Report of the Workshop to Review Seabird Bycatch Mitigation Measures for Hawaii's Pelagic Longline Fisheries

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Report of the Workshop to Review Seabird Bycatch Mitigation Measures for Hawaii's Pelagic Longline Fisheries
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1 EXECUTIVE SUMMARY

The Western Pacific Regional Fishery Management Council, at its 173rd Meeting, directed Council staff to convene a workshop to review seabird mitigation requirements and the best scientific information available for Hawaii's pelagic longline fisheries, considering operational aspects of the fisheries, seasonal and spatial distributions of seabird interactions, alternative bycatch mitigation measures and findings from cost-benefit analyses. To implement the Council's directions, a *Workshop to Review Seabird Bycatch Mitigation Measures for Hawaii's Pelagic Longline Fisheries* was convened at the Council office on September 18-19, 2018.

Workshop participants reviewed and discussed causes of increasing seabird catch rates and levels in the Hawaii pelagic longline fisheries. Catch levels of the black-footed albatross (*Phoebastria nigripes*) have been steadily increasing in the Hawaii deep-set longline fishery over the past decade, with a large spike in recent years. This significant increase was caused by a combination of increasing temporal trends in annual effort and in black-footed albatross catch rates over the time period. The rise in catch rates may have been due to variability in the temporal and spatial distribution of fishing effort, a unique captain effect (i.e., seabird catch rates are significantly explained by which person is the captain), an increase in the number of albatrosses attending Hawaii longline vessels, and a shift in the relative use of seabird bycatch mitigation methods. Notably, there was increased use of blue-dyed fish bait and decreased use of the more effective side setting. While the black-footed albatross population size has not changed significantly in the last decade, their distribution and attendance at longline vessels changed in response to inter-annual (El Niño – Southern Oscillation) and decadal (Pacific Decadal Oscillation) climate variability in the north Pacific Ocean.

Participants evaluated the relative promise of a comprehensive suite of alternative seabird bycatch mitigation methods for use in Hawaii's longline fisheries. These included methods currently prescribed in the Hawaii longline seabird regulations, seabird measures adopted by Pacific tuna regional fisheries management organizations (Inter-American Tropical Tuna Commission, Western and Central Pacific Fisheries Commission) and methods identified as best practice by the Agreement for the Conservation of Albatrosses and Petrels. Participants reviewed 35 seabird bycatch mitigation measures and assessed them against criteria on efficacy, cross-taxa conflicts, practicality, economic viability, safety, durability and ability to facilitate compliance monitoring (Table 1). While seabird bycatch mitigation methods are presented individually in Table 1, participants recognized that combinations of methods are prescribed, in Hawaii and elsewhere, to obtain desired reductions in seabird bycatch rates.

Table 1. Participant rankings of the promise of seabird bycatch mitigation methods for potential use in the Hawaii deep- and shallow-set longline fisheries when assessed for efficacy, cross-taxa conflicts, practicality, economic viability, safety, durability and compliance monitoring.

Ranking	Bycatch Mitigation Method
High	Bird curtain
	Branchline weighting
	Captain and crew training
	Side setting
	Tori (streamer) line
	Towed buoy
Medium	Night setting
	Offal management (strategic offal discards and offal retention)
Low	Artificial bait
	Automatic branchline coiler
	Bait caster
	Bait type
	Banned use of live bait
	Blue-dyed bait
	Compensatory mitigation
	Fish bait hooked in head or tail
	Fish bait with punctured swim bladders
	Fish and vegetable oil slick
	Fleet communication
	Fully-thawed bait
	Hookpod
	Hook size and shape
	Individual transferable vessel-based quotas on bird catch levels or rates
	Lasers
	Mainline line shooter
	Sliding weights
	Smart tuna hook
	Temporal and spatial management of fishing effort
	Underwater setting chute
	Underwater bait setting capsule
	Water cannon

Most measures ranked as high and medium priority are included in current seabird regulations for Hawaii's longline fisheries. Participants discussed how the seabird bycatch mitigation methods included in the current regulations have been found to significantly reduce seabird catch risk through at-sea research and, more importantly, through analyses of observer program data, where the latter documents efficacy in practice. Participants discussed how minor modifications could make the Hawaii seabird regulations simpler, more flexible and thus more practical, and could augment their efficacy. Participants identified tori (streamer) lines, which are not part of the Hawaii seabird regulations, as having high potential for use in Hawaii's deep-set longline fishery as they are likely to be highly effective and potentially more practical to use than existing regulatory options. Tori lines, which were tested in Hawaii's fisheries in 1999 prior to the adoption of seabird regulations, were not considered practical at that time due to gear entanglement problems. Subsequently, through trials and broad industry use of tori lines in other longline fisheries, researchers have identified tori line designs and materials that reduced the incidence of entanglement with gear and improved durability. Participants agreed that tori line trials in Hawaii and development of minimum standards would now be useful.

Participants categorized 23 measures as being of relatively low priority (Table 1) due to issues with one or more of the criteria used to assess their promise. Some methods were deemed to not effectively reduce seabird catch risk (bait species, hook size and shape, water cannon during setting, line shooter, puncturing swim bladders of fish bait). Others raised concerns over possible deleterious effects on seabirds (lasers, slicks of fish or vegetable oil). Participants considered several methods to not be economically viable and/or practical (underwater setting devices, hook shielding devices, night setting to target bigeye tuna, artificial bait, automatic bait caster, management of the temporal and spatial distribution of effort). For example, while participants recognized that a hook shielding device called the Hookpod has very high promise for substantially reducing seabird catch risk during setting, they expressed concern over the high cost for the initial outlay and for replacing damaged and lost devices, as well as concerns over low compliance with use of the device when setting is not observed.

Participants viewed additional methods as being impractical (automatic branchline coiler, fully thawed bait, sliding weights in deep-set gear with wire leaders) or not being applicable to Hawaii's fisheries (banned use of live bait, anatomical location of hooking fish bait, blue-dyed squid bait). Participants identified several concerns over compensatory mitigation and vessel-based individual transferable quotas on seabird catch levels or rates, including that they would create a safety risk for at-sea observers, and would not be perceived by the public as being a sufficiently robust approach to managing seabird bycatch. Participants felt that a fleet communication program where the government provides captains with information on areas with high abundance of albatrosses holds promise but should be voluntary. Participants viewed communication between vessels to share information real-time on the location of areas with high seabird interactions to not be feasible, as they expected that fishers would refrain from sharing commercially sensitive information on the location of their fishing grounds. Participants identified blue-dyed bait as a candidate for removal from Hawaii's seabird regulations because of concerns with efficacy and practicality. The requirement for using blue-dyed bait was intended to be used for squid bait, but currently only fish are used for bait in both Hawaii longline fisheries. Blue-dyed fish bait may be less effective at mitigating seabird catch risk than blue-dyed squid bait, and participants considered blue-dyed bait to be impractical. Additionally, participants noted that mainline line shooters, which are currently included in Hawaii's seabird regulations and are conventionally used by deep-set vessels to set the mainline slack in order to achieve the target gear soak depth, are not likely to affect seabird catch rates in the Hawaii longline deep-set fishery because the sink rate of the mainline is unlikely to affect the sink rate of baited hooks until the hooks are below ca. 10 m depth, which is substantially deeper than black-footed and Laysan albatrosses can access.

Workshop participants also discussed and identified potential combinations of measures and associated research needs to inform options for modifying seabird bycatch mitigation requirements. Participants emphasized the importance of providing flexibility to fishers to use mitigation methods that are effective, safe and practical for individual vessels, while having tools in place to ensure that mitigation measures are implemented as intended when observers are not present. Some participants suggested that known sources contributing to relatively high seabird catch rates, such as a unique captain effect, should be addressed before considering requiring more stringent seabird bycatch management measures. Participants suggested that consequences for individual vessel owners from their seabird catch rates and levels, such as notifying vessels when they have relatively high seabird catch rates, might improve compliance with prescribed methods for using mitigation measures and might reduce seabird captures by vessels with relatively high interaction rates.

Participants discussed the following potential modifications to seabird regulations for the Hawaii deep-set longline fishery:

- Adding tori lines, either by adding tori lines as an additional option, replacing blue-dyed bait with tori lines, or replacing blue-dyed bait if and when tori lines are documented in a comparative experiment to be an effective alternative;
- Adopting a "menu" approach as used by tuna regional fisheries management organizations, where vessels can select a combination of a specified number of measures from each of two lists, in place of the current approach in the Hawaii regulations where vessels select between two suites of measures; and
- Moving the 23°N southern boundary for required use of seabird bycatch mitigation methods further south, or requiring the use of measures in all areas.

Participants identified research needs to inform the identification of options to modify seabird requirements for the deep-set fishery, including developing minimum standards for tori lines (e.g., to ensure that the areal extent effectively protects areas where baited hooks are available to Laysan and black-footed albatrosses during setting, and to prescribe minimum requirements for the design and materials of each component). Participants also prioritized trialing branchline weighting designs that reduce the leader length and/or increase the weight amount, and conducting comparative studies of seabird bycatch rates of single and paired tori lines, side setting and blue-dyed fish bait. Participants also brainstormed new methods and approaches to identify new concepts for seabird bycatch mitigation methods.

Discussion on potential modifications to the seabird regulations for the Hawaii shallow-set longline fishery centered on options for further reducing seabird catch rates during the haul. Participants discussed several methods to mitigate seabird bycatch during gear haulback, including using strategic offal discards only during the haul, discharging offal in batches instead of continuously, using a bird curtain, and using branchline weighting designs that increase baited hook sink rates, such as sliding weights above light sticks. Participants felt that required night setting should be maintained for the shallow-set fishery, while side-setting could be removed as an option given that almost no shallow-set vessels now opt to use the regulatory defined suite of measures that includes side setting. Participants identified analyses of observer data to assess seabird interaction rates between side-set and stern-set regulatory options, research to determine the effect of blue-dyed bait in combination with night setting on seabird catch rates, and the use of alternative branchline weighting designs as research needed to inform potential modifications to seabird bycatch mitigation requirements.

Participants identified additional research needs of relevance to both the deep- and shallow-set fisheries that would inform options to modify prescribed seabird mitigation measures. This included research to identify the effects on baited hook sink rates and seabird interaction rates from minor modifications to branchline weighting designs of locating weights at the hook in the deep-set fishery and using sliding weights above light sticks in the shallow-set fishery. Participants identified a need for research on effects on seabird density around vessels and interaction rates from replacing 'strategic' offal discards with retention of offal and bait during setting and hauling, or discharging offal in batches. Participants prioritized research that would enable vessels to use more effective combinations of seabird bycatch mitigation methods when fishing at hotspots of high densities of Laysan and black-footed albatrosses and during seasons and at areas when and where more biologically important mature age classes overlap with vessels. Use of more effective combinations of methods could be implemented through dynamic spatial bycatch management and/or by identifying temporally and spatially predictable, fixed, bycatch hotspots. Participants prioritized research to determine the ability of electronic monitoring systems to monitor the employment of seabird bycatch mitigation methods and identify seabird capture events. Assessments of the effects of outreach and training activities on fisher behavior, including compliance with prescribed seabird bycatch mitigation methods, handling and release methods, and seabird bycatch rates, were also prioritized. Participants also identified research priorities to improve understanding of factors influencing captain and crew behavior related to their use of seabird bycatch mitigation methods. Participants also discussed research to improve the understanding of seabird interaction patterns and trends, and other research priorities.

Workshop participants also discussed and identified several non-regulatory approaches to mitigate seabird interactions in the Hawaii longline fisheries. This included expanding training and outreach on seabird bycatch mitigation to crew, conducting strategic outreach targeting vessels and captains with relatively high interactions, producing a seabird interaction "report card" to inform vessels/captains of how their seabird catch rate and level compares to other vessels in the fleet, and establishing liaison officers to work with individual vessels/captain to generate individualized plans for seabird bycatch mitigation.

2 MEETING OBJECTIVES, TARGET OUTPUTS

The Western Pacific Regional Fishery Management Council, at its 173rd Meeting, directed Council staff to convene a workshop to review seabird mitigation requirements and the best scientific information available for the Hawaii longline fishery while considering operational aspects of the fisheries, seasonality, the location of seabird interactions, alternative mitigation measures, and cost/benefit analyses. This workshop was convened to address this directive, and had the following objectives:

- Review current seabird bycatch management measures for Hawaii longline fisheries under the Council's *Pelagics Fishery Ecosystem Plan*
- Review alternative seabird bycatch mitigation measures and discuss their potential applicability to the Hawaii longline fisheries, considering, as defined in Section 3:
    - Operational aspects of the Hawaii longline fisheries
    - Seasonality of seabird interactions
    - Location of seabird interactions
    - Efficacy at reducing seabird catch rates
    - Cross-taxa conflicts and mutual benefits
    - Economic viability
    - Practicality
    - Crew safety
    - Ability to monitor compliance

Target outputs of the workshop were to:

- Identify and prioritize what measures may warrant testing in the Hawaii longline fisheries
- Identify potential areas of improvements to seabird measures for Hawaii's longline fisheries

3 WORKSHOP STRUCTURE AND PARTICIPANTS

Overview presentations were provided on the morning of the first day to provide background information on current mitigation measures, potential factors for recent increase in interactions, and introduction of various mitigation measures to be discussed. Remainder of the workshop was designed around facilitated discussion focused on achieving the objectives. Facilitated discussion sessions included the following components:

- Mitigation measures: Participants were provided with a worksheet (Appendix 6) to facilitate their taking notes and scoring individual measures during the workshop, in advance of a group prioritization exercise. Participants used the worksheet to score each measure against the following criteria: efficacy, cross-taxa conflicts, practicality, crew safety, economic viability, durability and suitability for compliance monitoring.[1]
- Group prioritization exercise: A "dot exercise" was conducted - each participant received eight sticker dots that they then used to identify measures with relatively high potential for use in the Hawaii longline fisheries. Participants were instructed to place one dot per method only, and were not required to use all of their dots.
- Higher-priority measures: Detailed discussion of measures that rose to the top from the dot exercise to identify applicability for the shallow-set longline (SSLL) and deep-set longline (DSLL) fisheries, as well as for use during setting vs. during hauling for each fishery.
- Lower-priority measures: Discussion on measures that received relatively low numbers of dots to identify low priority measures.
- Rescoring: Participants used the worksheet to assign an overall score for each measure.
- Additional facilitated discussion on specific topics, including captain and crew training; tori lines and minimum standards; branchline weighting; combining measures, and research needs

A list of workshop participants is provided in Appendix 3. The 23 participants were with the National Marine Fisheries Service (11 participants), Hawaii fishing industry (5 participants), academia (3 participants), the Western Pacific Regional Fishery Management Council (3 participants), and the Agreement on the Conservation of Albatrosses and Petrels (1 participant).

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[1] The criteria were defined as follows

- Efficacy at reducing seabird catch rates: has the method been demonstrated to reduce seabird bycatch rates, e.g., relative to fishing without any seabird bycatch methods, or to close to 0, or below a threshold bycatch rate, under various conditions, demonstrated through an adequate number of studies with adequate sample sizes, with robust study designs, including control treatments or explicitly accounting for potentially confounding factors
- Cross-taxa conflicts, mutual benefits: Does use of the method risk increasing catch rates or injury, or mutual benefits, to other endangered, threatened or protected species
- Practicality: How does use of the bycatch mitigation method affect fishing operations
- Crew safety: Does use of the method create a safety risk the crew
- Economic viability: What is the net economic effect of using the method
- Durability: A cross-cutting criterion related to practicality, economic viability, and efficacy; is the method likely to require frequent maintenance or replacement, or otherwise is it likely to be long-lasting and not require frequent repairs or replacement.
- Ability to monitor compliance: Can fisher compliance with prescribed procedures to employ the method be determined through dockside inspection, human onboard observers, electronic monitoring, vessel monitoring systems, other methods.

4 MANAGEMENT FRAMEWORK

4.1. Seabird regulations for the Hawaii pelagic longline deep- and shallow-set longline fisheries

Presentation Abstract, Sarah Ellgen, NMFS Pacific Islands Regional Office

Between 2001 and 2006, the Western Pacific Regional Fishery Management Council recommended and the National Marine Fisheries Service (NMFS) implemented a series of seabird mitigation regulations for the Hawaii longline fisheries. The regulations apply to both SSLL vessels targeting swordfish anywhere, and to DSLL vessel targeting bigeye tuna fishing north of 23 degrees N. The regulations allow vessel operators to choose between two sets of requirements for stern-setting or side-setting configurations. The table below shows the combinations of requirements fishermen may choose when stern-setting or side-setting. Between 2010 and 2017, the majority of DSLL and SSLL vessels set from the stern.

Table 2. Summary of seabird regulations for Hawaii pelagic longline fisheries.

1. How do you set your gear →	STERN-SETTING		SIDE-SETTING	
2. Do you shallow-set or deep-set, and where are you → 3. What you need to do ↓	Shallow-Set Anywhere	Deep-Set North of 23° N	Shallow-Set Anywhere	Deep-Set North of 23° N
Deploy mainline from port or starboard side at least 1 m forward of stern corner			Yes	Yes
If line shooter is used, mount it at least 1 m forward from stern corner			Yes	Yes
Use a specified bird curtain aft of the setting station during the set			Yes	Yes
Deploy gear so that hooks do not resurface			Yes	Yes
Attach 45 g or heavier weights within 1 m of hook of each hook		Yes	Yes	Yes
Use a line shooter to set the mainline		Yes		
Keep two 1-pound containers of blue-dye on boat	Yes	Yes		
Use completely thawed and blue-dyed bait	Yes	Yes		
Keep fish parts and spent bait with all hooks removed for strategic offal discard	Yes	Yes		
Cut all swordfish heads in half, and use heads and livers for strategic offal discard	Yes	Yes		
Night Set - begin set 1 hour after local sunset and finish 1 hour before next sunrise and keep lighting to a minimum	Yes			

Summary of Discussion Following Presentation

- What factors caused the decline in use of side setting by the DSLL fishery? Cessation of a NMFS-funded technical assistance program to assist vessels to convert to side setting was raised as a potential factor. The program provided financial support that covered welding costs and provided a free bird curtain, and termination of the program likely eliminated an incentive for additional vessels to make the change, but would not have been a factor for side setting vessels to revert to stern setting. One captain said he believes side setting to be unsafe during bad weather when turning the vessel. Changes in deck designs on some vessels have also caused the area where gear needs to be placed to side set to become too crowded.

- Clarification was sought on whether the regulatory option for side setting requires that a bird curtain also be used (yes, both are needed to maintain compliance).

4.2 WCPFC and IATTC seabird bycatch management measures

Presentation Abstract, Valerie Post, NMFS Pacific Islands Regional Office

Both the Western and Central Pacific Fisheries Commission (WCPFC) as well as the Inter-American Tropical Tuna Commission (IATTC) have adopted measures to mitigate seabird bycatch. WCPFC's Conservation and Management Measure (CMM) 2017-06 applies to areas north of 23° N and to areas south of 20° S. In areas north of 23° N, longline vessels that are greater or equal to 24 m in length are required to use at least two mitigation methods from those listed in Table 1 in CMM 2017-06 with at least one from column A, and longline vessels that are less than 24 m in length are required to use at least one mitigation method from column A. Mitigation methods listed in column A of CMM 2017-06 include side setting with a bird curtain and weighted branch lines, night setting, tori line and weighted branch lines. Mitigation methods listed in column B of CMM 2017-06 include tori line, blue-dyed bait, deep setting line shooter and management of offal discharge. In areas south of 30° S, all longline vessel are required to use at least two of three mitigation methods: night setting, tori lines and weighted branch lines. IATTC's Resolution C-11-02 applies to longline vessels greater than 20 m in overall length and generally north of 23° N and south of 30° S with some deviations in the area of applicability near the continents of North America and South America. The resolution requires longline vessels to use at least two mitigation methods listed in Table 1 of the resolution, with at least one coming from column A. Mitigation methods listed in column A of Resolution C-11-02 include side-setting with bird curtains and weighted branch lines, night setting with minimum deck lighting, tori line and weighted branch lines. Mitigation methods listed in column B of Resolution C-11-02 include tori line, blue-dyed bait, deep setting line shooter and management of offal discharge.

Summary of Discussion Following Presentation

- Why did the Pacific tuna Regional Fishery Management Organizations (RFMOs) adopt a vessel size-class cut-off at 24 meters, and why were outboards excluded in the IATTC seabird measure? The presenter believed that both may have been due to the insistence of the Japanese delegation. The Hawaii seabird regulations do not have exemptions for smaller vessels, so the Hawaii regulations are more restrictive than the regional measures.
- What degree of compliance exists with the tuna RFMO seabird measures? It was noted that most pelagic longline fisheries in the region have very low or no observer coverage, and it is likely that vessels without observers do not comply with the measures.
- Discussion on whether banning the use of wire leaders is best practice, given safety issues from fly-backs when a fish throws a hook or severs the line and monofilament line is used as the leader.
- Why did the Hawaii longline DSLL fishery conventionally incorporate weights near the hook, even before the seabird regulations came into effect? One explanation posited was that this maintains the hook at a desired position in the water column during the gear soak, and reduces entanglement of branchlines and the mainline.

5 TIME SERIES OF ESTIMATED FLEET-WIDE SEABIRD CATCH LEVELS AND RATES, HYPOTHESIZED CAUSES OF OBSERVED INCREASING TEMPORAL TRENDS IN BYCATCH LEVEL AND RATE

5.1 Time series of seabird catch levels and rates, including seasonal and spatial patterns and trends

Presentation Abstract, Asuka Ishizaki, WPRFMC

Seabird interactions in the Hawaii longline fishery are monitored through the NMFS Pacific Islands Regional Office (PIRO) Observer Program, with the swordfish-targeting SSLL fishery monitored at 100% coverage and the bigeye tuna-targeting DSLL fishery monitored at a minimum of 20% coverage annually.

Black-footed (*Phoebastria nigripes*) and Laysan (*P. immutabilis*) albatross interaction data for the Hawaii SSLL and DSLL fisheries are summarized in Table 1 and Table 2. The data are based on the summaries published by the PIRO Observer Program, which compiles the number of annual interactions using the vessel arrival date rather than the interaction date due to the quarterly sampling timeframe for the DSLL fishery. Because longline trips typically last several weeks, observed interactions from a trip beginning in December and ending in January are counted as January interactions for the purpose of PIRO Observer Program summaries. The annual summaries are compiled in a time series starting in 2004 for the SSLL fishery and 2002 for the DSLL fishery in the Pelagic FEP SAFE Report (WPRFMC 2018).

The observer data show that black-footed albatross interactions in the Hawaii DSLL fishery have been substantially higher since 2015 compared to years prior, while Laysan albatross interactions have remained relatively stable over the past decade. A similar, but less pronounced pattern has been observed in the SSLL fishery. In both fisheries, interactions are highest in first and second quarters of the calendar year (January-June) due to fishing effort overlapping with the black-footed and Laysan albatross foraging distribution during breeding season in the northwestern Hawaiian Islands. The SSLL fishery has a single peak in March and April, while the DSLL fishery has two peaks, in February and May.

Reference

WPRFMC. 2018. *Annual Stock Assessment and Fishery Evaluation Report Pacific Island Pelagic Fishery Ecosystem Plan*. Kingma, E., Ishizaki, A., Remington, T., Spalding, S. (Eds.) Available at http://www.wpcouncil.org/fishery-plans-policies-reports/fishery-reports-2/. Western Pacific Regional Fishery Management Council. Honolulu, Hawaii 96813 USA.

Table 3. Observed number of interactions and released dead, and interactions per 1,000 hooks for Laysan and black-footed albatrosses in the Hawaii SSLL fishery, 2004-2017.[a]

				Laysan Albatross			Black-footed Albatross		
Year	Obs. Cov. (%)	Obs. Sets	Obs. Hooks	Total observed interactions	Released dead	Interactions/ 1,000 hooks	Total observed interactions	Released dead	Interactions/ 1,000 hooks
2004	100	88	76,750	1	0	0.013	0	0	0.000
2005	100	1,604	1,328,806	62	18	0.047	7	4	0.005
2006	100	939	745,125	8	3	0.011	3	3	0.004
2007[b]	100	1,496	1,292,036	39	6	0.030	8	2	0.006
2008	100	1,487	1,350,127	33	11	0.024	6	4	0.004
2009	100	1,833	1,767,128	81	17	0.046	29	7	0.016
2010	100	1,879	1,828,529	40	7	0.022	39	11	0.021
2011	100	1,579	1,611,395	49	10	0.030	19	5	0.012
2012	100	1,307	1,418,843	61	11	0.043	37	10	0.026
2013	100	912	1,000,084	46	10	0.046	28	17	0.028
2014	100	1,349	1,509,727	36	2	0.024	29	14	0.019
2015	100	1,178	1,286,628	45	6	0.035	41	10	0.032
2016	100	778	849,681	26	3	0.031	40	12	0.047
2017	100	973	1,051,426	6	1	0.006	21	20	0.049

[a] Take data are based on vessel arrival dates.
[b] Due to vessel confidentiality rules, data for the fourth quarter in 2007 are combined with data for 2008. Take data for 2007 reflect those from first, second and third quarters.
Source: WPRFMC 2018.

Table 4. Observed number of interactions and released dead, interactions per 1,000 hooks, and estimated total interactions for Laysan and black-footed albatrosses in the Hawaii DSLL fishery, 2002-2017.[a]

				Laysan albatross				Black-footed albatross			
				Observed				Observed			
Year	Obs. Cov. (%)	Obs. Sets	Obs. Hooks	Total	Released dead	Interactions/ 1,000 hooks	Estimated total interactions[b]	Total	Released dead	Interactions/ 1,000 hooks	Estimated total interactions[b]
2002	24.6	3,523	6,786,303	16	13	0.002	65	18	17	0.003	73
2003	22.2	3,204	6,442,221	44	44	0.007	198	24	23	0.004	108
2004	24.6	3,958	7,900,681	2	2	0.000	10	4	4	0.001	16
2005	26.1	4,602	9,360,671	6	6	0.001	43	12	12	0.001	82
2006	21.2	3,605	7,540,286	1	1	0.000	7	17	17	0.002	70
2007	20.1	3,506	7,620,083	7	7	0.001	44	14	14	0.002	77
2008	21.7	3,915	8,775,951	14	13	0.002	55	34	33	0.004	118
2009	20.6	3,520	7,877,861	18	18	0.002	60	23	23	0.003	110
2010	21.1	3,580	8,184,127	39	38	0.005	155	17	17	0.002	65
2011	20.3	3,540	8,260,092	32	31	0.004	187	13	12	0.002	73
2012	20.4	3,659	8,768,728	30	25	0.003	136	35	35	0.004	167
2013	20.4	3,830	9,278,133	48	46	0.005	236	50	47	0.005	257
2014	20.8	3,831	9,608,244	13	10	0.001	77	32	29	0.003	175
2015	20.6	3,728	9,393,234	24	22	0.003	119	107	92	0.011	541
2016	20.1	3,880	9,872,439	34	32	0.003	166	104	99	0.011	485
2017	20.4	3,832	10,148,195	38	38	0.004	186	97	85	0.010	475

[a] Take data are based on vessel arrival dates.
[b] Estimated total interactions for 2002 and 2017 are based on expansion factor estimates (observed interactions divided by observer coverage rate); estimated interactions for 2003-2016 are point estimates generated by the NMFS.
Source: WPRFMC 2018.

Summary of Discussion Following Presentation

- Clarification was sought on whether some vessels have a disproportionate share of bird captures each year, or whether bird captures are somewhat evenly distribute amongst the vessels. This issue was addressed in further detail in Mark Fitchett's presentation (see Section 5.5).
- Clarification was sought on how the 23 degree N. latitude boundary was selected for the seabird regulations applicable to the Hawaii DSLL fishery. The basis was due to the distribution of the short-tailed albatross and the boundary was required by the US Fish and Wildlife Service under the Endangered Species Act (noting that black-footed and Laysan albatrosses are not listed under the Endangered Species Act). Observer data indicate that there has been a 5.5 times lower seabird catch rate south of this boundary than north of the boundary, so while the boundary may not be based on the risk of catching black-footed and Laysan albatrosses, it has ended up being effective.
- Discussion on whether changes over time in the spatial distribution of effort by the DSLL fishery may significantly explain the observed increasing trend in seabird catch rate.

5.2 Risk factors for seabird bycatch in the Hawaii longline deep-set fishery

Presentation Abstract, Eric Gilman, Fisheries Consultant

The following abstract is taken from: Gilman, E., Chaloupka, M., Peschon, J., Ellgen, S. 2016. Risk factors for seabird bycatch in a pelagic longline tuna fishery. *PLoS ONE* 1(5): e0155477. doi:10.1371/journal.pone.0155477. http://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0155477.

Capture in global pelagic longline fisheries threatens the viability of some seabird populations. The Hawaii longline tuna fishery annually catches hundreds of seabirds, primarily Laysan (*Phoebastria immutabilis*) and black-footed (*P. nigripes*) albatrosses. Since seabird regulations were introduced in 2001, the seabird catch rate has declined 74%. However, over the past decade, seabird catch levels significantly increased due to significant increasing trends in both effort and nominal seabird catch rates. We modelled observer data using a spatio-temporal generalized additive mixed model with zero-inflated Poisson likelihood to determine the significance of the effect of various risk factors on the seabird catch rate. The seabird catch rate significantly increased as annual mean multivariate ENSO index values increased, suggesting that decreasing ocean productivity observed in recent years in the central north Pacific may have contributed to the increasing trend in nominal seabird catch rate. A significant increasing trend in number of albatrosses attending vessels, possibly linked to declining regional ocean productivity and increasing absolute abundance of black-footed albatrosses, may also have contributed to the increasing nominal seabird catch rate. Largest opportunities for reductions are through augmented efficacy of seabird bycatch mitigation north of 23° N where mitigation methods are required and during setting instead of during hauling. Both side vs. stern setting, and blue-dyed vs. untreated bait significantly reduced the seabird catch rate. Of two options for meeting regulatory requirements, side setting had a significantly lower seabird catch rate than blue-dyed bait. There was significant spatio-temporal and seasonal variation in the risk of seabird capture with highest catch rates in April and May and to the northwest of the main Hawaiian Islands.

Summary of Discussion Following Presentation

- Clarification was sought on whether proximity to the breeding colonies in the northwestern Hawaiian Islands significantly increased seabird catch rates. The study presented employed a spatially explicit model and did therefore account for the spatial distribution of effort on seabird catch risk.
- Clarification was sought on whether the study assessed the effect of individual seabird bycatch mitigation methods (e.g., blue-dyed bait) or the full regulatory-suite of measures. The presenter explained that the categorical model term was designed to assess single factors to make the findings of relevance globally. However, about 90% of sets using blue-dyed bait also used all of the elements required in the regulatory suite of measures that includes blue bait, and the same with sets that side set, so the categorical model term (blue-dyed bait vs. side set) in effect assessed the two Hawaii regulatory-required suites of mitigation measures. When the term was defined using the two regulatory suites, the same results were found (sets using side setting had a significantly lower seabird catch rate than sets using blue-dyed bait).

5.3 Findings from WPRFMC's November 2017 albatross workshop

Presentation Abstract, David Hyrenbach, Hawaii Pacific University

The Western Pacific Regional Fishery Management Council convened a *Workshop on the Factors Influencing Albatross Interactions in the Hawaii Longline Fishery: Towards Identifying Drivers and Quantifying Impacts* from November 7-9, 2017. The goal of the workshop was to explore potential drivers and implications of higher seabird interaction rates observed in 2015-2016, in the context of longer-term oceanographic variability, shifts in fishery effort and distribution, changes in albatross at-sea distribution, and albatross demography and population trends. The main findings were that: (i) black-footed albatross distributions varied by colony and by period of the breeding season; (ii) the overlap between black-footed albatrosses and the Hawaii DSLL fishery shifted spatially by quarter within years, and interannually; and (iii) the age and sex of black-footed albatross catch varied temporally, by quarter and year. The Pacific Decadal Oscillation (PDO) was found to significantly explain black-footed albatross scan counts and catch rates for the DSLL fishery in 2015 and 2016. During positive PDO periods, anomalously strong westerly winds resulted in higher overlap between black-footed albatross and the Hawaii DSLL fishing effort.

Summary of Discussion Following Presentation

- One participant commented that some seabirds dive down to lures while trolling and it looked as if the adults were teaching the young ones how to dive on their prey (given that mature individuals can be distinguished from immature individuals based on their coloration). The presenter said that older looking birds tend to crowd out the younger birds away from bait and hooks, so there may be hierarchical interactions.
- Clarification was sought on the mature/immature ratio in the population for Laysan albatross (response: about 25:75 percent).

5.4 Fleet dynamics and oceanographic drivers behind variations in black-footed albatross sightings in the Hawaii longline fishery

Presentation Abstract, Johanna L.K. Wren, Joint Institute for Marine and Atmospheric Research, University of Hawaii, and Jeffrey J. Polovina, NMFS PIFSC

A serious threat to pelagic seabird populations today is interactions with longline fisheries. While current seabird mitigation efforts have proven successful in substantially reducing seabird interactions in the Hawaii-based longline fishery, in recent years black-footed albatross (*Phoebastria nigripes*) interactions have increased. In an effort to better understand when and where these interactions take place, we explore the relationship between black-footed albatross sightings in the Hawaiʻi-based DSLL fishery and fleet dynamics and environmental variables. Environmental drivers include both large scale climate variability due to the Pacific Decadal Oscillation (PDO) and El Niño – Southern Oscillation as well as local oceanographic and atmospheric drivers, such as wind patterns, sea surface temperature, and surface chlorophyll. Using generalized linear models, we found that while fleet dynamics (month, latitude and longitude of fishing) explained much of the variation throughout the time series, both large scale and local climate variables – positive PDO, strong westerly winds, and cooler sea surface temperatures – explained the increase in black-footed albatross sightings in recent years. Black-footed albatross nest in the Northwestern Hawaiian Islands and their main foraging habitat during nesting are the productive fronts to the north and east of the Hawaiian Islands. During a positive PDO a more intense and expanded Aleutian Low shifts westerly winds southward replacing trade winds in the northern region of the longline fishing grounds. The expanded westerly winds may have two impacts: Firstly, they drive productive surface waters to the south, increasing the overlap of the albatross foraging grounds and the DSLL fishing grounds. Secondly, when the Westerlies move south, it appears that more birds transit through the fishing grounds to the east rather than traveling north to reach the westerlies before travelling eastward north of the fishing grounds. This movement is supported by GPS-tracking which showed that nesting birds spend 27% more time below 30°N during positive PDO years compared with negative PDO years. PDO operates on decadal timescales thus this increased spatial overlap between the black-footed albatross and the fishing fleet may persist for years rather than being a short episodic event. However, for 2017 – a positive PDO and La Niña year - the behavior of the fleet was a better predictor of sightings than PDO, highlighting the complexity of the albatross and fleet interactions and the need for further research into both mitigation methods and albatross dynamics.

Summary of Discussion Following Presentation

- How did the weak La Nina phase in the spring of 2018 impact PDO and associated temperatures and chlorophyll concentrations? The presenter explained that the movement of the fleet explained the patterns relatively well for past data but not in the most recent years during the La Nina phase.
- Does the Pacific Garbage Patch affect seabird distributions and catch risk? The garbage patch is East of the Hawaii DSLL fleet's fishing grounds. Few albatrosses occur at the Garbage Patch because there are too low wind velocities.

5.5 Unique captain effect

Presentation Abstract, Mark Fitchett and Asuka Ishizaki, WPRFMC

The Hawaii DSLL fishery has experienced a conspicuous increase in seabird interactions from 2014 to 2018. The purpose of this study was to explore fisher effects unique to any specific fishing captain and vessel on the probability of interacting with seabirds per longline set. The presence and absence of seabirds (black-footed albatross, Laysan albatross, and all seabird species) per set using filtered records in the NOAA Pacific Islands Region Observer Program database was analyzed to determine fisher effects that are likely impacting the probability of interacting with seabirds. Binomial and multinomial regression models were implemented, exploring the following variables: unique captain identifier, vessel identifier, cumulative trip experience per captain for each set record, presence and absence of particular mitigation measures (blue-dyed bait, side-setting, line-shooters, tori lines), and latitudinal effects. Captain effects accounted for a significant amount of variability, partitioning 20 to 28% of total deviance. Annual effects and latitudinal effects were also included in best fit models predicting the probability of interacting with albatrosses and other seabird species. Mean annual captain effects (calculated as odds ratios) increased significantly from 2010 to 2012 and again from 2016 to 2018, commensurate with the recent increase in seabird interactions. Captain experience and presence of mitigation measures did not significantly explain variability in encounters in any explored model configuration that included captain, year, or latitude effects. However, blue-dyed bait was found to be a significant variable if latitude was excluded from the model, possibly due to autocorrelation of spatial effects and efficacy of mitigation measures required north of 23°N. Examining spatial kernel density of seabird observations versus longline fishing effort through time could render a qualitative inference that recent northward shift of longline effort may have led to greater propensity of interaction probabilities by certain longline operators. Continuing future works on investigating captain and vessel effects are needed to account for spatial overlap of fishing effort and seasonal ‘hotspots’ of seabirds estimated from observations independent of seabird interaction data.

Summary of Discussion Following Presentation

- Clarification was sought on whether 20% observer coverage in the DSLL fishery means that a captain on average is observed once every five years. It was clarified that the coverage means a captain on average is observed once every five trips. Most individual captains have an observed on board at least one trip each year.
- Clarification was made that vessel effect was auto-correlated with captain effect.
- Although the unique captain effect was observed to be increasing over the study period, there still would have been an increase in seabird catch levels in recent years even if all captains acted the same (i.e., if there had been no captain effect).
- Discussion on the potential benefit of outreach to captains to ensure that they understand the need for mitigating seabird bycatch.
- Clarification was sought on whether vessel size is corrected with a captain effect. The presenter explained that this was not explored in the study because vessel length data were not available.
- Discussion on whether seabird scan count levels are correlated with a captain effect (the presenter indicated he plans to investigate this).

6 SEABIRD BYCATCH MITIGATION METHODS FOR PELAGIC LONGLINE FISHERIES DURING SETTING AND HAULING

6.1 Overview of fact sheets on seabird bycatch mitigation measures for pelagic longline fisheries and findings from research on seabird bycatch mitigation in Hawaii pelagic longline fisheries

Presentation Abstract, Eric Gilman, Fisheries Consultant

Brief descriptions of 25 seabird bycatch mitigation methods for pelagic longline fisheries during setting and hauling that involve changes in fishing methods and gear were provided. A description of the method and the underlying mechanism for the method's effect on seabird catch risk were provided. Findings from research on seabird bycatch conducted in the Hawaii pelagic longline fisheries were also reviewed. This review of seabird bycatch mitigation methods and Hawaii research provided workshop participants with a starting point to discuss the suitability of bycatch management methods for the Hawaii fisheries based on considerations of relative efficacy, cross-taxa conflicts, practicality, crew safety, economic viability and suitability for compliance monitoring. The following methods were reviewed (those with an asterisk (*) are required under current regulations for seabird bycatch management in Hawaii's pelagic longline fisheries, and with those with an ampersand (&) have undergone research in Hawaii's pelagic longline fisheries):

- &*Tori* line
- *& Side setting
- Hook shielding
- *& Night setting
- *& Blue-dyed bait
- *& Branchline weights
- Sliding weights
- &Underwater setting
- *& Bird curtain
- *& Offal management
- Bait type (species, artificial, live/dead, swim bladder)
- Bait treatment (thaw, thread)
- Automatic branchline coiler
- Bait caster
- Water cannon
- Line shooter
- Fish and vegetable oil
- Lasers
- &Hook shape and minimum width
- Bait type (species, artificial, live/dead, swim bladder)

Other approaches to mitigating unwanted bycatch that do not involve changes in fishing methods and gear, including input and output controls (i.e., restrictions on catch and effort, such as temporal and spatial restrictions on effort, individual and fleet caps on bycatch levels and rates), compensatory mitigation (offsets), fleet communication, avoiding the generation of derelict gear and mitigating ghost fishing efficiency, handling and release practices, and skipper and crew training, were not covered in the presentation. While methods were reviewed individually in the presentation, combinations of methods are prescribed, in Hawaii and elsewhere, to obtain desired bycatch rate reductions.

Summary of Discussion Following Presentation

- Discussion on whether trip limits on seabird catch levels may be a suitable approach to manage seabird bycatch. This may be appropriate if there are a small number of participants catching a disproportionately large number of seabirds. However, a participant noted that during 2017 and 2018, seabird interactions were somewhat evenly distributed amongst vessels.

- Was the high catch levels in recent years an anomaly, and will seabird catch drop to more normal levels?
- Clarification was sought on whether strategic offal discards is effectively mitigating seabird bycatch. Participants discussed the findings from the McNamara et al. (1999) study which found that, in the short-term, retaining offal increased seabird catch rates by distracting seabirds away from where baited hooks were accessible. However, in the long-term, discharging offal may increase the number of birds that follows a vessel, resulting in higher seabird catch rates than if no offal were discarded during setting by DSLL vessels.
- One participant commented that using strategic offal discards when highly threatened species such as the short-tailed albatross is present, may make sense. Fishers could also stop setting or hauling when this occurs.

6.2 ACAP best practices

Presentation Abstract, Nathan Walker, representing the ACAP Secretariat

The Agreement on the Conservation of Albatrosses and Petrels (ACAP) is a multilateral agreement which seeks to conserve albatrosses and petrels by coordinating international activity to mitigate known threats to their populations. ACAP came into force in February 2004 and currently has 13 member countries and covers 31 species of albatrosses, petrels and shearwaters. In September 2017, ACAP adopted updated *Best Practice Advice for Reducing the Impact of Pelagic Longline Fisheries on Seabirds*, which should be applied in areas where fishing effort overlaps with seabirds susceptible to bycatch. The document is available online at https://www.acap.aq/en/bycatch-mitigation/mitigation-advice/3242-acap-2017-review-and-best-practice-advice-for-reducing-the-impact-of-pelagic-longline-fisheries-on-seabirds/file. ACAP's criteria used to identify best practice mitigation methods are summarized as follows:

- … shown by experimental research to significantly reduce the rate of seabird incidental mortality to the lowest achievable levels.
- … have clear and proven specifications and minimum performance standards for their deployment and use.
- … demonstrated to be practical, cost effective and widely available.
- … to the extent practicable, maintain catch rates of target species.
- … to the extent practicable not increase the bycatch of other taxa.
- Minimum performance standards and methods of ensuring compliance should be provided …

ACAP's current best practice advice for pelagic longline fisheries is to use a combination of weighted branchlines, a bird scaring line and night setting, or otherwise to use a hook shielding device. The minimum standards for branchline weighting are to either use (i) a minimum of 40 g within 0.5 m of the hook, (ii) a minimum of 60 g within 1 m of the hook, or (iii) a minimum of 80 g within 2 m of the hook. For vessels > 35 m, the ACAP recommendation is to use two bird-scaring lines with 100 m aerial extent, and for vessels < 35 m to use a single bird-scaring line with a 75 m aerial extent. Hook shielding devices should shield baited hooks to at least 10 m deep or for 10 minutes of immersion, and should meet the minimum branchline weighting specifications. ACAP also identifies various methods that are not recommended: line shooters, olfactory deterrents, hook size and design, blue-dyed bait, bait thaw status, and laser technology.

Summary of Discussion Following Presentation

- One participant pointed out that neither of the hook shielding devices (the Hookpod and smart tuna hook) protect baited hooks from seabirds during the gear haulback.
- One participant emphasized that the two Hawaii longline fisheries have very different hauling speeds, which affects seabird catch risk.
- Participants discussed the efficacy of blue-dyed bait. Assessing compliance with blue-dyed bait requirements can be difficult because of the difficulty in determining if the prescribed degree of darkness has been achieved. A study comparing seabird scavenging success between untreated and bait blue-dyed bait found that the blue dye worked well on squid bait but not on fish bait. It was noted that there has been inconsistent findings of the efficacy of blue-dyed bait in different fisheries, although some longline fishers in New Zealand properly utilize blue-dyed-bait. Participants also discussed whether there are better options than blue-dyed bait to achieve higher compliance when an observer is not present.

6.3 Recent discussions at WCPFC and IATTC on possible amendments to seabird measures

Presentation Abstract, Valerie Post, NMFS PIRO

Both the WCPFC and IATTC have in recent years discussed potential amendments to their seabird mitigation measures. The WCPFC's Scientific Committee last met in August 2018 (the 14th regular session of the Scientific Committee, SC14), and provided some recommendations related to revising the southern boundary from 30° S to 25° S to provide greater protections to the Antipodean wandering albatross, a species uplisted in 2017 from vulnerable to endangered. SC14 also reviewed some information on hook pods, and recommended with some reservations that hook pods be considered as a stand-alone seabird mitigation method. The WCPFC may consider these recommendations if revisions to the seabird measure are proposed at its next regular session of the commission in December 2018. The IATTC completed its annual meeting cycle in August 2018, and there were no discussions at the meeting on revising its seabird measure. The U.S. in 2015 and 2016 proposed some revisions to the area of applicability as well as mitigation methods, but was unable to reach consensus for their adoption. In 2018, IATTC staff, the IATTC Bycatch Working Group and the IATTC Scientific Advisory Committee recommended that the IATTC consider revising its seabird resolution to reflect current advice from ACAP and Birdlife International, but no members submitted proposals for consideration at the annual IATTC meeting.

Summary of Discussion Following Presentation

- New Zealand is pushing for stronger seabird measures because of the dire condition of the Antipodean albatross, which may be subject to bycatch in waters north of New Zealand and in the central and eastern Pacific between 20-30 degrees south.
- In part to try to increase compliance, BirdLife International has been active in conducting skipper training programs and outreach, and there are efforts to increase observer coverage.
- Because the IATTC and WCPFC seabird measures differ, some countries that have longline vessels fishing in both convention areas might have to comply with two different sets of measures. Harmonizing the two Pacific tuna RFMO seabird measures could result in improved compliance. Operational measures of each fleet should be taken into consideration when developing these measures.
- One participant wondered if IATTC recommended removing blue-dyed bait, mainline line shooters and underwater setting chutes as options in their seabird measure, this should serve as precedence for the US following suite. The presenter responded that seabird measure was not a priority for the US delegation to the IATTC annual session this year.

7 PARTICIPANT RANKINGS OF SEABIRD BYCATCH MITIGATION METHODS

7.1 High potential mitigation methods

The group prioritization activity at the end of Day 1 resulted in the following measures receiving eight or more votes of having relatively high potential for use in Hawaii's longline fisheries:

1. Captain and crew training
2. Side setting
3. Bird curtain
4. Tori lines
5. Towed buoy
6. Branchline weighting
7. Bait caster

Captain and crew training was identified as the highest priority based on the group prioritization activity. Dedicated discussion on training was conducted on Day 2. A summary of this discussion is presented in Section 7.1.3.

Of these, measures #2-6 were discussed in detail for their applicability for use in SSLL and DSLL fisheries, as well as during setting and hauling for each fishery. A summary of general discussions on these high priority measures are presented in Table 5, and the applicability of each measure to each fishery and set/haul is presented in Table 6.

Automatic bait casters received eight votes in the group prioritization activity, but was deprioritized during group discussion. A summary of discussion is included in Section 7.2.

High ranking measures from the group prioritization activity (#1-6 above) were consistent with the mean overall scores from the worksheets that participants completed independently, with most participants scoring the measures 3-5 on a scale of 0-5 (Fig. 1). Participants had relatively high agreement (i.e., low variance) in their scores for tori lines and captain and crew training, whereas side setting and towed buoy had relatively large variance.

Participants also completed a similar survey prior to the workshop. A comparison of scores from these two surveys, conducted prior to and during the workshop, are presented in Appendix 7 (Fig. 10). For all but three of the measures, the mean overall score for methods declined from the pre-workshop survey to the survey completed during the workshop. The score for bird curtain remained the same, and the scores for streamer (tori) line and towed buoy increased.

Table 5. Summary of discussion of high priority measures that involve changes in fishing gear or use of equipment.

Measure	General Discussion Summary
Side setting	While research has shown that side setting in combination with line weighting and a bird curtain is highly effective at mitigating seabird bycatch in both the shallow and deep set fisheries, almost no vessels are now using this method in the shallow set fishery. This may be because some SSLL fishers perceive that it is not practical to set the mainline from the side of the vessel, because SSLL vessels use the tension of the mainline to drag the line off the spool rather than using a mainline line shooter to get the line taught. A minority of DSLL vessels select the suite of regulatory measures that includes side setting (from 2010 to 2017, a mean of 25% of DSLL vessels made one or more side sets per year, range 19-29%, see Section 3.1). The ca. 75% of vessels that do not side set may find blue-dyed bait to be more practical, or may have changed their vessel configurations causing the area where side setting occurs to become too crowded. Analyses of observer program data for the DSLL fishery found that vessels that side set do so even in areas where they are not required to, suggesting that they likely comply with the side setting requirement even when an observer is not onboard. One captain commented that side setting is dangerous for crew when they need to turn the vessel sharply in bad weather. Another captain commented that some captains use side setting as a preferred method and find the method to be practical and safe. An industry participant also explained that the current regulations requiring deployment of the mainline from at least 1 m forward from the stern may create conditions similar to stern setting depending on the behavior of the crew in how they set baited hooks, such that the effectiveness of side setting may be affected by crew behavior.
Bird curtain	Participants recognized that bird curtain likely augments the bird bycatch mitigation efficacy when used in combination with side setting, and holds promise for mitigating seabird catch risk during gear haulback. Concerns over the durability of prototype bird curtains used during haulback were raised. Some participants expressed that the bird curtain design used with side setting is easy to use, inexpensive and likely improves bycatch mitigation efficacy.
Tori (streamer) line	Participants felt that tori lines should be considered as an additional option for the Hawaii longline fisheries. A study by McNamara et al. (1999) found that blue-dyed fish bait resulted in a lower seabird attempt rate than a single tori line in the DSLL fishery. A comparison of seabird catch risk between tori lines and side setting has not been conducted, nor between tori lines and blue-dyed fish bait in the SSLL fishery. Paired tori lines have not been trialed in Hawaii longline fisheries. Extensive research has been conducted on tori line efficacy, designs and materials in numerous pelagic and demersal longline fisheries globally. Tori lines are one of the most commonly prescribed seabird bycatch mitigation methods for pelagic and demersal longline fisheries, and are relatively inexpensive. Single tori lines rely heavily on crew behavior to ensure the streamer line is protecting the area where baited hooks are available to seabirds and to obtain levels of efficacy observed in experiments, in particular in high winds when seabirds are most agile and have higher capability of scavenging bait from hooks. Paired tori lines are more effective than a single tori line, and may rely less on crew behavior to maintain their position. Participants noted that minimum standards would be needed to ensure that tori lines used by Hawaii vessels effectively protect an area astern where the seabirds that are susceptible to capture in these fisheries can access baited hooks during setting (discussed further in Section 7.1.1). Participants also noted that branchline weighting should be used in conjunction with tori lines.

Towed buoy	Some participants felt that towed buoys hold promise for effectively reducing bird interactions in Hawaii longline fisheries, perhaps in combination with other methods, such as with a single tori line during setting, and as a stand-alone method during shallow-set haulback. It is likely not as effective as many other options available during setting. Participants noted that towed buoys can be impractical due to entangling with gear components. There was some discussion of how to define this device, and the broad definition provided in the Fact Sheet (Appendix 5) was deemed adequate.
Branchline weighting	Participants noted that branchline weighting provides a simple, gear-based measure that likely results in high compliance even when observers are not aboard. Safety issues with fly-back of the lead weights were identified as a concern, especially for the SSLL fishery that does not use wire leaders. Participants discussed alternative designs to affix weights closer to or at the hook in the DSLL fishery (discussed in more detail in Section 7.1.2). Sliding weights may be a possible branchline weighting design for the SSLL fishery, although sliding weights was not considered by participants to be a high priority measure (see Table 7 for an additional summary of discussion on sliding weights). Some participants raised the concern that when weights are located close to the hook, it could damage the catch.

Table 6. Applicability of high priority seabird bycatch mitigation measures for use during setting and hauling in the Hawaii SSLL and DSLL fisheries.

Method	SSLL		DSLL	
	SET	HAUL	SET	HAUL
Side setting	NO *Not practical for SSLL due to the way gear is set	NA	YES *Used in conjunction with bird curtain	NA
Bird curtain	NO *Needs to be used in conjunction with side setting	YES *Potential area for research and development to make them durable (better than any towed or dragging material due to haul behavior where vessel circles around)	YES *Used in conjunction with side setting	N/A *Low priority due to very few bird captures during haul
Tori (streamer) line	Night: NO *Not useful because of night setting (can't see it anyway), although there may be some benefit when setting during full moon; not allowed to set during the day Day: YES *Night setting is currently required so SSLL setting does not occur in daylight, but could be effective if setting during the day or before sunset was allowed	NO *Tangle risk is high due to vessel behavior during haul.	YES * Need development of minimum standards for Hawaii longline vessels (but leave room for adaptation and innovation)	NO *Tangle risk is high due to vessel behavior during haul.
Towed Buoy	NO *Currently not necessary due to night setting	YES *Potential option during the haul	YES? *Could be used as an optional/voluntary method in conjunction with a tori line (instead of the 2nd tori line)	NA *Low priority due to very few bird captures during haul
Branchline weighting design – heavier weights closer to the hook	YES *Good complement to other mitigation measures such as tori lines	YES *Helps keep hook underwater during haul	YES *Good complement to other mitigation measures such as side set and tori lines	N/A *Low priority due to very few bird captures during haul

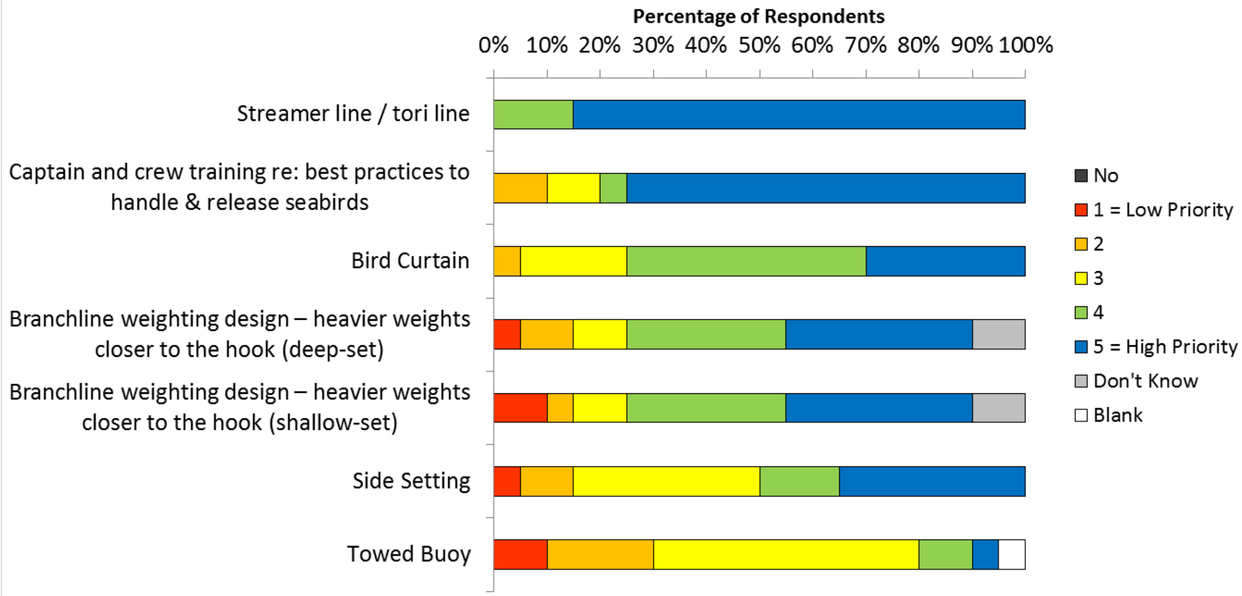

Fig. 1. Summary of overall scores from worksheets completed individually by participants during the workshop for measures identified as high priority during a group prioritization exercise.

Of the high priority gear-based measures, the group discussed additional considerations for implementation, specification details and research needs for tori lines and branchline weighting designs, summarized below.

7.1.1 Tori Lines

Tori lines were previously tested in the Hawaii longline fishery (McNamara et al. 1999, Boggs 2001), but were not included in regulations due to concerns over safety and practicality resulting from tori line entanglement with gear. Those issues have been addressed in Alaska and other longline fisheries, and tori lines are now used in a large number of longline fisheries worldwide. One industry participant attending the workshop had experience using tori lines in Alaska fisheries and noted that the design used in that fishery is easy to deploy. Another industry workshop participant has been voluntarily using a simple design of a tori line, constructed from leftover, readily available materials found on their vessel.

Workshop participants agreed that tori lines are a high priority for consideration for use in the Hawaii longline fisheries, but acknowledged that minimum standards for the fishery would be needed to allow flexibility in design while maintaining efficacy and ensuring crew safety. Participants also acknowledged that tori line efficacy relies heavily on crew behavior to ensure that the streamer lines are maintained in a position that covers the area where baited hooks occur. Discussion on developing minimum standards raised the following considerations:

- Tori line standards for Hawaii's longline fisheries that:
    - Achieve an aerial extent that covers a distance astern where baited hooks are available to seabirds, where:

        - The branchline weighting design determines the baited hook sink rate and distance astern that it is within diving range of Laysan and black-footed albatrosses; and
        - Infrastructure is needed on the vessel to achieve the requisite height of the tori pole to achieve the needed aerial coverage by the tori line;
    - Minimizes torque (e.g., use barrel swivel to allow line to rotate)
    - Includes break-away mechanism for safety and operation practicality (in the event of entanglement)
    - Maintain room for innovation
    - Allows flexibility on what materials are used for the visibility mechanism
        - Materials attached to the streamer line do not need to be specified, but should reach almost to the sea surface
        - Suggestions on materials could be provided (tori lines can be easily created using materials readily available on vessels, including monofilament line, packing material tape, old swivels)
    - Takes into account difference in efficacy under different wind conditions (Alaska has provisions on how to use tori lines in different wind conditions)
- Consider minimum standards in ACAP Best Practice Advice
- Ensure consistency with WCPFC and IATTC seabird measures, which include specifications for tori lines

Participants also discussed the following research and development needs for considering tori line use in the Hawaii longline fishery:

- Work with industry on research and development prior to tori lines being required, and use that experience to refine minimum standards.
- Work with each vessel to design tori lines that work for their specific vessel configuration.
- Encourage voluntary adoption through use of small grants to work with each vessel to develop tori line design suitable for their vessel.

7.1.2 Branchline Weighting Configurations

Branchline weighting is currently required as part of the suite of seabird measures for the Hawaii longline fishery when vessels are side setting, or when DSLL vessels are stern setting. Weights are not required for SSLL vessels when stern setting (stern setting SSLL vessels are required to night set, use blue-dyed bait, and employ strategic offal discard methods). Where required, regulations specify that a 45 gram or heavier weight must be attached within 1 m of the hook. A majority of the DSLL vessels use 45 gram or heavier weights within approximately 0.5 meters of the hook. Most SSLL vessels stern set, and while not required under the current seabird measures, use weighted swivels several meters above the hook.

ACAP best practice recommendations include minimum standards for branchline weighting configurations of 40 grams or greater within 0.5 meter of the hook; 60 grams or greater within 1 meter of the hook; or 80 grams or greater attached within 2 meters of the hook (Section 5.2). Workshop participants discussed branchline weighting considerations for the Hawaii DSLL and SSLL fisheries. While participants generally agreed that weights provide a simple solution to seabird bycatch mitigation especially as it does not rely on crew behavior, they noted that safety considerations are important due to fly-back risk. Other considerations raised in discussion were:

- Sink rate research in other areas looks at sink rate to 10-meter depth, but the depth needed to get bait out of the diving range for North Pacific albatrosses is much shallower, as Laysan and black-footed albatrosses are only capable of making body thrusts underwater to a depth of perhaps 0.5 m. Time-depth recorders and other devices may not be available to accurately measure sink rates at the necessary resolution.
- DSLL-specific considerations:
    - Previous Hawaii longline observer data analysis (Appendix 4) showed that 60-gram weights had lower bird catchability than 45-gram weights, both at 0.5. from the hook.
    - Sink rate is likely to be affected by branchline and hook size/weight, which are likely to change in the DSLL fishery in the near future due to measures considered under the False Killer Whale Take Reduction Plan.
    - Branchline weighting trials on which ACAP best practices are based likely did not use wire leaders, and sink rate is likely faster when wire leaders are used between the hook and weight, as is the case for the DSLL fishery.
    - Current weights used in the DSLL (commonly 45 g at approximately 0.6 m from hook), while not meeting exact specifications of the ACAP best practice, is very close to the minimum standard (<40 g within 0.5 m of hook), so it is likely to have similar effectiveness in reducing interaction rates.
    - Regulations could be modified to reflect common practice in the DSLL fishery.
- SSLL-specific considerations:
    - With night set requirements, there are limited SSLL seabird interactions during the set, so weight specification is not a high priority for gear measures for setting (except perhaps during periods of high lunar illumination). However, interactions on the haul remain, so branchline weighting may have benefits for reducing interactions on SSLL haul.
    - Safety issue is greater with SSLL due to speed of line retrieval during hauling and greater fly-back risk. Fly-back prevention should be explored in conjunction with branchline weighting requirements for the SSLL fishery.

7.1.3 Captain and Crew Training

Outreach and training were identified as high priority for mitigating seabird interactions in Hawaii’s longline fisheries. Current training requirements are limited to the protected species workshop for vessel owners and captains, and there are no training requirements for crew. Some participants commented that captain and crew outreach holds promise because, over the past decade, participants in the fishery gradually lost their concern over adverse consequences resulting from seabird bycatch. As a result there was a gradual reduction in the use of side setting, replaced by the less effective blue-dyed fish bait in the DSLL fishery. Additionally, some participants expressed that there has been a recent influx of new entrants to the fishery, who may place a lower importance on mitigating seabird bycatch. Participants emphasized the importance of expanding training and outreach to crew members (with an emphasis on the importance of minimizing seabird interactions and how to correctly use various seabird bycatch mitigation methods), and providing training in crew's native language (e.g., Bahasa Indonesia, Tagalog). Participants also recognized that it is important to understand basic principles of and incentives for behavioral change, as education does not always effectively catalyze positive changes.

Participants provided a number of specific suggestions for developing and improving captain and crew training. These include:

- Strengthen existing training by ensuring materials are concise and providing options for training format (e.g., print media, digital media, visual heavy and text light).
- Develop training with a goal of building a sense of responsibility for crew members to contribute to seabird bycatch mitigation.
- Develop training materials in crews' native language.
- Expand training to incorporate approaches that address the intended behavioral change for the specific audience to achieve the training goal.
- Strategic outreach targeting vessels and/or captain with higher interactions to address captain effect.
- Inform vessel owners, captains and/or crew of vessels of their seabird bycatch performance relative to other vessels (captains and crew may not realize that their seabird interactions are atypical of the fleet) and assess to determine if such information results in reductions in seabird interaction rates by vessels with relatively high interaction rates (similar to comparative energy usage graphs on electricity bills in which one's electricity usage is compared to others in the same neighborhood)
- Establish liaison officers who would work with individual vessel, captain and/or crew to generate individualized plans for bycatch mitigation.
- Update previously developed outreach materials (such as "“Catch Fish not Birds” by Nigel Brothers) and make them available in crew languages.
- Develop a video series on seabird mitigation measures that is entertaining as well as educational (shared on social media or otherwise broadly)

7.1.4 Measures with Moderate Potential

Two additional measures, night setting and offal management (retention and strategic discard), received moderate overall scores based on the worksheet responses (Fig. 2) and received considerable discussion. Both of these measures were considered suitable for SSLL vessels, but not practical or appropriate for DSLL vessels.

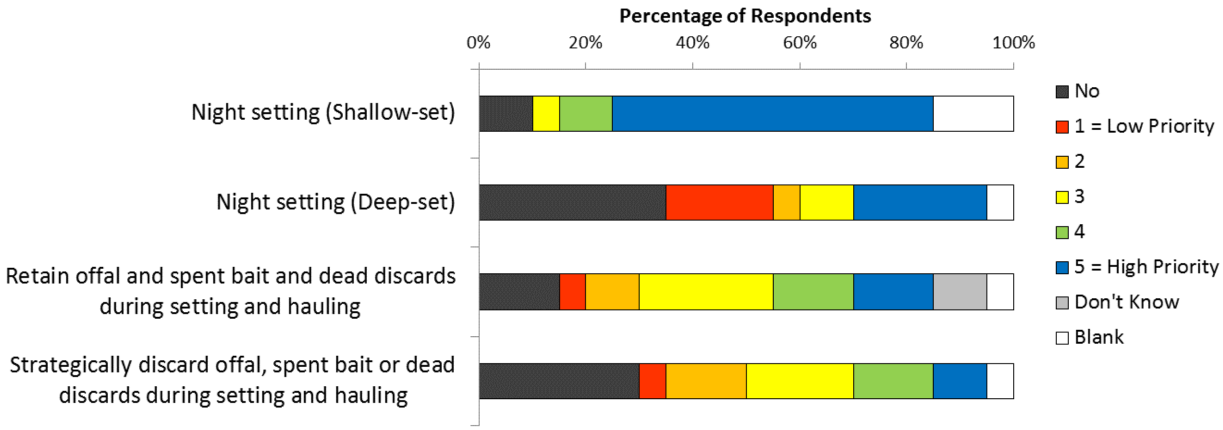

Fig. 2. Summary of overall scores from worksheets completed during the workshop individually by the participants for seabird bycatch mitigation measures with mixed potential.

Night Setting: Night setting (setting conducted only between nautical dusk and dawn) is currently required for Hawaii SSLL vessels when stern-setting, in combination with using blue-dyed fish bait (Section 3.1). The measure has been extremely effective at reducing seabird catch rates in the SSLL fishery, and has been documented to be an effective method in numerous other longline fisheries. Participants discussed how the efficacy of night setting may be reduced when there is strong moonlight, if deck lighting is not adequately shielded, and possibly when lightsticks are used. During these situations, the combined use of night setting and blue-dyed bait may have been critical for achieving the observed low seabird bycatch rates. One participant (longline vessel captain) explained that he used to set gear earlier in full moon when shallow-setting, but the night-setting requirement no longer allows for that flexibility.

Some participants stated that it may be useful to allow night setting as an option for seabird bycatch mitigation by the DSLL fishery. Other participants, however, explained that night setting is not practical for targeting bigeye tuna using DSLL gear. Participants noted that having daytime DSLL vessels switch to nighttime setting may require fishing shallow to overlap with the depth distribution of bigeye tuna, which would increase catch rates of other at-risk taxa, including sea turtles and epipelagic sharks. One participant explained that hauling during the day (which takes 10-12 hours for the DSLL fishery) in the subtropics would make it too hot for crew, in particular on vessels with open decks at the hauling station, and another participant indicated that bait depredation by squid is higher at night.

Offal Management (Strategic Offal Discards and Offal Retention): Three offal management measures, retention of offal (including fish parts, spent bait and dead discards), strategic offal discard continuously during setting or hauling, and discharging offal in batches, were discussed during the workshop. Hawaii DSLL and SSLL vessels that stern set are required to discard offal on the opposite side of the vessel where the gear is being set or hauled, when seabirds are present (Section 3.1). Offal discards are discouraged internationally based on the potential that the practice attracts more birds around the vessels over the long term (days to years). Vessels that retain offal and other organic matter have been found to reduce, over the long term, the number of birds attending the vessel, based primarily on studies in trawl fisheries (Appendix 5). Lower seabird abundance around vessels, in turn, may reduce the capture risk in fisheries where seabird abundance around vessels is correlated with catch risk (Appendix 4). Participants noted that the use of strategic discards in the Hawaii fishery was a practice that started in the SSLL sector, and the applicability of offal for SSLL and DSLL, and for setting and hauling, should be clarified. Several participants expressed that strategic offal discards works well in the SSLL fishery during the haul and should be maintained as a seabird bycatch mitigation measure, but could be removed for the DSLL fishery. Some participants were in favor of offal retention, while others acknowledged that a requirement to retain all offal throughout an entire trip may be impractical.

7.2 Deprioritized measures

The group prioritization activity and additional facilitated discussion resulted in the measures in Table 7 to be identified as having low potential for use in the Hawaii longline fishery. Additionally, two measures currently included in the Hawaii seabird regulations, blue-dyed bait and mainline line shooter, were also ranked low. The basis for the low overall scores for these two methods were as follows:

- <u>Blue-dyed bait</u>: Blue-dyed bait was originally tested on squid bait in the Hawaii longline fisheries. The size of the effect of dyeing fish bait blue on reducing seabird catch risk is likely much smaller than that for squid bait. The SSLL has been required to use fish bait since 2004, and the DSLL discontinued using squid for bait due to an increase in the price for squid. While there is evidence that blue-dyed fish bait reduces seabird interaction rates in Hawaii's longline fisheries (Appendix 4), using side-setting has been found to have a significantly lower seabird catch risk than using blue-dyed fish bait, and trials of blue-dyed bait conducted elsewhere have had mixed results. Industry workshop participants commented that blue-dyed bait is not favored by fishermen. Blue-dyed bait is impractical because the dye is messy, and bait must be fully thawed to get it to the regulatory-required darkness, which reduces retention on hooks. Furthermore, fully thawed bait is more difficult for crew to handle than conventionally used partially thawed bait. Participants also acknowledged that compliance with the blue-dyed bait measure may be low when observers are not on board.
- <u>Mainline line shooter</u>: Mainline line shooters are conventionally used by DSLL vessels to set the mainline slack in order to achieve the targeted gear soak depth.[2] Participants believed that line shooters do not have an effect on seabird catch risk in Hawaii's longline fisheries. The sink rate of baited hooks will be unaffected by the sink rate of the mainline until the hook has settled to the full length of the branchline. In Hawaii's longline fisheries, hooks are likely to sink to several meters below the depth accessible to black-footed and Laysan albatrosses before the sink rate of the mainline begins to affect the sink rate of baited hooks.

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[2] Hydraulic line shooters can be set to deploy the mainline faster than the vessel speed, so that the line is set slack. In other words, the length of mainline between two floats exceeds the distance between two floats. The smaller the sagging ratio, which is the distance between floats divided by the length of mainline between two floats, the faster the mainline sink rate, and the larger the catenary angle (and deeper depth of deepest hook between two floats). Setting a slack mainline into the prop wash was found in one study to result in a slower sink rate than setting a taught mainline into the turbulent prop wash, however setting the mainline into the prop wash is not a conventional practice by longline vessels.

Participants' overall scores from worksheets are provided in Fig. 3. A summary of reasons that participants deprioritized the remaining seabird bycatch mitigation measures is provided in Table 7.

Table 7. Deprioritized seabird mitigation measures for the Hawaii longline fishery based on group prioritization activity and additional facilitated discussions, and reasons for the low priority.

Mitigation Measure	Rationale for Low Priority Ranking
Measures involving changes in fishing gear or use of additional equipment	
Artificial bait	There are no commercially viable artificial baits available for use in pelagic longline fisheries, and no research findings on the effect on seabird catch risk.
Automatic branchline coiler	When used with modern monofilament gear, they are expected to be less efficient than manual coiling into bins, and to be more likely to result in branchline tangles during setting than when branchlines are manually coiled. Unlike with manual coiling, if a bird were captured while using an automatic coiler, this could risk injuring or killing the seabird if crew could not quickly turn off the coiler.
Bait caster	Some workshop participants felt that an automatic bait caster had low promise as it would be yet one more mechanical piece of equipment onboard that would break and require constant maintenance. When used with a tori line, if not set correctly, it could compromise the efficacy of the tori line (by setting the baited hooks outside the coverage of the bird-scaring line). Bait casters are used by Japanese pelagic longline vessels to make setting easier for crew (not as a seabird avoidance method). Some participants, however, expressed that an automatic bait casters has promise to be used in conjunction with side setting, if a model that enables setting the distance and direction of casting, in order to ensure that baited hooks are consistently set far forward and near the vessel hull, and thus eliminating variability in where baited hooks are side set by crew.
Bait species	There is no empirical evidence of an effect of bait type on albatross catch rates. Consideration of effect on target species catch is also warranted.
Ban the use of live bait	Live bait has not been used in the Hawaii longline fisheries, and thus there is no need to manage or ban its use.
Fish used for bait that have swim bladders punctured	Likely to have a very small effect on baited hook sink rates and seabird catch risk. Too impractical/time consuming for crew to puncture bladders.
Fish and vegetable oil slicks	Participants indicated that it is illegal to discharge oil from a vessel. The oil slicks may oil seabirds, eliminating their waterproofing.
Fully thawed bait	There is only a small difference in sink rates between hooks with partially vs. fully-thawed bait and there are several reasons why using fully-thawed bait is impractical, discussed in the Fact Sheets (Appendix 5).

Hookpod	Participants noted that the device may have promise for substantially reducing seabird catch risk during setting but indicated that the high cost for the initial outlay and ongoing maintenance to replace damaged and lost devices is a substantial limiting factor for implementation. Participants also expressed concerns over compliance with use of the device when setting is not observed. Participants reviewed findings from two studies that have been conducted on the Hookpod for which findings are currently available (Appendix 5), which found that the Hookpod, due either to the effect from shielding the barb and point and/or from adding weight at the hook, is likely to substantially reduce seabird catch risk during setting. The device may have potential for reducing seabird captures in the DSLL fishery, but not for the SSLL fishery where most bird captures are now during the haul, during which the Hookpod is not shielding hooks. Findings from one study also suggested that it may reduce sea turtle catch rates (the Hookpod in this study protected baited hooks during the initial part of setting as baited hooks sink to 10 m depth).
Hook size and shape	Circle hooks are required for use by the DSLL fishery, as a measure to mitigate false killer whale bycatch, and wider circle hooks are required for use by the SSLL fishery to mitigate sea turtle bycatch, so varying hook shape is not an option in these fisheries. Albatrosses are mainly captured by hooking in the bill (very few are foul-hooked) so it is unlikely that the shape of the hook affects their catch risk. Small differences in hook size likely have no effect on large species of seabirds to ingest hooks, but larger hooks may reduce the catch risk of smaller seabird species. The larger and likely heavier hooks may have a faster sink rate during setting, and may make baited hooks less likely to be available at the sea surface during haul-back, but likely the difference in weight between different sized hooks is minimal and thus likely has a very small effect on sink rates.
Lasers	Lasers may damage seabirds' eyes, as well as fishers' eyes. Research is at a very early stage. They may work well in the dark for some species. The cost for the devices that have undergone trials is prohibitive.
Require fish bait to be hooked either in the head or tail	Bait are already threaded in the head or tail, so there is no need and would be no benefit in requiring this.
Sliding weights	Most DSLL vessels crimp weights to branchlines at the top of a wire leader, within about 0.5 m of the hook, and a sliding weight would not work on the wire leader. However, alternative designs to affix weights closer to or at the hook are likely feasible in the DSLL fishery. Sliding weights, however, may be a possible branchline weighting design for the SSLL fishery. SSLL vessels crimp weights onto branchlines relatively far from the hook, and do not use wire leaders. Previous interviews with captains found that they want the weight above the lightstick so that the bait moves freely during the soak, but they do not want to place the weight too close to the hook due to the risk of fly-backs and crew injury. Sliding weights might be practical for use by the SSLL fishery to get the weight closer to the hook but above the lightstick in order to reduce seabird catch risk during setting and hauling. However, some participants explained their belief that when a fish throws the hook (versus breaks the branchline by biting through or abrading it), a sliding weight may not slide on the line, and might have the same velocity as a conventional weight crimped onto the line.
Smart Tuna hook	It is not commercially available, and the cost for use is prohibitive given one-time use, and it litters the seabed (which may be illegal), although it purportedly degrades over a year or so.
Underwater setting chute	More research and development would be required to address design flaws and durability with long-term use.

Underwater bait setting capsule	It is not commercially available, and would likely be expensive. Some participants expressed the same concern as raised with the bait caster, than any additional mechanical equipment will break and require maintenance. Results from trials conducted to date show that it has promise for effectively reducing seabird catch risk.
Water Cannon	As discussed in the Fact Sheet (Appendix 5), prototypes lack the reach to cover the area astern where birds can access baited hooks during setting, although it could work during hauling. It has not been trialed during hauling, and investment in research and development, and trials, would be required. Some participants were concerned that it might be impractical and expensive to maintain a water spray device, and might create a safety risk and be inconvenient to crew (if the wind blows the spray at the crew).
Measures other than changes in gear and use of equipment	
Compensatory mitigation (offsets)	Some participants expressed concerns over a measure where the catch sector would pay for catching seabirds, as this would create an unsafe situation for at-sea observers, who might be subject to coercion or corruption to misreport seabird interactions. Electronic monitoring was identified as a potential solution to this concern. It would require 100% coverage by at-sea observers or electronic monitoring, which is expensive.
Fleet Communications	Some participants felt that communication between vessels real-time to identify areas where they experienced high seabird interactions could enable other vessels to be more prepared to employ rigorous seabird bycatch mitigation methods. Participants did not expect that vessels would avoid an area with high seabird abundance if it also was productive fishing grounds. Some participants thought that it might not work, because fishers do not want to share commercially sensitive information on the location of their fishing grounds. Some participants considered a program where the government provides the fleet with information on predicted hotspots for albatrosses would work better than an industry-led communication program.
Individual transferable vessel-based quotas on bird catch levels or rates	Some participants commented that vessel-based individual transferrable quotas on catch levels or rates, by trip, season or year, might be perceived as a loophole enabling them to catch more seabirds. As with compensatory mitigation, this could result in an unsafe role for at-sea observers, which could be resolved through fleet-wide use of electronic monitoring. And, it would require real-time monitoring with 100% coverage by at-sea observers or electronic monitoring in the DSLL fishery, which is expensive.
Temporal and spatial management	Participants discussed the potential of identifying temporally and/or spatially predictable hotspots of high seabird density, or when scan counts were above some threshold level, and during seasons and areas when and where more biologically important mature age classes overlap with vessels, where more robust combinations of seabird bycatch mitigation methods could be required in the DSLL fishery. Participants were generally not supportive of creating temporal or spatial restrictions on fishing effort, as this could result in a substantial economic burden. The displaced effort (spatially, temporally) might create cross-taxa conflicts. Vessels from other fisheries may increase their effort during these periods in these areas to replace the Hawaii effort. Some participants expressed that there are numerous other options that should be explored before considering restricting the timing and location of the DSLL fishery.

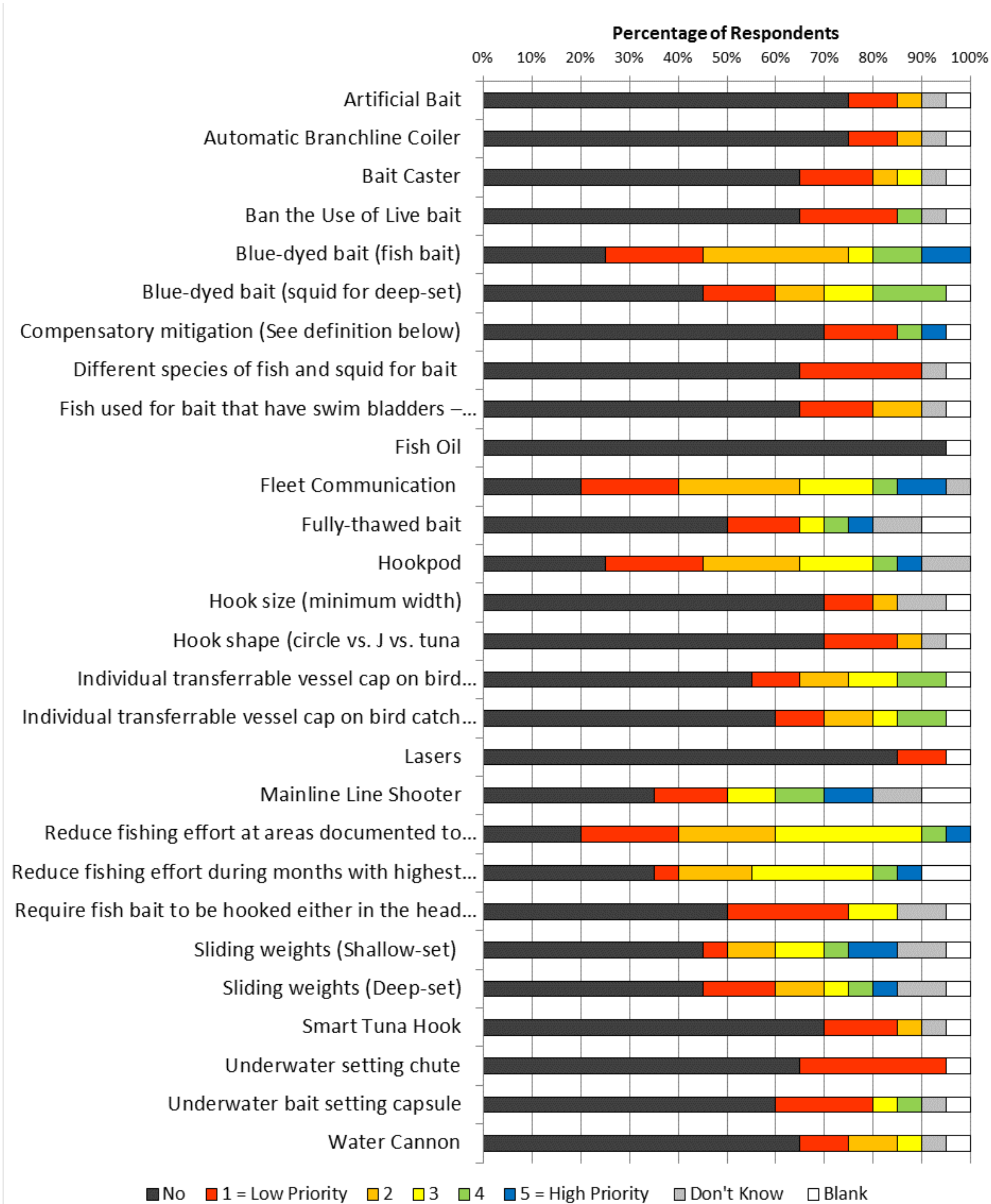

Fig. 3. Summary of overall scores from participants' worksheets for low priority measures.

7.3 Combinations of Seabird Bycatch Mitigation Measures and Research Needs

Participants discussed potential options for the use of combinations of seabird bycatch mitigation measures in the Hawaii longline fisheries to improve existing regulations. Additionally, participants identified research needed to inform potential amendments to required seabird bycatch mitigation measures. Participants noted that changes to the Hawaii longline requirements would need to be consistent with WCPFC's and IATTC's binding seabird measures. Participants also emphasized the importance of providing flexibility of measures, so vessels have the ability to choose a combination of measures to implement.

7.3.1 Deep-set Fishery: Potential Combination of Measures

Current DSLL seabird mitigation measure requirements are shown in Table 8. Discussion on options for DSLL fishery requirements centered on the addition of tori lines and potential removal of blue-dyed bait. Participants' suggestions included the following:

- Add tori lines to the stern set option, and consider ways to allow the use of tori lines when fishermen need it rather than requiring the use of tori lines at all times.
- Remove blue-dyed bait and replace it with tori line.
- Maintain blue-dyed bait until tori lines are shown to be a comparable measure.
- If tori lines are required, consider ways to ensure that they are used as intended without an observer on board.
- Modify requirements to a "menu" approach used in WCPFC, where vessels can choose from "column A" and "column B", rather than requiring a combination of measures.
- Change the 23°N requirement further south or require measures regardless of fishing location.[3]

Table 8. Current seabird mitigation measures required in the Hawaii DSLL fishery.

When side-setting north of 23°N, also use:	When stern-setting north of 23°N, use:
Bird curtain	Blue-dyed bait (thawed)
>45g weight within 1m of hook	>45g weight within 1m of hooks Line shooter Strategic offal discard

7.3.2 Deep-set Fishery: Research Needs to Inform Potential Modification of Seabird Mitigation Requirements

Participants identified the following research needs to inform modifications to seabird mitigation measure requirements in the Hawaii DSLL fishery:

- Determine tori line design (including single and paired designs) so that the aerial extent effectively protects areas where baited hooks are available to albatrosses during setting.

[3] Johanna Wren, PIFSC, provided summary interaction data, which showed that from 2015-June 2018, 91.2% of all black-footed albatross interactions occurred north of 23°N, whereas 93.9% of interactions during the same period occurred north of 20°N.

Different designs of tori lines could also be compared for efficacy and practicality. See Section 7.1.1 for a discussion on developing tori line minimum standards for Hawaii's pelagic longline fisheries.

- Compare seabird bycatch rates of tori lines (single and paired) to that of side setting and blue-dyed bait to determine if tori lines may be a suitable replacement for blue-dyed fish bait. Participants suggested having DSLL vessels that stern-set trial single and paired tori lines, with the same line weighting requirement and a mainline line shooter, and compare seabird catch rates to that of fishing using the current combination of stern-setting methods (line weighting, blue-dyed and thawed fish bait, strategic offal discards, line shooter). Trails of this nature under the current regulations would require an Experimental Fishing Permit (EFP) to allow DSLL vessels to stern-set north of 23°N without using blue-dyed bait.

7.3.3 Shallow-set Fishery: Potential Combination of Measures

Current SSLL seabird mitigation measure requirements are shown in Table 9. Discussion on options for SSLL fishery requirements centered on options for further reducing interactions during the haul. Participant suggestions included the following:

- Maintain night setting requirement.
- Remove side-set option for SSLL.
- Explore strategic offal issue for SSLL (consider requiring only on haul).
- Explore bird curtain for haul.
- Explore branchline weighting specifications for reducing interactions on haul (consider fly-back prevention in conjunction).

Table 9. Current seabird mitigation measures required in the Hawaii SSLL fishery.

When side-setting, also use:	When stern-setting, use:
Bird curtain	Blue-dyed bait (thawed)
>45g weight within 1m of hook	Strategic offal discard
	Night set

7.3.4 Shallow-set Fishery: Research Needs to Inform Potential Modification of Seabird Mitigation Requirements

Participants identified the following research needs to inform modifications to seabird mitigation measure requirements in the Hawaii SSLL fishery:

- Analyses of observer data from the SSLL fishery to assess the differences in seabird catch rates with standardized effort between the two options of regulatory required suites of measures. If side setting with a portion of the set conducted prior to local sunset and after local sunrise was demonstrated to have a large and significantly higher seabird catch rate than night setting, then the option for side setting could be eliminated. However, this research project is a relatively low priority given the low proportion of shallow sets that employ side setting.

- Research to determine the effect of using blue-dyed fish bait in combination with night setting on seabird catch risk. If effect is minimal, then the dyed bait requirement could be eliminated, or replaced with a more effective alternative.

7.3.5 Additional Research Needs to Inform Modification of Seabird Mitigation Requirements in Hawaii's Longline Fisheries

- Determine if the efficacy of currently required seabird bycatch mitigation methods for the DSLL fishery could be augmented through combinations of minor modifications. For example, participants identified as a priority research area modifying branchline weighting designs to increase baited hook sink rates by reducing the leader length and/or increasing the weight amount, where in the DSLL fishery, research could be conducted on attaching weights at the hook (between the hook and the wire leader).
- Assess the effect on seabird catch rates of replacing 'strategic' offal discards with retention of offal and bait during setting and hauling, where the latter is expected to reduce seabird attendance of vessels over the long-term (months to decades), based on research conducted in other fisheries. Similarly, participants referred to research in trawl fisheries on batching offal instead of discharging offal continuously, to reduce seabird catch risk. Some participants expressed interest in retaining strategic offal discards by SSLL vessels.
- Determine if using more robust combinations of seabird bycatch mitigation methods would be effective in areas and/or seasons with relatively high densities of seabirds and in areas and seasons when the fleet is at fishing grounds where the seabird species composition has a relatively high proportion of mature albatrosses. This could be designed to use near real-time identification of hotspots using climate, oceanographic and seabird scan count data to support dynamic spatial management of the bycatch of seabirds and other protected species, and/or use models that identify relatively fixed temporally and spatially predicable hotspots during individual ENSO and PDO phases. To inform these two approaches, analyses of observer program data from the DSLL fishery should be updated to identify spatial and seasonal hotspots for seabird catch rates with standardized effort during individual ENSO and PDO phases, and to identify additional potentially significant environmental factors.
- Research how contemporary electronic monitoring (EM) technology can be used to monitor seabird interactions, and whether innovations in EM technology and adaptations to existing technology are needed to conduct accurate seabird scan counts, monitor the use of seabird bycatch mitigation methods during setting and hauling, and enable EM analysts to identify all captured seabirds during the gear haulback.
- Assess the effect of outreach and training activities on fisher behavior, including compliance with prescribed seabird bycatch mitigation methods, handling and release methods, and seabird bycatch rates.
- Conduct audience research with Hawaii longline fishery captain and crew to improve understanding of their priorities, concerns, and motivations related to seabird interactions

and mitigation, and to determine factors affecting their use of seabird bycatch mitigation methods.

- Conduct research and development of new methods for mitigating seabird bycatch, such as using a weather balloon to maintain the desired position of streamer (tori) lines.

7.4 General Participant Feedback on Considerations for Future Modification of Mitigation Measures

- Provide flexibility for fishermen to use mitigation methods that are effective, safe and sustainable for their vessel and characteristics of fishing operations
- Have tools in place to ensure that mitigation measures are implemented as intended when observers are not on board (gear-based measures that do not rely on crew behavior are preferred)
- Identify and address known sources contributing to interaction increases (e.g., captain effect) before requiring changes to the entire fleet
- Consider individual consequences to incentivize compliance with mitigation measures (e.g., notifying vessels/captains of high interactions)
- Conduct a contest, similar to the now dissolved WWF Smart Gear competition, to catalyze the development of new innovative methods to mitigate seabird bycatch that meet the criteria defined in the participant survey/worksheet (Appendix 6).

7.5 Additional Research Needs for Improved Understanding of Interaction Patterns and Trends

- Post-release survival studies to determine what proportion of seabirds that are released alive survive the interaction. The study could shed light on how different handling and release practices affect the probability of post-release survival.
- Analyses of seabird band data from seabirds that are captured by the Hawaii longline fisheries to determine the age, sex and colony of seabirds that interact with the fishery in specific areas, seasons and years.
- Continue demographic research on bycaught seabirds
- Integrate Laysan and black-footed albatross tracking data with longline fishing vessel location data (e.g., from VMS and AIS data) to improve understanding of seabird interactions.

APPENDICES

Appendix 1. Opening Remarks, Kitty Simonds, Executive Director, WPRFMC

I would like to welcome everyone to the Council office for the Workshop to Review Seabird Bycatch Mitigation Measures for the Hawaii Pelagic Longline Fisheries.

The Council began working on seabird bycatch issues in the mid-1990s when mandatory observer coverage for the Hawaii longline fishery started and we began learning more about interactions with black-footed and Laysan albatrosses. Working with the fishermen, we started by encouraging voluntary adoption of mitigation measures that were known to have some promise at the time. Following this initial effort, most longline vessels voluntarily adopted some form of mitigation measure in an effort to keep the albatrosses away from their vessels and gear.

In 1998, the Council convened the Black-Footed Albatross Population Biology Workshop to understand the bycatch impacts to the bird populations. At the same time, the Council also supported a study to test mitigation measures in the Hawaii longline fishery, some of which were measures devised by fishermen. Drawing upon the work we did in the late 1990s and additional research conducted by the Honolulu Laboratory (now PIFSC), we developed a suite of seabird mitigation measures for the Hawaii longline fishery that was first implemented in 2001. These measures included blue-dyed bait, strategic offal discards, towed deterrents, weighted hooks, and night setting. The option to use side setting was added to the mix in 2006.

The measures were successful in reducing interactions by 90% in all of Hawaii longline fishery and 67% in the deep-set longline fishery. These measures implemented in our fishery also became a basis for conservation measures at the Tuna RFMOs, namely the WCPFC and IATTC. For a number of years following the implementation of the seabird measures, our former senior scientist would say “seabirds are *so* 1990s!”

Our seabird story does not end there, and that is why we are convening the workshop today. Over the past decade, we have seen a gradual uptick in albatross interactions over time, with a substantial increase in black-footed albatross interactions since 2015. The Council has been keeping a close watch of recent interaction patterns, and taking proactive steps to understand what is happening. The first of these efforts was our workshop last November to explore the extent to which oceanographic and environmental factors that may be influencing the interactions, the results of which you will be hearing more today.

The second effort is this workshop, to take a closer look at the mitigation measures that we have in place now, and other measures developed or implemented elsewhere, and begin discussions on what improvements we may need for the seabird bycatch mitigation measures not only in the Hawaii longline fishery, but also in the international arena.

I encourage you to keep an open mind, listen and learn, and most importantly, explore ideas new and old, big and small. Your discussions here will help the Council and its advisory bodies decide what the next steps should be to address the recent interaction patterns and to ensure that the Hawaii longline fishery continues to be the gold standard in the Pacific. I wish you a productive meeting and I look forward to seeing the outcomes of the workshop.

Appendix 2. Agenda

Tuesday, September, 18 2018

9:00 – 10:00	
Opening	Kitty Simonds, WPRFMC
Meeting objectives and target outputs	Asuka Ishizaki, WPRFMC
Participants self-introductions	All
10:00 – 10:20	
1. Management Framework	
1.1. Seabird Regulations for the Hawaii Pelagic Longline Deep- and Shallow-set Longline Fisheries (10 minutes)	Sarah Ellgen, PIRO
1.2. WCPFC and IATTC Seabird Bycatch Management Measures (10 minutes)	Valerie Post, PIRO
10:20 – 11:40	
2. Time Series of Estimated Fleetwide Seabird Catch Levels and Rates, Hypothesized Causes of Observed Increasing Temporal Trends in Bycatch Level and Rate	
2.1. Time series of seabird catch levels and rates, including seasonal and spatial patterns/trends (10 minutes)	Asuka Ishizaki, WPFMC
2.2. Risk factors for seabird bycatch in the Hawaii longline deep-set fishery (10 minutes)	Eric Gilman
2.3. Findings from the November 2017 Albatross Workshop (10 minutes)	David Hyrenbach, HPU
10:50 – 11:10 Break	
2.4. Fleet dynamics and oceanographic drivers behind variations in black-footed albatross sightings in the Hawaii longline fishery (10 minutes)	Johanna Wren, PIFSC
2.5. Unique captain effect (10 minutes)	Mark Fitchett, WPRFMC
2.6. Q&A, facilitated discussion (10 minutes)	All
11:40 – 12:00	
3. Seabird Bycatch Mitigation Methods for Pelagic Longline Fisheries During Setting and Hauling - continued	
3.1. Overview of Fact Sheets on seabird bycatch mitigation measures for pelagic longline fisheries & findings from research on seabird bycatch mitigation in Hawaii pelagic longline fisheries (20 minutes)	Eric Gilman

12:00 – 13:30	Lunch	

13:30 – 16:45

3. Seabird Bycatch Mitigation Methods for Pelagic Longline Fisheries During Setting and Hauling - continued

3.2. ACAP Best Practices (20 minutes)	Nathan Walker, ACAP
3.3. Recent discussions at WCPFC and IATTC on possible amendments to seabird measures (10 minutes)	Valerie Post, PIRO
3.4. Facilitated discussion on prioritized seabird bycatch mitigation methods on relative:	All

- Effectiveness (has the method been demonstrated to reduce seabird bycatch rates [e.g., relative to fishing without any seabird bycatch methods, or to close to 0, or below a threshold bycatch rate], under various conditions, demonstrated through an adequate number of studies with adequate sample sizes, with robust study designs, including control or explicitly account for potentially confounding factors)
- Cross-taxa conflicts
- Practicality (how does use of the bycatch mitigation method affect fishing operations, e.g., increase the hook setting rate, cause tangles in the gear during haulback)
- Crew safety
- Economic viability (e.g., effect on target species catch rates, initial and ongoing cost)
- Ability to monitor compliance by dockside inspections, conventional human onboard observers, electronic monitoring, VMS, other methods.
- And see ACAP criteria for identifying best practice bycatch mitigation methods

16:45 – 17:00	Recap Day 1, Review Agenda for Day 2	Facilitator

Wednesday, September 19, 2018

9:00 – 9:15	Recap Day 1, Review Agenda for Day 2	Facilitator

9:15 – 9:45

3. Seabird Bycatch Mitigation Methods for Pelagic Longline Fisheries During Setting and Hauling

3.5. Facilitated discussion, continue from end of Day 1

9:45 – 10:15

4. Captain and crew training and education – Facilitated Discussion

10:15 – 12:00

5. Next Steps – Facilitated Discussion

5.1. Priority seabird bycatch mitigation research (e.g., commercial demonstration of practicality, economic viability; controlled and comparative research, analyses of observer program data) in Hawaii pelagic longline fisheries	All

12:00 – 13:30	Lunch	
13:30 – 15:15		
5. Next Steps – continued		
5.2. Potential options for improving Hawaii pelagic longline seabird mitigation measures (pending results of any new research/demonstrations)		All
15:15 – 15:35	Break	
15:35 – 16:00		
6. Review Meeting Recommendations on priority research and improving mitigation measures		
16:00 – 16:15	Meeting summary and closing	Facilitator

Appendix 3. Participants List and Steering Committee

Table 10. Participant list and steering committee members.

Name	Affiliation
Adam Ayers	NMFS PIFSC Ecosystem Sciences Division
Steve Beverly*	Fresh Island Fish Co Inc.
Chris Boggs	NMFS PIFSC Fisheries Research and Monitoring Division
Colby Brady	NMFS PIRO Sustainable Fisheries Division
Sarah Ellgen*	NMFS PIRO Sustainable Fisheries Division
Mark Fitchett	Western Pacific Regional Fishery Management Council
Eric Gilman*	Fisheries Consultant
David Hyrenbach	Hawaii Pacific University
Asuka Ishizaki*	Western Pacific Regional Fishery Management Council
Mi Ae Kim*	NMFS Office of International Affairs and Seafood Inspection
Eric Kingma	Western Pacific Regional Fishery Management Council
Kirsten Leong	NMFS PIFSC Ecosystem Sciences Division
Sean Martin*	Hawaii Longline Association
Caleb McMahan	Hawaiian Fresh Seafood
Ed Melvin	Washington Sea Grant
Travis Myking	Fisherman
John Peschon	NMFS PIRO Observer Program
Valerie Post*	NMFS PIRO International Fisheries Division
Jen Raynor	NMFS PIFSC Ecosystem Sciences Division
Trevor Ryder	Fisherman
Nathan Walker	Agreement on the Conservation of Albatrosses and Petrels Advisory Committee
John Wang	NMFS PIFSC Fisheries Research and Monitoring Division
Johanna Wren	NMFS PIFSC Ecosystem Sciences Division
Observers	
Emily Crigler	NMFS PIRO International Fisheries Division
Facilitation & Meeting Support	
Michelle Gorham	Facilitator
Thomas Remington	Council Contractor

* Steering Committee Member
NMFS = National Marine Fisheries Service
PIRO = Pacific Islands Regional Office
PIFSC = Pacific Islands Fisheries Science Center

Appendix 4. Summary of Findings of Seabird Bycatch Research in Hawaii Pelagic Longline Fisheries

Eric Gilman, Pelagic Ecosystems Research Group

This review, commissioned by the Western Pacific Regional Fishery Management Council, summarizes research conducted in the Hawaii pelagic longline fisheries on the effects of fishing methods and gear on seabird catch rates. Section 1 summarizes relevant research findings through an annotated bibliography, while Section 2 summarizes findings by individual gear technology bycatch mitigation method.

Several gear technology seabird bycatch methods have not undergone research in the Hawaii longline fisheries, including a bait caster, underwater-setting bait capsule, bait species, live v. dead bait, degree of thawing bait, hook threading practices, automatic branchline coiler, fish oil, hook shielding devices, lasers, mainline line shooter, sliding branchline weights, paired bird-scaring *tori* lines, and water cannon/fire hose. Other approaches to mitigating unwanted bycatch that do not involve changes in fishing methods and gear, including traditional input and output controls (i.e., restrictions on catch and effort), compensatory mitigation (offsets), fleet communication, avoiding the generation of derelict gear and mitigating ghost fishing efficiency, and handling and release practices (FAO, 2010) were outside the scope of this review. Also, while in Section 2 we review the methods individually, it is important to clarify that combinations of individual methods are prescribed, in Hawaii and elsewhere, to obtain desired bycatch rate reduction efficacy.

1. ANNOTATED BIBLIOGRAPHY

1.1 Hawaii Longline Seabird Mortality Mitigation Project (McNamara et al., 1999)

A controlled experiment was conducted to assess the seabird bycatch mitigation efficacy of bird-scaring *tori* lines, towed buoys, management of offal (retention vs. 'strategic' discharging on the opposite side of the vessel from where baited hooks enter and leave the water), blue-dyed bait and night setting.

The authors conclude that, of the six methods, blue-dyed bait, followed by strategic offal discards, were most effective at reducing seabird contacts with fishing gear during setting, while during gear haulback, blue-dyed bait and tori lines were the most effective at reducing seabird contact with gear, followed by towed buoys.

During setting, for shallow-sets, except for the treatment of retention of offal, the other experiment treatments resulted in significantly lower mortality rates (number of dead seabirds per number of seabirds attending the vessel per 1000 hooks) than the control treatment. Results were not presented comparing catch per unit of effort standardized by seabird abundance.

During setting, for deep-sets, the control treatment rate of seabird "attempts to pick up baited hooks" per seabird per 1000 hooks was 10.7, and was 0.8, 4.3, 0 and 0 for treatments using tori lines, no offal discards, blue-dyed fish bait and towed buoys, respectively. For shallow sets, there were 76.7 attempts per seabird per 1000 hooks with the control treatment, and 47.1, 29.4, 39.3 and 37.1 attempts per seabird per 1000 hooks for treatments with tori lines, strategic offal discards, blue-dyed squid bait and towed buoys, respectively.

During sets, for shallow-sets, the control treatment had 33 seabird contacts with gear per seabird per 1000 hooks, and 47.1, 39.3, 37.1 and 29.4 using tori lines, blue-dyed squid bait, towed buoys and strategic offal discards, respectively. During shallow sets, dyed bait reduced the seabird contact rate by 77% compared to the control, while strategic offal discards, tori lines and towed buoys all reduced the rate by about 52%. Only a single bird contact with gear was observed during deep-set fishing.

During shallow-set gear haulback, for the control treatment there were 16 attempts per seabird per 1000 hooks, and 25.5, 5.2, 2.0 and 1.2 attempts per seabird per 1000 hooks for no offal discards, blue-dyed squid bait, towed buoy and tori line, respectively. Expressed as contacts per seabird per 1000 hooks, the control treatment contact rate was 1, and was 1.3, 0.2, 0.1 and 0.1 for no offal discards, towed buoy, blue-dyed bait and tori line, respectively. While no offal discards increased the contact rate by 15%, dyed bait, tori line and towed buoy reduced the contact rate by 93%, 93% and 85%, respectively. An assessment of bycatch measures during hauling was not conducted for deep sets.

1.2 Deterring albatrosses from contacting baits during swordfish longline sets (Boggs, 2001)

A controlled experiment was conducted to assess the seabird contact mitigation efficacy of bird-scaring *tori* lines, branchline weighting, and thawed and blue-dyed bait during setting in the Hawaii shallow-set longline fishery. Blue-dyed and thawed squid bait and baits with 60 g weights attached both reduced the number of albatross contacts with baits by about 90% compared to the control treatment. *Tori* lines reduced albatross contacts with baits by about 70%. There was no significant difference in albatross contact rates between the three experimental treatments.

1.3 Performance assessment of an underwater setting chute to mitigate seabird bycatch in the Hawaii pelagic longline tuna fishery (Gilman et al., 2003)

A controlled experiment of an underwater setting chute during Hawaii pelagic longline deep-setting found that setting with the chute reduced the albatross contact rate (number of seabird contacts per number of albatrosses within 137 m of the vessel during setting per 1000 hooks) by 95%. There were no seabird captures when setting with the chute (4,966 hooks were set with the chute), while the control treatment seabird catch rate was 0.114 captures per albatross per 1000 hooks (5,077 hooks were observed under the control treatment). Setting with the chute also increased bait retention. The chute used in the trial was 9 m long, and 5.4 m of the chute's shaft was submerged when deployed from the vessel used for the research.

1.4 Comparison of the efficacy of three seabird bycatch avoidance methods in Hawaii pelagic longline fisheries (Gilman et al., 2007)

A comparative experiment of three seabird bycatch mitigation methods was conducted in the Hawaii pelagic longline fishery using shallow- and deep-sets. Side setting with a bird curtain resulted in the lowest seabird catch rates for both shallow- and deep-set fishing. A 9 m length chute (same design as employed in Gilman et al. [2003]) was the second most effective seabird bycatch mitigation method during shallow sets, while a 6.5 m length chute was the second most effective method during deep sets. Blue-dyed bait was the third most effective method in both shallow and deep sets. Engineering issues occurred with both chutes during the latter trial - the longer chute fractured and bent, and branchlines periodically jammed inside the chutes

1.5 Reducing seabird bycatch in the Hawaii longline tuna fishery (Gilman et al., 2008)

With fishing effort standardized to explicitly account for the time of day of the start of sets, season and location, there was a 67% reduction in the seabird catch rate since seabird bycatch mitigation methods become compulsory for use in the Hawaii pelagic longline deep-set fishery. Seabird catch rates were highest during the first quarter of the year, and lowest in the fourth quarter. Catch rates significantly increased as the time of day of starting sets increased. Highest seabird catch rates occurred in the northwestern area of fishing grounds at ca. 25°N, 170°W.

Side-setting with 45 g weights located within 1 m of the hook resulted in a seabird catch rate with standardized effort that was 40% lower than the pre-regulation seabird catch rate. No seabirds were caught in sets employing the combination of side-setting with 60 g weights located within 1 m of the hook. Stern setting with 45 g weights located within 1 m of the hook resulted in a seabird catch rate with standardized effort 60% lower, and stern setting with 60 g weights located within 1 m of the hook 41% lower than the pre-regulation seabird catch rate. There was no significant difference in seabird catch rates between the 3 categories of sets where birds were caught.

During the period since seabird regulations first came into effect, with effort standardized for the time of starting setting, season, location, side- vs. stern-setting, and blue-dyed vs. untreated bait, sets with 60 g weights within 1 m of the hook had 63% significantly lower seabird catch rates than sets with 45 g weights within 1 m of the hook.

1.6 Seabird Interaction Rates in the Hawaii-based Shallow and Deep-set Longline Fisheries as Estimated from Observer Data (2004-2013) (Bigelow, 2014)

Seabird catch rates for vessels < 24 m and ≥ 24 m length for the Hawaii pelagic longline fisheries were disaggregated by fishery (shallow- and deep-set) and by latitude for the deep-set fishery (north vs. south of 23° N. latitude). Seabird catch rates for the two length classes were similar for both fisheries and areas. Findings suggest that the single factor vessel size does not significantly explain seabird catch risk.

1.7 Mitigating seabird bycatch during hauling by pelagic longline vessels (Gilman et al., 2014)

Observer data from the Hawaii shallow-set pelagic longline fishery were fit to a generalized additive regression model with mixed effects to determine the significance of the effect of various factors on the standardized seabird haul catch rate. The haul catch rate significantly increased with increased albatross density during hauling. Catch rate was significantly higher the longer the leader. There was a significant linear increasing temporal trend in seabird haul catch rate, possibly partly due to an observed increasing temporal trend in the number of albatrosses attending vessels during hauling. Swivel weight, Beaufort scale and season were also significant but smaller model effects. Regarding season, the seabird haul catch rate with standardized effort was significantly highest from January through March (first quarter of the year) and significantly lowest from July through September (third quarter). Most (81%) haul captures were on branchlines actively being retrieved. The authors recommend that future haul mitigation research focus on reducing bird access to hooks as crew coil branchlines, including shorter leaders and heavier swivels, and other potentially effective methods, including faster branchline coiling and shielding the area where hooks becomes accessible. The proportion of Laysan albatross (*Phoebastria immutabilis*) haul captures was significantly, 1.6 times, higher than for black-footed albatrosses (*P. nigripes*), perhaps due to differences in the time of day of foraging and in daytime scavenging competitiveness.

1.8 Risk factors for seabird bycatch in a pelagic longline tuna fishery (Gilman et al., 2016)

Observer data from the Hawaii deep-set pelagic longline fishery were modelled using a spatio-temporal generalized additive mixed model with zero-inflated Poisson likelihood to determine the significance of the effect of various risk factors on the seabird catch rate. The seabird catch rate significantly increased as annual mean multivariate ENSO index values increased, suggesting that decreasing ocean productivity observed in recent years in the central north Pacific may have contributed to the increasing trend in nominal seabird catch rate. A significant increasing trend in number of albatrosses attending vessels, possibly linked to declining regional ocean productivity and increasing absolute abundance of black-footed albatrosses, may also have contributed to the increasing nominal seabird catch rate. Largest opportunities for reductions are through augmented efficacy of seabird bycatch mitigation north of 23° N where mitigation methods are required and during setting instead of during hauling. Both side vs. stern setting, and blue-dyed vs. untreated bait significantly reduced the seabird catch rate. Of two options for meeting regulatory requirements, the regulatory suite of measures that includes side setting had a significantly lower seabird catch rate than regulatory suite of measures that includes blue-dyed bait. There was significant spatio-temporal and seasonal variation in the risk of seabird capture with highest catch rates in April and May and to the northwest of the main Hawaiian Islands. There was no significant difference in albatross catch rates between wider circle and narrower J-shaped hooks.

1.9 Captain and Observer Perspectives on the Commercial Viability and Efficacy of Alternative Methods to Reduce Seabird Bycatch during Gear Haulback in the Hawaii-based Pelagic Longline Swordfish Fishery (Gilman and Musyl, 2017)

A survey of captains of the Hawaii shallow-set pelagic longline fishery obtained information on expected practicality, safety, economic viability and efficacy of eight candidate methods for mitigating seabird bycatch during gear haulback. Captains identified a bird curtain, towed buoy, and optimizing crew branchline coiling rates as holding the most promise based on the various criteria. Reducing leader lengths (to place weighted swivels closer to the hook) was not deemed to be safe. Adjusting the current position of crew who are coiling branchlines was considered to not be possible. Captains did not predict that use of a water spraying device during hauling would be effective at reducing seabird haul bycatch rates.

A demonstration of a bird curtain used during gear haulback during three shallow-set trips was conducted. The pole was designed to swing ca. 4 m side-to-side when deployed. Overall, the device was perceived by the captain and crew to be practical for use, economically viable, safe for use, and effective at keeping seabirds out of the area where baited hooks come to the sea surface during gear haulback. The captain and crew recommended modifying the curtain design, including the material of the sleeves covering the streamers, and the length of the streamers, in order to reduce the risk of hook entanglement and increase durability. The bird curtain streamers tangled with branchlines 9 times during the trial while crew were coiling branchlines. This occurred when the vessel made sharp turns during gear retrieval. Positioning the bird curtain at about a 30 degree angle off the starboard side instead of directly perpendicular to the vessel stern, was found to reduce entanglement risk. Overall, accounting for the gear entanglement, and time to deploy and retrieve the bird curtain, because the bird curtain seems to have reduced the incidence of bird captures, reducing the amount of time crew have to spend dealing with caught birds, the captain reported that he found using the curtain to make gear hauling more efficient.

2 SUMMARY OF RESEARCH FINDINGS BY BYCATCH MITIGATION METHOD

Table 11 summarizes findings of research on seabird bycatch mitigation methods conducted in Hawaii’s pelagic longline fisheries, organized by mitigation method.

Table 11. Research findings from studies on seabird bycatch mitigation in Hawaii pelagic longline fisheries.

Seabird bycatch mitigation measure	Mitigate bycatch during set, haul?	Citations	Findings on Efficacy	Other Findings (Practicality, Safety, Economic Viability)
Bird curtain	Both	Gilman et al., 2007	Research has been conducted in Hawaii pelagic longline deep- and shallow-set fisheries on the combination of side setting, a bird curtain and 45 g weights within 1 m of the hook, summarized under "side setting". The single factor effect of bird curtain use during setting has not been assessed in Hawaii or other pelagic longline fisheries.	None reported.
		Gilman and Musyl, 2017	A demonstration of a bird curtain during gear hauback on a Hawaii longline vessel conducting shallow-sets was conducted in 2016-17. The pole was designed to swing ca. 4 m side-to-side when deployed. The captain and crew perceived the bird curtain was effective at keeping seabirds out of the area where baited hooks come to the sea surface during gear haulback.	The captain and crew perceived the bird curtain to be practical, economically viable, and safe for use. The captain made recommendations to modify the curtain design, including the material of the sleeves covering the streamers, and the length of the streamers, in order to reduce the risk of hook entanglement and increase durability.
Bird-scaring *tori* line / streamer line	Both	McNamara et al., 1999	A controlled experiment found that *tori* lines resulted in lower attempt rate (no. of seabird attempts to pick up baited hooks per seabird per 1000 hooks) and contact rate (no. of seabird contacts with gear per seabird per 1000 hooks) than a control treatment in the Hawaii longline shallow- and deep-set fishery. *Tori* lines also resulted in lower attempt and contact rates during hauling in shallow-sets.	Captain and crew had to continuously monitor and maintain the tori line's position to ensure it covered baited hooks but was not too close to the fishing gear, which could result in entanglement. Towing the tori line compromised vessel maneuverability. Changes in vessel heading sometimes resulted in tori line entanglement with gear. Crew safety issues occurred when the tori line became entangled with gear, extreme stresses periodically resulted in broken tori poles, back-spooling of mainline onto the deck, and broken mainlines. These conditions were more serious at night when entanglements might not be detected until something broke. Cost for the tori line was $1,165. Compliance monitoring requires at-sea coverage.

		Boggs, 2001	A controlled experiment using Hawaii pelagic longline shallow-set gear and methods found that tori lines reduced albatross contacts with baits by about 70%.	None reported.
Branchline weighting	Both	Boggs, 2001	A controlled experiment using Hawaii pelagic longline shallow-set gear and methods found that attaching a 60 g weight to the bait reduced albatross contacts with baits by about 90% relative to control fishing with a 60 g weight located 3.7 m from the hook.	None reported.
		Gilman et al., 2008	Based on analyses of observer program data from the Hawaii deep-set longline fishery, during the period since seabird regulations first came into effect, with effort standardized for the time of starting setting, season, location, side- vs. stern-setting, and blue-dyed vs. untreated bait, sets with 60 g weights within 1 m of the hook had 63% significantly lower seabird catch rates than sets with 45 g weights within 1 m of the hook. Stern setting with 45 g weights located within 1 m of the hook resulted in a seabird catch rate 60% lower, and stern setting with 60 g weights located within 1 m of the hook 41% lower than the pre-regulation seabird catch rate.	Branchline weighting (≥ 45 g within 1 m of the hook) is a conventional practice by the Hawaii deep-set pelagic longline fishery.
		Gilman et al., 2014	Modeling observer program haul data from the Hawaii shallow-set pelagic longline fishery found that the seabird haul catch rate with standardized effort significantly declined the closer weights were to the hook and the larger the weight amount.	None reported

Dyed bait	Both	McNamara et al., 1999	A controlled experiment found that blue-dyed and thawed bait resulted in lower attempt rate (no. of seabird attempts to pick up baited hooks per seabird per 1000 hooks) and contact rate (no. of seabird contacts with gear per seabird per 1000 hooks) than a control treatment in the Hawaii longline shallow- and deep-set fisheries (squid bait in the shallow-set fishery, fish bait in the deep-set fishery). Blue-dyed bait also resulted in lower attempt and contact rates during hauling in shallow-sets.	Dyeing bait required preliminary preparation of the dye solution, and thawing and separating baits prior to immersion in the blue dye solution. Crew handling due and baits used leak-proof gloves. Additional clean-up time was required, but the dye is water soluble and easily removed. Crew safety issues were minimal, the only concern being to mix the dye in a place with minimal wind to avoid having the powder blow into eyes. The cost for 1 container of Virginia Dare FDC No. 1 blue food dye was \$53.20, which provides enough dye for 1,000 baits. The cost would be less if purchasing dye by the case. A large bucket used for the dye container costs about \$35, and a mesh basket that is put inside the bucket costs about \$7. Compliance monitoring require at-sea coverage to ensure that fishers dye the bait to the prescribed darkness, unless pre-dyed bait were available.
		Boggs, 2001	A controlled experiment using Hawaii pelagic longline shallow-set gear and methods found that blue-dyed and thawed squid bait reduced albatross contacts with baits by about 90%.	Blue-dyed bait could be safe, inexpensive and convenient to use. The cost of the food color used to dye the bait in this study was about USD \$1 US per 100 squid.

		Gilman et al., 2007	A comparative experiment found that blue-dyed fish bait had a lower seabird catch rate than a 9 m length underwater setting chute during Hawaii longline deep-sets, however, engineering problems occurred with the chute during the trial. Blue-dyed fish bait had a higher seabird catch rate than a 6.5 m length chute and side setting with a bird curtain during deep sets. In Hawaii longline shallow sets, blue dyed fish bait had a higher seabird catch rate than a 9 m length chute and side setting with a bird curtain.	Blue-dyed bait was impractical due to the amount of time required for crew to dye the bait, and the need to fully thaw bait, which increases bait loss from hooks and precludes retaining bait quality if a set is cut short. These inconveniences could be eliminated if pre-dyed bait were used.
		Gilman et al., 2016	Modeling observer program data from the Hawaii deep-set pelagic longline fishery found that the seabird catch rate with standardized effort was significantly lower when using blue-dyed vs. untreated fish bait, and that the regulatory suite of measures that includes side setting had a significantly lower seabird catch rate than the suite of measures that includes blue-dyed bait.	None reported.
Hook shape/size	Both	Gilman et al., 2016	There was no significant difference in albatross catch rates between wider circle and narrower J-shaped hooks.	None reported.
Offal management	Both	McNamara et al., 1999	A controlled experiment found that 'strategic' offal discharging on the opposite side of the vessel from where baited hooks enter the water resulted in lower attempt rate (no. of seabird attempts to pick up baited hooks per seabird per 1000 hooks) and contact rate (no. of seabird contacts with gear per seabird per 1000 hooks) than a control treatment in the Hawaii longline shallow- and deep-set fishery. Not discharging offal during setting or hauling resulted in higher attempt and contact rates during setting in shallow and deep sets.	Retention of offal can result in large quantities stored on deck over the course of a haul, which could lead to safety issues. Some extra effort is required to retain, move and store offal and bycatch. The smell from the retained offal is unpleasant. Strategic offal discharging requires retaining and preparing the offal from hauls to be used on sets. It also requires a crew member to monitor the approaching seabirds and discard the offal at the appropriate times, which can reduce manpower for fishing activities.

Side setting	Set	Gilman et al., 2007	Research in Hawaii pelagic longline deep- and shallow-set fisheries found the combination of side setting with a bird curtain produced significantly lower seabird bycatch rates than blue dyed bait, an underwater setting chute and a control treatment of fishing methods and gear employed during the period prior to seabird regulations. The single factor effect of side setting without a bird curtain has not been assessed.	Side setting provides large operational benefits. It eliminates the need to move gear and bait between separate setting and hauling work stations, and increases available deck space by condensing the gear storage area. There is no cost associated with side setting after the initial expense of converting the vessel deck design, which costs about USD $1,000. There were no incidences of gear being fouled in the propeller while side-setting, even when the captain turned the vessel hard to port and starboard to purposely attempt to foul the gear.
		Gilman et al., 2008	Analyses of observer program data from the Hawaii deep-set longline fishery, during the period since seabird regulations first came into effect, with effort standardized for several significant variables, found that side-setting with 45 g weights located within 1 m of the hook resulted in a seabird catch rate with standardized effort that was 40% lower than the pre-regulation seabird catch rate. No seabirds were caught in sets employing the combination of side-setting with 60 g weights located within 1 m of the hook.	When fishing in areas where employment of seabird bycatch mitigation measures is not required, Hawaii deep-set longline vessels, side setting was voluntarily used more frequently than blue-dyed bait.
		Gilman et al., 2016	Modeling observer program data from the Hawaii deep-set pelagic longline fishery found that the seabird catch rate with standardized effort was significantly lower when side vs. stern setting, and that the regulatory suite of measures that includes side setting had a significantly lower seabird catch rate than the suite of measures that includes blue-dyed bait.	None reported.

		McNamara et al., 1999	A controlled experiment found that night setting resulted in a significant 73% lower seabird mortality rate (number of dead seabirds per number of seabirds attending the vessel per 1000 hooks) than a control treatment in the Hawaii longline shallow-set fishery.	Reduces available setting options with regard to time-of-day and moon phase. Safety concerns are minimal, since the majority of most swordfish sets conventionally occur in the dark.
Spatial and temporal measures	Both	Gilman et al., 2008, 2016	Analyses of observer program data from the Hawaii deep-set longline fishery, with effort standardized for several significant variables, found that seabird catch rates significantly increased as the time of day of starting sets increased, and highest seabird catch rates occurred in the northwestern area of fishing grounds at ca. 25°N, 170°W. Seabird catch rates were highest during the first half of the year from January through May, and were lowest in the fourth quarter.	None reported.
		Gilman et al., 2014	Modeling observer program haul data from the Hawaii shallow-set pelagic longline fishery found that the seabird haul catch rate with standardized effort was significantly highest from January through March (first quarter of the year) and significantly lowest from July through September (third quarter).	None reported.
Towed buoy	Both	McNamara et al., 1999	A controlled experiment found that towed buoys resulted in lower attempt rate (no. of seabird attempts to pick up baited hooks per seabird per 1000 hooks) and contact rate (no. of seabird contacts with gear per seabird per 1000 hooks) than a control treatment in the Hawaii longline shallow- and deep-set fishery. Towed buoys also resulted in lower attempt and contact rates during hauling in shallow-sets.	The towed buoy had to be constantly monitored by crew because the buoys were at risk of entangling with the longline floats. Same issues as described for the tori line. Crew safety was an issue if the towed buoy became entangled with the gear, extreme stresses resulted in broken attachment poles, back-spooling of mainline onto the deck, and broken mainlines. This was more serious at night when entanglement might not be detected until something broke. Cost was was $1,165.

Underwater setting chute	Set	Gilman et al., 2003	A controlled experiment of an underwater setting chute during Hawaii pelagic longline deep-setting found that setting with the chute reduced the albatross contact rate (number of seabird contacts per number of albatrosses within 137 m of the vessel during setting per 1000 hooks) by 95%. There were no seabird captures when setting with the chute (4,966 hooks were set with the chute), while the control treatment seabird catch rate was 0.114 captures per albatross per 1000 hooks (5,077 hooks were observed under the control treatment). Setting with the chute also increased bait retention. The chute used in the trial was 9 m long, and 5.4 m of the chute's shaft was submerged when deployed from the vessel used for the research.	The chute increased fishing efficiency by increasing bait retention on hooks but decreased efficiency by increasing crew hook setting rate. The cost for purchasing and installing the chute would be recouped after a maximum of two fishing trips. Fishers identified several desirable design and installation improvements. The trough design and placement made it difficult to set branchlines. Crew had difficulty sliding the chute across the rail. It created a safety issue by increasing the incidence of branchline tangles when crew prematurely grasped the mainline in anticipation of clipping on branchlines. The effort required to deploy and retract the chute was inconvenient.
		Gilman et al., 2007	A comparative experiment trialed the original 9 m length chute and a shorter 6.5 m length chute, which when deployed had 5.4 m and 2.9 m of the shaft underwater, respectively. The chutes were more effective at mitigating seabird catch rates than blue dyed bait, but less effective than side setting in both shallow and deep sets.	Design problems were experienced with the two chutes. The longer chute fractured and bent at a welding joint.

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Appendix 5. Fact Sheets on Seabird Bycatch Mitigation Methods for Pelagic Longline Fisheries

1. Introduction

The following Fact Sheets on seabird bycatch methods for use during setting and/or hauling by pelagic longline vessels are included in this appendix, which were written by Eric Gilman as background material for the workshop:

- Bait species
- Thawed vs. frozen bait
- Live vs. dead bait
- Hook threading
- Baits with swim bladders
- Bird curtain
- Branchline coiler
- Fish and vegetable oil
- Lasers
- Artificial bait
- Hook shape (circle vs. J-shaped)
- Hook minimum width
- Hook shielding devices
- Sliding branchline weights
- Towed buoy
- Underwater setting devices
- Water cannon

The following additional Fact Sheets by BirdLife International are available online at https://www.birdlife.org/bycatch:

- Night setting
- Streamer (tori) lines for vessels ≥ 35 m
- Streamer (tori) lines for vessels ≤ 35 m
- Branchline weighting
- Side setting
- Blue-dyed bait
- Bait caster and line shooter
- Haul mitigation methods

2 Treatment of Bait Other than Dyeing Blue

2.1 Bait Species

Li et al. (2012) found a significantly higher seabird catch rate on mackerel bait than squid bait. Small fish species and squid species had similar and non-significantly different sink rates during an at-sea trial, but squid had a significantly slower sink rate than fish bait in a tank trial (Robertson and van den Hoff, 2010).

2.2 Thawed vs. Frozen

Thawed bait has a faster sink rate than frozen bait, however, fishers do not set baited hooks with the bait fully frozen (as it is not possible to thread a frozen bait onto a hook), and the difference in sink rates between partially and fully thawed bait may have no significant effect on seabird catch risk.

Fisher prefer to use partially thawed instead of fully thawed bait as fully thawed bait has a higher tendency to fall off of hooks, and precludes retaining bait quality if a set is cut short, and are more difficult (slippery) for crew to handle (Gilman et al., 2007; Robertson and van den Hoff, 2010).

Brothers et al. (1995, 1999a) observed significantly higher seabird catch rates on frozen than fully thawed bait in a Japanese pelagic longline tuna fishery operating in the Australia exclusive economic zone. Robertson and van den Hoff (2010) conducted a tank trial and found small but significant differences between partially and fully thawed fish bait, and between partially and fully thawed squid bait, with fully thawed fish bait having a faster sink rate than partially thawed fish bait, and partially thawed squid having a faster sink rate than fully thawed squid. Partially thawed squid was hypothesized by the authors to have a faster sink rate than fully thawed squid because the stiffer body of the former squid bait had a more linear sink profile. Robertson and van den Hoff (2010) found no significant differences in sink rates between frozen, partially- and fully-thawed fish bait, and between these three conditions for squid bait, when 60 g weights were attached 0.2 m from the hook.

2.3 Live vs. Dead Bait

Live bait may swim towards the sea surface after baited hooks are deployed, increasing seabird catch risk. Seabird catch rates have been observed to be higher on live vs. dead fish bait (Trebilco et al., 2010). Live bait has been found to have a slower sink rate than dead bait (Robertson et al., 2010).

2.4 Hook Threading

Bait hooked in the head or tail may have a faster sink rate than when hooked in the center of their body (Robertson and van den Hoff, 2010).

2.5 Swim Bladder

If species of fish with swim bladders are used for bait, bait with bladders that are not punctured can have a slower sink rate than when punctured (Brothers et al., 1999b).

2.6 References

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3 Bird Curtain

A bird curtain is a pole with streamers attached, which can be deployed during setting or hauling to attempt to reduce the risk of catching seabirds.

The seabird regulations for Hawaii pelagic longline fisheries include as part of one suite of measures the use of a bird curtain when side setting. The designed used in Hawaii during setting, shown in Fig. 4 and Fig. 5, was developed by Nigel Brothers (Brothers and Gilman, 2006; Gilman et al., 2007; NMFS, 2005, 2018). The mechanism for efficacy of the bird curtain used during setting has been hypothesized to be due to the curtain preventing scavenging seabirds from getting into a flight pattern that brings them close to the vessel hull where they might have access to baited hooks during setting, and to protect baited hooks when a tote tangle occurs or if crew inadvertently throw baited hooks away from the protection of the vessel hull (Brothers and Gilman, 2006; Gilman et al., 2008, 2016). The cost for materials to construct the Hawaii bird curtain for use during setting and for installation was about USD $200 (Brothers and Gilman, 2006).

Research in the Hawaii longline fisheries has demonstrated the efficacy of a combination of seabird bycatch mitigation methods that included a bird curtain (e.g., Gilman et al., 2016); the single factor effect of a bird curtain during setting, however, has not been assessed.

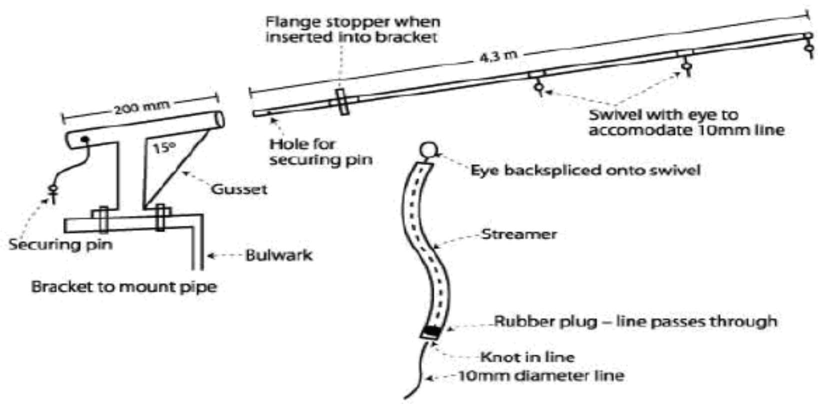

Fig. 4. Schematic of a bird curtain design developed by Nigel Brothers and adopted in US regulations for use during side setting in the Hawaii longline fisheries (Brothers and Gilman, 2006).

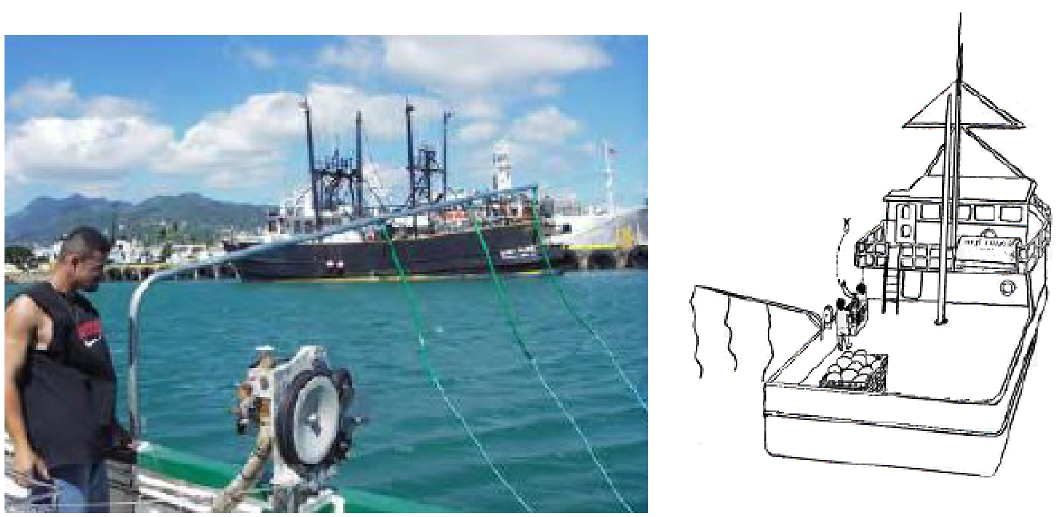

Fig. 5. A bird curtain for use during side setting in the deployed position (from Brothers and Gilman, 2006).

A demonstration of a bird curtain during gear hauback on a Hawaii longline vessel conducting shallow-sets was conducted in 2016-17 (Fig. 6) (Gilman and Musyl, 2017). The pole was designed to swing ca. 4 m side-to-side when deployed. Overall, the bird curtain was perceived by the captain and crew to be practical for use, economically viable, safe for use, and effective at keeping seabirds out of the area where baited hooks come to the sea surface during gear haulback. The captain recommended modifications to the curtain design, including to the material of the sleeves covering the streamers, and the length of the streamers so that they drag on the sea surface in the absence of wind, in order to reduce the risk of hook entanglement and increase durability.

Fig. 6. Bird curtain used during gear haulback in a Hawaii pelagic longline fishery (from Gilman and Musyl, 2017).

Melvin and Walker (2008) describe a bird curtain used during hauling by a Japanese pelagic longline vessel operating in New Zealand waters. The bird curtain was made of two bamboo booms extending horizontally from the vessel, with ropes used as streamers of lengths so that the ends almost reached the sea surface. Pierre (2018) describes a similar bird curtain used by Japanese pelagic longline vessels in New Zealand waters.

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4 Automatic Branchline Coiler / Hauler

An automatic electric branchline coiler (known as snood pullers for demersal longline vessels) may take less time for crew to retrieve branchlines relative to manual retrieval, and hence reduce the time that baited hooks are available to scavenging seabirds (BirdLife International, 2014; Gilman and Musyl, 2017). However, these devices may not be practical for use with modern pelagic longline gear: “Automatic coilers were historically used in the Hawaii longline fishery when traditional basket-style gear with tarred rope was used, before transitioning to monofilament gear. With the modern gear, manual coiling into bins may be more efficient and be less likely to result in branchline tangles during setting than using automatic coilers,” (Jim Cook, Hawaii Longline Association, personal communication, 15 Nov. 2012, from Gilman and Musyl, 2017).

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5 Fish and Vegetable Oil

Research has been conducted on the effect of dispersing fish and vegetable oils on the sea surface on seabird bycatch in demersal longline fisheries, finding that efficacy varied by seabird species assemblages (Pierre and Norden, 2005, 2006; Norden and Pierre, 2007). Study periods were too short to test whether habituation to the fish oil occurs. Research has found that exposure to fish oil disrupted feather microstructure, causing the feathers to absorb water and oil, suggesting that seabirds that come into contact with slicks of fish oil will have compromised waterproofing (Morandin and O'Hara, 2014). There have been no studies of the efficacy of fish oil at mitigating seabird bycatch in pelagic longline fisheries.

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6 Lasers

No peer reviewed publications were identified that assessed the efficacy and safety of laser technology to mitigate seabird bycatch.

A device manufactured by Mustad and Save Wave, called the Seabird Saver, uses both a laser and acoustic deterrent to mitigate seabird bycatch on pelagic longline vessels (Department of Conservation, 2014).

Preliminary research using lasers in a North Pacific trawl fishery did not detect a response by seabirds during the daytime, and there were species-specific reactions to laser use at night (Melvin et al. 2016).

Research is required to investigate the safety to seabirds and fishers from the use of lasers.

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7 Artificial Bait

Studies in demersal longline fisheries have found artificial baits promising at maintaining viable catch rates of target species and sizes while reducing catch rates of unwanted bycatch species and sizes of target species (Lokkeborg, 1990; Erickson et al., 2000; Erickson and Berkeley, 2008). Most recently, Cortes and Gonzalez-Solis (2018) found that an artificial bait manufactured by Arom Bait, which was a "mix of products derived from fish", reduced target species catch rates by 77% in a hake demersal longline fishery. A trial of artificial bait in pelagic longline fisheries, which used a polyurethane mold stuffed with fish pulp, found that the artificial bait avoided unwanted capture of pelagic stingrays and dolphinfish but also reduced target species catch rates (Bach et al., 2012).

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8 Hook Shape and Minimum Width

No studies were identified that assessed the single factor effects of hook shape or hook size on seabird catch rates. Four studies assessed effects of pelagic longline hook shape and size on seabird catch risk. Two studies observed that wider circle hooks had lower seabird catch rates than narrower J-shaped hooks (Hata 2006; Li et al. 2012). Two other studies found no significant difference in albatross catch rates between wider circle and narrower J-shaped hooks (Domingo et al. 2012; Gilman et al. 2016).

Small differences in hook minimum width will likely have no effect on the ability of albatrosses, large petrels and other large species of seabirds that are susceptible to capture in pelagic longline fisheries to ingest the hooks, but might affect the catch risk of smaller seabird species. Because larger hooks are likely heavier than smaller hooks, heavier hooks may have a faster sink rate during setting, and may make baited hooks less likely to become available at the sea surface during haulback, reducing seabird catch risk (Gilman et al. 2016).

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9 Hook Shielding Devices

Hook shielding devices are a seabird bycatch mitigation method for longline fisheries that encase the point and barb of baited hooks to prevent seabird hooking during line setting. The devices are intended to detach from the baited hooks when the hook reaches a threshold depth where seabirds that are susceptible to capture in longline fisheries cannot reach them.

In 2016 the Agreement on the Conservation of Albatrosses and Petrels (ACAP) recognized hook-shielding devices as a best practice and stand-alone seabird mitigation option (ACAP, 2017).

There are two commercially available hook shielding devices. The following is an excerpt from Debski et al. (2018) describing the Hookpod:

> "The Hookpod is a polycarbonate capsule that is attached to each individual branchline using a simple locking collar mechanism that grips the monofilament at any desired distance from the hook. During line setting operations the baited hook is loaded into the Hookpod to encase the point and bard [barb] of the hook, preventing seabirds from becoming hooked as they scavenge for baits at the stern of vessels. The device encompasses a pressure release system that opens the Hookpod and releases the baited hook at a predetermined depth while the Hookpod remains attached to the snood. During hauling, the Hookpod, still attached to the branchline in an open state, is recovered and rearmed by closing it by hand."

There are two Hookpod models available, a larger unit with an LED light, and a Hookpod-mini, which lacks the LED light and is 25% lighter than the larger unit (Fig. 7) (Debski et al., 2018). Hookpods cost US $6.50 each, with up to a 20% reduction for bulk orders (Debski et al., 2018).

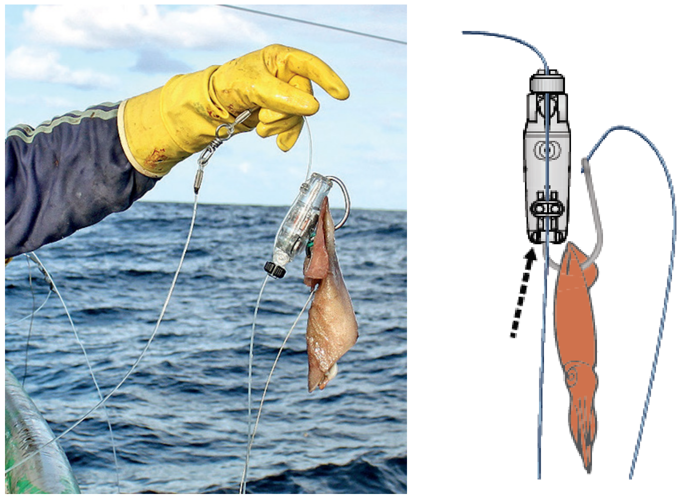

Fig. 7. Hookpod attached to a baited pelagic longline hook (from https://www.hookpod.com/, 7 Aug. 2018).

Results from two completed experiments of the Hookpod are available (as of Sept. 2018). Sullivan et al. (2017) reports the findings from data pooled from controlled experiments of the Hookpod during18 at-sea trials conducted on pelagic longliners in South African, Brazilian and Australian fisheries. They found that branchlines with the Hookpod had 1 mortality in 27,692 hooks, a seabird mortality rate of 0.04 mortalities/1000 hooks, compared to 24 mortalities in 31,438 control hooks or a mortality rate of 0.8 mortalities /1000 hooks. Branchlines with the hookpod have 65 g at the hook, while the control had 60 to 80 g weights within 2-7 m from the hook, so in addition to protecting the hook point and barb, the experimental treatment also alters (likely increases) the baited hook sink rate relative to the control. Information was not provided comparing seabird catch rates (total birds captured, alive and dead) between the hookpod and control treatments. Estimate of variance between the seabird mortality rates of the hookpod and control treatments were not reported.

Goad et al. (2017) found that fishing with the Hookpod-mini resulted in a similar seabird bycatch rate to fishing with tori lines and unweighted and weighted snoods in a New Zealand longline fishery. In a second experiment in a New Zealand longline fishery, Goad et al. (2017) found that fishing with the Hookpod-mini resulted in a seabird catch rate of 0.079 birds/1000 hooks (3 seabird captures in 38,152 hooks set) while fishing with a tori line and either weighted branchlines or night setting resulted in a bird catch rate of 0.248 birds/1000 hooks (13 birds in 52,404 hooks). Estimates of variance of observed seabird catch rates were not presented.

Preliminary results from a third study of a Hookpod in a Brazilian pelagic longline fishery are also available, presented by Silva-Costa et al. (2017). The Hookpod-mini was used on 11,380 hooks during 3 trips, during which 1 seabird was captured.

The second commercially available hook shielding device is called the Smart Tuna Hook that is used with a modified pelagic longline hook (Fig. 8). The 40 g device is positioned at the hook, covering the barb and point. An alloy component of the device corrodes in seawater, so that the device releases from the hook and sinks after about 15 minutes of being immersed in seawater (i.e., it is a disposable one-time-use device) (Baker et al., 2016; Barrington, 2016b).

The device dissolves within 12 months (Barrington, 2016b). The device was tested in the South African pelagic longline fishery, where 11 seabirds were captured during a control treatment and 2 birds on hooks with the Smart Tuna Hook; the experimental treatment reduced the seabird bycatch rate by between 82-91% (Baker et al., 2016).

Fig. 8. Smart Tuna Hook (photos by Barry Baker; from ACAP, https://acap.aq/en/links/14-news/latest-news/1993-testing-the-smart-tuna-hook, 7 Aug. 2018).

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10 Sliding Branchline Weights

Sliding Leads, manufactured by the company Fishtek, are designed to slide down or off pelagic longline branchlines away from crew when the branchline is under tension, so that when the branchline breaks or when a fish 'throws' the hook (the hook is pulled from a fish's mouth), there is a reduced incidence of weights flying back towards the vessel, as can occur with conventional lead-centered swivels that are crimped onto the line. Thus, longline fishers can attach branchline weights close to the hook, increasing the baited hook sink rate and reducing seabird catch risk, with reduced safety risk to crew than when conventional weights are used. Lumo Leads, another product manufactured by Fishtek, include a luminescent nylon sheath that glows for up to 6 hours (Sullivan et al., 2012; FishTek Marine, No Date).

Sullivan et al. (2012) compared the Safe Lead to conventional weighted swivels in a pelagic longline fishery and found that 4% of Safe Lead fly-backs reached the vessel while 73% of fly-backs by conventional weighted swivels reached the vessel. Simulated bite-offs in a laboratory found that the Safe Lead slid substantial distances along the branchline and that there was significant reduction in the velocity on impact of Safe Leads compared to conventional weighted swivels.

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11 Towed Buoy

Towing one or more buoy or other objects behind a longline vessel during setting and gear haulback where baited hooks are available to scavenging seabirds may prevent or scare seabirds from entering the area protected by the line and buoy (Brothers et al., 1999). This is similar to a bird scaring *tori* line except that with a towed buoy, the line has no streamers attached.

A controlled experiment found that towed buoys resulted in lower attempt rate (no. of seabird attempts to pick up baited hooks per seabird per 1000 hooks) and contact rate (no. of seabird contacts with gear per seabird per 1000 hooks) than a control treatment in the Hawaii longline shallow- and deep-set fishery (McNamara et al., 1999). Towed buoys also resulted in lower attempt and contact rates during hauling in shallow-sets (McNamara et al., 1999).

Goad (2018) conducted a preliminary trial of a buoy device on a small New Zealand demersal longline vessel, and found significantly fewer seabirds were counted close to the longline when the buoy device was deployed.

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12 Underwater Setting Devices

Underwater setting devices deploy baited hooks below the sea surface, out of sight and/or reach of foraging seabirds. ACAP (2017) does not recommend their use, categorizes the devices as being 'under development', and states that:

> "New technologies that set or release baited hooks at depth (underwater setting device) or disarm hooks to specific depths, thus preventing seabird access to baits, are currently under development and undergoing sea trials."

and,

> "In pelagic fisheries, existing equipment is not yet sturdy enough for large vessels in rough seas. Problems with malfunctions and performance inconsistencies have been reported (e.g. Gilman *et al*. 2003a, and Australian trials cited in Baker and Wise 2005)."

The underwater bait setting capsule for pelagic longline fisheries deploys baited hooks through a stainless steel capsule. One design includes (Robertson et al., 2008):

- A demountable track, which attaches to the transom, and extends 1.4 m underwater. The track is stored inboard when transiting to and from fishing;
- The capability for the captain to set the maximum depth and cycle time from the wheelhouse and deck; and
- Modular construction comprising a box with hydraulic motors and winches, de-mountable track section and electronic control system and data logger operated from the wheel-house.

Similarly, the underwater setting chute for pelagic longline fisheries, first developed in 1995 and trialed in New Zealand (O'Toole and Molloy, 2000) and subsequently trialed in Australia and Hawaii (Brothers et al., 2000; Gilman et al., 2003, 2007), deploys baited hooks underwater through a metal chute. Crew throw baited hooks into the funnel of the chute, the branchline extends out of a slot in the chute, which is clipped onto the mainline (Fig. 9) (Gilman et al., 2003).

Fig. 9. Underwater setting chute trialed in Hawaii pelagic longline fisheries (photos from Gilman et al., 2003 [and taken by Nigel Brothers]).

References and for More Information

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13 Water Cannon

Spraying water over the area where baited hooks are being set or retrieved by longline vessels can reduce seabird interactions (Brothers et al., 1999). The Japan Tuna Fisheries Co-operative Association trialed a high pressure fire hose and qualitatively observed reduced seabird interactions (Brothers et al., 1999). During setting, the distance astern that seabirds can access baited hooks may exceed the range of water spraying devices. For example, Kiyota *et al*. (2001) trialed various nozzles, flow stabilizers and angles of deployment of a water jet using an electric centrifugal pump to measure the devices range. The maximum range of the device was 60 m, but was much less when used with strong crosswinds.

The device may be more suitable for mitigating seabird bycatch during gear haulback given the relatively smaller area where birds have access to baited hooks.

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Appendix 6. Worksheet for Participant Ranking of Alternative Seabird Bycatch Mitigation Methods

WESTERN PACIFIC REGIONAL FISHERY MANAGEMENT COUNCIL

Seabird Bycatch Mitigation Measures Worksheet

NAME:

Use this worksheet on Day 1 to:
* Evaluate each mitigation method as you hear the presentations and participate in the discussions.
* We will be doing a collective prioritization "dot" exercise during the afternoon session. Use this worksheet as your guide to decide where to place your dots.

Please turn in this worksheet to the facilitator at the end of Day 1.

Definitions and Directions for Scoring

Score each mitigation meathod across the seven criteria described below. Use the comment column to make note of any justification for high/low scores.
We duplicated branch line weighting, sliding weights, blue dyed bait, and night setting for deep and shallow setting to ensure that you can evaluate each separately for the two fisheries.

Score each evaluation criteria using the definition and scoring scale below:

Efficacy [0 = not sure; 1 = very low efficacy; 5 = very high efficacy]: how large an effect it has on seabird bycatch rates either or both during setting and gear haulback
Cross-taxa conflicts [0 = not sure; Y = likely to increase risk to other species; N = not likely to increase risk to other species]: whether the method risk increasing catch rate of other species of concern such as sharks, rays, marine mammals and/or sea turtles
Practicality [0 = not sure; 1 = very low practicality; 5 = very high practicality]: how large an effect the mitigation method has on fishing operations, e.g., increase the hook setting rate, cause tangles in the gear during haulback
Safety [0 = not sure; 1 = not at all safe; 5 = very safe]: how large an effect does using the method have on crew safety
Durability [0 = not sure; 1 = very low durability; 5 = very high durability]: how durable is the method over long-term use
Economic viability [0 = not sure; 1 = very low economic viability; 5 = very high economic viability]: Does use of the method cause a reduction in the catch rates of market species, and if yes, is the change in catch rates small or large? Is the cost for the initial outlay and ongoing costs to maintain or replace equipment required for the method small or large?
Compliance monitoring [0 = not sure; A = dockside inspection; B = human observers onboard; C = electronic monitoring; D = VMS; E = other methods (specify)]: Method(s) that can be used to monitor fisher compliance with the mitigation method.

Method		Efficacy (0-5)	Cross-taxa conflicts (0/Y/N)	Practicality (0-5)	Crew safety (0-5)	Durability (0-5)	Economic viability (0-5)	Compliance monitoring (list A, B, C, D, E)	Comments
Artificial Bait									
Automatic Branchline Coiler									
Bait Caster									
Ban the Use of Live bait									
Bird Curtain									
Blue-dyed bait	Fish bait								
	Squid bait (Deep-set only)								
Branchline weighting design – heavier weights closer to the hook	Shallow-set								
	Deep-set								
Captain and crew training re: best practices to handle & release seabirds									
Compensatory mitigation (See definition below)									
Different species of fish and squid for bait									
Fish used for bait that have swim bladders – puncture bladders before setting									

Method		Efficacy (0-5)	Cross-taxa conflicts (0/Y/N)	Practicality (0-5)	Crew safety (0-5)	Durability (0-5)	Economic viability (0-5)	Compliance monitoring (list A, B, C, D, E)	Comments
Fish Oil									
Fleet Communication									
Fully-thawed bait									
Hookpod									
Hook size (minimum width)									
Hook shape (circle vs. J vs. tuna									
Individual transferrable vessel cap on bird captures per year or season									
Individual transferrable vessel cap on bird catch rate (# per 1000 hooks) per year or season									
Lasers									
Mainline Line Shooter									
Night setting	Shallow-set								
	Deep-set								
Reduce fishing effort during months with highest seabird catch rates									

Method		Efficacy (0-5)	Cross-taxa conflicts (0/Y/N)	Practicality (0-5)	Crew safety (0-5)	Durability (0-5)	Economic viability (0-5)	Compliance monitoring (list A, B, C, D, E)	Comments
Reduce fishing effort at areas documented to have highest seabird catch rates, during certain seasons									
Require fish bait to be hooked either in the head or tail									
Retain offal and spent bait and dead discards during setting and hauling									
Side Setting									
Sliding weights	Shallow-set								
	Deep-set								
Smart Tuna Hook									
Streamer line / tori line									
Strategically discard offal, spent bait or dead discards during setting and hauling									
Towed Buoy									
Underwater setting chute									
Underwater bait setting capsule									
Water Cannon									

Definitions

Compensatory mitigation – fees paid for each bird captured - often used for conservation activities, such as predator control at breeding colonies, establishment of new breeding colony sites, etc.

Appendix 7. Comparison of Seabird Bycatch Mitigation Method Scores from the Pre-workshop Survey and Worksheets Completed during the Workshop

Scores for the pre-workshop survey (scale of 1-5) and the workshop worksheet overall scores (scale of 1-5 and "no = measure should not be considered for use") were standardized as follows to allow a comparison of results:

1. Rescored "no" in the worksheet completed during the workshop as 1 (i.e., combined "no" and 1 scores to allow comparison with the 1-5 scale in the pre-workshop survey)
2. For categories where DSLL and SSLL were separated (blue-dyed bait, branchline weighting, night setting, sliding weights) in the worksheet completed during the workshop, scores were averaged for comparison with pre-survey.

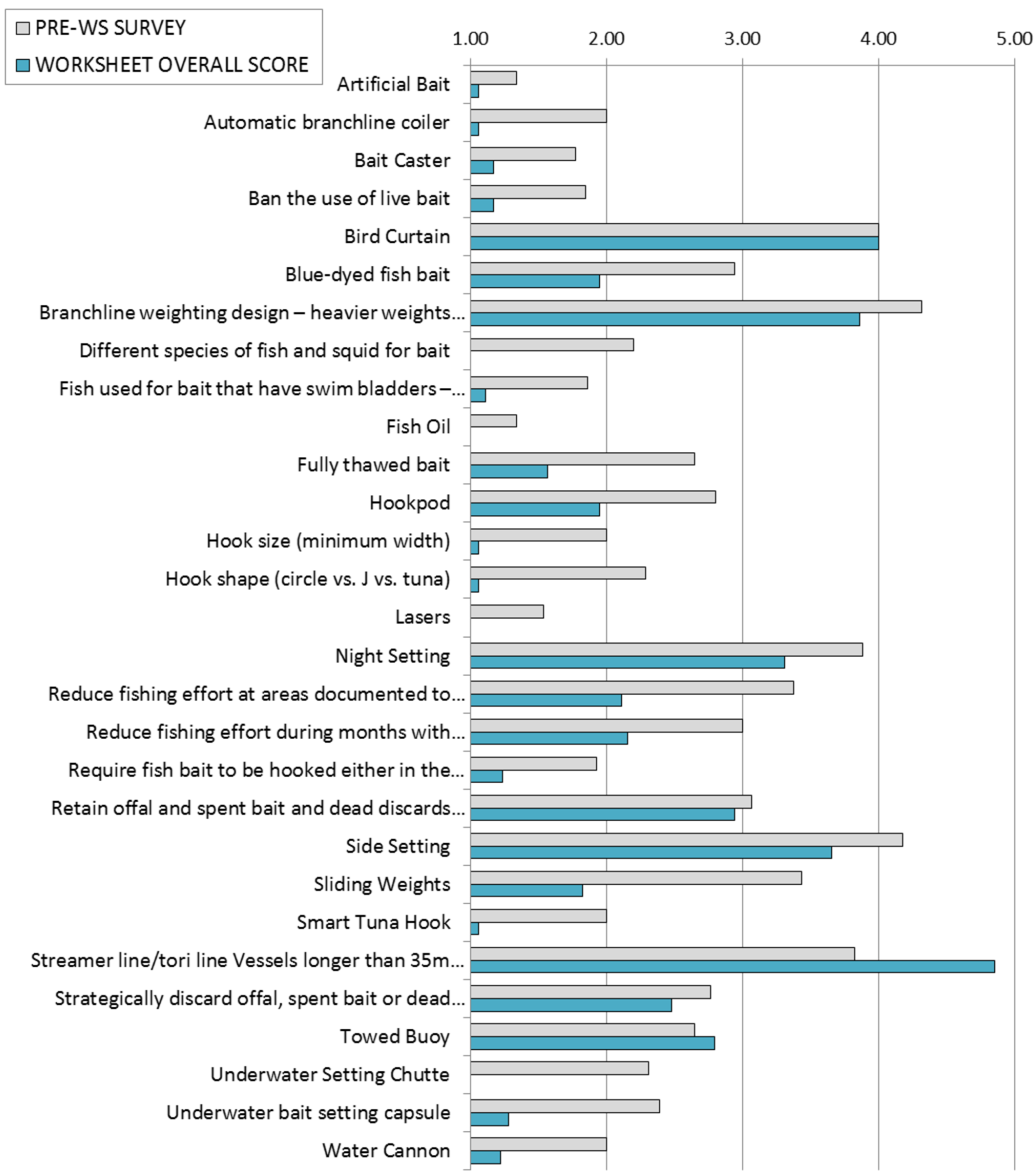

Fig. 10. Comparison of mean overall scores of alternative seabird bycatch mitigation methods' suitability for use in Hawaii's pelagic longline fisheries from the pre-workshop survey and worksheet completed during the workshop.