FINAL REPORT

Lipid Content in Troll-caught Albacore Tuna and Correlations with Geographical Location, Physical Measurements and Seasonality

For: American Fisheries Research Foundation

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Introduction

Albacore tuna (*Thunnus alalunga*) is a migratory fish found in the temperate and tropical oceans of the world. Three to four year-old albacore begin their journey off the coast of Japan and migrate across the Pacific Ocean where they arrive off the coast of California in the spring (Kimura et al 1997). They work their way northward feeding along the West Coast upwelling front. Their offshore range is approximately 20 to more than a hundred nautical miles off the Pacific Coastline. It is this close proximity that allows small-scale troll fishing vessels to harvest albacore during summer months.

The West Coast troll-caught albacore fishery season lasts from June through October each year and the albacore is primarily sold frozen, whole fish that is further processed as a canned product in foreign and domestic markets. Albacore has good market value compared to other fisheries in the Pacific Northwest, however, the potential to market this fish using public opinion as well as its nutritional aspects is very high. Firstly, West Coast troll-caught albacore is a small-scale fishery based out of rural coastal port cities aiding to its marketability as a locally caught small-scale seafood product. Secondly, there is very little by-catch as compared to many other fisheries, and the stock is considered sustainable (Cox et al. 2002). The marketing of these aspects could promote a positive public opinion of the albacore fishery. Lastly, albacore has high nutritional value in both its protein content and Omega-3 fat content. Omega-3 fatty acids have recently gained public attention for their numerous health benefits (Nettleton, 1995).

At the present time, the market value of albacore is directly proportional to its fat content. The cannery market prefers a low lipid content albacore while the Asian and Spanish markets prefer albacore with high lipid content. Lipids affect the flavor and sensory characteristics of seafood products in general. Products that contain high lipid content generally have a smooth texture, enhanced flavor and increased overall acceptability. A greater understanding of lipids in albacore is essential in developing the albacore market to its full potential. Since albacore market value is dependant on lipid content, there is also a great need for a method to measure lipid content quickly. Lipid content is inversely proportional to moisture content in albacore muscle, which could allow for a rapid and indirect measurement of lipid content (Love 1997). Such a method would help fishermen classify albacore quickly and maximize the profitability of individual fish. This preliminary analysis is part of an ongoing West Coast albacore lipid study to determine the year-to-year patterns between lipid content and moisture, weight, length, harvest date and catch location.

Materials and Methods

Sample preparation

Two hundred and thirty-nine albacore tuna from twenty-nine harvest events were troll caught and tagged for identification during the 2003 season from June to October. The albacore were delivered by Gayle Parker of Ilwaco Fish Company, Inc. and were captured in the open Pacific and off the Washington, Oregon, California coasts. Whole fish were frozen at sea and transferred to the Oregon State University Seafood Laboratory, Astoria, OR, where they were stored at –30C for later analysis. The weight, length and circumference of each albacore tuna were measured right before sample preparation. Whole muscle sections were cut with a band-saw and stored at - 25°C for analysis. On the day of analysis, the sections were thawed and white muscle samples were collected from the upper loin section and homogenized in a blender at low speed for 1 minute.

Lipid extraction

The lipid analysis was done according to the modified AOAC Official Method 948.15 (Crude Fat in Seafood, Acid Hydrolysis method, 1995). Blended 3g samples were placed in 50ml centrifuge tubes, and mixed well with 10 ml of HCl. The samples were heated in a 100°C water bath for 45 min and mixed by vortex, and then heated another 45 min. The samples were cooled, and 5 ml of methanol was added. A 15 ml aliquot of diethyl ether and 15 ml of petroleum ether were added and the samples were shaken vigorously for 1 min. The samples were then centrifuged for 5 min at 1200 RPM, and the ether-fat layer was transferred to a pre-weighed clean flask-beaker. The extraction was repeated twice and the ether-fat layer was transferred to a flask and evaporated on a hot plate. Samples were analyzed in triplicate.

Moisture content

The moisture contents were determined according to AOAC Official Method 950.46 B (Convection, Gravity method, 1995) by measuring the mass of a sample before and after drying overnight in an oven.

Results and Discussion

Lipid content and weight

Harvest information and laboratory data collected for 239 West Coast albacore are shown in Table 1. The fat content is highly variable, with an average of 8.57% lipid and a range of 0.67% to 18.74%. The average standard deviation for the lipid percentages was ±0.30. The moisture content ranged from 56.93% to 73.07%, with an average of 65.17% and an average standard deviation of 0.12. The average weight of the albacore was 6.07 kg, with a range of 2.46 kg to 11.62 kg.

This is similar to the weights of tuna analyzed in the 2002 season, which ranged from 3.5 kg to 10.0 kg. The lipid content was found to vary considerably from one fish to another within the groups, even when caught at the same location and time. Fat and moisture together contributed to an average of 73.74% of albacore muscle composition. This result is consistent with Sidwell et al. (1974) who found that tunas and other Scombroids have combined lipid and moisture percentages close to 74% due to their high protein content, whereas moisture and lipid comprise 80% of most fish.

Correlations

Lipid and moisture

Fig. 1 shows an inverse correlation between the lipid and moisture content of albacore tuna (R^2 = 0.93) analyzed in this study. Garcia-Arias et al. (1994) also reported an inverse correlation (R^2= 0.95) between lipid and moisture content of albacore tuna caught in the Atlantic Ocean. This is consistent with previous tests in albacore tuna in a more limited study showing a strong correlation between lipid and moisture (Wheeler and Morrissey 2003).

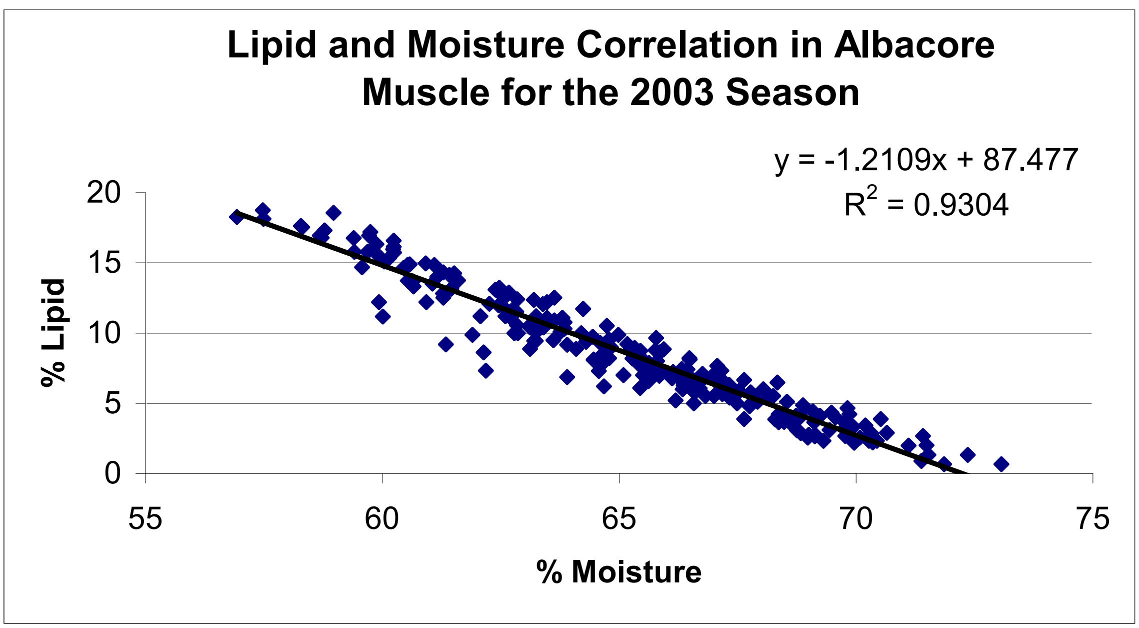

Figure 1. Lipid and moisture correlation for 239 West Coast albacore tuna

Love (1997) concluded that over 80% of the variation in lipid content correlates inversely and significantly with moisture content. Because lipid content can vary widely through migration, the moisture content also varies. This is a consequence of the fish maintaining a constant density slightly greater than that of water (Perez-Villarreal and Pozo 1990). Given this relationship between lipid and moisture, Kent (1990) stated that a measurement of one serves to determine the other. The equation developed based on the trend line in Fig. 1 would allow the lipid content to be estimated based on the moisture content. Since moisture is considerably easier to measure than lipid content, it is conceivable that lipid content could be estimated by determining moisture content. A simple regression equation could be used to estimate lipid content. The standard deviation would be on the order of $\pm$ 0.30% and would not replace the standard AOAC procedure for precise measurement of fat content. However, it would allow processors to have estimates of the fat content of their fish, which they may then, direct toward appropriate markets.

Lipid and Size Correlations

Using a relative size measurement to determine overall health of the fish allows us to take into consideration some of the dynamics of growth. During periods of high food abundance weight can increase disproportionately to length and circumference (Busacker et al. 1990). During these periods, tissue growth in addition to storage of energy in muscle and the liver can cause fish to have a greater than average weight to length ratio. The condition factor considers this disproportionality by assuming a nonlinear relationship between weight and length.

The formula for the condition factor, CF=(100W)/L^3, where W=weight in grams and L=length in centimeters considers this disproportionality by assuming a nonlinear relationship between weight and length. The condition factor would give higher values to immature fish because a large portion of their growth goes to somatic tissue (Moyle and Chech 1988).

In Fig. 2, condition factor CF is correlated with percent lipid content. There is a weak correlation between CF and lipid content. This correlation is higher than the length and lipid correlation (R^2=. 0023) and the weight and Lipid correlation (Fig. 3, $R^2=8.00\times10^{-7}$) showing that perhaps the condition factor may be a better measure of size then either weight or length alone. Similar results were found in a study where no relationship was found between fish length and lipid content in West Coast albacore tuna (Dotson 1978). Additionally, Craven et al. (1997) reported a weak correlation ($R^2 = 0.23$) between percent lipid and weight for West Coast albacore tuna caught 130 miles offshore. Conversely, a significant interaction was reported between lipid content and size of albacore tuna from the Atlantic Ocean (Perez-Villarreal and Pozo 1990).

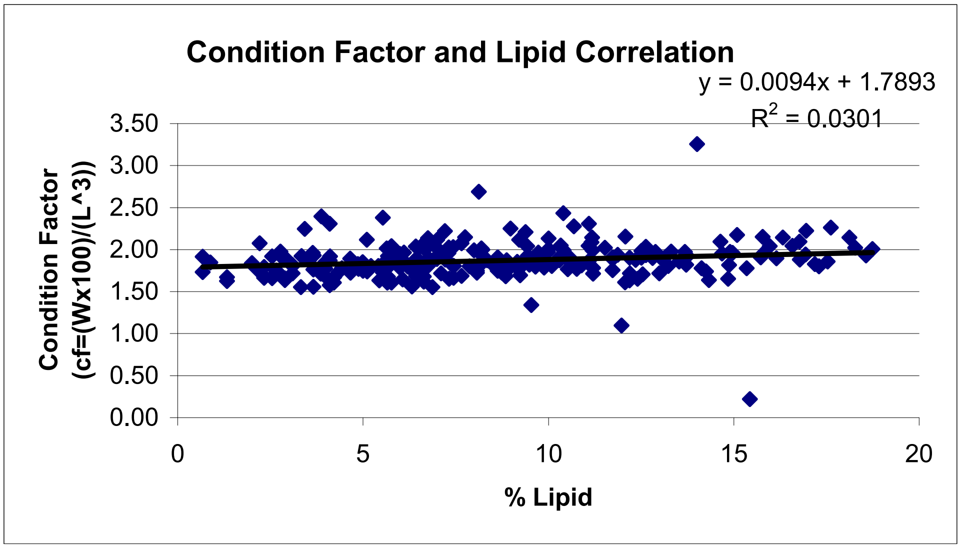

Figure 2. Lipid and condition factor correlation for 239 West Coast albacore tuna

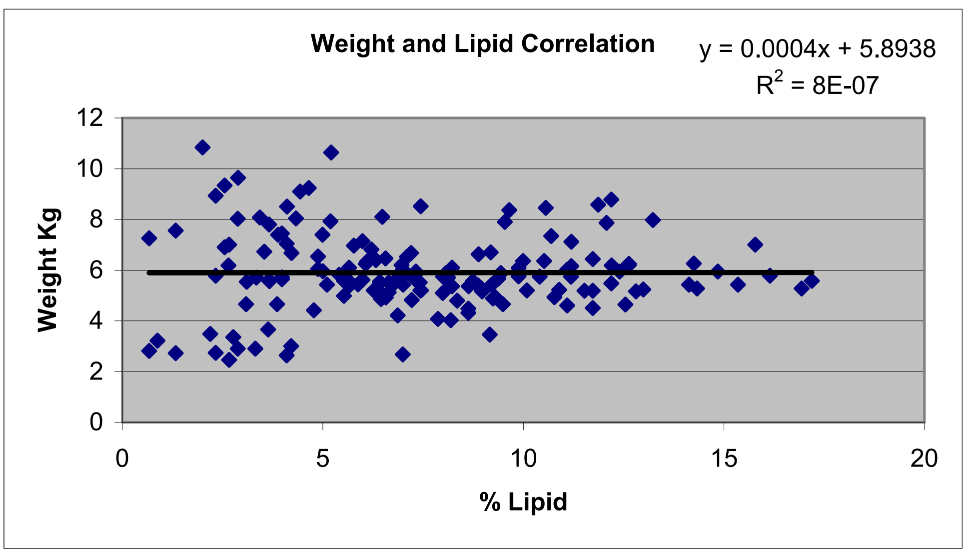

Figure 3. Lipid and weight correlation for 162 West Coast albacore tuna

Lipid and Date Correlation

Fig. 4 shows a slight tendency for higher lipid content during the later portion of the Pacific Northwest Albacore season. It was predicted that the tuna would have a higher percentage of lipids later in the season, because the species does not feed until after they cross the Pacific Ocean when they reach the Eastern Pacific fronts where productivity is high due to upwelling. Upon arrival to the west coast, they begin feeding and grow a considerable amount throughout the summer. Therefore it is a reasonable assumption that as the season progresses, albacore would have a higher fat content. However, the data show a significant amount of variability throughout the season.

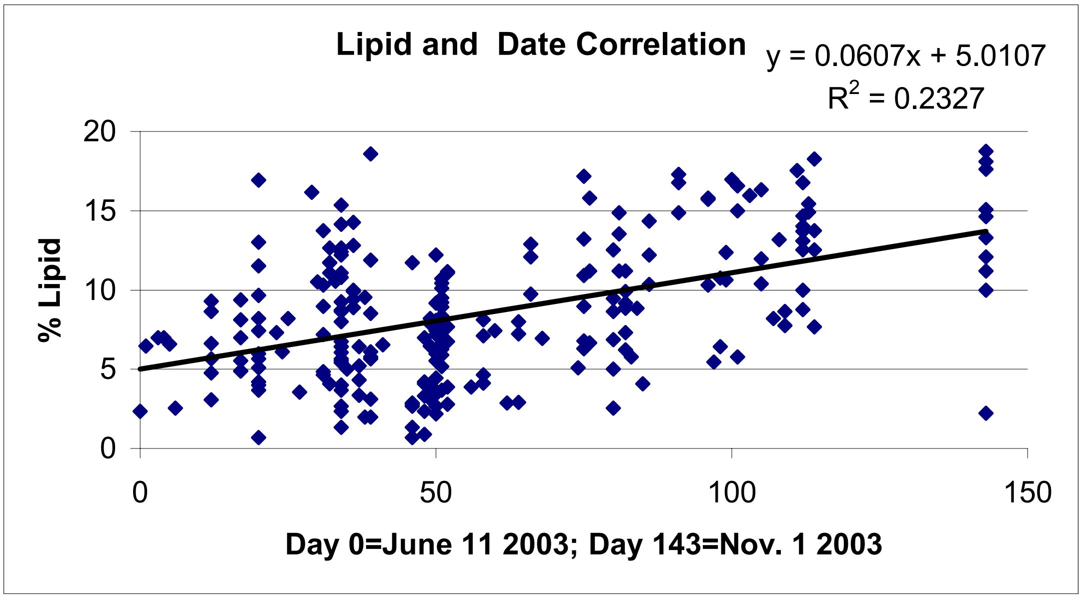

Figure 4. Lipid and date correlation for West Coast albacore tuna**.**

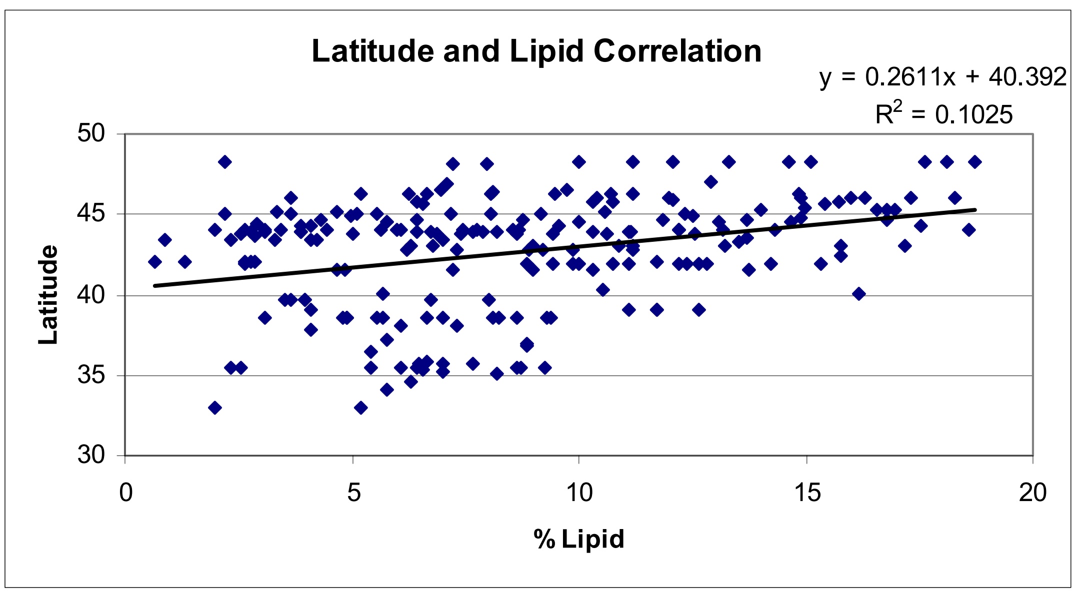

Figure 5. Latitude and lipid correlation for West Coast Albacore tuna.

Lipid and Location

As shown in Fig. 5, the majority of the fish were harvested between 29.25 degrees north (off Sothern California) and 48.17 degrees north (off the coast of British Columbia, Canada). Although the lipid content varies considerably among tuna caught at similar latitudes, albacore caught at lower latitudes tended to have lower lipid contents. Most of the fish caught below 40 degrees north had a lipid content of less than 10% while the higher-fat fish (13-19% lipid) were all harvested above 40 degrees north. This agrees with the migratory and feeding patterns of West Coast albacore. Albacore eat very little while migrating across the Pacific Ocean and survive primarily on reserve fat until they reach the West Coast. At this point, albacore begin feeding as they move to the north. Moreover, Dotson (1978) explained that fish species, such as tuna, migrate extensively and have a greater variation in lipid content between individuals. The use of reserve fats during migration may help to explain the high variability of fat content found in albacore. Some fish may have been recently feeding when harvested, while others may have just traveled through an area of scarce food, thus depleting their lipid stores.

Conclusions

The results of this study give a more complete picture of the unique characteristics and proximate composition of West Coast albacore tuna. There are a number of biological questions that can be addressed with a large data set from albacore harvested in different locations. Do juvenile albacore show increased lipid levels as a part of their physiological needs for growth and maturation? Is there a seasonality effect in the lipid content as in many species or is it more specific to feeding regimes as fish migrate across the Pacific to the West Coast of the U.S.? Apart from the biology/physiology aspects of lipid content in albacore, there are economic considerations as well.

The variation in lipid content between individual fish can present problems and opportunities for processors, as tuna high in lipids have unique eating characteristics and are more suited for certain products. The inverse relationship of lipid and moisture creates a potential for measuring lipid content indirectly through moisture. There was some correlation with seasonality and lipid content. Albacore captured in the beginning of the year tended to have lower fat content than those captured later in the season. Although there was a slight trend between latitude and lipid content, a spatial autocorrelation should be used to further investigate the relationship between geographic location and lipid content.

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Appendix

Comparisons of Data Collected During the 2002 and 2003 Seasons

Table 1a. T-Test: Two-sample assuming equal variances for lipid content for samples collected during the 2002 and 2003 seasons.

Comparison of % Lipid for 2002 and 2003 Season		
	Lipid (%) 2003	*Lipid (%) 2002*
Mean	8.565583333	13.29874926
Variance	18.29734192	33.04423283
Observations	240	166
Pooled Variance	24.32020578	
Hypothesized Mean Difference	0	
Df	404	
t Stat	-9.507465418	
P(T<=t) one-tail	8.87951E-20	
t Critical one-tail	1.648634225	
P(T<=t) two-tail	1.7759E-19	
t Critical two-tail	1.965854608	

Table 1b. T-Test: two-sample assuming equal variances for moisture content for samples collected during the 2002 and 2003 seasons.

Comparison of % Lipid for 2002 and 2003 Season		
	Moisture (%) 2003	*moisture (%) 2004*
Mean	65.16933333	61.17263231
Variance	11.6106824	16.9776504
Observations	240	166
Pooled Variance	13.80263715	
Hypothesized Mean Difference	0	
Df	404	
t Stat	10.65656588	
P(T<=t) one-tail	7.79213E-24	
t Critical one-tail	1.648634225	
P(T<=t) two-tail	1.55843E-23	
t Critical two-tail	1.965854608	

Data Comparisons for 2002 and 2003 Seasons

T-tests were performed for both % lipid and % moisture for both the 2002 and 2003 seasons to compare mean differences between the two seasons. These data are summarized in Table 1a and Table 1b in the appendix. For percent lipid of the two years the differences were highly significant ($p=1.77 \times 10^{-20}$) between the two seasons. Percent moisture shows a similar difference ($p=1.56 \times 10^{-23}$)

Fig. 1 of the appendix shows the two lipid and moisture correlations for both seasons. There was more lipid variation and a lower correlation for the 2002 season in addition to a higher range of lipid values. Both R^2 values are high (Figs. 1 and 2) and the regression equations are similar showing that percent lipid may be calculated from moisture content with little degree of error from one year to the next. However, the differences are highly significant from one another, and additional data over subsequent years may decrease this difference. Fig. 2 shows that there is a strong correlation between the two years, and this is concurrent with the above data in this report.

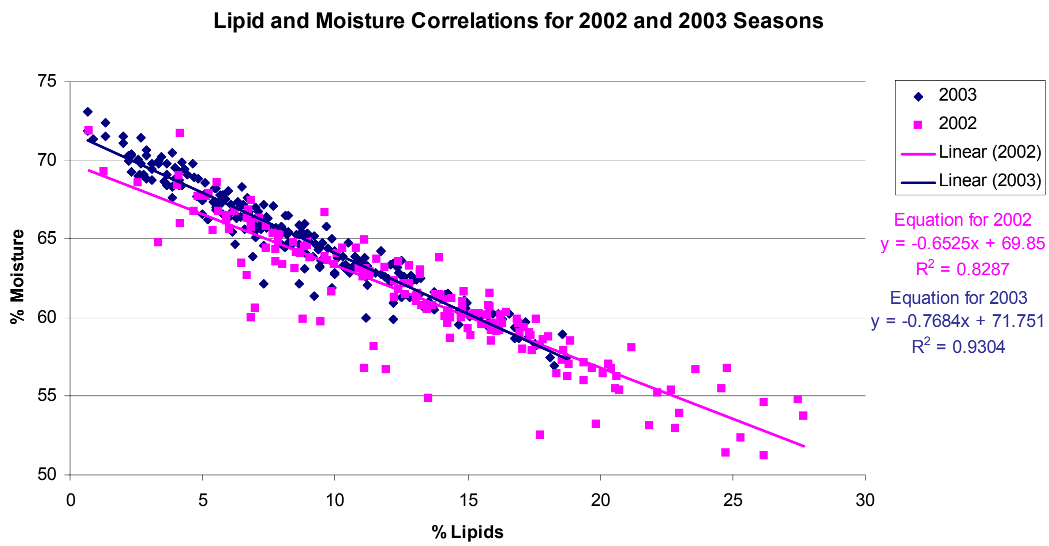


Figure 1. Comparison between % lipid and moisture correlations for the 2002 and 2003 sample seasons

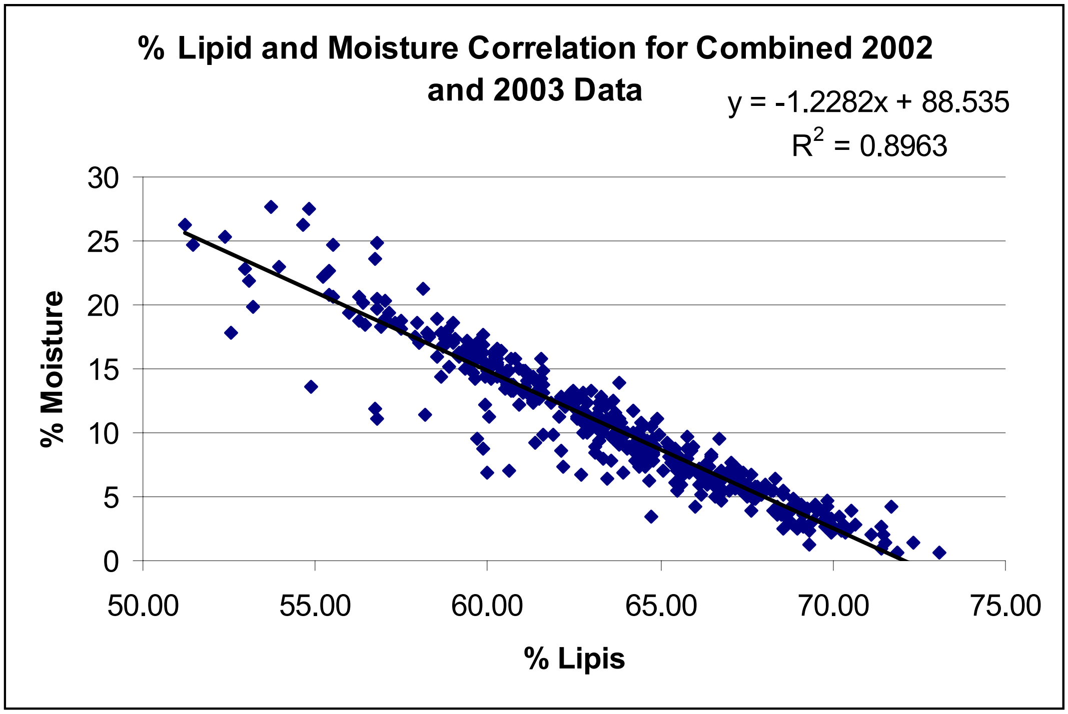
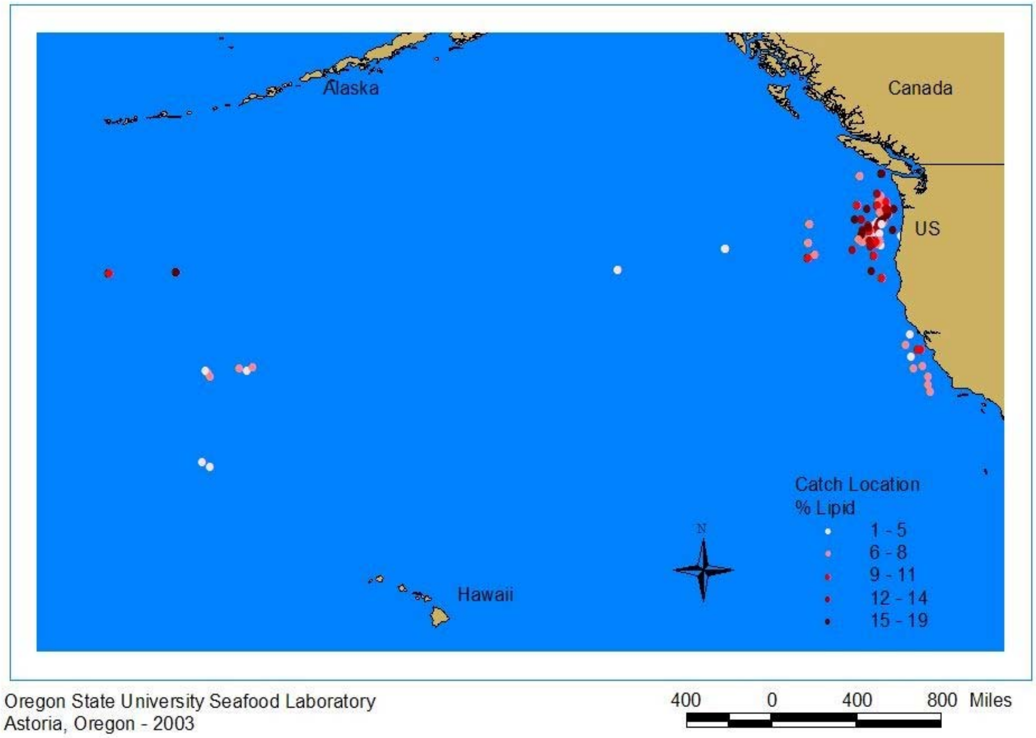


Figure 2. Correlation for combined lipid and moisture data for the 2002 and 2003 sample seasons

Catch Location of Troll-Caught Albacore
Samples for 2003 Lipid Study



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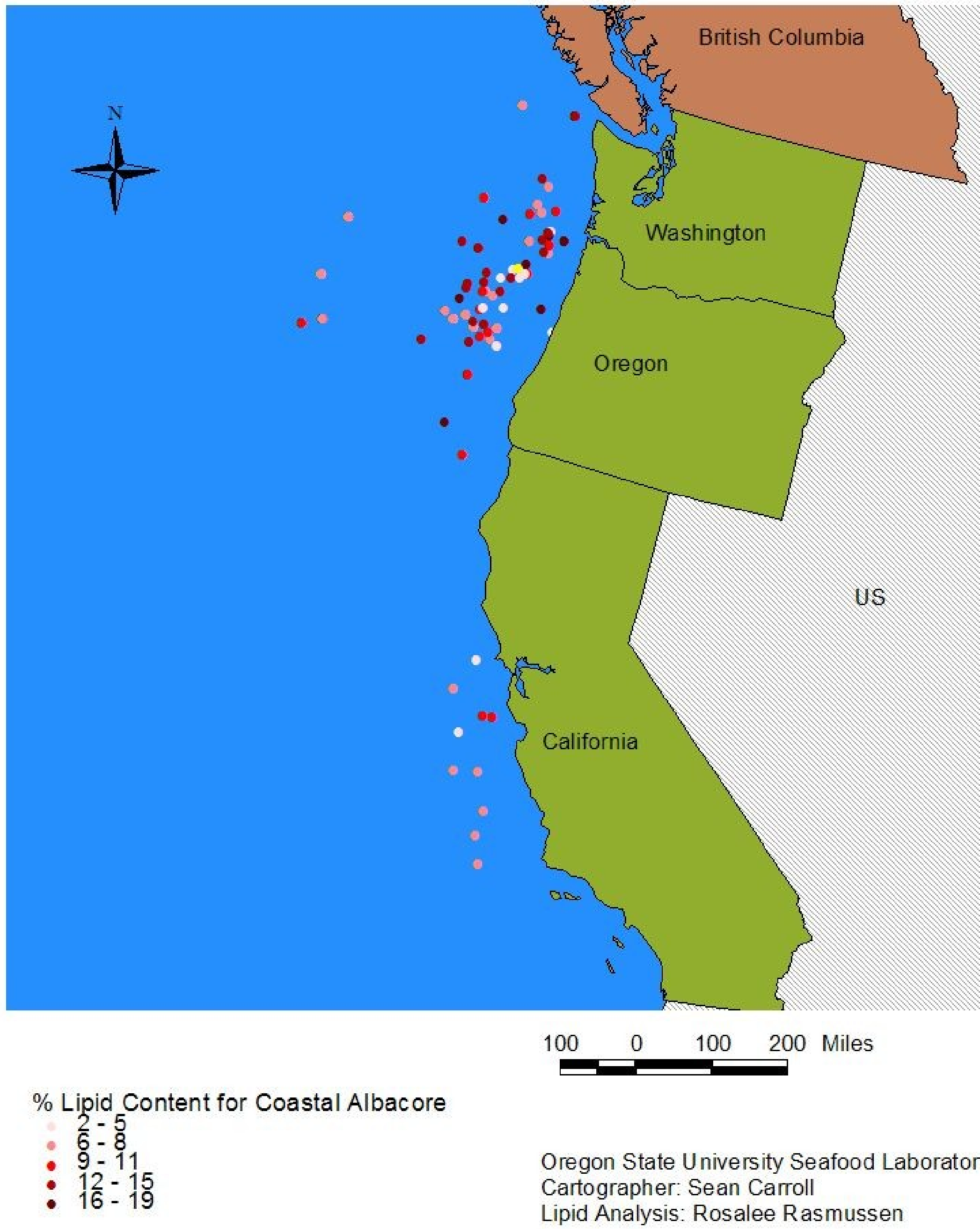
Lipid Composition and Location for Northwest Albacore Caught Within 400 Miles for the 2003 Season



Oregon State University Seafood Laboratory
Cartographer: Sean Carroll
Lipid Analysis: Rosalee Rasmussen