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Salting Reduces Mercury Concentrations in Odontocete Muscle Tissue

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Abstract—High mercury (Hg) concentrations in seafood present a major global public health concern, especially in regions heavily dependent upon seafood like the Caribbean. Tissues from predatory fishes and other high trophic-level marine organisms such as odontocetes (toothed whales and dolphins) are often elevated in mercury, owing to biomagnification. We investigated whether salting reduces the total mercury (THg) concentration in muscle tissue from odontocetes ("blackfish") taken for human consumption in St. Vincent and the Grenadines. Muscle from 21 odontocetes was coated in table salt or sea salt and dried for one, three, or seven days, after which the THg concentration in each sample was determined and compared to the THg concentration in the corresponding unsalted control. Every salted sample had a lower THg concentration than the unsalted control (mean decrease = 29.4%). There was no difference in the effectiveness of table salt versus sea salt at reducing the THg concentration. Our results show that, while salting successfully removed Hg, only 11% of samples had a methylmercury (MeHg) concentration below the World Health Organization's 1.0 µg/g wet weight advisory level, indicating that consuming odontocete muscle still poses a risk to human health—though that risk may be reduced by the application of salt during drying. The method that we present here may also be applicable to tissues from other marine species with lower initial THg concentrations and may be effective at rendering those tissues safer for human consumption.

The presence of high mercury (Hg) concentrations in seafood is a major global public health concern (Baishaw et al. 2007; Karimi et al. 2012; Sheehan et al. 2014). Mercury is known to bioaccumulate in marine organisms and to biomagnify in marine food webs; therefore, long-lived and high trophic level organisms including predatory fishes and odontocetes (toothed whales and dolphins) generally have the highest Hg concentrations in their tissues (Karimi et al. 2012; Evers et al. 2016).

In muscle tissue of fishes and odontocetes, Hg is predominantly found as methylmercury (CH_3Hg^+; MeHg), which poses a threat to human health due to its deleterious neurotoxic and cardiovascular effects and can be transferred from mother to child via the placenta and breast milk (Endo et al. 2005; Karimi et al. 2012; Rice et al. 2014). To inform and protect seafood consumers, the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) jointly recommend that predatory fishes with a muscle MeHg concentration >1.0 µg/g wet weight not be traded internationally, and that governments should consider whether they are distributed and consumed within their countries (Food and Agriculture Organization of the United Nations/World Health Organization 2015). While not considered under the FAO/WHO advisory, muscle tissue from odontocetes has been found to contain Hg concentrations exceeding that of predatory fishes (Evers et al. 2016; McCormack et al. 2020).

In St. Vincent and the Grenadines (SVG) in the Eastern Caribbean, the town of Barrouallie on the main island of St. Vincent supports a whaling operation that since 2007 has taken, on average, 340 odontocetes (locally called "blackfish") annually for human consumption (Fielding and Kiszka 2021). After landing and butchering, odontocete muscle tissue is dried in the sun for preservation (Fig. 1) and sold throughout the country in established markets or by mobile vendors. These food products are popular in SVG: a public survey in 2018 showed that odontocete meat is consumed by 60% of the Vincentian population (Fielding et al. 2021). A recent study found that total Hg (THg) concentrations in muscle tissue from odontocetes taken for human consumption in SVG were on average 19.1-times higher and up to 202-times higher than the FAO/WHO 1.0

FIG. 1. A man tends to odontocete muscle tissue drying in the sun on racks erected near the beach at Barrouallie, St. Vincent and the Grenadines. Photo by R. Fielding.

µg/g wet weight guideline (McCormack et al. 2020). These results indicate that the consumption of odontocete-based food products in SVG may present serious health risks to the local population.

Previous studies have investigated whether the treatment of fish muscle tissue with various compounds (e.g., cysteine, thiolated aminoethyl cellulose, and sodium borohydride reduction) is successful at removing Hg (Lee and Richardson 1973; Yannai and Saltzman 1973; Cohen and Schreier 1975; Schab et al. 1978; Aizpurúa et al. 1997; Hajeb and Jinap 2012). While many of these processes did result in reduced Hg concentrations, their practical application is limited by the lack of accessibility and in some cases the cost of the necessary chemical compounds.

Dry-salting is an ancient technique of food preservation, by which, through the application of salt to a food's surface, water is extracted from the tissue (Arason et al. 2014). In one recent study, dry-salting was found to reduce concentrations of some metals in fish tissue. The study did not report Hg concentrations before or after salting, however (Edwards et al. 2020).

In this experiment we measured the THg concentration in odontocete muscle tissue that was preserved in table salt purchased at a major US supermarket, or sea salt produced at Union Island in the Grenadines, for up to seven days and compared the resulting THg concentrations to the THg concentrations in unsalted, dried controls to determine how effective salting was at removing Hg. If effective, dry-salting may provide a low cost, readily accessible, and easy method to remove Hg from odontocete muscle tissue, which may ultimately reduce the public health risk associated with Hg exposure from the consumption of odontocete-based food products.

MATERIALS AND METHODS

Sample Collection

Muscle tissue was collected from odontocetes (n = 21) taken for food by whalers based in Barrouallie, on the west coast of the island of St. Vincent, between July 2015 and August 2016 and stored at -20°C in individually labeled plastic bags. Muscle samples were collected from short-finned pilot whales (*Globicephala macrorhynchus*; n = 13), killer whales (*Orcinus orca*; n = 4), false killer whales (*Pseudorca crassidens*; n = 3), and an unidentified dolphin species (*Stenella* sp.; n = 1). All samples were imported into the United States under CITES Import Permit 16US774223/9 and NMFS Permit 19091 in December 2016 and stored at -80°C until further processing and analysis.

Dry-Salting Experiment

Our guiding principle in the methodological design for this experiment was to process tissue samples using materials and methods such that our work could be easily and affordably replicated *in situ* by processors of odontocete-based food products in SVG or within artisanal fisheries and whaling operations more broadly. In the past, and to a limited extent today, Vincentian culinary traditions made use of salt harvested from "salt ponds" in the southern Grenadine islands of Mayreau and Union Island (Howard 1952; Fielding and Ollivierre 2017). As such, we designed the experiment to compare not only the difference in THg concentration after drying odontocete muscle tissue with and without salt, but to test the relative effectiveness of commercially available non-iodized table salt versus locally available sea salt from Union Island.

The salting experiment took place at the University of the South (Sewanee, TN). Each odontocete muscle sample was divided into at least one control (unsalted) subsample and one experimental subsample. When the size of the initial sample was sufficient, we subdivided it into multiple subsamples: up to three controls and six experimental subsamples (accommodating up to three drying timepoints and two salt types). Altogether, our preliminary tissue processing produced 113 subsamples of approximately 1 g wet weight each. Forty randomly selected subsamples (at least one from each original sample) were designated as controls to be left unsalted and 73 were salted as experimental samples.

Experimental samples were randomly assigned to be coated either with commercially available generic brand non-iodized table salt (T) or with sea salt from Union Island, SVG (U). Salt was applied to thawed tissue samples liberally by rolling the tissue in salt that had been spread on a dry sanitized surface. The salt readily adhered to the tissue and any excess salt was shaken off and discarded. Controls and salted samples were then placed in a consumer-grade food dehydrator (FD-75A Snackmaster Pro; NESCO, Two Rivers, WI), set to 35°C and allowed to dry for up to seven days (Fig. 2). To determine how drying time influenced the amount of Hg that was removed from muscle tissue, if enough tissue was available, samples preserved in both salt types were removed from the food dehydrator after one, three, and seven days. The salt was removed from the salted samples by scraping with a clean scalpel and then rinsing in deionized water and blot dried. If not enough muscle tissue for a given odontocete was available initially, then samples were removed at a subset of timepoints. All samples were then shipped to Texas State University (San Marcos, TX) for further processing and THg analysis.

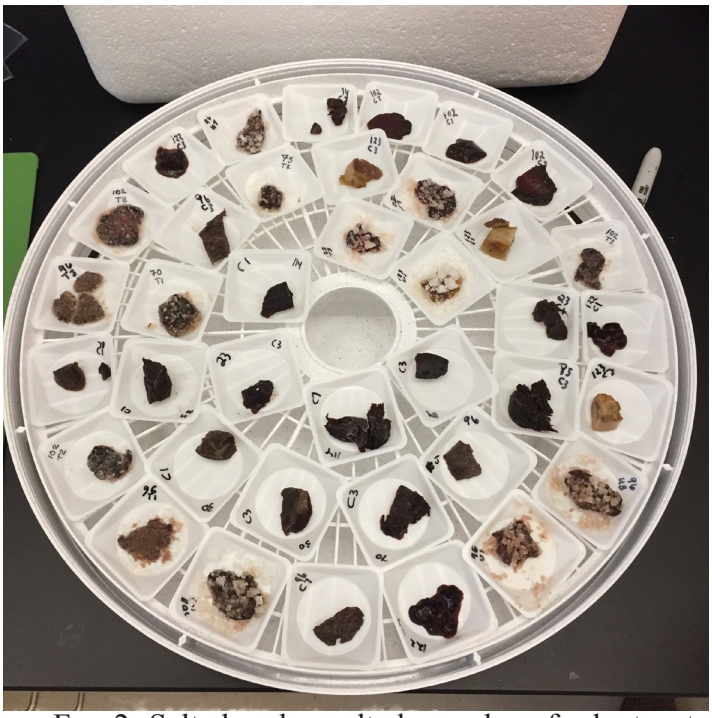

FIG. 2. Salted and unsalted samples of odontocete muscle tissue are prepared for drying on the rack of a food dehydrator for this experiment. Photo by R. Fielding.

THg Analysis

All samples were further dried at 60°C for 48 hours to obtain a consistent dry weight, after which approx-

imately 75 mg of each sample was homogenized into a powder. The THg concentration in a subsample of each dried muscle sample (mean 14 mg; range 10 to 21.5 mg) was determined by thermal combustion, gold amalgamation, and atomic absorption spectrometry using a Direct Mercury Analyzer (DMA-80; Milestone Inc., Shelton, CT), following the method described in U.S. EPA Method 7473 (United States Environmental Protection Agency 2007). The DMA was calibrated as needed using three certified reference materials (CRM) from the National Research Council Canada [MESS-4 marine sediment (0.08 µg/g THg), TORT-3 lobster hepatopancreas (0.292 µg/g THg), and PACS-3 marine sediment (2.98 µg/g THg)]. In SVG, odontocete muscle is typically rehydrated prior to cooking and consumption; therefore, we converted the dry weight THg concentrations to wet weight THg concentrations using the mean percentage moisture content reported for short-finned pilot whales (72%), killer whales (74%), false killer whales (75%), and unidentified *Stenella* sp. (73%) in a previous study (McCormack et al. 2020).

To ensure the validity of the reported THg concentrations, quality control included blanks (empty quartz boats), CRMs (ERM-CE464 tuna, 5.24 µg/g THg, European Reference Materials), and duplicate samples. The blanks (n = 12) had a THg concentration ≤ 0.0003 µg/g, the mean percentage recovery of ERM-CE464 (n = 18) was 96.4%, and the mean relative percentage difference between duplicate samples (n = 31) was 8.0%.

Data Analysis

We compared THg concentrations in salted samples with THg concentrations in corresponding unsalted controls, specifically addressing whether differences existed between salted and unsalted subsamples of the same original samples, as well as between salt types, among drying times, and among species. If available, the THg concentrations of multiple controls from the same individual odontocete were averaged for comparison with salted samples. The mean percentage difference in THg concentrations in unsalted controls was 7.5% which was comparable to the mean percentage difference between duplicate samples used for quality control; as a result, the mean control THg concentration was used when determining the percentage difference in THg concentration between salted samples and the unsalted control for each odontocete.

Owing to the low sample size for each species, drying time, and salt type, in addition to the loss of species identity as food products are processed in SVG (Fielding 2014), samples from all species were combined for statistical analyses. For each salt type, a one-way analysis of variance (ANOVA) was used to determine whether a significant difference in the percentage decrease in THg concentration across time points existed. For each time point, a t-test was used to determine whether a significant difference in the percentage decrease in THg concentration between the two salt types existed. All statistical analysis was carried out using SigmaPlot v.14 (Systat Software, Inc., San Jose, CA) and the level of significance set at $\alpha = 0.05$.

RESULTS

In SVG, people generally do not know what cetacean species they are consuming because meat from various odontocetes are all marketed as "blackfish" (Fielding 2014); therefore, the majority of our results focused on THg concentrations for all species combined. The THg concentration in all salted samples was lower than the corresponding unsalted controls (Fig. 3; Table 1). Short-finned pilot whales had salted samples with a >50% reduction in THg concentration (Fig. 4A), killer whales and false killer whales had a maximum reduction in THg concentration of 36.2% and 47.3%, respectively (Fig. 4B and 4C), and the unidentified *Stenella* sp. had a THg reduction of <25% (Fig. 4D). Based on the mean THg concentrations for all species combined (Table 1), the mean THg concentration in the unsalted controls was 6.30 µg/g wet weight and the mean THg concentration in salted samples (all timepoints and the two salt types combined) was 4.45 µg/g wet weight, representing an average THg reduction of 29.4% (Table 1). The full dataset for this experiment is presented in Appendix 1.

When comparing the effectiveness of table salt and Union Island sea salt in reducing THg concentrations in salted samples for all species and timepoints combined (Table 1), table salt was found to reduce the mean THg concentration by 27.3% and Union Island sea salt by 31.4%. Even though there was a 4.1% difference in the overall decrease in THg concentration between salt type, when comparing the difference in the percentage reduction in THg concentration between the two salt types at each timepoint using a t-test there was found to be no significant difference at day one ($t = -0.185$, $df = 22$, $p = 0.855$) and day seven ($t = -0.393$, $df = 17$, p

TABLE 1. Summary results of experiment comparing THg concentrations in salted (T = table salt; U = Union Island sea salt) samples compared to unsalted controls (C). Results are shown for each species (SPW = short-finned pilot whale; KW = killer whale; FKW = false killer whale; SS = unidentified Stenella sp.) and all species combined. The C values are the THg concentrations (µg/g wet weight) in the unsalted samples and the values for T 1-7 and U 1-7 are the percentage change in THg concentrations compared to the unsalted controls (100%). *n* = sample size; SD = standard deviation; ND = not determined due to small sample size.

Species	Salt	Day	*n*	Median	Mean	SD	Min	Max
Combined	C	C	21	5.90	6.30	3.44	1.19	13.1
	T	1	12	-27.1	-30.2	-14.6	-7.0	-56.5
	T	3	14	-25.3	-25.4	-10.0	-7.9	-37.7
	T	7	10	-27.3	-26.3	-10.2	-10.9	-47.3
	U	1	12	-34.4	-31.2	-10.5	-9.4	-44.8
	U	3	16	-34.5	-34.8	-8.8	-18.5	-52.9
	U	7	9	-31.0	-28.2	-11.8	-12.2	-50.6
SPW	C	C	13	3.76	5.07	3.12	1.19	10.7
	T	1	8	-27.8	-33.8	-13.3	-19.2	-56.5
	T	3	9	-29.4	-26.7	-11.0	-7.9	-37.7
	T	7	7	-27.3	-24.2	-8.1	-10.9	-35.3
	U	1	6	-34.1	-32.3	-10.2	-13.5	-44.8
	U	3	10	-34.9	-37.8	-8.1	-26.2	-52.9
	U	7	6	-24.2	-26.2	-14.4	-12.2	-50.6
KW	C	C	4	10.1	9.78	3.00	5.90	13.1
	T	1	2	-17.0	-17.0	ND	-7.0	-27.0
	T	3	3	-25.6	-28.4	-5.5	-24.9	-34.7
	T	7	2	-22.9	-22.9	ND	-18.6	-27.2
	U	1	3	-35.2	-31.8	-6.8	-24.0	-36.2
	U	3	4	-30.4	-30.0	-5.6	-24.1	-35.3
	U	7	2	-32.4	-32.4	ND	-31.5	-33.2
FKW	C	C	3	8.76	7.97	1.97	5.73	9.42
	T	1	1	ND	-44.5	ND	ND	ND
	T	3	2	-14.9	-14.9	ND	-14.4	-15.3
	T	7	1	ND	-47.3	ND	ND	ND
	U	1	2	-37.9	-37.9	ND	-34.6	-41.2
	U	3	2	-29.3	-29.3	ND	-18.5	-40.0
	U	7	1	ND	-32.6	ND	ND	ND
SS	C	C	1	ND	3.33	ND	ND	ND
	T	1	1	ND	-14.4	ND	ND	ND
	U	1	1	ND	-9.4	ND	ND	ND

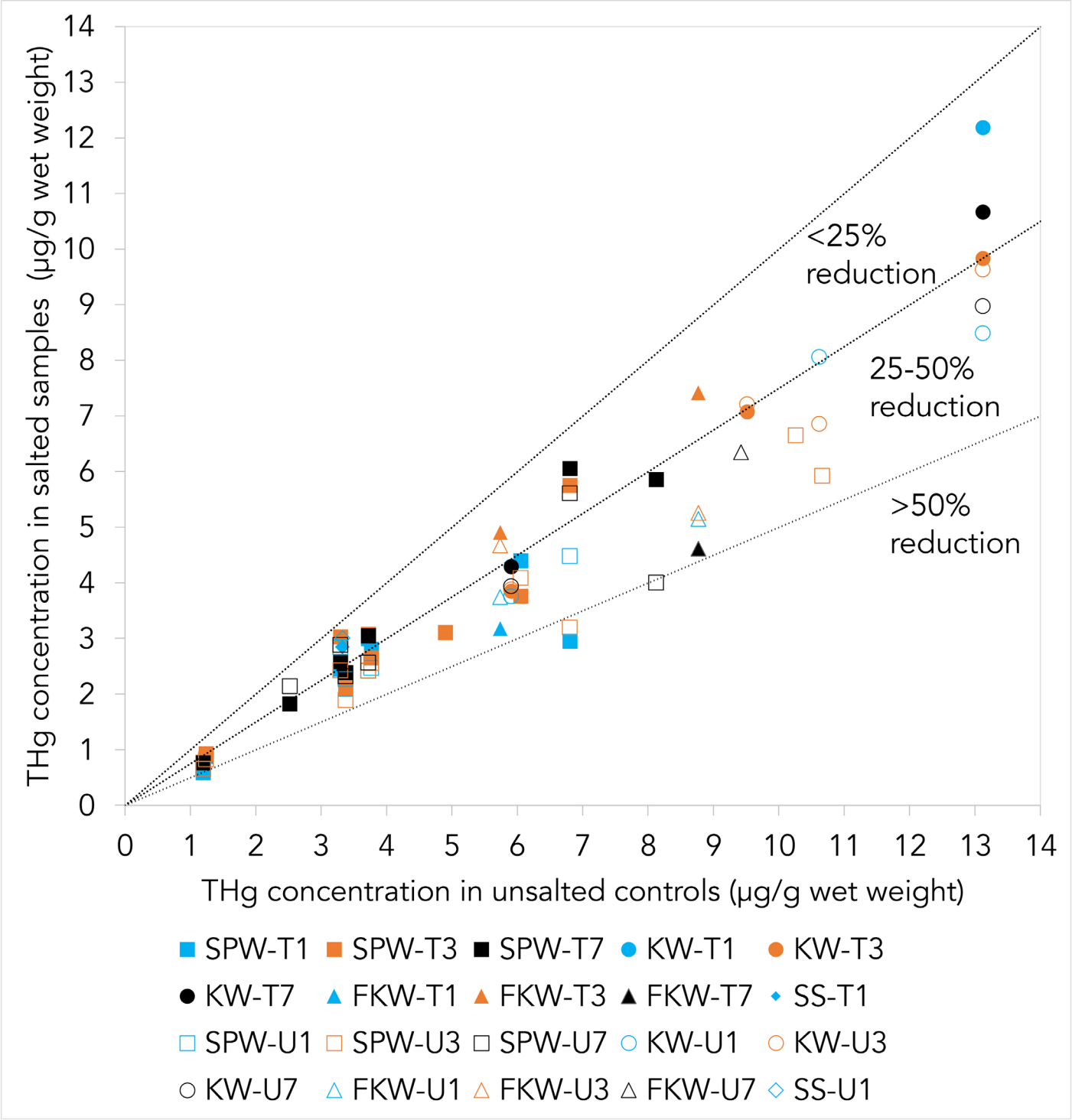

FIG. 3. Comparison of THg concentrations (µg/g, wet weight) in unsalted control samples of odontocete muscle tissue (x-axis) and corresponding salted experimental samples (y-axis) for all species combined. Percentage ranges for reductions in THg concentrations indicated by diagonal lines. SPW = short-finned pilot whale (Globicephala macrorhynchus), KW = killer whale (Orcinus orca), FKW = false killer whale (Pseudorca crassidens), SS = unknown dolphin (Stenella sp.); T = table salt, U = Union Island sea salt; 1 = one-day drying, 3 = three-days drying, 7 = seven-days drying.

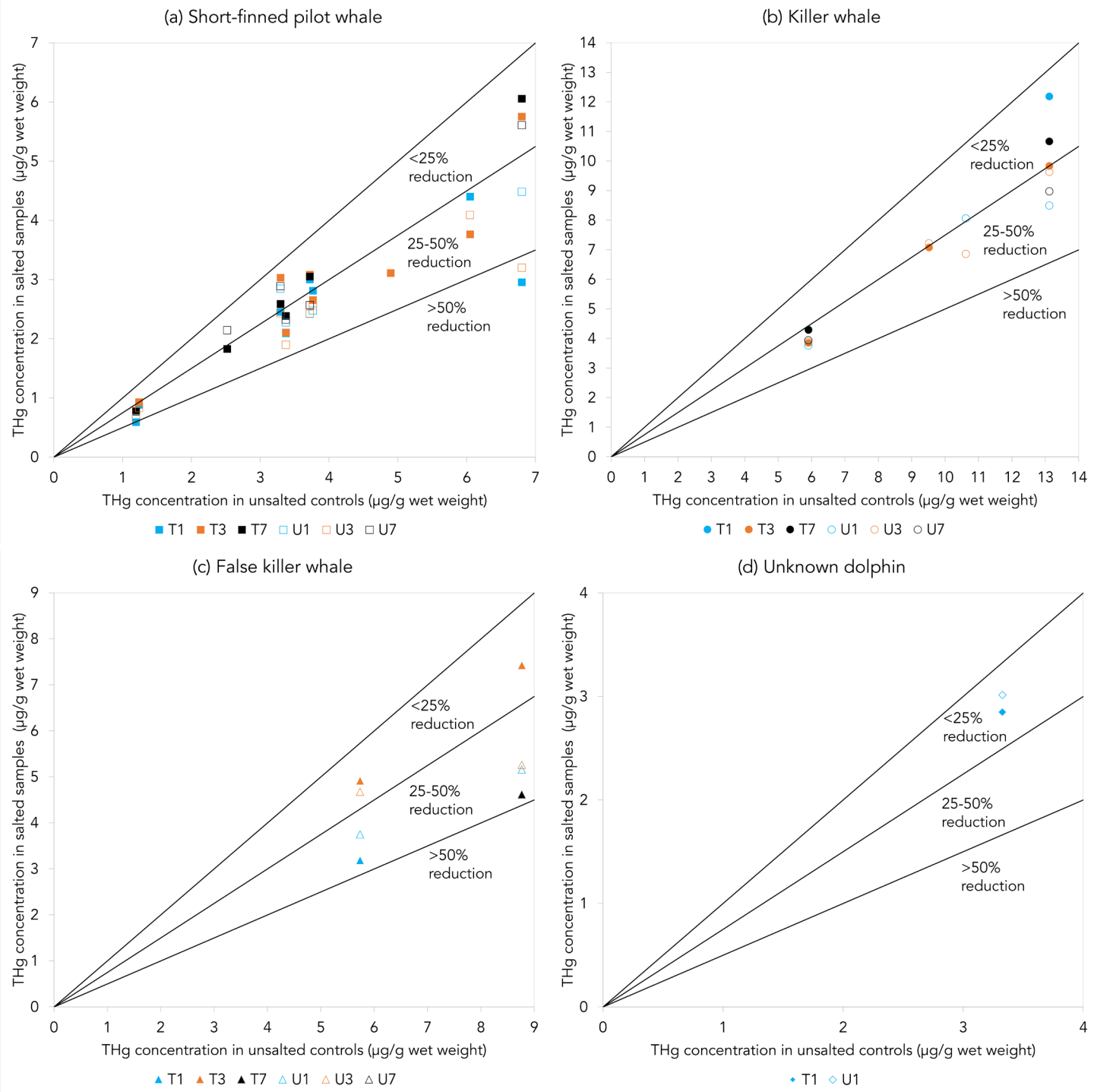

FIG. 4. Comparison of THg concentrations (µg/g, wet weight) in unsalted control samples of odontocete muscle tissue (x-axis) and corresponding salted experimental samples (y-axis) by species (panels a–d). Percentage ranges for reductions in THg concentrations indicated by diagonal lines. T = table salt, U = Union Island sea salt; 1 = one-day drying, 3 = three-days drying, 7 = seven-days drying.

= 0.699), however, there was a significant difference at day three ($t = -2.756$, $df = 28$, $p = 0.010$).

The relationship between the percentage reduction in THg concentration in salted samples compared to unsalted controls and length of time samples spent in the dry-salting process is shown in Fig. 5. This relationship is shown for all species combined (Fig. 5A) and for individual short-finned pilot whales and killer whales that had a complete data set (both salt types and all three timepoints; Fig. 5B and 5C). For both salt types, the greatest reduction in THg concentration was found on day one or day three and the THg concentra-

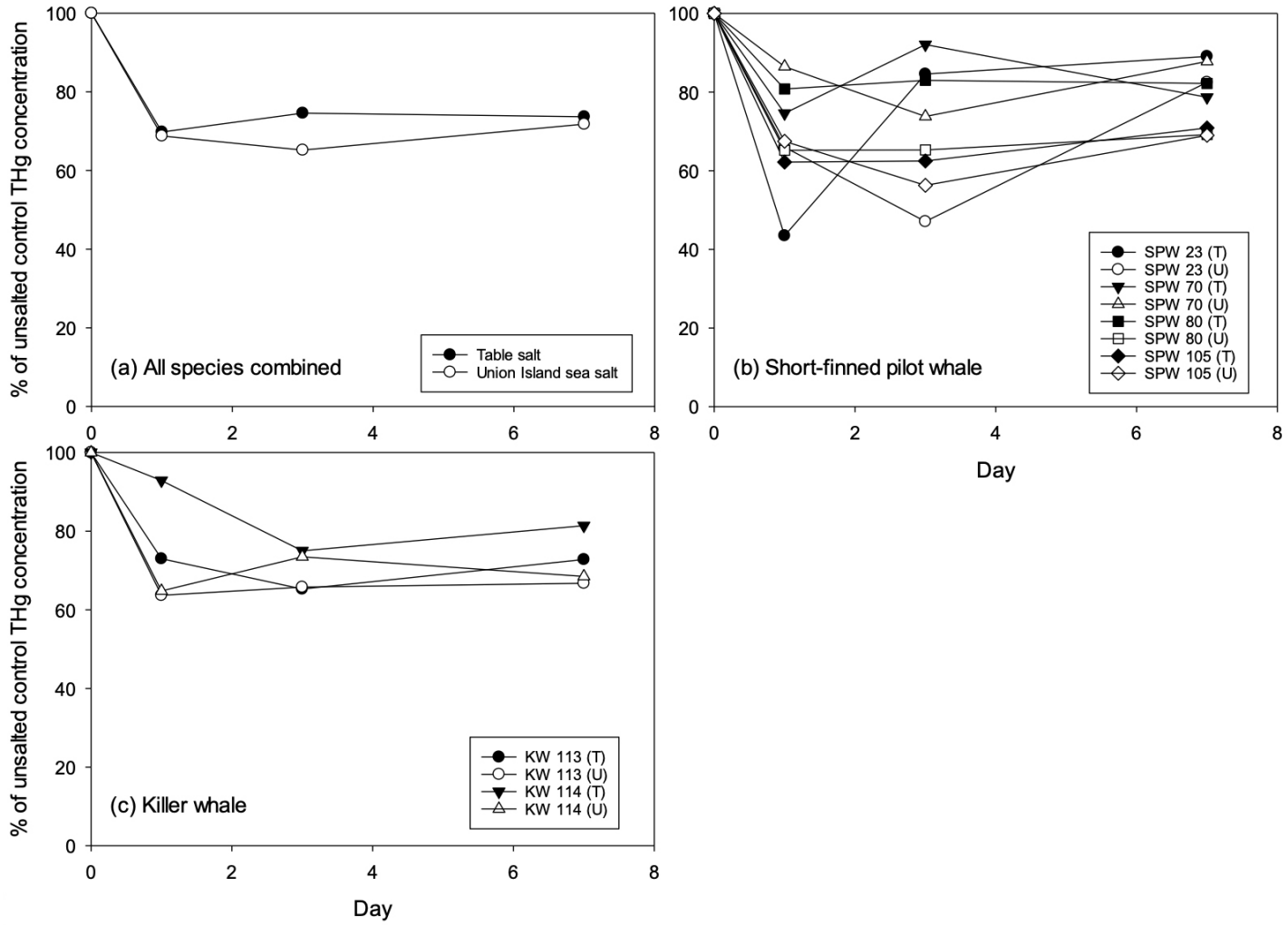

FIG. 5. THg concentrations in salted samples (T = table salt; U = Union Island sea salt) as a percentage of unsalted control THg concentrations. Mean percentages are shown for all species combined (A). Data for short-finned pilot whales (B; SPW) and killer whales (C; KW) are shown for individuals that have values for both salt types and all time points. Sample sizes for all species combined (A) are shown in Table 1.

tion increased again by day seven, although it should be noted there was intra- and interspecies variability in this relationship for both short-finned pilot whales and killer whales. When investigating this trend using a one-way ANOVA for all species combined (Fig. 5A), there was no significant difference in the percentage decline in THg concentration between day one, three, and seven of salt treatment for table salt ($F = 0.604$, $df = 35$, $p = 0.553$) and Union Island sea salt ($F = 1.270$, $df = 36$, $p = 0.294$). For both salt types and all species combined the mean decrease in THg concentration was 30.7% for day one, 30.1% for day three, and 26.8% for day seven compared to unsalted controls (Table 1).

Samples were not analyzed to determine the percentage of THg that was present as MeHg in each sample; however, previous studies have determined that MeHg accounts for approximately 84% of THg concentration in odontocete muscle tissue (Endo et al. 2005; Endo et al. 2006). Using this estimate, it was determined that all unsalted controls exceeded the WHO/FAO advisory of 1 μg/g wet weight MeHg (mean = 5.29 μg/g; range = 1.00 to 11.0 μg/g). After salting, 11.0% of the 73 samples (n = 8) had a MeHg concentration that was lower than the WHO/FAO advisory level (mean = 0.643 μg/g; range = 0.499 to 0.782 μg/g); all of these samples came from two short-finned pilot whales. The remainder of the short-finned pilot whales, and all killer whales, false killer whales, and the unidentified *Stenella* sp. included in this study (n = 19) still had a MeHg concentration > 1 μg/g wet weight after salting (mean = 3.69 μg/g; range = 1.35 to 10.2 μg/g; n = 65 salted samples).

DISCUSSION

Vincentians are known to consume odontocete-based food products (muscle, blubber, liver, and kidney) with high Hg concentrations (McCormack et al. 2020). While the establishment of dietary recommendations by the SVG government to inform the public of the amount of odontocete-based food products that can be safely consumed to minimize Hg exposure would be an appropriate response to this issue, public acceptance of such recommendations may be elusive given the popularity of these food products (Fielding et al. 2021). As a result, other recommendations or preparation techniques could be introduced to reduce the public health risk.

For example, previous studies have recommended the co-consumption of fresh fruit, yeast, coffee, green tea, or black tea with fish as a way to reduce the bioaccessibility of Hg (Passos et al. 2003; Jadán-Piedra et al. 2017; Ouédraogo and Amyot 2011). Additionally, certain cooking methods including boiling, grilling, and frying have been found to reduce the THg and MeHg concentration in fish muscle tissue, compared to raw controls (Mieiro et al. 2016; Schmidt et al. 2015; Ouédraogo and Amyot 2011).

The effectiveness of introducing food products to be co-consumed with odontocete meat or changing the cooking methods typically applied to these foods would rely upon the aggregate compliance of many individuals throughout SVG at the household level. Applying the technique of dry-salting during the production process, however, would require only an additional step in the process of drying odontocete muscle tissue that is already practiced by a relatively small, expert guild of processors (Fielding 2018). Therefore, we consider dry-salting prior to food preparation to be the most promising method to reduce Hg exposure among consumers of odontocete-based food products in SVG.

This study determined that dry-salting is an affordable and effective method to remove Hg from odontocete muscle tissue—a method that may reduce consumers' exposure to THg, on average, by 29.4%. Since both unsalted controls and salted samples were fully dried for the same amount of time during the experiment, this result is not merely an effect of differences in moisture content between unsalted and salted tissue.

The results of this study differed starkly from the results of a study in the Canary Islands where no significant difference in THg concentration was observed between salted and unsalted marine fish (Diaz et al. 1994). Based upon a close reading of the Canary Islands study's methods, we believe that after salting and before THg analysis, the salt—which would contain any Hg it removed from the muscle tissue—was not removed from the fish tissue as the salt was removed from the odontocete tissue in our study.

The effectiveness of dry-salting in reducing the THg concentration in odontocete muscle tissue is potentially promising from a food safety perspective. The moderate reduction in THg concentration may mitigate some of the risk for consumers of odontocete-based food products in SVG who are unlikely to stop consuming a popular food product. Most of the salted samples in our study (89%; 65 of 73), however, still contained MeHg at concentrations greater than the 1.0 µg/g wet weight advisory level set by the FAO/WHO and should therefore not be considered safe for human consumption. Only two short-finned pilot whales had a THg concentration in salted samples that was below the 1.0 µg/g wet weight advisory level; since species identity is not maintained after butchering, consumers are unaware about the species they are consuming and the variability in the potential risk of Hg exposure (Fielding 2014). Furthermore, we must stress that only the THg concentration was measured in this experiment; future research should include analyzing the unsalted and salted samples to determine whether MeHg or inorganic Hg, or a combination of both, is being removed from the muscle tissue by dry-salting. If the MeHg concentration does not decrease significantly after dry-salting, this would indicate that only (or mostly) inorganic Hg is being removed and that dry-salting would be an ineffective method of reducing Hg exposure since MeHg is the most toxic form to humans.

Overall, for all timepoints combined, Union Island sea salt removed on average 4.1% more THg than table salt; however, when evaluating each time point individually there was only a significant difference between the two salt types on day three when table salt removed 25.4% of the THg and Union Island sea salt removed 34.8% of the THg. These results indicate that processors need only to be concerned about which salt type they use if they dry-salt the muscle tissue for three days, whereas, if dry-salting occurs for one day or seven days either salt type can be used. The reason for the

difference at the day three timepoint is not apparent to us, but may be a result of mineralogical impurities in the Union Island sea salt that have a greater binding affinity for THg.

The THg concentration in salted samples did not continually decrease throughout the seven-day experiment, instead for all individual odontocetes and all species combined the THg concentration was lowest on day one or three and increased again on day three or seven. This suggests that a reabsorption process may occur, by which THg previously removed by the salt transfers back into the muscle tissue. For all species combined, however, there was no statistically significant trend in the percentage reduction in THg concentration over time for both salt types. This trend also suggests that odontocete processors would only need to dry-salt muscle tissue for a maximum of three days to achieve the most effective reduction in Hg concentrations.

The purpose of this study was to determine the effectiveness of dry-salting in reducing THg concentrations in muscle tissue from a food safety perspective and not to determine the mechanism involved. Still, we are curious about possible mechanisms. A search of the scientific literature found that no previous study has investigated this observed trend of THg removal and subsequent reabsorption, however, we can hypothesize what may be occurring. During the dry-salting process, moisture is lost from the muscle tissue through osmosis. Salt (sodium and chloride) has a higher affinity for water than for protein in muscle tissue (Del Valle and Nickerson 1967); as a result, during dry-salting the small amount of water that is present in muscle tissue is lost to the surrounding salt and THg that is not strongly bound to protein in the muscle tissue is transferred with it. During the experiment, salted muscle tissue was still moist on day one (but less moist than the unsalted controls), drier by day three, and drier still on day seven; therefore, the majority, if not all, of the water was removed by the end of seven days. Even though the water was removed, there remained a flux of salt into the muscle throughout the salting process, as previously shown in salt-cured fish (Reay 1936; Zugarramurdi and Lupín 1980). Mercury binds to chloride (Mason et al. 1996) and can be transferred into the muscle tissue as the chloride is reabsorbed. Since all experimental and control samples were dried for 48 hours prior to THg analysis, the difference in THg concentration among time points is not a result of differences in moisture content.

The practical applicability of dry-salting in the context of the SVG-based blackfish whaling operation depends on several cultural, economic, and environmental factors. Culturally, the acceptance by consumers of any effects of the salting on the taste and texture of the finished food product would need to be addressed by those engaged in the processing and marketing of odontocete-based food products. While salt is not currently used in the processing of odontocete muscle in St. Vincent, it is, and has been, traditionally used to preserve meat from humpback whales taken in whaling operations based on the neighboring island of Bequia (Adams 1978). Saltfish [i.e., imported salted Atlantic cod (*Gadus morhua*)] is a staple of the Vincentian diet (Josupeit 2011), as it is throughout the Caribbean, and offers a salient example of the Vincentian tolerance for salt-dominated flavors in seafood. The first step in preparing saltfish in SVG is to typically soak the fish in water to reduce its salt content. Somewhat similarly, the first step in preparing dried odontocete meat for consumption is to partially rehydrate it through steaming (Fielding 2018). This indicates to us that soaking previously salted blackfish meat to remove excess salt may not unreasonably burden Vincentian food preparers.

The major economic obstacle to the practicality of dry-salting odontocete muscle tissue is likely to be the acquisition of adequate quantities of salt by odontocete processors. Salt is imported as well as produced locally in SVG. Table salt is imported and widely available in supermarkets and smaller shops throughout the country, whereas Union Island sea salt is produced locally. SVG imports approximately $109,000 USD worth of salt (table salt and salt for industrial uses) per year, as of 2019, most of which (53.7%) comes from Trinidad and Tobago, with another 30.7% from the United States, and 10.4% from India (Simoes 2019). The total amount of imported salt would likely need to increase to adequately supply the odontocete-based food product industry with sufficient salt for dry-salting to be widely implemented. The production of sea salt in the Grenadine Islands was once a thriving industry (Howard 1952), but has declined in scale over the past several decades to serve a smaller, luxury market dominated by export and tourism-related sales as well as some household-scale "salt-picking" or hand-harvesting from evaporated

salt ponds. The local sea salt industry would need to increase in scale to be able to provide enough salt to processors, were the dry-salting of odontocete muscle tissue to become commonplace. Whether the increased demand for salt would be met through increased production of local sea salt or the increased importation of salt from abroad, the inclusion of dry-salting in the processing of odontocete muscle tissue would add a cost, which in turn would likely increase the retail price of the end product.

The major environmental obstacle that would need to be overcome is the issue of how to properly dispose of the presumably Hg-laden salt or brine once it has been removed from the muscle tissue. Currently, within the SVG whaling operation, following the processing of blackfish, bones, internal organs, and other inedible parts are disposed at sea (Fielding 2018). When salt-fish is soaked prior to preparation, as we have observed, the brine produced is washed down the kitchen sink. If either of these practices were applied to the disposal of salt from dry-salting odontocete muscle tissue, over time the amount of Hg deposited into the sea may not be negligible.

Dry-salting as a method of Hg removal from muscle tissue may have broader application for commercially important fisheries than for small-scale whaling operations like that of SVG. Because marine fish typically show much lower original THg concentrations than the odontocete muscle tissue used in this study, future research should evaluate the efficacy of the dry-salting process on fish tissue, with particular focus on high-trophic level species such as sharks, billfish, king mackerel, and tunas, which are known to contain high THg concentrations (Karimi et al. 2012). In addition, future studies should evaluate the application of the dry-salting process in other countries (e.g., Canada, Faroe Islands, Japan, Norway, Russia, USA,) where food products derived from a wider range of marine mammals—odontocetes, mysticetes, pinnipeds, and fissipeds—are consumed (Robards and Reeves 2011).

While our findings are encouraging in that they represent a potentially applicable, low cost, low technology method of reducing Hg concentrations in seafood products, we would be overstating the significance of this research if we presented dry-salting as a solution to the problem of global Hg contamination. Salting cannot absolve pollution. Dry-salting does not completely eliminate Hg from odontocete muscle tissue, it merely transfers a portion of the Hg to the salt, which then must be disposed of. To meaningfully improve the safety of the world's seafood resources, anthropogenic Hg emissions, primarily from coal-fired power plants and artisanal gold mining operations—neither of which exists in SVG, we might add—should be reduced or curtailed in accordance with the goals of the United Nations Minamata Convention on Mercury (United Nations Environmental Programme 2013).

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APPENDIX 1. Full results of experiment comparing THg concentrations in salted (T = table salt; U = Union Island sea salt) short-finned pilot whale (SPW), killer whale (KW), false killer whale (FKW) and an unidentified dolphin species (*Stenella* sp.; SS) muscle tissue with unsalted controls (C). Data for individual odontocetes is reported as THg concentration (dry and wet weight), change in THg concentration compared to control (ΔTHg concentration dry and wet weight), and percentage change in THg concentration compared to control (ΔTHg concentration %).

Odontocete ID	Salt	Day	THg concentration (μg/g dry wt)	ΔTHg concentration (μg/g dry wt)	THg concentration (μg/g wet wt)	ΔTHg concentration (μg/g wet wt)	ΔTHg concentration (%)
SFW 21	C	C	36.6		10.3		
	U	3	23.8	-12.8	6.65	-3.60	-35.1
SFW 23	C	C	24.3		6.80		
	T	1	10.6	-13.7	2.96	-3.84	-56.5
	T	3	20.5	-3.73	5.75	-1.05	-15.4
	T	7	21.6	-2.65	6.06	-0.741	-10.9
	U	1	16.0	-8.26	4.49	-2.31	-34.0
	U	3	11.4	-12.8	3.20	-3.60	-52.9

	U	7	20.0	-4.24	5.61	-1.19	-17.5
SFW 67	C	C	4.42		1.24		
	T	1	3.17	-1.25	0.886	-0.351	-28.4
	T	3	3.32	-1.09	0.931	-0.307	-24.8
	U	3	2.96	-1.46	0.830	-0.407	-32.9
SFW 69	C	C	13.4		3.76		
	T	1	10.0	-3.40	2.81	-0.950	-25.2
	T	3	9.49	-3.95	2.66	-1.11	-29.4
	U	1	8.85	-4.59	2.48	-1.29	-34.2
	U	3	9.16	-4.28	2.56	-1.20	-31.9
SFW 70	C	C	11.8		3.29		
	T	1	8.77	-2.99	2.46	-0.836	-25.4
	T	3	10.8	-0.923	3.03	-0.259	-7.9
	T	7	9.25	-2.51	2.59	-0.702	-21.3
	U	1	10.2	-1.59	2.85	-0.446	-13.5
	U	3	8.68	-3.08	2.43	-0.862	-26.2
	U	7	10.3	-1.44	2.89	-0.402	-12.2
SPW 75	C	C	8.99		2.52		
	T	7	6.54	-2.45	1.83	-0.687	-27.3
	U	7	7.66	-1.33	2.15	-0.372	-14.8
SPW 80	C	C	13.3		3.72		
	T	1	10.7	-2.54	3.01	-0.712	-19.2
	T	3	11.0	-2.26	3.08	-0.633	-17.0
	T	7	10.9	-2.37	3.05	-0.663	-17.8
	U	1	8.66	-4.62	2.42	-1.29	-34.8
	U	3	8.67	-4.60	2.43	-1.29	-34.7
	U	7	9.18	-4.10	2.57	-1.15	-30.8
SPW 85	C	C	21.6		6.05		
	T	1	15.7	-5.87	4.40	-1.64	-27.2
	T	3	13.5	-8.14	3.77	-2.28	-37.7
	U	3	14.6	-6.98	4.09	-1.96	-32.3
SPW 105	C	C	12.0		3.37		
	T	1	7.49	-4.55	2.10	-1.27	-37.8
	T	3	7.53	-4.51	2.11	-1.26	-37.5
	T	7	8.53	-3.51	2.39	-0.982	-29.1
	U	1	8.13	-3.91	2.28	-1.09	-32.5
	U	3	6.78	-5.26	1.90	-1.47	-43.7
	U	7	8.31	-3.73	2.33	-1.05	-31.0
SPW 106	C	C	38.1		10.7		
	U	3	21.2	-16.9	5.93	-4.73	-44.4
SPW 122	C	C	4.26		1.19		
	T	1	2.12	-2.14	0.594	-0.600	-50.3
	T	3	2.81	-1.45	0.787	-0.407	-34.1

	T	7	2.76	-1.50	0.772	-0.421	-35.3
	U	1	2.35	-1.91	0.659	-0.535	-44.8
	U	3	2.38	-1.89	0.665	-0.528	-44.2
SPW 128	C	C	29.0		8.12		
	T	7	20.9	-8.05	5.86	-2.26	-27.8
	U	7	14.3	-14.7	4.01	-4.11	-50.6
SPW 134	C	C	17.5		4.89		
	T	3	11.1	-6.37	3.11	-1.78	-36.4
KW 8	C	C	40.8		10.6		
	U	1	31.0	-9.81	8.06	-2.55	-24.0
	U	3	26.4	-14.4	6.86	-3.75	-35.3
KW 92	C	C	36.6		9.51		
	T	3	27.2	-9.35	7.08	-2.43	-25.6
	U	3	27.8	-8.82	7.22	-2.29	-24.1
KW 113	C	C	22.7		5.90		
	T	1	16.6	-6.14	4.31	-1.60	-27.0
	T	3	14.8	-7.87	3.85	-2.05	-34.7
	T	7	16.5	-6.18	4.30	-1.61	-27.2
	U	1	14.5	-8.23	3.76	-2.14	-36.2
	U	3	14.9	-7.76	3.89	-2.02	-34.2
	U	7	15.2	-7.53	3.94	-1.96	-33.2
KW 114	C	C	50.4		13.1		
	T	1	46.9	-3.57	12.2	-0.928	-7.0
	T	3	37.8	-12.6	9.84	-3.28	-24.9
	T	7	41.0	-9.40	10.7	-2.44	-18.6
	U	1	32.7	-17.8	8.49	-4.62	-35.2
	U	3	37.1	-13.4	9.63	-3.48	-26.5
	U	7	34.5	-15.9	8.98	-4.14	-31.5
FKW 29	C	C	37.7		9.42		
	U	7	25.4	-12.3	6.35	-3.07	-32.6
FKW 30	C	C	22.9		5.73		
	T	1	12.7	-10.2	3.18	-2.55	-44.5
	T	3	19.6	-3.29	4.91	-0.823	-14.4
	U	1	15.0	-7.95	3.75	-1.99	-34.6
	U	3	18.7	-4.24	4.67	-1.06	-18.5
FKW 35	C	C	35.1		8.76		
	T	3	29.7	-5.37	7.42	-1.34	-15.3
	T	7	18.5	-16.6	4.62	-4.15	-47.3
	U	1	20.6	-14.4	5.16	-3.61	-41.2
	U	3	21.0	-14.0	5.26	-3.51	-40.0
SS 4	C	C	12.3		3.33		
	T	1	10.5	-1.77	2.85	-0.478	-14.4
	U	1	11.2	-1.16	3.01	-0.312	-9.4