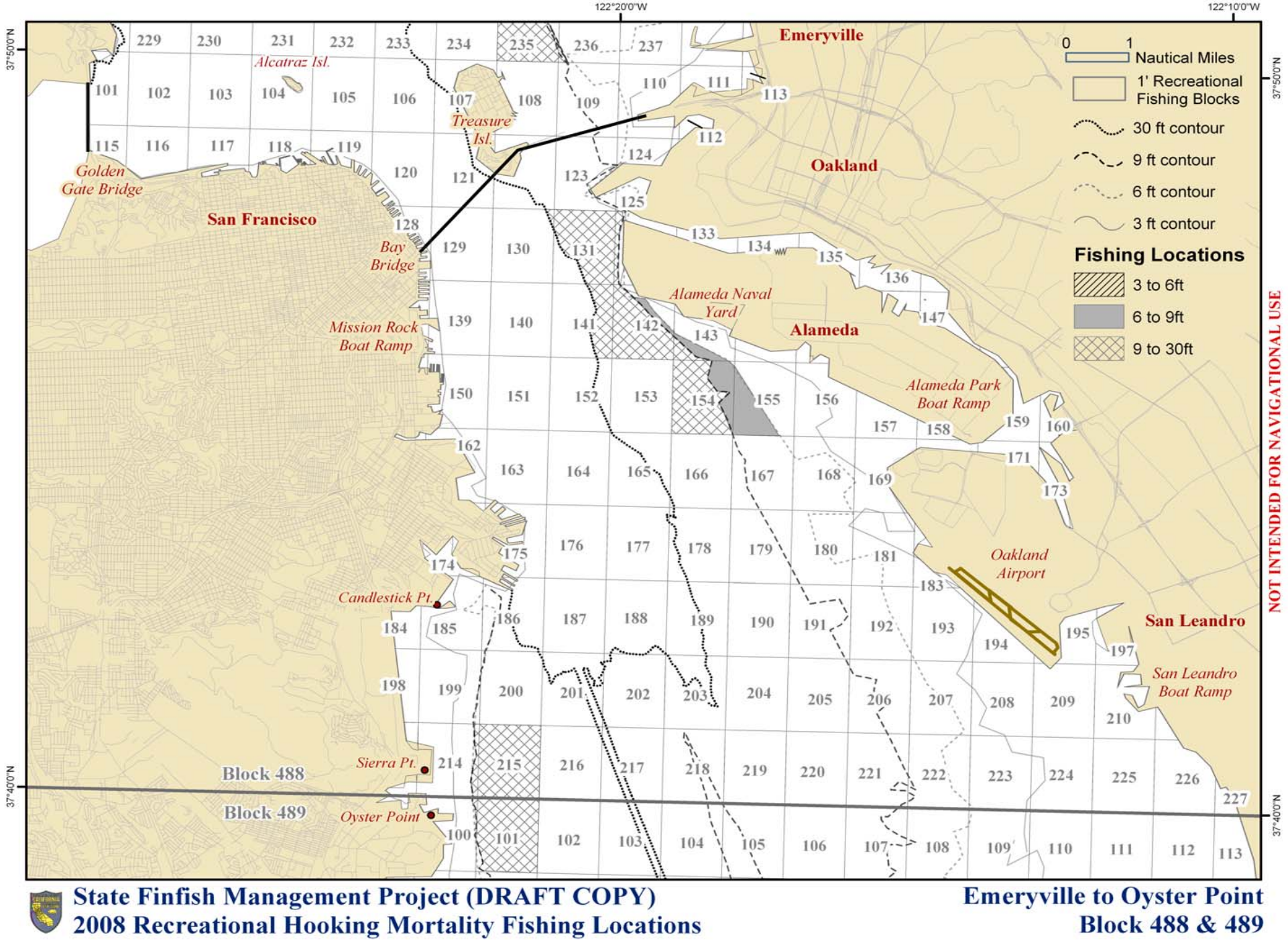
Appendix 1: Approximate 2008 fishing locations, North Bay



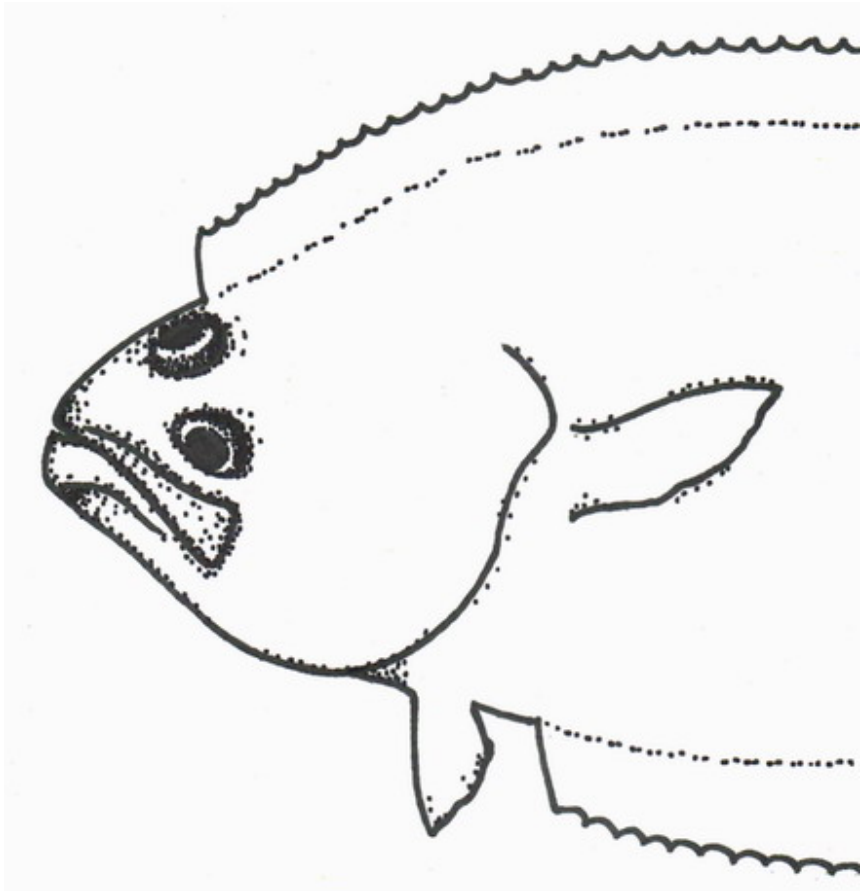
State Finfish Management Project (DRAFT COPY)
2008 Recreational Hooking Mortality Fishing Locations

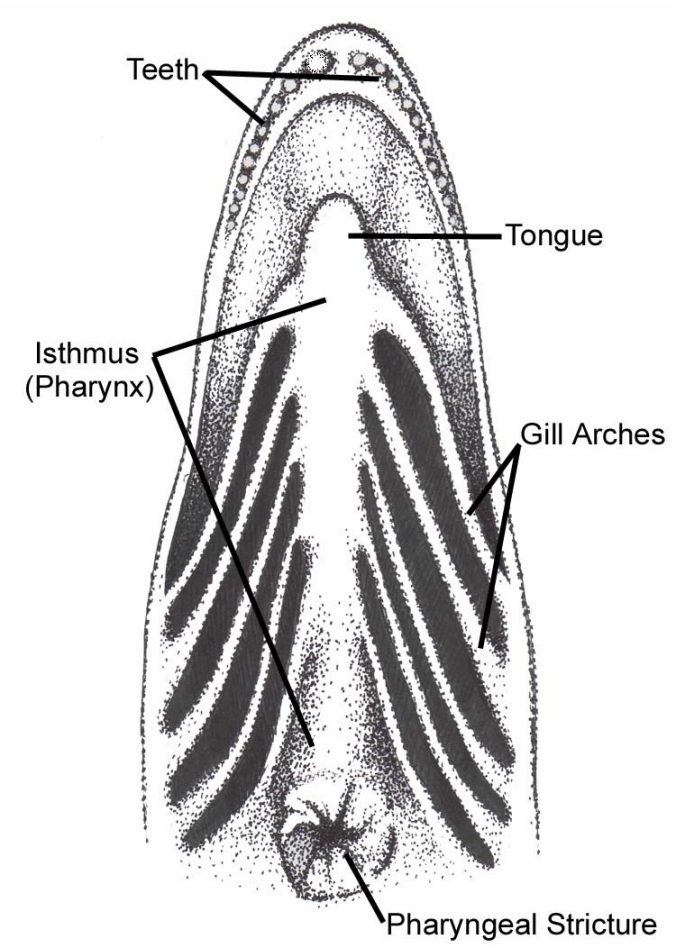
China Camp to Emeryville
Block 488

Appendix 1: Approximate 2008 fishing locations, South Bay



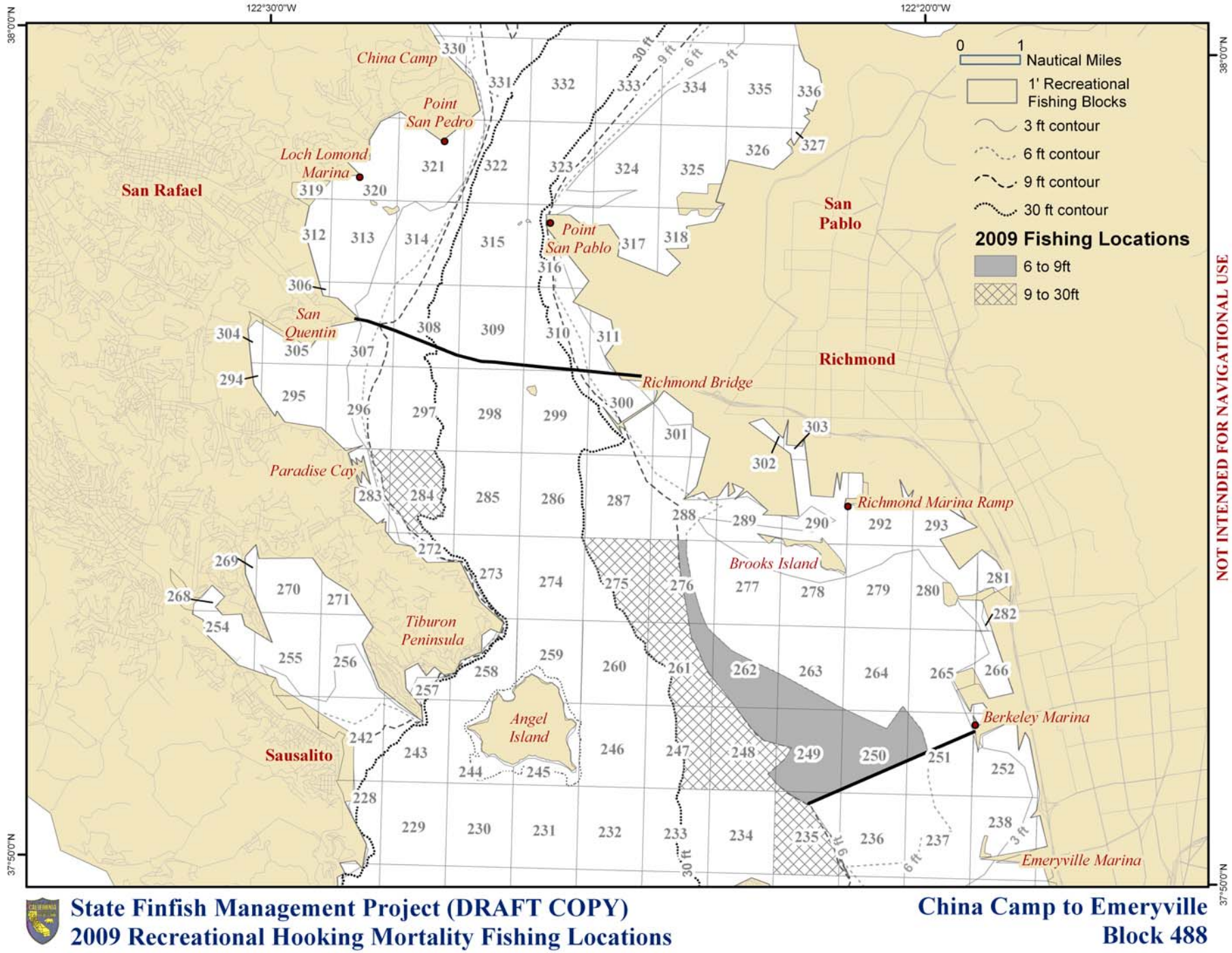
Appendix 2: Hooking location diagrams



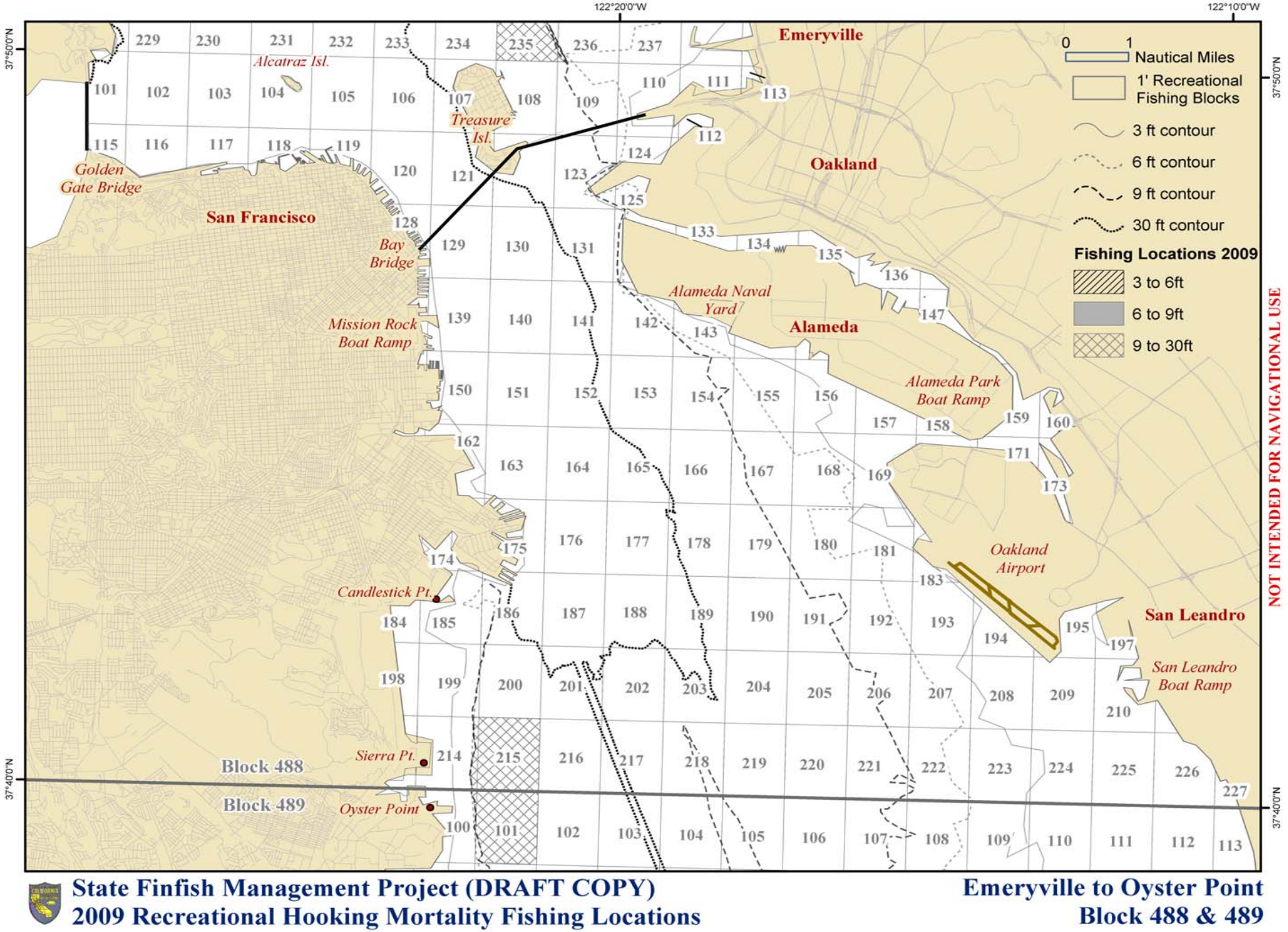


Illustrations: Ashok Sadrozinski, CDFG

Appendix 3: Approximate 2009 fishing locations, North Bay



Appendix 3: Approximate 2009 fishing locations, South Bay



Appendix 4. 2008 Hooking locations and frequency

HOOK TYPE	HOOKING LOCATION	HALIBUT RELEASED	HALIBUT RETAINED	OTHER FISH	CAPTIVE MORTs	OTHER MORTs	NOTES
J	Mouth	7	2	9	0	0	
	Roof	1	1	0	0	0	
	Gill/Isthmus	0	1	0	0	0	
	Post Phar.	0	2	0	0	2*	*fish sacrificed
	Snag	1	0	1	0	0	
	TOTAL	**9**	**6**	**10**	**0**	**2**	
Circle	Mouth	10	9	3	3	3**/1*	*fish sacrificed as control/** fish died before delivery
	Gill/Isthmus	0	0	1	0	0	
	Post phar.	0	1	0	0	1*	*fish sacrificed
	Unknown	0	0	1	0	0	
	TOTAL	**10**	**10**	**5**	**3**	**5**	
Treble	Mouth	0	3	1	2	0	
	Roof	0	1	0	0	0	
	Gill/Isthmus	0	1	0	0	0	
	Post phar.	0	2	1	0	1*	*fish sacrificed
	Snag	0	0	2	0	0	
	Tongue	0	1	0	1	0	
	Tongue/ roof	0	1	0	1	0	
	Unknown	0	0	1	0	0	
	TOTAL	**0**	**9**	**5**	**4**	**1**	
Trap-J	Mouth	2	3	6	0	0	
	Gill/Isthmus	0	2	0	0	1*	*fish sacrificed
	Post phar.	0	1	0	1	0	
	TOTAL	**2**	**6**	**6**	**1**	**1**	
Trap-treble	Mouth	3	1	7	0	0	
	Roof	0	0	1	0	0	
	Gill/Roof	0	1		1		
	Post phar.	0	2	3	1	1*	*fish sacrificed
	Snag	0	1	2	0	1*	*fish sacrificed as control
	Roof/ tongue	1	0	0	0	0	
	TOTAL	**4**	**5**	**13**	**2**	**2**	
Trap-J/treb	Post phar.	0	0	2	0	0	
Trap-J/treb	Unknown	0	2	2	0	0	
Trap-J/treb	Snag	0	0	1	0	0	
Trap-J/treb	Mouth/ roof	0	0	1	0	0	
	TOTAL	**0**	**2**	**6**	**0**	**0**	
	GRAND TOTAL	**25**	**38***	**45**	**10**	**11**	*Three fish remain in main display, remainder were released into the Bay

Appendix 5. 2009 Hooking locations and frequency

HOOK TYPE	HOOKING LOCATION	HALIBUT RELEASED	HALIBUT RETAINED	OTHER FISH	CAPTIVE MORTs	OTHER MORTs	NOTES
J	Mouth	1	5	10	3	1*	*Fish died before delivery
	Post Phar.	0	3	1	3	0	
	Snag	0	0	1	0	0	
	TOTAL	**1**	**8**	**12**	**6**	**1**	
Circle	Mouth	0	0	2	0	0	
	Snag	0	0	2	0	0	
	Unknown	0	0	1	0	0	
	TOTAL	**0**	**0**	**5**	**0**	**0**	
Trap-J	Mouth	2	1	2	1	0	
	Gill/Isthmus	0	0	1	0	0	
	Post phar.	0	0	1	0	0	
	Snag	0	0	3	0	0	
	TOTAL	**2**	**1**	**7**	**1**	0	
Trap-treble	Mouth	2	0	6	0	0	
	Gill/Isthmus	0	1	0	0	1*	*Fish died before delivery
	Post phar.	0	2	2	1	1*	*Sacrificed
	Tongue	0	1	0	1		
	Roof/tongue	0	1	0	0		
	Snag	1	1	1	0	0	
	TOTAL	**3**	**6**	**9**	**2**	**2**	
Trap-J/treb	Post phar.	0	1	0	1	0	
Trap-J/treb	Unknown	1	0	1	0	0	
Trap-J/treb	Mouth/roof	0	0	2	0	0	
Trap-J/treb	Mouth/ PP	0	1	0	1	0	
Trap-J/treb	Snag/ gill	0	1	0	0	1*	*Fish died before delivery
	TOTAL	**1**	**3**	**3**	**2**	**1**	
	GRAND TOTAL	**7**	**18****	**36**	**11**	**4**	**Three fish remain in main display