Histamine Control in the Hawaii Tuna Longline Fishery

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Challenge:

Controlling Histamine on Fishing Vessels

- Need to understand commercial fishing and onboard fish handling practices.
- Determine if commercial practices control histamine.
- Determine if inspection procedures at receiving are effective histamine controls.
- Establish HACCP-based controls and records that are practical and effective.

Our approach was to document commercial fishing and fish handling practices and their impact on histamine control. We did not manipulate fishing or fish handling practices.

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The Hawaii Tuna Longline Fishery

- Produces fresh tuna, billfish and other pelagic fish species.
- Many species are histamine-formers.
- Fishing and fish handling practices are focused on producing high-quality fish.
- Main product: Sashimi Bigeye Tuna

The Hazard Analysis Critical Control Point (HACCP) approach to seafood safety begins with an understanding of the fish or seafood species and how these products are consumed.

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Sashimi tuna requires good fish handling practices

The Hawaii fishery produces high-quality, high-value fish for the sashimi market. Fish that meet the quality requirements for raw consumption can only be produced when fishers and processors exercise good fish handling practices keeping fish clean, cold and moving through the production and distribution chain to the end consumer.

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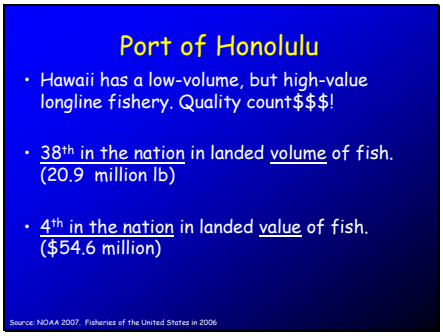

Recent NOAA statistics on US ports reflect the commitment to high quality, good fish handling practices in the Hawaii fishery.

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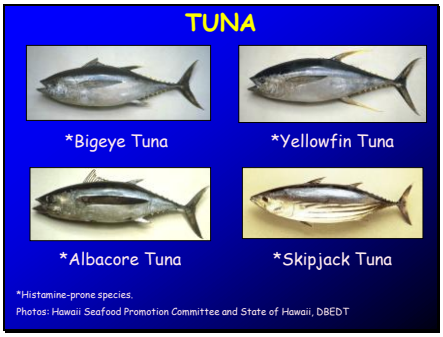

The primary pelagic fish species in the Hawaii Longline Fishery is the bigeye tuna, prized by discriminating sashimi markets. Other tunas are also caught and all are known to be histamine-prone.

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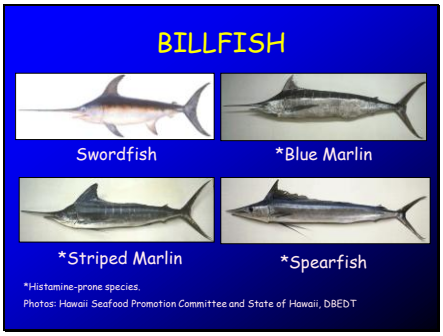

Four species of billfish are also landed, three of which are known to be histamine-prone. In Hawaii, blue marlin and striped marlin are commonly eaten raw and must meet high quality standards.

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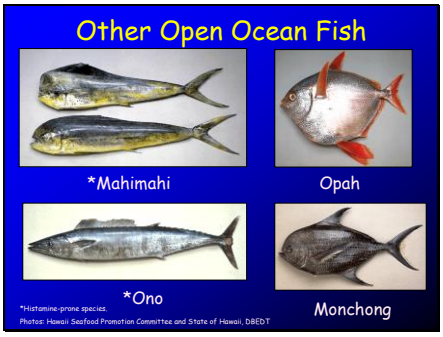

Other associated pelagic fish species are also caught in the Hawaii Longline Fishery. Not shown here is the escolar (*Lepidocybium flavobrunneum*) which is also a histamine-prone species. The point to emphasize is that many of the fish caught in this fishery are histamine-prone and control measures need to take into account the range of species, sizes and body shapes.

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The Honolulu Fish Auction is operated by the United Fishing Agency. The Hawaii Longline Fishing fleet sells its landings through the auction where the market demand is focused on daily landings of fish and prices are derived from open market competition, quality, supply and demand factors. With an auction system, fishers with good quality fish receive higher prices, creating a strong incentive for fishers to apply good fish handling practices and to maximize fish quality as a matter of business survival.

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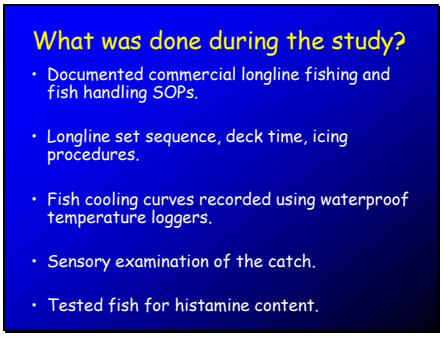

These are the basic methods and approach used during the study. This type of detail for onboard fish handling is generally unavailable to companies that receive fish from fishing vessels. Researchers went on commercial fishing trips to observe, document and monitor fish handling practices. Fish temperatures were recorded using waterproof loggers (Onset Commputer Corp, Stowaway®Tidbit XT). They were implanted at the time the fish were hauled aboard and recorded temperatures up until the time the fish were delivered and evaluated at the auction at the end of the fishing trips. Sensory examination was conducted at the time the fish were delivered to the auction after the fishing trips. Sensory examination involves the use of visual, tactile and olfactory senses to determine if fish are spoiled (decomposed) or are acceptable for commerce and consumption. Muscle samples were collected at the end of the fishing trips from the anterior portion of the dorsal muscle mass (loin) and tested using AOAC 1995 Official Method 977.13 for histamine in

seafood.

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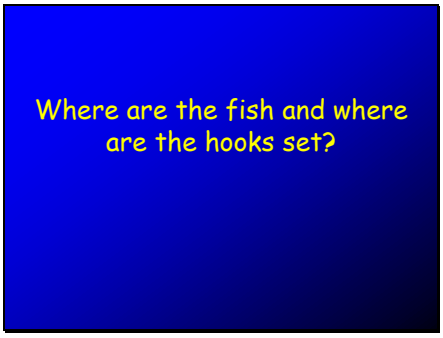

The histamine hazard analysis requires an understanding of the water temperatures where fish are caught because this will have an impact on the initial fish temperatures and the starting point for the cooling phase.

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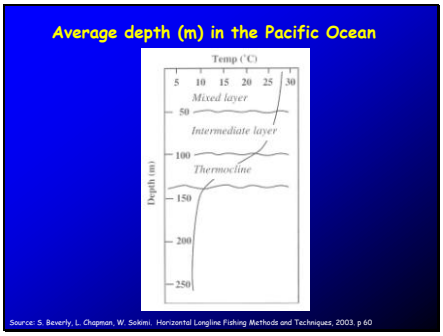

This is a typical vertical thermal profile of the central Pacific Ocean where Hawaii longliners operate. Sea surface water temperatures and the depth of the thermocline can change but this figure represents a typical temperature profile.

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Water Depth and Temperature Range for Pelagic Fish in Pacific Longline Fisheries

Species	Capture Depth	Temp. Range
Bigeye tuna	50 – 600 m, thermocline	10 – 17°C (50 - 62.6°F)
Albacore tuna	50 – 600 m, thermocline	10 – 17°C (50 - 62.6°F)
Swordfish	50 – 150 m, mixed and intermediate layer	18 – 22°C (64.4 - 71.6°F)
Blue marlin	50 – 250 m, mixed and intermediate layer	20 – 23°C (68 - 73.4°F)
Yellowfin tuna	50 – 250 m, mixed and intermediate layer	18 - 28°C (64.4 - 82.4°F)

Beverly, S. et al., 2003. Horizontal Longline Fishing Methods and Techniques. Secretariat of the Pacific Community, 129 p.

Fishers target the depth of water where temperatures are favored by the target species, in this case bigeye tuna. Water temperatures favored by bigeye tuna range from 10 to 17 °C, corresponding to depths of 50 to 600 m.

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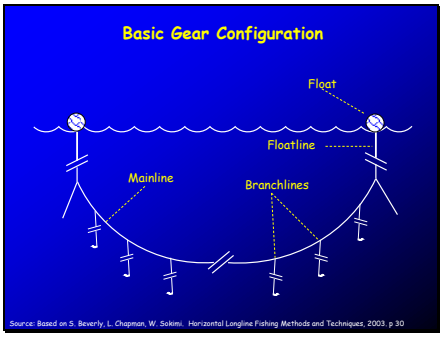

Longline gear can be adjusted and deployed to target different depths by changing the length of floatlines, the number of hooks (branchlines) set between floats and the amount of slack in the line as it is deployed. If TDRs (temperature depth recorders) are set on the shallowest, intermediate and deepest hooks between floats, the range of temperature and depth can be determined as in the next slide.

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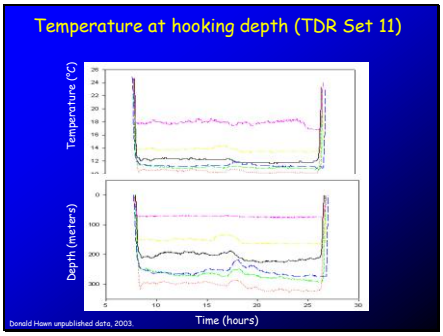

Time runs along the X axis and temperature and depth run along the Y axis in this Figure. In this longline set, the shallowest hook was placed at about 70 m depth in water of about 18 °C. The deepest hook settled at about 300 m depth where water temperature was about 10 °C.

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How many fish are hauled per hour?

- Estimated mean = **3.2 fish per hour**
- Estimated max = **4.4 fish per hour**

- Calculation basis.
  - 3-year mean CPUE = 12.9 fish / 1000 hooks
  - 3-year mean number of hooks/set = 1900
  - Mean = 24.5 fish/set, max = 33.5 fish/set
  - Mean line hauling rate = 250 hooks per hour*
  - Mean hauling time = 7.6 hours

Source: NOAA PIFSC unpublished data; *Sean Martin, Pacific Ocean Producers

It important to know how fast fish are hauled to the vessel during fishing operations because this provides insight on how long fish might remain on deck (deck time) to be bled, gilled and gutted and finally iced in the fish hold. The typical hauling rate in from 3 to 4 fish per hour providing ample time to quickly prepare and ice fish.

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How long does it take to ice the fish?

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DECK TIME (minutes) for fish caught in the Hawaii Tuna Longline Fishery (Kaneko et al., 2004)

Fish	N	Mean	Max	SD
Bigeye Tuna	164	23	101	15.2
Yellowfin Tuna	12	19	69	18.0
Albacore Tuna	3	10	13	2.3
Pacific Blue Marlin	4	10	11	3.0
Striped Marlin	7	11	23	7.7
Mahimahi	9	9	14	3.3
Wahoo	3	57	58	0.6
Escolar	29	14	48	9.8
All species	**231**	**20**	**101**	**14.7**

Based on 68 observed commercial longline sets.

The mean observed time fish remained on deck after being hauled aboard was 20 minutes. During this study a longline set with an unusually high catch rate was observed during which one fish was on deck for 101 minutes before being iced. Most Hawaii longline captains understand that the faster they start to chill the fish in the ice, the better the fish quality and landed value at auction. For most captains the operating limit is no more than 15 to 20 minutes on deck before icing.

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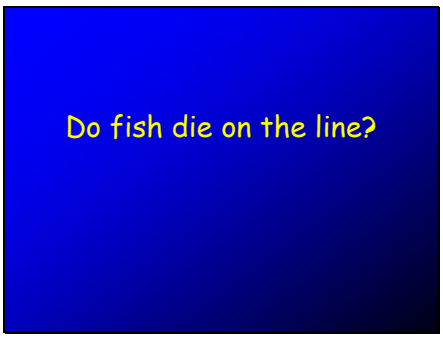

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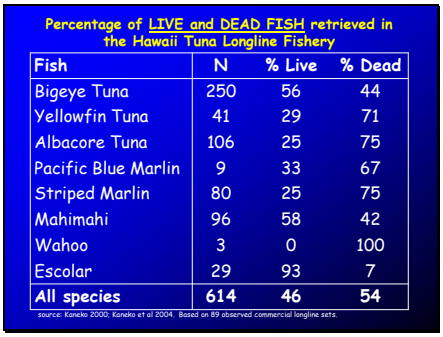

The post-harvest handling sequence begins once the fish is hauled aboard. However, if fish die on the line in the water, the post-mortem handling period begins at some unknown time in the water. Knowing if fish die on the line and the proportions of live and dead fish based on species is potentially important if there is a significant difference in the likelihood and rate of histamine formation. In the Hawaii Longline Fishery, roughly half of the fish die on the line in the water.

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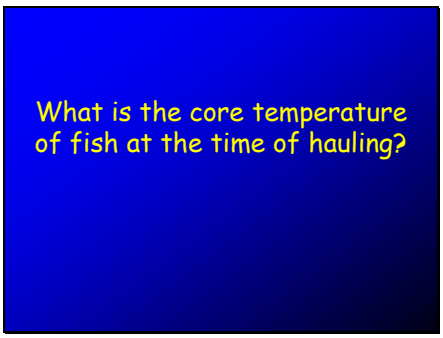

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INITIAL CORE TEMPERATURE of BIGEYE TUNA at the time of retrieval in the Hawaii Tuna Longline Fishery

Status of fish at time of retrieval	Initial Core Temperature (°F)			
	N	Mean	Max	SD
Live	98	77	86	4.7
Dead	66	64	78	5.3
***P < 0.0001		***		

Source: Kaneko et al., 2004.

The initial core temperatures of bigeye tuna hauled alive and after dying on the line were determined. The dead fish tended to be 13 °F cooler (64 °F) than live fish (77 °F) indicating that fish died in water that is cooler than the sea surface and that chilling began at the hooking depth.

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Is there a difference in histamine between fish hauled live and after death on the line ?

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HISTAMINE CONTENT of BIGEYE TUNA at the time of unloading that were retrieved alive and dead and stored in ice in the Hawaii Tuna Longline Fishery

Status of fish at time of retrieval	Histamine (ppm)			
	N	Mean	Max	SD
Live	98	0.8	3.6	0.64
Dead	66	1.2	9.0	1.31
**P < 0.01		**		

Source: Kaneko et al., 2004.

The testing results comparing bigeye tuna hauled alive and after dying on the line reveled a significant statistical difference in histamine content. It should be noted however, that the histamine concentrations of both live and dead fish were well below the defect action limit of 50-ppm and toxic level of >200-ppm. So for practical purposes in the Hawaii fishery, fish that die on the line do not appear to pose a significant histamine risk.

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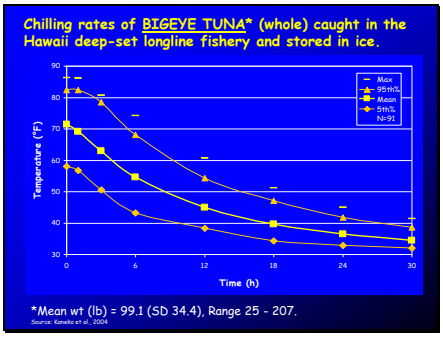

The temperature loggers were placed in the fish to record core temperatures continuously during the post harvest sequence at sea until the fish were delivered to the Honolulu fish auction at which time the loggers were removed, the fish evaluated for sensory indicators of spoilage and muscle samples were collected for histamine testing. This cooling curve depicts the initial core fish temperatures through the time the fish were chilled below 40 °F. This figure depicts the cooling rates for bigeye tuna left whole (uneviscerated). It should be noted there is a wide range of initial fish temperatures and chilling rates because of the range of sizes of fish (25 lb to 207 lb), whether the fish was dead or alive when hauled aboard and the temperature at the hooking depth.

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Time to chill BIGEYE TUNA* (whole) caught in the Hawaii deep-set longline fishery to core temperature targets of 50°F and 40°F in ice.

Fish temperature target	Time (h:min) to reach temperature target				
	N	Mean	SD	95%	Max
< 50°F	91	8:30	3:47	15:20	19:00
< 40°F	91	17:08	5:48	27:20	34:00

*Mean wt (lb) = 99.1 (SD 34.4), Range 25 - 207.

Source: Kaneko et al., 2004

This table reports the mean time to chill the same whole bigeye in the previous slide to below 50 °F and to below 40 °F. It also shows the maximum times recorded of 19 hr to below 50 °F and 34 hr to below 40 °F.

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What happens to chilling rate when fish are gilled & gutted?

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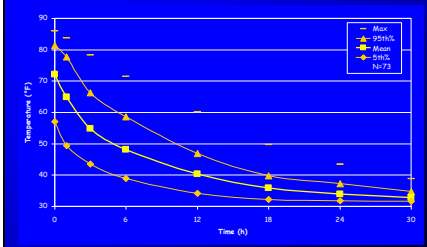
Chilling rates of BIGEYE TUNA* (gilled & gutted) caught in the Hawaii deep-set longline fishery and stored in ice.



*Mean wt (lb) = 70.7 (SD 33.5), Range 27 - 180.

Source: Kaneko et al., 2004

Eviscerating bigeye tuna prior to icing reduces the body weight to be chilled by over 10% and allows the visceral and gill cavities to be packed with ice. This helps to increase the chilling rate.

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Time to chill BIGEYE TUNA* (gilled & gutted) caught in the Hawaii deep-set longline fishery to core temperature targets of 50°F and 40°F in ice.

Fish temperature target	Time (h:min) to reach temperature target				
	N	Mean	SD	95%	Max
< 50°F	73	5:23	3:23	10:12	17:50
< 40°F	73	11:57	4:47	17:50	27:50

*Mean wt (lb) = 70.7 (SD 33.5), Range 27 - 180.

Source: Kaneko et al., 2004

The time to chill gilled and gutted bigeye tuna was faster than for whole fish.

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COMPARISON of harvest and post-harvest factors and histamine concentration of WHOLE and GILLED & GUTTED BIGEYE TUNA caught by Hawaii deep-set longline gear.

Bigeye Tuna	Whole N=91 Mean (±) SD	Gilled & Gutted N=73 Mean (±) SD	Probability
Fish Wt (lb)	99.1 (±) 34.4	70.7 (±) 33.5	<0.01
Initial Core Temp (°F)	71.5 (±) 7.9	72.1 (±) 7.8	0.592
Time to 50°F (h:min)	8:30 (±) 3:47	5:23 (±) 3:22	<0.01
Time to 40°F (h:min)	17:08 (±) 5:48	11:57 (±) 4:47	<0.01
Histamine (ppm)	0.92 (±) 1.16	1.02 (±) 0.70	0.521

(Source: Kaneko et al., 2004)

Comparing the chilling rates and resulting histamine concentrations demonstrates that gilling and gutting significantly increases the chilling rate, but in this fishery did not result in a statistically different outcome in histamine concentration. Both gilled and gutted and whole fish contained about 1-ppm histamine. It should be noted that the gilled and gutted fish weighed less than the whole fish so that chilling rates should be expected to be more rapid due to this factor alone.

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Sensory Examination and Histamine Control During Unloading

Sensory examination of the catch at the time of unloading fish involves the sense of smell, sight and touch. Fish are examined for signs of mishandling and spoilage by the auction personnel as well as the fish buyers.

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Sensory examination and histamine concentration (ppm) of mixed pelagic fish caught by Hawaii deep-set gear and stored in ice.

*FISH	PASSED Sensory Exam Histamine (ppm)				FAILED Sensory Exam Histamine (ppm)				P
	N	Mean	SD	Max	N	Mean	SD	max	
BE	186	1.06	1.34	11.50	37	2.88	11.57	71.0	0.038
YF	55	1.19	1.20	6.31	21	1.11	2.17	10.40	0.827
AL	3	0.67	0.29	1	4	0.50	0.00	0.50	0.286
BM	27	0.70	0.42	2	0				
SM	8	0.88	0.88	3	1	0.50	0.00	0.50	0.699
MM	30	0.63	0.64	4.00	29	1.96	4.32	21.80	0.102
ON	3	0.50	0.00	0.50	8	0.50	0.00	0.50	1.000
WA	54	1.42	2.76	19	16	0.68	0.65	3.10	0.294
ALL	**366**	**1.06**	**1.53**	**19**	**116**	**1.76**	**6.94**	**71.0**	**0.074**

*AL = albacore; BE = bigeye; BM = pacific blue marlin; MM = mahimahi; ON = wahoo; SM = striped marlin; WA = escolar; YF = yellowfin

Source: Kaneko et al., 2004.

The histamine testing results of mixed pelagic fish species that underwent sensory examination are presented in this table. The mean histamine concentration of fish that passed sensory (no persistent odors of decomposition in the muscle) was low (1.06-ppm) and the maximum value was 19-ppm, still below the defect action limit of 50-ppm. The mean histamine concentration of fish that failed sensory examination was also low (1.76-ppm), but the maximum value was 71-ppm exceeding the defect action limit. It should be noted that the fish evaluated do not occur in this proportion of sensory passes and failures. Fish that fail sensory are rare in this fishery.

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Sensory Examination and Histamine Testing of Mixed Longline-caught Pelagic Fish

Sensory Exam	N	No. of Fish > 50 ppm	% of fish > 50 ppm
PASSED	830	0	0%
FAILED	235	15	6.4%
Total	1,065	Comment: 100% of histamine reject fish were culled from market by sensory examination.	

Source: Kaneko, 2000; Kaneko et al., 2004

Combining the results of two studies, over 1000 individual fish underwent sensory examination and histamine testing. Only 15 fish exceeded the 50-ppm defect action limit for histamine, and each one was first culled from the market because of odors of decomposition. This demonstrates the practical and effective nature of sensory examination in reducing the likelihood of fish containing high histamine from entering commerce in this fishery. This amounts to only 6.4% histamine rejects within the 235 fish that failed sensory examination. This demonstrates that high and toxic levels of histamine are not the inevitable outcome of spoilage.

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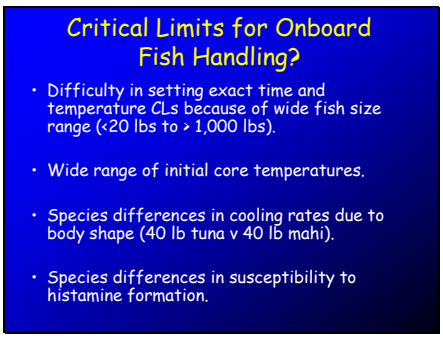

Establishing Critical Limits for fish handling and chilling rates to control histamine formation is complicated by these factors. It would be very difficult and time consuming to determine Critical Limits for temperature control for each species, size class and initial body temperature experienced in this and other fisheries.

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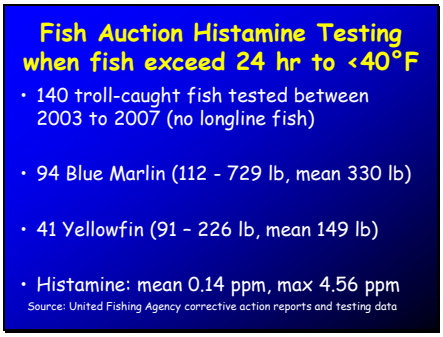

The Honolulu Fish Auction provided access to review corrective action reports for fish that exceeded 24 hr to be chilled below 40 °F between 2003 and 2007. None of the longline fish exceeded this critical limit during this period. The challenge has been for trolling vessels that make day-trips and catch large fish because they deliver fish within 24 hr of capture. Large blue marlin and yellowfin tuna are difficult (impossible) to chill to below 40 °F within 24 hr using ice alone. However, with 140 individual fish tested to date, some that took up over 40 hours to chill to below 40 °F, the mean histamine concentration was 0.14-ppm and the maximum value was 4.56-ppm, well below the defect action limit of 50-ppm and toxic level of 200-ppm. This supports the concept that the most critical steps in controlling histamine formation occur in the immediate post-harvest period at sea. Eviscerating the fish, limiting the time it takes to ice the fish and keeping the fish properly iced during the trip and after delivered to the first receiver are the most important histamine control measures without

knowing the exact cooling time and temperatures.

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The simplest advice is often the best advice. In the case of histamine controls, fishers need to chill fish immediately and keep them properly iced throughout the trip. Gilling and gutting of all tunas and mahimahi greater than 20 lb (whole weight basis) and all marlins greater than 40 lb (whole weight basis) has been required by the Honolulu Fish Auction since 2004. Training fishers has been effective by approaching them with ways to improve quality and fish prices through gilling and gutting and proper icing. Once open to the actions they can take to imrpove their "bottomline", fishers are also open to understanding how with rapid chilling and proper storage, histamine is effectively controlled. With strict operating limits for fish quality on deck time (no more than 30 minutes), fishers will achieve more rapid chilling, better quality and prices, while operating with a wide margin away from Critical Control Limits for cooling rates (minimum controls standards) that may be needed to prevent histamine formation. Fish temperatures should be checked by the receiving company to be certain

they are consistent with the quality of the fish being delivered and the reported time of capture. In longline fishing and troll fishing, each fish has a unique capture history and can vary greatly in body size and initial body temperature. Because of this, each fish should undergo sensory examination to be certain that no single fish enters the market with obvious and persistent signs of decomposition which is a company's obligation under GMPs, and especially important with histamine-prone fish species. With the unique harvest and post-harvest histories of each fish, each should be treated as a "lot".

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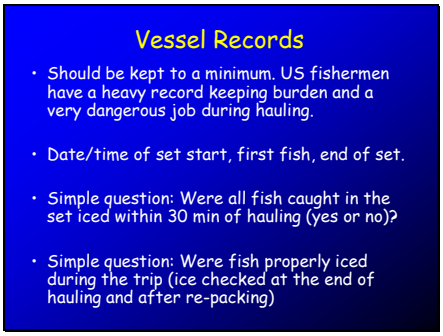

Hawaii longline fishers have mandatory federal logbook reporting requirements. Fish handling records should be limited to collecting only those data essential to determining the safety of the catch. Logbooks already require information on the longline sets and these are not necessary to determine safety of the fish. It is important that fishers report on whether each of the fish harvested was iced within 30 minutes of hauling and whether the fish in the hold were properly iced during the fishing trip. To be certain the information collected is valuable to the captains, it is proposed that checking (twice per day) whether the fish are properly iced at the end of line hauling and again after line setting should suffice. These are the times when the crew responsible for icing fish finally leave the fish hold and should report to the captain that the fish are properly iced.

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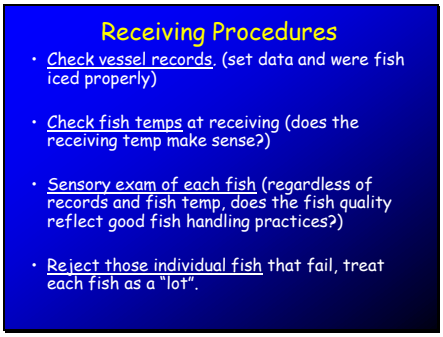

Receiving companies should focus on carefully evaluating the catch, by measuring fish temperatures and conducting sensory examination. The study results indicate that sensory examination in this fishery is effective in culling fish containing high histamine from entering commerce.

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