CRUISE REPORT

NWFSC/NOAA Fisheries

FV *Ocean Starr*

Cruise 50

29 June-3 July, 2014

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Cruise Area:
Washington Coast

Itinerary:
Depart: June 29– Astoria, Oregon
Commence sampling: June 29– Willapa Bay Transect
End sampling: July 2 – Willapa Bay Transect
Disembark: July 3 – Newport, Oregon

Participating organizations:
NOAA – Northwest Fisheries Science Center (NWFSC)
NOAA – Southwest Fisheries Science Center (SWFSC)
Oregon State University
University of Oregon

Scientific Personnel:

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Cruise Objectives and Description

Due to concerns about the capture of marine mammals and large non-target fishes during surface trawls for pelagic species (Zeeberg et al. 2006; Dotson et al. 2010), the use of marine mammal excluder devices[1] (MMEDs; Fig. 1) is increasingly being required during commercial fisheries (Benaka et al. 2012) and research cruises. However, use of MMEDs has been shown to affect fish catches of target species, with some species or life history stages being particularly vulnerable to escape through the MMED (Dotson et al. 2010; T. Wainwright, unpublished data). Net-mounted camera footage taken during a SWFSC research cruise (S. Hayes, unpubl. data) clearly showed the flap open (Fig. 1) and fish escaping through the flap when the net was fishing. Such catch bias makes direct comparisons of surveys with and without MMEDs problematic. Specifically, the ability to maintain the continuity of fishery survey databases requires that the MMED not affect fish catches. This cruise was used to 1) test the effects of surface trawling with and without a MMED present on catch of fish and nekton, and 2) experiment with modifying the MMED to minimize catch bias for target species (juvenile salmon). Up to 4 cameras were installed in the net to record fish and net behavior, which proved extremely informative.

The primary objectives of this research cruise were to:

1. Conduct pairs of surface trawls with and without the MMED in place to quantitatively document the effects of the MMED on fish and nekton catches. This occurred in locations historically known to have high densities of juvenile salmon (Willapa Bay and Grays Harbor transects) and consisted of repeated pairs of 15 minute hauls with and without a MMED in place. A total of 8 such pairs were conducted.

2. Make experimental modifications to the MMED to qualitatively evaluate whether we could reduce catch bias of target species (juvenile salmon) while still allowing the MMED to function to exclude marine mammals or other large fishes. These modifications included 1) adding variable amounts of weight to the MMED flap, 2) adding floats to the MMED section, and 3) adding floats to the MMED flap when the MMED was installed in an up-side-down position. Nine experimental hauls were completed.

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[1] A Marine Mammal Excluder Device consists of a rigid aluminum grid installed at a 45° angle forward of the codend that expels marine mammals and other large animals (e.g. turtles, sharks) before they are swept into the codend at the end of the net.

Methods

<u>Stations</u>

Because of the objectives of the study, sampling stations were specifically selected to be locations where we would likely encounter large numbers of juvenile salmon and few jelly fish. Instead of fishing on specific stations, we repeatedly fished in the same general area, with starting locations within ½ mile of each other between consecutive hauls. We conducted three CTD profiles daily to document physical water column properties, but no other plankton or water quality measurements were made.

<u>Trawl Sampling</u>

Fish were collected using a Nordic 264 rope trawl (Net Systems, Bainbridge Island, WA) fished at the surface directly astern of the FV *Ocean Starr.* To fish the head-rope of the trawl at the surface, a cluster of two meshed A-4 polyform buoys were tethered to each wing tip and two A-3 polyform floats were clipped at the center of the head-rope. The foot-rope was pulled down by weight integrated into the footrope and bridle. The trawl mouth was spread apart by a pair of weighted 3.0 m Lite® trawl doors (200 lbs of weight was attached to the bottom of each door), creating a trawl opening of about 30 m wide by 20 m deep when fishing. Trawl mesh sizes ranged from 162.6 cm in the throat of the trawl near the jib lines to 8.9 cm in the cod end. To retain catches of small fish and squid, a 6.1 m long, 0.8 cm knotless mesh liner was sewn into the cod end. The net and doors used by this study were owned by SWFSC, which differs from the NWFSC trawl by having the foot-rope weight integrated into the net (rather than being detachable), and the doors were weighted. All hauls were15 minutes long (timing starting when the doors were fully deployed and stopped when net retrieval was initiated).

In order to avoid the accidental capture of marine mammals during trawl operations, at least three scientists were posted on the flying bridge to watch for marine mammals in the vicinity of the boat and trawl. This watch started 10 minutes prior to setting the net in accordance with NWFSC protocols (NWFSC 2014). In the event that marine mammals were sighted before the net was deployed, the ship moved to a new location, and marine mammal watch was restarted for the full 10 minutes before the net was deployed. Additional deterrents to marine mammals were the use of two NOAA-approved pingers (AQUAmark 300, www.aquatecgroup.com) fixed on the net foot-rope.

We estimated the numbers of fishes, squid, and gelatinous species (mainly medusae) retained in each trawl sample. When numbers were low, all individuals were enumerated. When numbers were high, the catch was weighed and the total numbers of each species in the catch were estimated from numbers in weighed subsamples. We also used volumetric methods (number per liter) to enumerate whitebait smelt caught in several large hauls. No attempt was made to estimate total abundance of small animals (e.g. fish larvae, krill) not quantitatively retained by the small meshes of the cod end. For each trawl sample we measured all salmonids and up to 50 individuals of non-salmonid fishes (lengths), squid (dorsal mantle length) and gelatinous species (bell diameter for medusae).

All juvenile salmonids were identified to species, checked for external marks (fin clips or latex marks) and internal tags (coded wire or PIT), and measured to the nearest millimeter (mm) fork length (FL). All salmon were released after measurement, except for juvenile salmon which had internal tags. Retained juvenile salmon were individually labeled and bagged and immediately frozen.

Oceanographic sampling

Physical conditions were sampled three times each day. We used a CTD (conductivity-temperature-depth profiler, Sea-Bird SBE 19plus) to profile the water column to a maximum of 200 m or to within 5 m of the bottom. The CTD was also equipped with a WETstar fluorometer (WET Labs, Inc.) to measure chlorophyll *a* fluorescence, a C-Star transmissometer (WET Labs, Inc.) to record light beam transmission as percent water clarity, and a Sea-Bird SBE 43 dissolved oxygen sensor. Typically, we made a CTD profile before fishing commenced in the morning, one at mid-day, and a final profile after the last haul.

Results

Sampling

During the 4 days of sampling, we made 25, 15 minute fish trawls (Table 1), and 12 CTD casts (Table 2). The first and last days were spent on the Willapa Bay transect, and the 2nd and 3rd days on the Grays Harbor transect. During this time we completed eight pairs of hauls with and without the excluder present in the net (indicated by the “Y” or “N” on the haul number, respectively), with nine additional hauls during which we experimentally altered the excluder (indicated by an “X” in the haul number). Water depth at the start of each haul averaged 49.5 m (range 30 – 71 m), and each haul covered an average of 1.9 km (range 1.3 - 3.0 km). Haul locations on the Willapa Bay transect were farther from shore (mean = 17.0 km, range 13.7 -

20.2 km) than on the Grays Harbor transect (mean = 12.2 km, range 7.3 - 18.1 km).

Oceanography

Water temperature measured at 1 m depth was fairly consistent between the four days of sampling, ranging from 14.3 - 16.5° C, with the mean on the Willapa Bay transect (15.3° C) similar to the mean on the Grays Harbor transect (15.8° C) (Table 2, Fig. 2). In contrast, the salinities were lower on the Grays Harbor transect (mean = 26.3 PSU, range 24.4 - 27.9 PSU) than on the Willapa Bay transect (mean = 30.4 PSU, range 30.6 – 31.6 PSU) (Table 2, Fig. 3). Lower salinity water on the more northern transect suggest of a parcel of Columbia River plume water that was transported northwards by moderately strong winds (24 hour average $\geq$ 17 km/hr) from the south on June 24, 26, 28 and 30th, as measured at the Columbia River bar buoy (NOAA buoy 46029; 20 nm west of the Columbia River mouth). Thermocline depth (as indicated by maximum change in temperature) was similar on both transects, occurring between 15 and 21 meters. Minimum oxygen levels were slightly lower on the Willapa Bay transect (mean = 1.228 ml/L, range 1.076 – 1.357 ml/L) than along the Gray Harbor transect (mean = 2.238 ml/L, range 1.700 – 3.222 ml/L; Table 2). The minimum oxygen levels measured on the Willapa Bay transect were below the commonly identified threshold where animal life cannot be sustained (2 ml/L).

Catch of fish and nekton

Twenty three species of fish and nekton were caught during the 4 days of sampling (Table 3). This list included 6 species of jelly fish, one species of squid, one jawless fish (Class Agnatha), one cartilaginous fish (Class Chondrichthyes), and 14 species of bony fishes (Class Osteichthyes), including three species of salmon. Two additional fishes, ocean sunfish (*Mola mola*) and soupfin shark (*Galeorhinus galeus*; tentative identification) were also observed either passing by the ship (ocean sunfish) or on video within the net (both species), but no individuals were actually caught in the net. Sea nettles (*Chrysaora fuscescens)* were by far the largest jelly fish caught (maximum bell diameter = 340 mm; mean = 185 mm), while fish ranged in size from 31 mm-long whitebait smelt (*Allosmerus elongatus*) to 990 mm-long spiny dogfish (*Squalus acanthias*; Table 4).

Catches of fish and nekton were generally greater on the Grays Harbor transect (mean catch = 415 individuals) than on the Willapa Bay transect (mean = 89 individuals), due to moderate numbers of Northern anchovy (*Engraulis mordax*) farther from shore (17-18 km) and large numbers Pacific herring (*Clupea pallasii*) and whitebait smelt at stations close to shore (7.3-8.0 km), which were largely absent on the Willapa Bay transect. Nekton (primarily sea nettles) were also roughly twice as abundant on the Grays Harbors transect (mean = 143 individuals/haul) as on the Willapa transect (74 individuals/haul).

<u>Catch of salmonids</u>

Five species/age classes of juvenile salmon (subyearling, yearling, and mixed-age Chinook [*Oncorhynchus tshawytscha*], yearling coho [*O. kisutch*], and juvenile chum [*O. keta*] salmon) and two species of adult salmon (Chinook and coho) were caught during the four days of sampling (Table 3). Mean densities were higher on the Willapa Bay transect than Grays Harbors transect for subyearling (3.10 vs. 1.65 fish/km), mixed-age (0.69 vs. 0.29 fish/km), and subadult/adult (0.23 vs. 0.16 fish/km) Chinook salmon, yearling (1.13 vs. 0.31 fish/km) and subadult/adult (2.29 vs. 0.73 fish/km) coho and chum salmon (0.05 vs. 0.0 fish/km). The only exception to this pattern were yearling Chinook salmon, which had higher densities on the Gray Harbor transect (mean = 0.81 fish/km) than Willapa Bay transect (0.45 fish/km).

We retained 47 juvenile salmon (6 coho and 41 Chinook) that contained CWTs. Although detailed release information was not available for all tags, the agency code provided by the first two digits of tag number indicated that most tagged fish originated from the Columbia River system (Appendix A). For the tagged coho salmon, one was released from the Quinault River (Washington coast), three from the lower Columbia River (Cowlitz and Lewis Rivers) and the remaining two fish did not have detailed tag information but were released by Washington Department of Fish and Wildlife (WDFW). For tagged Chinook salmon, all were released in the Columbia River basin (Appendix A), with the possible exception of one that contained an Oregon Department of Fisheries agency tag (‘090909’). These Columbia River Chinook salmon included 10 individuals from the upper Columbia River (Chief Joseph, Wells, Chelan and Similameen hatcheries), 3 from the lower Columbia River (Clackamas and Cowlitz hatcheries), 2 from the mid-Columbia (Umatilla and Priest Rapids hatcheries) and 24 fish from the Snake River[2](Nez Pierce Tribal, Lyons Ferry, and Irrigon hatcheries). The origins of the tagged salmon caught during the cruise is consistent with origins of salmon caught during the normal ocean salmon surveys conducted off the coasts of Washington and Oregon, with most Chinook salmon

[2] These Snake River fish included 15 individuals that had Nez Pierce Tribal tag codes (starting with ‘22’) but for which detailed release information was not available. The Nez Pierce reservation is on the Snake River, therefore it was assumed that the fish were released in the Snake River.

originating from the Columbia River (Pearcy and Fisher 1990, Trudel et al. 2009) and coho salmon consisting of mixtures of Columbia, Washington Coast, and Oregon coast populations (Teel et al. 2003, Van Doornik et al. 2007).

Paired catches with and without the excluder

Although a formal statistical analysis of catches with and without the excluder is underway (T. Wainwright, unpubl. data), it was clear that the presence of the excluder affected fish and nekton catches. In paired hauls in which the excluder was absent, we caught more individuals overall (mean = 458) than when it was present (mean =173). This relationship was also true for the catch of all fish (excluding jellyfish and squid) and juvenile salmon: an average of 404 individuals were caught when the excluder was absent versus 74 when it was present, while the catch per unit effort (CPUE; fish/km towed) of all juvenile salmon groups was roughly twice as high when the excluder was not in the net, with the exception of mixed age Chinook salmon (Table 5). Most of these juvenile salmon, fish, jellyfish, and squid were too small to be ejected from the net by the excluder, suggesting they were able to escape through the flap. In contrast, adult salmon were large enough that they might be ejected from the net by the excluder, yet they showed mixed results: adult coho salmon were roughly three times more abundant when the excluder was absent, while less abundant adult Chinook salmon had similar catches regardless of whether the excluder was present or not (Table 6).

Experimental modifications to the MMED

We made 9 hauls during which we experimentally modified the MMED (Table 7; Appendix B). These modifications ranged from covering the MMED grid bars with colored tape to adding weight to the MMED flap to installing the MMED up-side-down and putting floats on the flap.

In almost all trials in which the MMED was in the upright position, pressure within the net kept the flap open and fish were observed escaping through the flap on the video footage. Our catch data was consistent with this observation, and the number of all individuals caught during experimental hauls (mean = 141 fish and nekton) was much closer to the number of fish and jellyfish caught when the excluder was present during paired hauls (mean = 173) than when it was absent (458).

Fishing the MMED in the up-side-down position with floats on the flap (modifications 34X and 35X; Appendix B) appeared to have the least number of fish escaping through the flap based on video footage, although relatively few fish were actually caught in those hauls (mean = 11). However, larger fish (e.g., small sharks) were observed being ejected from the net by the MMED, indicating it was still functioning.

Discussion

We successfully completed eight pairs of hauls with and without the MMED in the net in order to statistically evaluate the effect of the MMED on the catch of fish and nekton. This data will be combined with data collected on similar cruises conducted in 2011 to fully analyze the effects of MMEDs with statistical rigor (T. Wainwright, in prep.). Because of the high quality video footage we were able to collect on this cruise, we will be able to supplement catch data with counts of fish and nekton entering the net (recorded on the forward pointing camera in front of the MMED) to compare to the number actually caught, adding additional insight to the catch data.

Video observations--especially by the camera mounted directly behind the MMED flap--clearly showed that when fishing, the flap covering the MMED remains open with a sizeable gap between the flap and the body of the net. We also observed entire schools of fish exiting the net via this flap, including many that were far too small to get ejected by MMED. Taken together with the catch data showing much lower catches when the MMED was installed in the net than when it wasn't, it is clear that what was actually caught in the net was **not** representative of what had entered the net. Our results indicate that use of un-modified MMEDs allows large numbers of fish to escape, making catch data collected without a MMED incompatible with data collected with a MMED.

Our experimentation with the MMED indicated that the up-side-down configuration (34X, 35X) appeared to have the least number of fish escaping through the flap, although the right-side-up configurations with at least 10 kg of weight on the flap (32X, 33X) also prevented the flap from remaining wide open. However, it appeared that the behavior of the fish themselves made the up-side-down configuration more successful: video footage showed fish willingly swimming upwards and out the gap in the flap, but were hesitant to swim downwards when the flap was on the bottom of the MMED. Clearly, additional trials with multiple cameras in the net are needed to fully evaluate the modifications to the MMED to find a configuration that minimizes catch bias but still allows large fish and marine mammals to escape from the net.

Acknowledgments

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Literature Cited

Benaka, L. R., L. F. Cimo, and L. Jenkins. 2012. Bycatch provisions in the reauthorized Magnuson-Stevens Act. Mar. Fish. Rev. 74(2):1-12.

Dotson, R.C., D. A. Griffin, D. L. King, and R. L. Emmett. 2010. Evaluation of a marine mammal excluder device (MMED) for a Nordic 264 midwater rope trawl. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-455.

NWFSC (Northwest Fisheries Science Center). 2014. Protocols: Mitigating Marine Mammal Interactions. Survey and Research Operations document, dated April 22, 2014. Available from NWFSC.

Pearcy, W. G., and J. P. Fisher. 1990. Distribution and abundance of juvenile salmonids off Oregon and Washington, 1981-1984. U.S. Department of Commerce NOAA Technical Report NMFS 93.

Teel, D. J., D. M. Van Doornik, D. Kuligowski, and W. S. Grant. 2003. Genetic analysis of juvenile coho salmon (Oncorhynchus kisutch) off Oregon and Washington reveals few Columbia River wild fish. Fishery Bulletin 101:640-652.

Trudel, M., J. Fisher, J. A. Orsi, J. F. Morris, M. E. Thiess, R. M. Sweeting, S. Hinton, E. A. Fergusson, and D. W. Welch. 2009. Distribution and migration of juvenile Chinook salmon derived from coded wire tag recoveries along the continental shelf of western North America. Transactions of the American Fisheries Society 138:1369-1391.

Van Doornik, D. M., D. J. Teel, D. R. Kuligowski, C. A. Morgan, and E. Casillas. 2007. Genetic analyses provide insight into the early ocean stock distribution and survival of juvenile coho salmon off the coasts of Washington and Oregon. North American Journal of Fisheries Management 27:220-237.

Zeeberg, J., A. Corten, and E. de Graaf. 2006. Bycatch and release of pelagic megafauna in industrial trawler fisheries off Northwest Africa. Fish. Res. 78:186-195.

Table 1. Locations, offshore distances, bottom depths, trawling distance and direction and timing of trawl sampling from the FV *Ocean Starr,* 29 June-2 July, 2014. Trawl number letters "N" and "Y" refer to whether the MMED was in ("Y") or out ("N") of the net, while "X" indicates an experimental modification to the MMED.

Transect	Date	Trawl #	Distance Offshore (km)	Station Depth (m)	Start Latitude (decimal degrees north)	Start Longitude (decimal degrees west)	Trawling distance (km)	Bearing (degrees)	Start Time	End Time
Willapa Bay	6/29/14	20N	15.34	57	46.685	124.275	1.73	41	9:51	10:06
Willapa Bay	6/29/14	21N	17.50	61	46.680	124.303	2.06	353	11:50	12:05
Willapa Bay	6/29/14	20Y	18.15	65	46.678	124.312	1.67	356	15:03	15:18
Willapa Bay	6/29/14	21Y	19.41	68	46.678	124.328	1.30	354	16:29	16:44
Willapa Bay	6/29/14	21X	20.15	71	46.685	124.338	1.30	0	18:01	18:16
Grays Harbor	6/30/14	22N	18.13	51	47.000	124.413	3.04	348	6:41	6:56
Grays Harbor	6/30/14	23N	16.98	48	47.018	124.398	2.00	338	8:29	8:44
Grays Harbor	6/30/14	22Y	15.24	46	47.020	124.375	2.71	16	10:11	10:24
Grays Harbor	6/30/14	23Y	13.72	43	47.018	124.355	1.71	13	11:52	12:07
Grays Harbor	6/30/14	24X	11.83	40	46.992	124.330	1.74	163	13:40	13:50
Grays Harbor	6/30/14	25X	10.46	39	46.985	124.312	1.61	157	15:17	15:32
Grays Harbor	7/1/14	26N	7.88	32	46.992	124.278	2.26	190	6:49	7:02
Grays Harbor	7/1/14	27N	8.03	32	46.990	124.280	2.60	180	8:26	8:41
Grays Harbor	7/1/14	26Y	7.27	30	46.987	124.270	1.86	184	10:07	10:22
Grays Harbor	7/1/14	27Y	7.65	32	46.988	124.275	2.04	176	11:45	12:00
Grays Harbor	7/1/14	28N	12.21	40	46.995	124.335	2.08	169	13:41	13:56
Grays Harbor	7/1/14	29N	13.35	44	46.995	124.350	2.04	180	15:06	15:21
Grays Harbor	7/1/14	28Y	14.64	48	46.990	124.367	2.28	193	16:33	16:48
Grays Harbor	7/1/14	29Y	13.50	44	46.988	124.352	2.23	183	17:52	18:07
Willapa Bay	7/2/14	30X	16.27	60	46.645	124.287	2.04	176	6:44	6:59
Willapa Bay	7/2/14	31X	15.58	57	46.647	124.278	2.04	180	8:18	8:33
Willapa Bay	7/2/14	32X	14.59	51	46.652	124.265	1.49	175	9:47	10:02
Willapa Bay	7/2/14	33X	13.67	48	46.655	124.253	1.30	186	11:22	11:37
Willapa Bay	7/2/14	34X	17.41	62	46.650	124.302	1.51	170	13:58	14:13
Willapa Bay	7/2/14	35X	18.57	69	46.630	124.317	1.67	180	16:05	16:20

Table 2. Temperature, salinity, fluorometer voltage, and % transmission at 1 m depth and oxygen minimum recorded during morning, mid-day, or evening CTD profiles in coastal marine waters of Washington collected off the FV *Ocean Starr,* 29 June-2 July, 2014. "–" indicates no surface measurements were taken.

Transect	Date	Time of day	Distance Offshore (km)	Temperature (°C)	Salinity	Fluorometer (voltage)	Transmission (%)	Oxygen Minimum (ml/L)
Willapa Bay 20N	29 June 14	8:19	15.34	15.0	31.5	1.17	2.99	1.304
Willapa Bay 21N	29 June 14	13:30	17.50	15.3	31.5	0.44	3.51	1.357
Willapa Bay 21X	29 June 14	18:59	20.15	16.5	31.6	2.34	2.08	1.293
Grays Harbor 22N	30 June 14	6:03	18.13	15.2	27.9	0.50	3.43	3.222
Grays Harbor 23Y	30 June 14	12:41	13.72	15.8	24.4	0.39	3.39	2.073
Grays Harbor 25X	30 June 14	16:16	10.46	15.9	25.8	0.38	3.41	3.011
Grays Harbor 26N	1 July 14	6:07	7.88	--	--	--	--	1.573
Grays Harbor 27Y	1 July 14	12:35	7.65	15.8	26.6	0.34	3.57	1.852
Grays Harbor 29Y	1 July 14	18:39	13.50	16.4	26.9	0.46	3.42	1.700
Willapa Bay 30X	2 July 14	6:08	16.27	15.3	28.7	0.47	3.41	1.076
Willapa Bay 33X	2 July 14	12:21	13.67	15.7	28.5	0.39	3.41	1.166
Willapa Bay 35X	2 July 14	16:52	18.57	14.3	30.6	0.44	3.59	1.173

Table 3. Number of fish and nekton collected off Washington by the FV *Ocean Starr,* 29 June-2 July, 2014.

	Transect	Willapa Bay, June 29				
	Distance Offshore (km)	15.3	17.5	18.1	19.4	20.2
	Trawl #	20N	21N	20Y	21Y	21X
Common Name	**Scientific Name**					
By-the-wind Sailor	*Velella velella*					
Water jelly	*Aequorea spp.*	14		3	11	13
Sea nettle	*Chrysaora fuscescens*	104	6	8	3	1
Lion's mane jelly	*Cyanea capillata*					
Eggyolk jelly	*Phacellophora camtschatica*					
Moon jelly	*Aurelia* spp.					1
California market squid	*Loligo opalescens*	2				
River lamprey	*Lampetra ayresii*					
Spiny dogfish	*Squalus acanthias*					
Pacific herring	*Clupea pallasii*					
Northern anchovy	*Engraulis mordax*					
Chum salmon (juvenile)	*Oncorhynchus keta*		1			1
Coho salmon (yearling)	*Oncorhynchus kisutch*	2	8	3		9
Coho salmon (subadult/adult)	*Oncorhynchus kisutch*		13			4
Chinook salmon (subyearling)	*Oncorhynchus tshawytscha*	3		1		
Chinook salmon (yearling)	*Oncorhynchus tshawytscha*					
Chinook salmon (mixed age juvenile)	*Oncorhynchus tshawytscha*		1	1		
Chinook salmon (subadult/adult)	*Oncorhynchus tshawytscha*					1
Whitebait smelt	*Allosmerus elongatus*					
Pacific tomcod (juvenile)	*Microgadus proximus*	7				
Black rockfish	*Sebastes melanops*					
Sablefish	*Anoplopoma fimbria*					1
Pacific staghorn sculpin	*Leptocottus armatus*					
Cabezon	*Scorpaenichthys marmoratus*					
Wolf-eel	*Anarrhichthys ocellatus*					
Pacific mackerel	*Scomber japonicus*			1		
Starry flounder	*Platichthys stellatus*					
	Trawl Totals	**132**	**29**	**17**	**14**	**31**

Table 3, continued.

	Transect	Grays Harbor, June 30					
	Distance Offshore (km)	18.1	17.0	15.2	13.7	11.8	10.5
	Trawl #	22N	23N	22Y	23Y	24X	25X
Common Name	**Scientific Name**						
By-the-wind Sailor	*Velella velella*						
Water jelly	*Aequorea spp.*	96	53	16	26	4	
Sea nettle	*Chrysaora fuscescens*	33	41	79	110	158	303
Lion's mane jelly	*Cyanea capillata*	3					
Eggyolk jelly	*Phacellophora camtschatica*			1			
Moon jelly	*Aurelia* spp.						
California market squid	*Loligo opalescens*				2	2	
River lamprey	*Lampetra ayresii*						
Spiny dogfish	*Squalus acanthias*				1		
Pacific herring	*Clupea pallasii*						
Northern anchovy	*Engraulis mordax*	50	393				
Chum salmon (juvenile)	*Oncorhynchus keta*						
Coho salmon (yearling)	*Oncorhynchus kisutch*	1	2			2	
Coho salmon (subadult/adult)	*Oncorhynchus kisutch*	3	2	2	3		1
Chinook salmon (subyearling)	*Oncorhynchus tshawytscha*	12	8	6	1	2	1
Chinook salmon (yearling)	*Oncorhynchus tshawytscha*	1	2		2		
Chinook salmon (mixed age juvenile)	*Oncorhynchus tshawytscha*				2	1	
Chinook salmon (subadult/adult)	*Oncorhynchus tshawytscha*		1			2	
Whitebait smelt	*Allosmerus elongatus*						
Pacific tomcod (juvenile)	*Microgadus proximus*		1	5	7	3	2
Black rockfish	*Sebastes melanops*						
Sablefish	*Anoplopoma fimbria*						
Pacific staghorn sculpin	*Leptocottus armatus*						
Cabezon	*Scorpaenichthys marmoratus*			1			
Wolf-eel	*Anarrhichthys ocellatus*				1		1
Pacific mackerel	*Scomber japonicus*						
Starry flounder	*Platichthys stellatus*					1	
	Trawl Totals	**199**	**503**	**110**	**155**	**175**	**308**

Table 3, continued.

	Transect	Grays Harbor, July 1							
	Distance Offshore (nmi)	7.9	8.0	7.3	7.7	12.2	13.3	14.6	13.5
	Trawl #	26N	27N	26Y	27Y	28N	29N	28Y	29Y
Common Name	**Scientific Name**								
By-the-wind Sailor	*Velella velella*								
Water jelly	*Aequorea spp.*			14	5	13	23	130	103
Sea nettle	*Chrysaora fuscescens*	160	205	78	69	75	51	39	50
Lion's mane jelly	*Cyanea capillata*								
Eggyolk jelly	*Phacellophora camtschatica*								
Moon jelly	*Aurelia* spp.							1	
California market squid	*Loligo opalescens*	3	1	17	10	4	9	6	11
River lamprey	*Lampetra ayresii*				1	1			
Spiny dogfish	*Squalus acanthias*						1		
Pacific herring	*Clupea pallasii*	364	186	57	1				
Northern anchovy	*Engraulis mordax*			1				1	
Chum salmon (juvenile)	*Oncorhynchus keta*								
Coho salmon (yearling)	*Oncorhynchus kisutch*	1		1	1				1
Coho salmon (subadult/adult)	*Oncorhynchus kisutch*					5	1	2	3
Chinook salmon (subyearling)	*Oncorhynchus tshawytscha*	9	1	6	4		2		
Chinook salmon (yearling)	*Oncorhynchus tshawytscha*	1	9	3	1	3	2	1	
Chinook salmon (mixed age juvenile)	*Oncorhynchus tshawytscha*		1		1	1	1		1
Chinook salmon (subadult/adult)	*Oncorhynchus tshawytscha*			1					
Whitebait smelt	*Allosmerus elongatus*	70	2048	419	45				
Pacific tomcod (juvenile)	*Microgadus proximus*	5		1	2	6	3		
Black rockfish	*Sebastes melanops*			1					
Sablefish	*Anoplopoma fimbria*								
Pacific staghorn sculpin	*Leptocottus armatus*							1	
Cabezon	*Scorpaenichthys marmoratus*								
Wolf-eel	*Anarrhichthys ocellatus*								
Pacific mackerel	*Scomber japonicus*								
Starry flounder	*Platichthys stellatus*			2	1				
	Trawl Totals	**613**	**2451**	**601**	**141**	**108**	**93**	**181**	**169**

Table 3, continued.

	Transect	Willapa Bay, July 2					
	Distance Offshore (nmi)	16.3	15.6	14.6	13.7	17.4	18.6
	Trawl #	30X	31X	32X	33X	34X	35X
Common Name	**Scientific Name**						
By-the-wind Sailor	*Velella velella*						2
Water jelly	*Aequorea spp.*	17	44	66	64	58	56
Sea nettle	*Chrysaora fuscescens*	9	27	115	119	17	5
Lion's mane jelly	*Cyanea capillata*						
Eggyolk jelly	*Phacellophora camtschatica*						
Moon jelly	*Aurelia* spp.						
California market squid	*Loligo opalescens*	5	5	1	3	39	
River lamprey	*Lampetra ayresii*						
Spiny dogfish	*Squalus acanthias*						
Pacific herring	*Clupea pallasii*						
Northern anchovy	*Engraulis mordax*						
Chum salmon (juvenile)	*Oncorhynchus keta*						
Coho salmon (yearling)	*Oncorhynchus kisutch*	1		1		4	1
Coho salmon (subadult/adult)	*Oncorhynchus kisutch*	4	6	6	6	1	4
Chinook salmon (subyearling)	*Oncorhynchus tshawytscha*	4	1	9	22	5	
Chinook salmon (yearling)	*Oncorhynchus tshawytscha*	3		2	1	1	1
Chinook salmon (mixed age juvenile)	*Oncorhynchus tshawytscha*		4	3		1	2
Chinook salmon (subadult/adult)	*Oncorhynchus tshawytscha*	1	1	2			
Whitebait smelt	*Allosmerus elongatus*						
Pacific tomcod (juvenile)	*Microgadus proximus*			2			1
Black rockfish	*Sebastes melanops*						
Sablefish	*Anoplopoma fimbria*						
Pacific staghorn sculpin	*Leptocottus armatus*						
Cabezon	*Scorpaenichthys marmoratus*						
Wolf-eel	*Anarrhichthys ocellatus*	1	1		1		1
Pacific mackerel	*Scomber japonicus*						
Starry flounder	*Platichthys stellatus*						
	Trawl Totals	**45**	**89**	**207**	**216**	**126**	**73**

Table 4. Minimum, maximum, and average length of fish, squid, and jellyfish species collected off Washington by the FV *Ocean Starr* 29 June-2 July, 2014. BD = Bell Diameter, DML = Dorsal Mantle length, FL = Fork Length, TL = Total Length.

Common Name	Species	Measure-ment	Number Measured	Average Length (mm)	Minimum Length (mm)	Maximum Length (mm)
By-the-wind Sailor	*Velella velella*	BD (mm)	0			
Water jelly	*Aequorea spp.*	BD (mm)	26	55.5	25	100
Sea nettle	*Chrysaora fuscescens*	BD (mm)	53	185.4	55	340
Lion’s mane jelly	*Cyanea capillata*	BD (mm)	3	196.7	90	270
Eggyolk jelly	*Phacellophora camtschatica*	BD (mm)	1	95.0		
Moon jelly	*Aurelia* spp.	BD (mm)	2	135.0	110	160
California market squid	*Loligo opalescens*	DML (mm)	38	48.9	22	94
River lamprey	*Lampetra ayresii*	TL (mm)	2	253.0	250	256
Spiny dogfish	*Squalus acanthias*	TL (mm)	2	935.0	880	990
Pacific herring	*Clupea pallasii*	FL (mm)	41	150.4	120	198
Northern anchovy	*Engraulis mordax*	FL (mm)	23	139.5	35	161
Chum salmon (juvenile)	*Oncorhynchus keta*	FL (mm)	2	151.5	145	158
Coho salmon (yearling)	*Oncorhynchus kisutch*	FL (mm)	29	201.6	119	267
Coho salmon (subadult/adult)	*Oncorhynchus kisutch*	FL (mm)	55	543.7	433	666
Chinook salmon (subyearling)	*Oncorhynchus tshawytscha*	FL (mm)	43	114.7	86	139
Chinook salmon (yearling)	*Oncorhynchus tshawytscha*	FL (mm)	29	234.6	155	279
Chinook salmon (mixed age juvenile)	*Oncorhynchus tshawytscha*	FL (mm)	18	396.2	283	448
Chinook salmon (subadult/adult)	*Oncorhynchus tshawytscha*	FL (mm)	9	577.3	455	813
Whitebait smelt	*Allosmerus elongatus*	FL (mm)	18	74.8	57	85
Pacific tomcod (juvenile)	*Microgadus proximus*	TL (mm)	17	52.6	31	65
Black rockfish	*Sebastes melanops*	TL (mm)	1	424.0		
Sablefish	*Anoplopoma fimbria*	TL (mm)	1	186.0		
Pacific staghorn sculpin	*Leptocottus armatus*	TL (mm)	1	228.0		
Cabezon	*Scorpaenichthys marmoratus*	TL (mm)	1	250.0		
Wolf-eel	*Anarrhichthys ocellatus*	TL (mm)	6	518.2	421	610
Pacific mackerel	*Scomber japonicus*	TL (mm)	1	306.0		
Starry flounder	*Platichthys stellatus*	TL (mm)	4	330.3	270	440

Table 5. Total number and average catch per unit effort (CPUE, number/km towed) of subyearling, yearling, and mixed-age Chinook, yearling coho, and juvenile chum salmon caught during hauls with the excluder present, absent, or during experimental hauls off Washington by the FV *Ocean Starr* 29 June-2 July 2014. In calculating average CPUE, each trawl was given equal weight. See text for descriptions of experimental hauls

		Total number captured					Average CPUE (number/km towed)				
Haul type	Number of Trawls	Chinook salmon (subyr.)	Chinook salmon (year.)	Chinook salmon (mixed age)	Coho salmon (year.)	Chum salmon (juv.)	Chinook salmon (subyr.)	Chinook salmon (year.)	Chinook salmon (mixed age)	Coho salmon (year.)	Chum salmon (juv.)
Excluder present	8	18	7	5	6	0	1.07	0.46	0.34	0.41	0.00
Excluder absent	8	35	18	4	14	1	1.88	0.96	0.23	0.85	0.06
Experiment	9	44	8	11	18	1	3.38	0.54	0.71	1.39	0.09
Total/Average		**97**	**33**	**20**	**38**	**2**	**2.11**	**0.65**	**0.43**	**0.88**	**0.05**

Table 6. Total number and average catch per unit effort (CPUE, number/km towed) of subadult/adult Chinook and coho salmon caught during hauls with the excluder present, absent, or during experimental hauls off Washington by the FV *Ocean Starr* 29 June-2 July 2014. In calculating average CPUE, each trawl was given equal weight. See text for descriptions of experimental hauls.

		Total number captured		Average CPUE (number/km towed)	
Haul type	Number of Trawls	Chinook salmon (subadult/adult)	Coho salmon (subadult/adult)	Chinook salmon (subadult/adult)	Coho salmon (subadult/adult)
Excluder present	8	1	10	0.07	0.59
Excluder absent	8	1	24	0.06	1.40
Experiment	9	7	32	0.47	2.25
Total/Average		**9**	**66**	**0.20**	**1.42**

Table 7. Descriptions of the nine experimental hauls. Drawings showing the configurations are provided in Appendix B. MMED orientation refers to whether the MMED was in the right-side-up ("Up") or up-side-down ("Down") position.

Haul Number	MMED Orientation	Description	Total Weight (kg)	Comments
21X	Up	Added 2 short pieces of heavy leadline to back edge of flap	1.5	Weights tangled in excluder and therefore didn't keep flap closed
24X	Up	Added light leadline around the flap perimeter and single rib down the middle.	1.6	Fish observed exiting through flap
25X	Up	Same as 24X, but also added all available hard round floats to excluder (20 total) to keep it higher in water column	1.6	Didn't noticeably change anything
30X	Up	Put camo duct tape on excluder bars	0.0	Didn't have camera on grate to record effects
31X	Up	Light leadline around flap perimeter + 2 ribs of medium leadline across body	2.4	Still big gap between net and flap; fish observed escaping
32X	Up	Same as 31X but with 2 stiff heavy leadline ribs	10.4	Video show gap between MMED and net
33X	Up	Same as 32X but added 5 hard floats per side, short pieces of heavy leadline to corners, and 5 ft bungee lazy ropes on flap corners	11.9	Video show gap between MMED and net
34X	Down	Upside down with 2 large-diameter elongate float ("noodles") down middle, regular-diameter elongate floats on each side, bungee slack lines, and 7 hard floats/side on upper surface (i.e., bottom) of excluder	0.0	Floats appeared to close flap with very few fish seen escaping. Side floats ended up in the middle of net, helping hold it closed. Video showed small shark being excluded.
35X	Down	Same as 35x but added 2 half-length regular-diameter floats to aft end of flap	0.0	Side floats stayed at net edges. Could see small gap between MMED and flap, but few fish escaped.

Figure 1. Top: Photograph showing the metal MMED grate in the net. The green mesh on top of the net is the flap. **Bottom**: Looking forward toward MMED during fishing, the flap is open allowing fish to escape (Photo by S. Hayes, SWFSC).

Flap

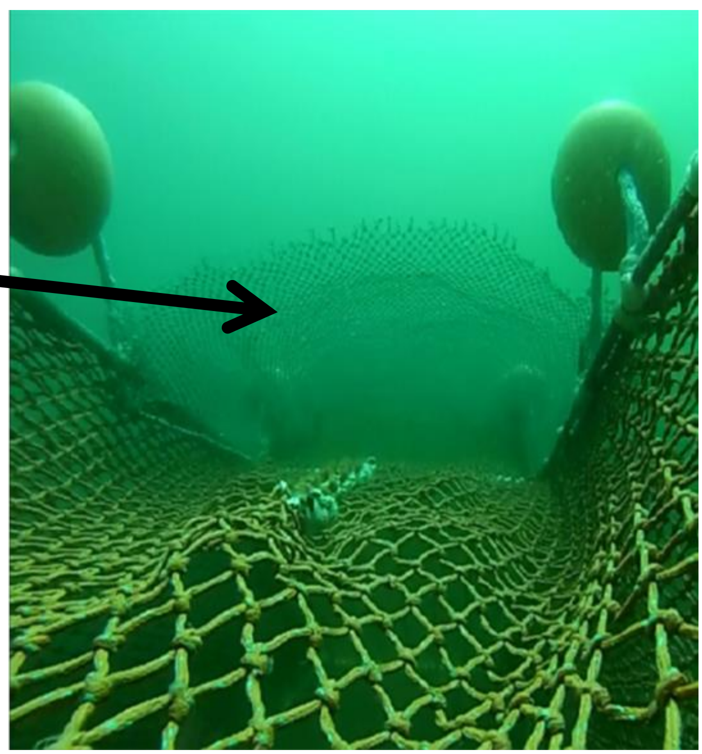


Figure 2. 1m temperature

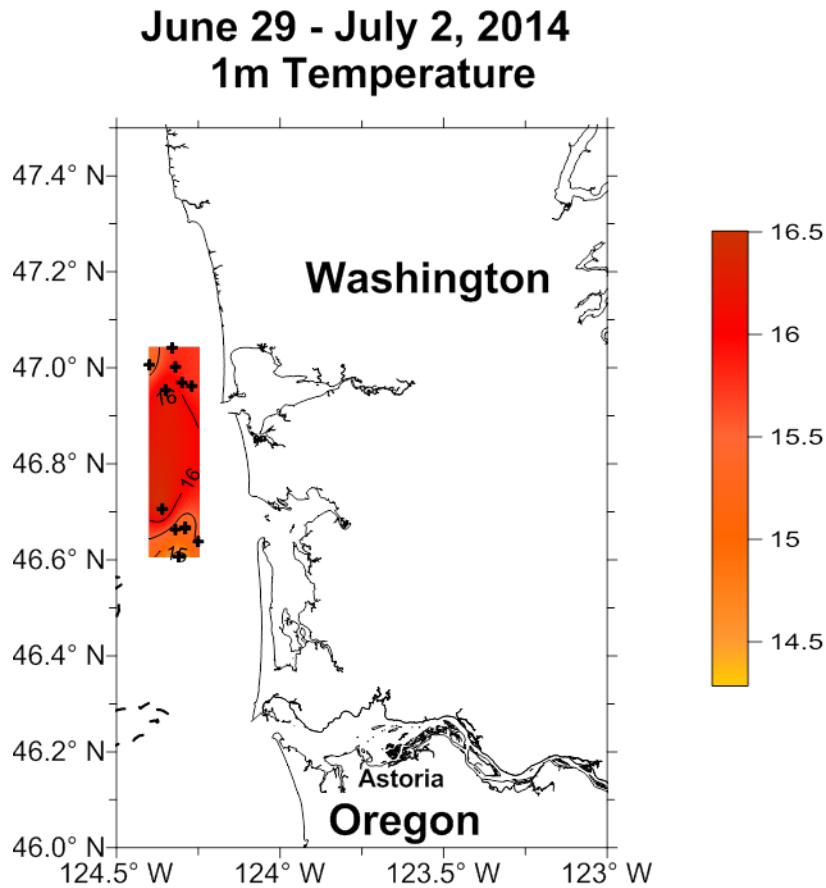
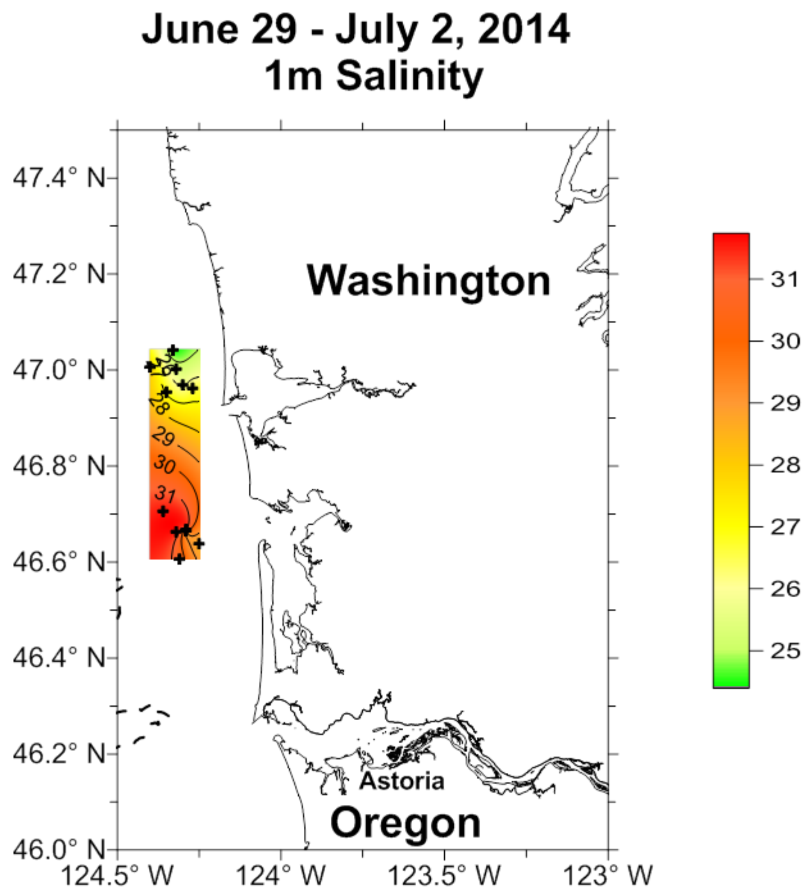


Figure 3. 1 m salinity



Appendix A. Release and recovery information for juvenile salmon with coded wire tags (CWTs) caught off the Washington by the FV *Ocean Starr* June 30-July 2, 2014. Release details reflect available information in the CWT tag database (www.rmis.org) on 15 December, 2014.

Salmon ID #	Date	Species	Field Length (mm)	CWT code	Release Agency[1]	Release Basin[2]	Run	Hatchery	Rel date
MESS2303	30-Jun-14	Chinook	226	090191	ODFW	LCR	Spr	Clackamas	3/17/2014
MESS2325	30-Jun-14	Chinook	285	636266	WDFW	LCR	Spr	Cowlitz	4/2/2014
MESS2372	1-Jul-14	Chinook	283	636266	WDFW	LCR	Spr	Cowlitz	4/2/2014
MESS2296	30-Jun-14	Chinook	98	636739	WDFW	MCR	Fall	Irrigon	5/2/2014
MESS2476	2-Jul-14	Chinook	102	636681	WDFW	MCR	Fall	Priest Rapids	6/12/2014
MESS2302	30-Jun-14	Chinook	221	090682	ODFW	MCR	Fall	Umatilla	3/3/2014
MESS2292	30-Jun-14	Chinook	125	090818	ODFW	Snk	Fall	Irrigon	5/19/2014
MESS2446	2-Jul-14	Chinook	129	090818	ODFW	Snk	Fall	Irrigon	5/19/2014
MESS2449	2-Jul-14	Chinook	130	090818	ODFW	Snk	Fall	Irrigon	5/19/2014
MESS2305	30-Jun-14	Chinook	115	636737	WDFW	Snk	Fall	Lyons Ferry	6/3/2014
MESS2327	30-Jun-14	Chinook	240	636584	WDFW	Snk	Fall	Lyons Ferry	4/8/2014
MESS2350	1-Jul-14	Chinook	240	636584	WDFW	Snk	Fall	Lyons Ferry	4/8/2014
MESS2390	1-Jul-14	Chinook	253	636584	WDFW	Snk	Fall	Lyons Ferry	4/8/2014
MESS2412	2-Jul-14	Chinook	126	636737	WDFW	Snk	Fall	Lyons Ferry	6/3/2014
MESS2349	1-Jul-14	Chinook	103	220240	Nez Pierce	Snk	Fall	Nez Perce Tribal	5/22/2014
MESS2293	30-Jun-14	Chinook	114	220343	Nez Pierce	Snk	Fall	Lyons Ferry	5/21/2014
MESS2294	30-Jun-14	Chinook	114	220345	Nez Pierce	Snk	Fall	Lyons Ferry	5/22/2014
MESS2295	30-Jun-14	Chinook	130	220346	Nez Pierce	Snk	Fall	Lyons Ferry	5/21/2014
MESS2297	30-Jun-14	Chinook	120	220343	Nez Pierce	Snk	Fall	Lyons Ferry	5/21/2014
MESS2298	30-Jun-14	Chinook	117	220342	Nez Pierce	Snk	Fall	Lyons Ferry	5/22/2014
MESS2306	30-Jun-14	Chinook	119	220346	Nez Pierce	Snk	Fall	Lyons Ferry	5/21/2014
MESS2313	30-Jun-14	Chinook	108	220345	Nez Pierce	Snk	Fall	Lyons Ferry	5/22/2014
MESS2316	30-Jun-14	Chinook	112	220344	Nez Pierce	Snk	Fall	Lyons Ferry	5/20/2014
MESS2326	30-Jun-14	Chinook	273	220338	Nez Pierce	Snk	Fall	Lyons Ferry	4/01/2014
MESS2338	30-Jun-14	Chinook	120	220342	Nez Pierce	Snk	Fall	Lyons Ferry	5/22/2014
MESS2347	1-Jul-14	Chinook	106	220233	Nez Pierce	Snk	Fall	Nez Perce Tribal	6/10/2014
MESS2348	1-Jul-14	Chinook	133	220342	Nez Pierce	Snk	Fall	Lyons Ferry	5/22/2014
MESS2373	1-Jul-14	Chinook	110	220346	Nez Pierce	Snk	Fall	Lyons Ferry	5/21/2014

Salmon ID #	Date	Species	Field Length (mm)	CWT code	Release Agency[1]	Release Basin[2]	Run	Hatchery	Rel date
MESS2391	1-Jul-14	Chinook	122	220344	Nez Pierce	Snk	Fall	Lyons Ferry	5/20/2014
MESS2414	2-Jul-14	Chinook	104	220236	Nez Pierce	Snk	Fall	Lyons Ferry	5/21/2014
MESS2413	2-Jul-14	Chinook	155	636481	WDFW	UCR	Sum	Chelan	4/15/2014
MESS2439	2-Jul-14	Chinook	218	636482	WDFW	UCR	Sum	Chelan	4/15/2014
MESS2489	2-Jul-14	Chinook	248	636481	WDFW	UCR	Sum	Chelan	4/15/2014
MESS2474	2-Jul-14	Chinook	123	200108	Colville Tribe	UCR	Sum	Chief Joseph	5/28/2014
MESS2351	1-Jul-14	Chinook	198	636293	WDFW	UCR	Sum	Similkameen	4/15/2014
MESS2362	1-Jul-14	Chinook	112	636680	WDFW	UCR	Sum	Wells	5/28/2014
MESS2363	1-Jul-14	Chinook	231	636504	WDFW	UCR	Sum	Wells	4/15/2014
MESS2442	2-Jul-14	Chinook	131	636680	WDFW	UCR	Sum	Wells	5/28/2014
MESS2444	2-Jul-14	Chinook	120	636680	WDFW	UCR	Sum	Wells	5/28/2014
MESS2475	2-Jul-14	Chinook	123	636680	WDFW	UCR	Sum	Wells	5/28/2014
MESS2490	2-Jul-14	Chinook	135	090909	ODFW			Agency tag	
MESS2254	29-Jun-14	Coho	197	636571	WDFW	LCR		Cowlitz	4/25/2014
MESS2275	29-Jun-14	Coho	186	636406	WDFW	LCR		Lewis River	4/16/2014
MESS2411	2-Jul-14	Coho	228	636404	WDFW	LCR		Lewis River	4/16/2014
MESS2304	30-Jun-14	Coho	233	055587	USFWS	WA cst		Quinault NFH	4/11/2014
MESS2253	29-Jun-14	Coho	209	636399	WDFW	--	--	--	--
MESS2333	30-Jun-14	Coho	267	636399	WDFW	--	--	--	--

[1]Release agency abbreviations are ODFW--Oregon Department of Fish and Wildlife; WDFW-Washington Department of Fish and Wildlife; USFWS—U.S. Fish and Wildlife Service

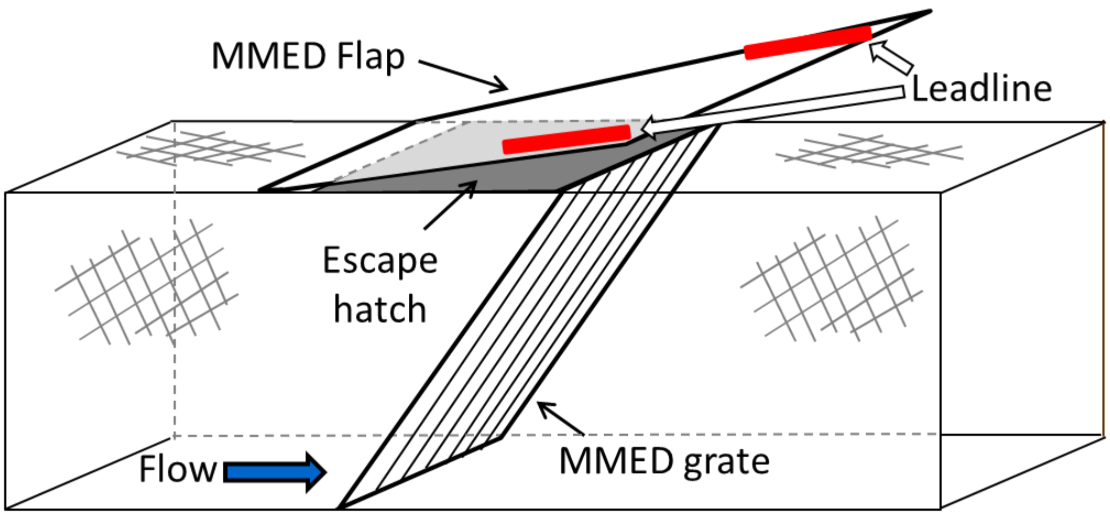
[2]Release basins abbreviations are LCR—Lower Columbia River (below Bonneville Dam); MCR—mid-Columbia River (between Bonneville and the Snake River confluence); UCR—Upper Columbia River (Columbia above the Snake River confluence); SNK—Snake River; WA cst—Washington coast.

Appendix B. Experimental configurations of the Marine Mammal Excluder Devise (MMED). See Table 7 for descriptions. Red lines represent lead line (line width reflects leadline weight), light red circles are balls (hard floats), and red rectangles are soft elongate floats ("water noodles"). All configurations have the MMED right side up (opening facing up) except 34X and 35X which have the MMED upside down (opening facing down). Also provided are photographs of configurations 33X and 35X.

Configuration 21X

Total weight: 1.5 kg

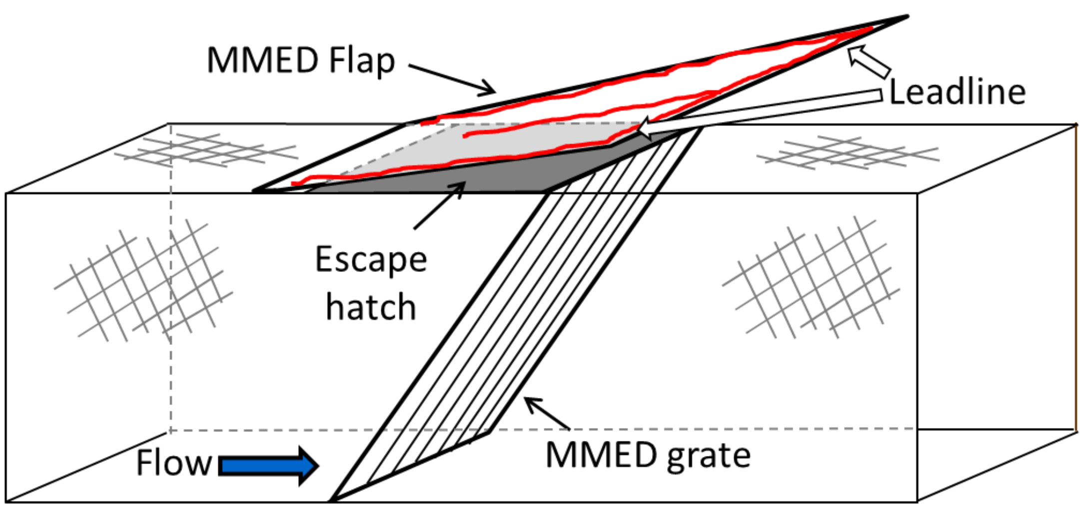
Heavy lead line on each corner of flap (43 cm long, 0.74 kg ea.)



Configuration 24X

Total weight: 1.6 kg

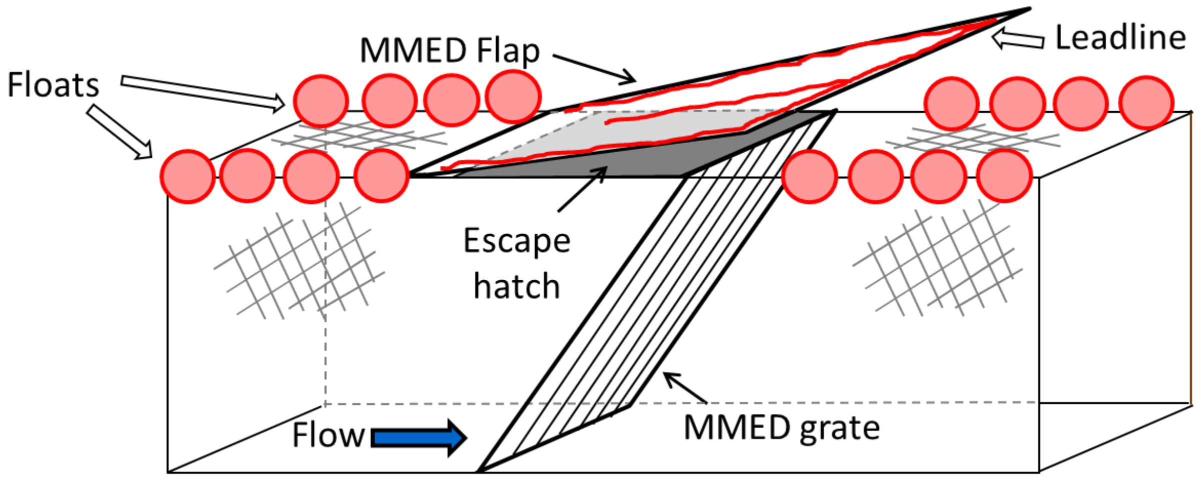
Light lead line around flap perimeter(4.3 m long), single light rib down middle (1.7 m)



Configuration 25X

Total weight: 1.6 kg

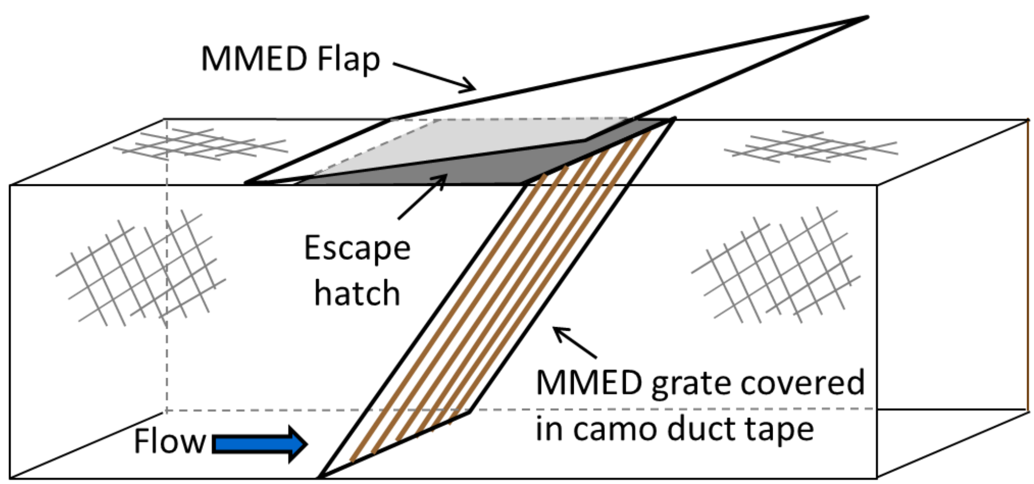
Same as 24x but added 16 extra floats to excluder



Configuration 30X

Total weight: 0.0 kg

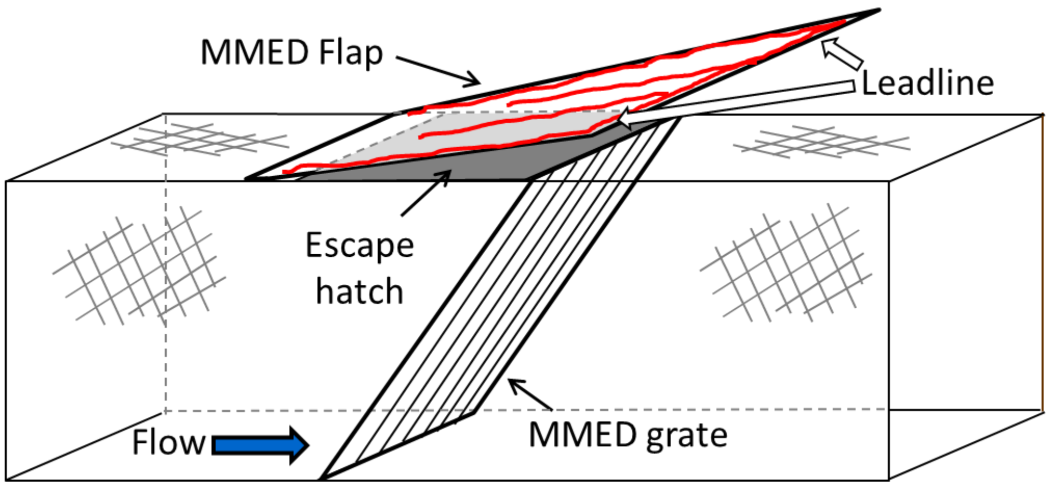
Camo-colored duct tape on MMED grate bars.



Configuration 31X

Total weight: 2.4 kg

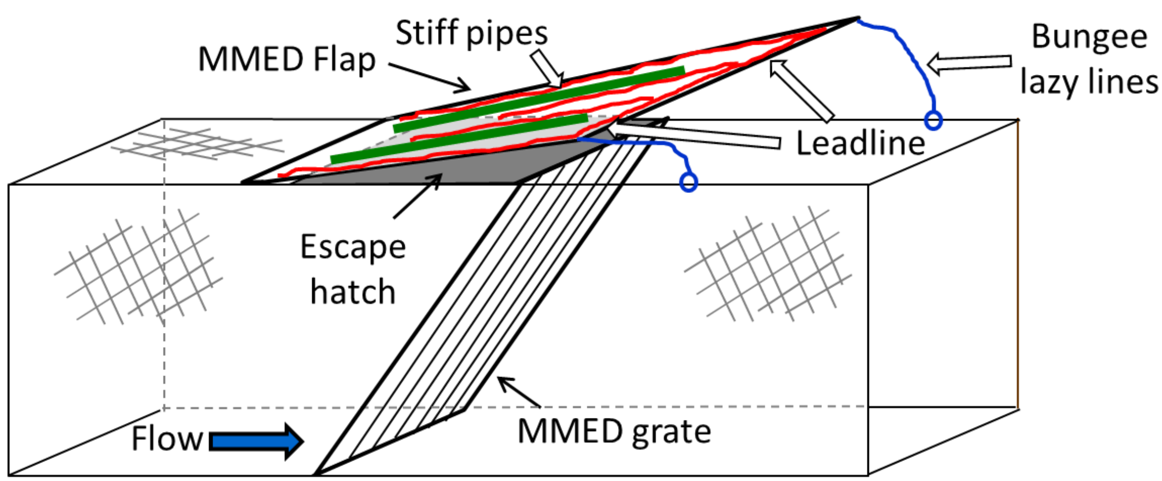
Light lead line around flap perimeter (4.3 m long), two medium lead line ribs (1.7 m long) on flap.



Configuration 32X

Total weight: 10.4 kg

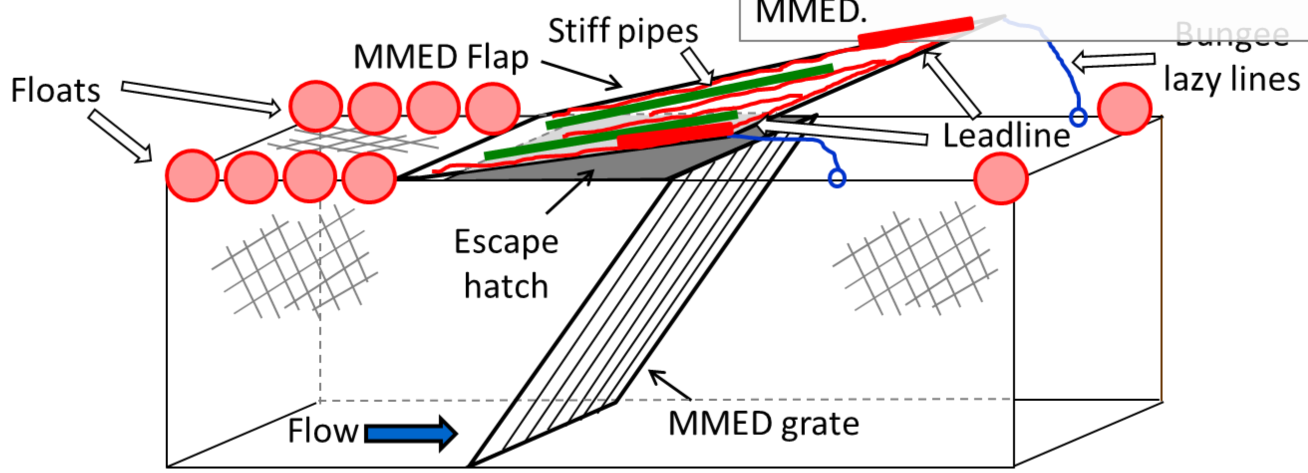
Same as 31X but with two stiff heavy pipes (1.8 m long) on flap, also bungee lazy lines to flap corners.



Configuration 33X

Total weight: 11.9 kg

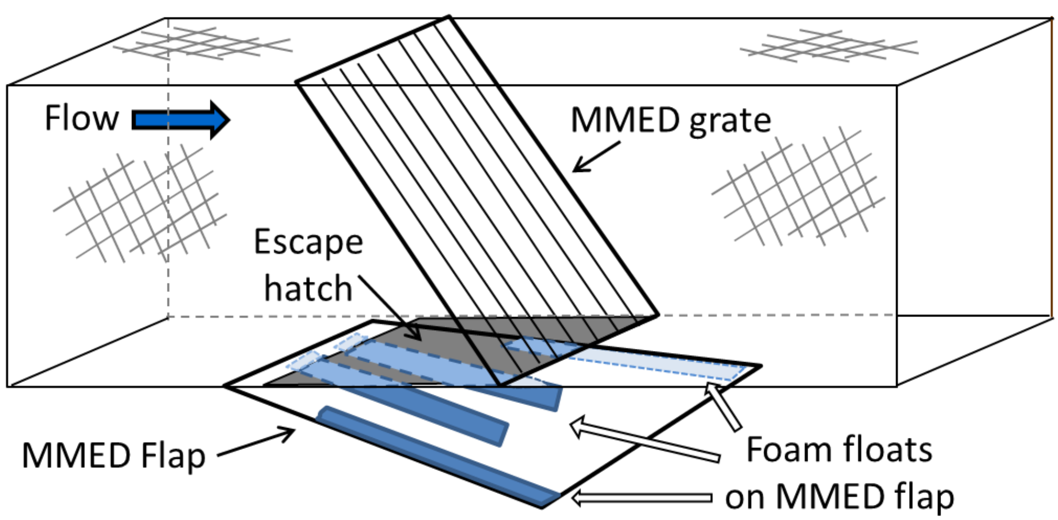
Same as 32X but with short heavy leadlines on corners and 5 additional floats to each side of MMED.



Configuration 34X

Total weight: 0.0 kg

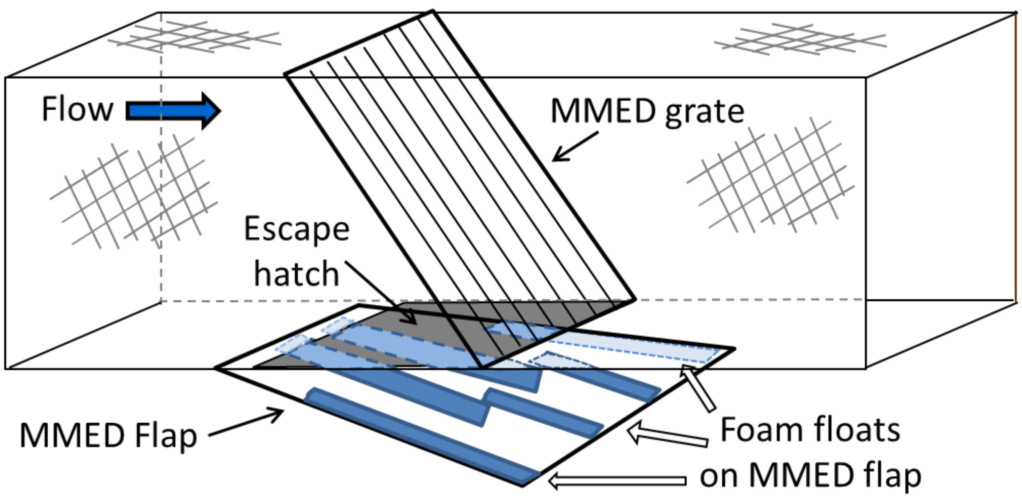
<u>MMED up side down</u> Two regular-diameter floats on sides of flap, two wide-diameter floats down middle.



Configuration 35X

Total weight: 0.0 kg

<u>MMED up side down</u> Same as 34X but with 2 short floats on aft edge of MMED flap.

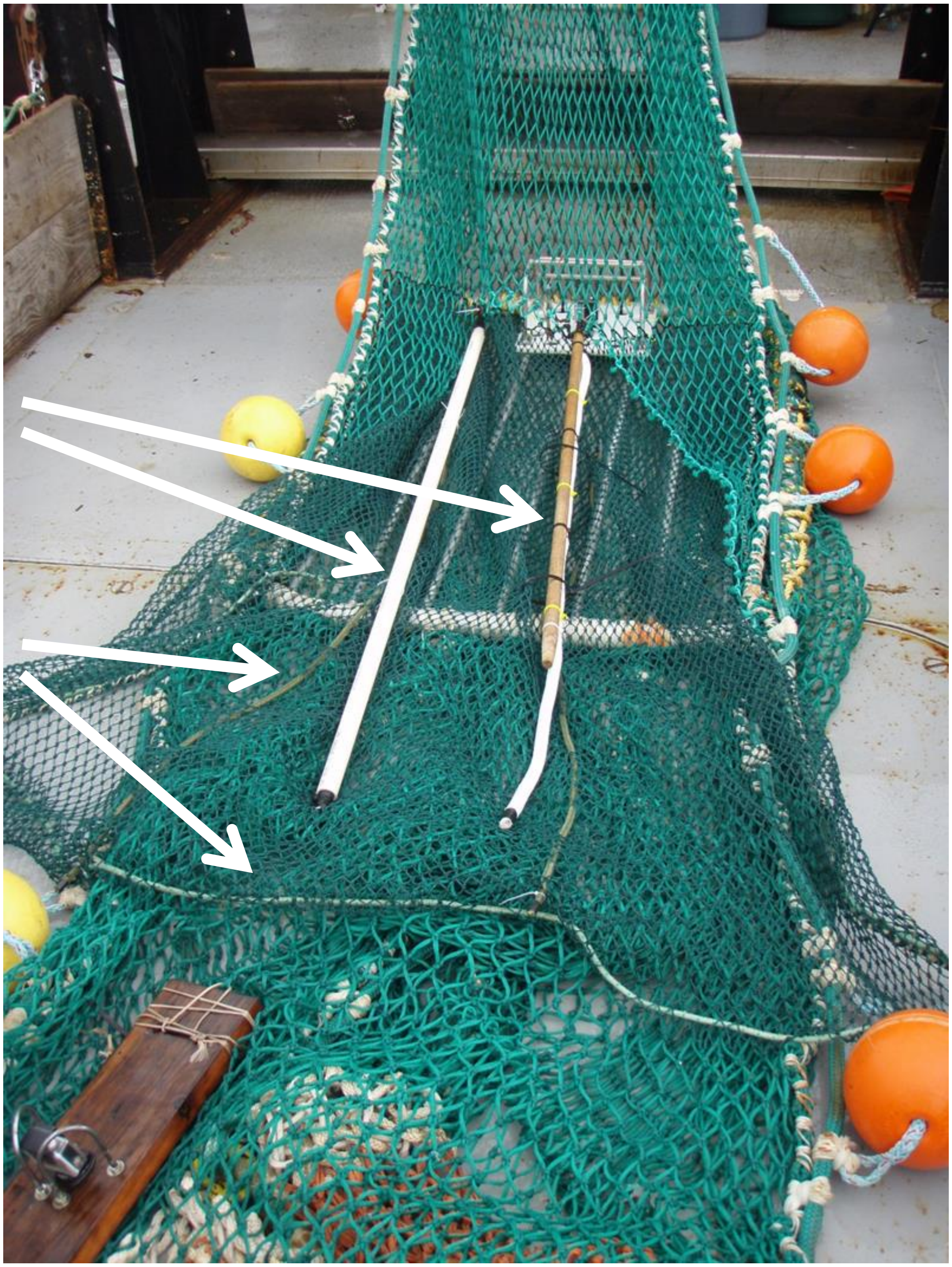


Configuration 32X

Water Flow

Weighted stiffners

Leadline ribs and along flap perimeter



Configuration 34X