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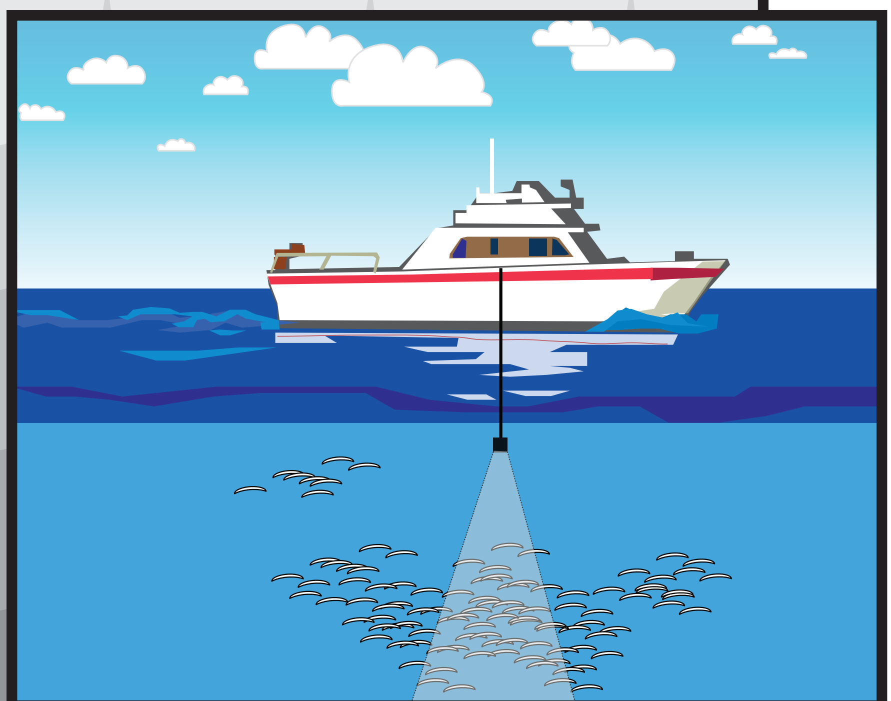
Estimating Acoustic Abundance of Forage Fish in Rosario Strait, Washington



by Darcy A. Wildermuth

Washington Department of
FISH AND WILDLIFE
Fish Program
Management Division

FPT 09-05

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Darcy A. Wildermuth
Washington Department of Fish and Wildlife
Fish Program
Region 4 Marine Resources
16018 Mill Creek Blvd
Mill Creek, Washington 98012

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Abstract

Lance and Jefferies determined that the seasonal change in the diet of harbor seals (*Phoca vitulina*) is related to the availability of pelagic forage near their haul-out. Hydroacoustic-trawl surveys were conducted in June of 2008 to assess pelagic forage abundance and composition in Rosario Strait and Burrows Bay, Washington.

Replicate surveys of each area were attempted during the second and third weeks of June. Mean acoustic density of pelagic forage varied between paired surveys: 0.0323 and .0128 kg/m^2 in Northern Rosario, 0.0067 and 0.0082 kg/m^2 in Burrows Bay. Pelagic forage species composition varied by area and survey date, but was dominated by juvenile Walleye Pollock (*Theragra chalcogramma*), (TL=60.9 mm) and pre-metamorphosed Pacific Herring (*Clupea pallasii*), (TL= 45.0 mm). From these results, 1,369 metric tons of pelagic forage, including 505 metric tons of juvenile pollock and 169 metric tons of pre-metamorphosed herring were estimated for the three areas combined.

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Introduction

Rosario Strait is a highly energetic waterway of Northern Puget Sound. Located just north and east of the confluence of the Strait of Juan de Fuca and Puget Sound, this channel runs along the west side of Burrows Island, then north between Blakely and Cypress Islands. A variety of marine mammals including harbor seals (*Phoca vitulina*) feed in these waters (Lance and Jefferies, 2007). As part of an ongoing study funded by the National Science Foundation (NSF #0550443, Alejandro Acevedo, Principal Investigator), the diet of harbor seals in the San Juan archipelago, of which Rosario Strait is a part, is being examined by Washington Department of Fish and Wildlife (WDFW) (SeaDoc Society Research Agreement No. K004431-25, Monique Lance and Steven Jefferies). Findings of this work indicate that harbor seal diet consists largely of Pacific herring (*Clupea pallasii*), adult salmonids, and Walleye Pollock (*Theragra chalcogramma*). The contribution of these species to harbor seal diet varies seasonally and is a function of their availability. Current work includes tracking movement of harbor seals in and around their haul outs by radio telemetry. In 2008, at least three seals have restricted their movement to Rosario Strait. We hypothesized that these animals are feeding on concentrations of pelagic forage, chiefly 1+ Pacific herring that have congregated in this area.

In addition to fecal samples collected for a harbor seal diet study, trawl net samples could provide species composition of pelagic forage. Acoustic surveys can obtain detailed information regarding spatial distribution and improve estimates of abundance over a wide area. Acoustic estimates have been shown to be useful in a number of predator-prey studies (Coyle, and Pinchuck, 2002, Kirsch et al., 2000). In this paper we estimate forage abundance, and examine the distribution of the acoustic biomass within the two areas of Rosario Strait and the adjacent waters of Burrows Bay.

Methods

Surveys were conducted on three nights; June 11, 12 and 17-18 of 2008. Acoustic sampling was conducted aboard the 36-foot WDFW Research Vessel Pasquale. Net sampling was conducted aboard the 45-foot National Marine Fisheries Service (NMFS) Research Vessel Streeter. Originally four nights of survey work were scheduled, two nights each during the second and fourth weeks of June. However, rough water, extreme daytime tides, and unseasonably bad weather significantly reduced our survey efforts to two areas in two nights during the first survey and three areas over one night during the second.

The survey areas were defined by distance from two harbor seal haul-outs and the results of satellite tracking data of three harbor seals using those haul-outs. Area 1: Northern Rosario; within about 3 nautical miles (nmi) from a point at the intersection of Seal Point and Pointer Island or approximately 12.8 nmi^2 (Figure 1). Area 2: Burrows Island; included those waters deeper than 60 ft within about 3 nmi of a point at the intersection of Burrows Island, Bird Rocks and Williamson Rocks or approximately 26.9 nmi^2 (Figure 2). Area two was later divided so the Burrows Bay (east of the island) and Southern Rosario Straits (west of the island) could be analyzed separately.

A one square nautical mile sampling grid was overlaid onto each survey area and a systematic random transect line was drawn at 45 degrees to the shore, forming a continuous zigzag line. The zigzag survey method maximizes the area covered during the few hours of darkness and relatively slack tides, available during the survey nights in June (Kimura and Lemberg, 1982). The final transect lines were constricted by hours of darkness and boat speed of the acoustic and trawl vessel.

The acoustic density and abundance of forage were estimated using a 105 kHz, Model 101 echo sounder (BioSonics Inc., Seattle, Washington), with an 8˚, 105 kHz Ross transducer. The transducer was mounted on a pole fixed to the starboard side of the RV Pasquale. The sounder's transmit rate (ping rate) was 2 pings/second and the pulse width was 0.7 m/second. Return acoustic signals were collected for echo integration using 20logR Time Varied Gain (TVG) for data acquisition and calibration.

Receiver gain drift was normalized by application of values collected by integration of the calibration signal. During the survey, an internal calibration procedure was used at the start and end of each area to check and record the echo sounder's receiver gain at-20dB.

A complete system calibration, including measurements of source levels, receiver gain and transducer receiver transmission sensitivities was conducted in February of 2008 (Precision

Acoustic Systems, Seattle, WA). Acoustic returns are documented as a paper echogram collected using a model SL600C Ross chart flasher/recorder.

Position of the RV Pasquale was determined using a Garmin GPS Map 230 and Garmin proprietary software V 3.20. Concentrations of acoustic biomass were marked as waypoints on this plotter and stored in a separate data file. These locations were then conveyed to the RV Streeter during the survey.

All data were processed using a BioSonics Model 121 digital echo integrator and stored on a laptop computer for post-processing. Quantitative transect data were processed using a mean target strength value of -33 dB/kg, a constant in our integration software and standard for WDFW adult herring (170mm) surveys (Lemberg, 1978).

Acoustic biomass is estimated by calculating mean surface referenced density for transects within regions and extrapolating the value over the region's surface area (Nunnallee, 1974). For each 180-ping output (approximately 1.5 minutes) the echo integrator generates an estimate of absolute volumetric density (kg/m^3) for each of eleven depth intervals. These estimates of volume are summed to result in an estimate of surface related density (kg/m^2). Noise is typically observed in the upper 9 m, or first two depth intervals, of the integrated data. These intervals are routinely excluded from analysis. Because the survey areas included shallow water along much of the transect lines, only the first interval, or 4.6m, was excluded.

For each area surveyed, estimates of the average surface related density and standard deviation are calculated (Williamson, 1982). Species abundance in metric tons (t) is obtained by apportioning the acoustic biomass by the species composition, by weight; from the trawl data collected using a small pelagic trawl aboard the RV Streeter. Tow locations and depths were selected ex tempore, based on observed acoustic abundance.

WDFW's Pelagic HydroAcoustic Research Trawl is a single wire mid-water trawl, 18m in length. Two 3m horizontal bars (pipe) replace the head and footrope of a common trawl net (Figure 3). Four 65-pound lead balls, two attached to each end of the foot bar, weight the net. The head and foot bars are attached to 2m bridals that are joined to a steel cable. The nylon mesh graduates from 120mm to 3mm stretch measure at the cod end. The net mouth theoretically measures 7m x 3m (10ft x 20ft) when fishing.

A Sensus Pro, and Sensus Pro Ultra depth recorders and Sensus Master v2.57 software (ReefNet Inc. West Seneca, NY), were used to document head bar and foot bar depth at 10-second intervals. These devices indicated that the net mouth opened 4.9m (16ft) when fishing. These same devices record water temperature and time at depth.

Each trawl sample was sorted to species. Individual fish length and weights were collected to the nearest 0.1g for at least a sub-sample of each species. When sub-sampled, the remaining fish were counted and weighed in the aggregate.

Results

Acoustic Results

Nekton or "sign" is commonly observed on an echogram as individual marks rather than a continuous wave. The total number of marks and the distance between them (scatter) are indicative of the total abundance and distribution of the nekton. During these surveys, nekton was most commonly observed as light to moderate scatter (Figure 4). Large aggregations typically associated with adult herring in pre-spawner holding aggregations were not observed at any time during these surveys. In general, the scatter increased in density as we entered shallow water, and decreased as we surveyed into deeper water. The main portions of most channels were relatively void of acoustic signal.

Acoustic results are summarized in Table 1. Acoustic densities were much higher during the first series of surveys in Northern Rosario Strait and comparable in Burrows Bay. We were unable to complete the first survey (June 12) in Southern Rosario as a result of weather conditions.

Mean acoustic density was highest in Northern Rosario. Replicate surveys produced very different results; .0323 kg/m^2 on June 11 and .0128 kg/m^2 on June 18. The average mean density for the pair of surveys was .0226 kg/m^2.

Figures 5 and 6. present the acoustic densities along the transect line for the two Northern Rosario surveys. Densities were highest on the Blakely Island (west) side during the first survey (June 11th), where the nekton was somewhat organized in shallow waters. Small areas off Tide Point, Cypress Island and near Black Rock had consistent concentrations of moderate to heavy nekton on both surveys.

The single survey in Southern Rosario produced a mean density in the same order of magnitude as the Northern Rosario survey of the same night (June 18) of .0118 kg/m^2 and .0128 kg/m^2 respectively. Nekton was poorly organized and concentrated in that portion of the transect line nearest Burrows and Allen Islands (Figure 7).

Mean densities from Burrows Bay were the lowest of the three areas averaging .0075 kg/m^2, and were consistently lower among the paired surveys. There was no organization of the nekton or relation to water depth during either survey (Figures 8. and 9). A single concentration of nekton in the channel between Burrows Island and Fidalgo Head was noted on both surveys.

Trawl Results

All trawl samples were small, with total catches ranging from 70 to 691 grams (Table 2). The most frequently observed species were juvenile pollock (*Theragra chalcogramma*) and pre-metamorphosed herring (*Clupea pallasii*). A total of 249 pollock were weighed and measured on deck, averaging 60.9 mm and 1.8 grams. A total of 131 herring were similarly measured averaging 45.0 mm and 0.9 grams.

In addition to pollock and herring, other pelagic fish were observed including species of stickleback, snailfish, lumpsucker, sculpin, prickleback, lanternfish and sand lance.

Total catch and total pollock, and herring catches were determined by summation of individual fish weights. When weights were not available, the average weight of each species, observed over all tows that night, was applied to the number of each species.

The proportion of the total catch consisting of pollock and herring were compiled for all tows within each area. The proportions of total forage, pollock and herring, were consistent between the two surveys in Northern Rosario at about 98% (Table 1). Results of Burrows Bay were not as consistent as the catch from June 17 was entirely pollock. In all cases, the dominant catch by number was pollock and herring, with pollock the major contributor and herring the minor.

Applied Trawl

All trawl catches within an area were combined and the averages were applied to the estimates from the acoustic surveys, generating estimates of total forage, pollock and herring biomass for each area and survey (Table 2). Averaging the results of paired surveys produced the final estimates for each area and the final estimates for all areas were produced by summation. A total of 1,368.7 metric tons of pelagic forage were estimated for the three areas combined. Of this, 505.4 metric tons of were juvenile pollock, 168.9 metric tons of pre-metamorphosed herring, and 694.4 metric tons were other pelagic species.

Estimates for the pollock and herring are somewhat deceiving. While pollock were the dominant catch by number in all areas, a few or even a single adult fish of a different pelagic species often dominated the total catch by weight. For example, the catch in Southern Rosario on June 18th was very small; 49.9 grams, including only 12 pollock and herring, and was dominated by two (2) Snake prickleback (*Lumpenus sagitta*); at 14.6 grams and 29% of the total catch and three (3) Pacific tomcod (*Microgadus proximus*); at 10.5 grams and 21% of the total catch. As a result the contribution of pollock and herring to the total catch by weight were greatly reduced.

Similarly, the catch in Burrows Bay on June 12th included a plainfin midshipman (*Porichthys notatus*) weighing 42.2 grams and contributing 23% of the total catch. Even though midshipmen make vertical migrations at night (Hart, 1973), it was eliminated from the analysis due to its comparatively large size (168 mm).

Discussion

Based on WDFW Forage Fish's long history of estimating forage fish abundance, the acoustic estimates appear reasonable and are mirrored in the trawl catch. A target strength for adult herring (170 mm) was applied to the acoustic data to produce estimates of forage biomass. Since the major forage species were juveniles, we may have underestimated the acoustic biomass, however the results will be useful for observing relative abundance.

We had expected herring to dominate the catch based on seal diet data from previous years. We were surprised by the abundance of juvenile pollock in the trawl catches; however, juvenile pollock dominated the diet of harbor seals in Rosario Straits in the months prior to the survey (Lance, personal communication). As stated previously, harbor seal diet is seasonal and a function of species availability. We extend our original hypothesis; that these animals were feeding on concentrations of 1+ Pacific herring to include all pelagic forage species as available. During June of 2008, juvenile pollock were in greater abundance in Rosario Strait, and the harbor seals shifted from herring to these pollock.

The estimated acoustic biomass was composed primarily of pre-metamorphosed herring and juvenile pollock, as determined by the trawl catches. We did not observe large, concentrated aggregations of nekton that would typically be seen during the winter herring surveys which are conducted on adult pre-spawning fish. Herring do not have the ability to form and maintain schools prior to metamorphosis (Gallego and Heath, 1994). While it is recognized that older 1+ herring could have avoided this trawl net, the absence of the distinctive echogram pattern associated with the schooling behavior of older herring and the absence of older herring in the trawl samples indicate that they were not in the area in any abundance.

Based on previous work collecting juvenile forage fish (Penttila et al., 1985, 1986) we suspected that the largest acoustic densities would be associated with the nearshore. We extended this idea to expect that Burrows Bay would have the highest acoustic densities since it is protected and shallow. While the highest densities were found associated with shallow water in Northern Rosario, Burrows Bay had the lowest acoustic densities. Juvenile herring and pollock are known to share nursery areas; aggregating in bays near the surface, and these nursery areas are isolated (Stokesbury et al., 1999). It is possible that Burrows Bay does not meet the requirements of either juvenile herring or pollock (Stokesbury et al., 2000).

Estimates of acoustic densities varied significantly between surveys in Northern Rosario Strait. This area is highly energetic and the particularly bad weather during the month of June as well as extreme tidal exchange may have contributed to the variation. Density estimates for Burrows

Bay were not as precise as those from the other areas. This indicates that the acoustic biomass was patchy in distribution.

Pollock and herring dominated all catches by number. However, of the estimated 1,368.7 metric tons of pelagic forage, 694.4 metric tons were neither pollock nor herring. The apportionment of pelagic forage is based on the trawl results. In almost all cases, the catch by weight was overwhelmed by one or several larger heavier fish, which displace pollock and herring dominance. Additionally it is possible that problems associated with individual weights of small fish (e.g. adhering water maybe a large fraction of the weight) under rigorous field conditions (rolling vessel late at night), may have resulted in error (Kimmerer, et al., 2005), the accumulation of which may be significant.

Table 1. Acoustic estimates.

	Northern Rosario		**Southern Rosario**		**Burrows Bay**	
	11-Jun-08	18-Jun-08	11-Jun-08	17-Jun-08	12-Jun-08	18-Jun-08
Surface area (10^6 M^2)	50.0		27.1		15.2	
Acoustic Densities						
Mean density (kg/m^2)	0.0323	0.0128		0.0118	0.0067	0.0082
Std Dev Mean Density	0.0064	0.0016		0.0017	0.0033	0.0064
Average Density (kg/m^2)	0.0226				0.0075	
Applied Trawl						
# Tows	3	2		1	1	1
% Forage	96.9%	100.0%		48.7%	74.5%	100.0%
% Pollock	41.0%	47.8%		31.7%	67.4%	100.0%
% Herring	23.9%	5.5%		2.2%	7.1%	0.0%
Acoustic Estimates						
Total Pelagic (Not TS corrected, T)	1,615.0	640.0		320.3	108.5	124.3
Total Forage (t)	1,252.3	512.0		124.8	72.7	124.3
Pollock (t)	513.4	244.8		39.6	49.0	124.3
Herring (t)	298.9	28.4		2.7	5.1	0.0
Average Total Forage (t)	1,127.5		124.8		116.4	
Average Pollock (t)	379.1		39.6		86.7	
Average Herring (t)	163.7		2.7		2.6	

Table 2. Trawl catch summary.

11-Jun-08			(gms)	%	#
Tow #1	Northern Rosario (Cypress_Blakely)	Total Catch	85.5		
Start Tow	48.35.913N 122.46.964W	Total Herring	20.0	23.4%	41
End Tow	48.35.739N 122.46.730W	Total Pollock	60.4	70.6%	41
Depth	head bar fished @ 43-63 feet	(Herring + Pollock)	80.4		
Time	set @ 20:54; pulled @ 23:10 / 16 minutes				
Tow #2	Northern Rosario (Cypress_Blakely)	Total Catch	325.8		
Start Tow	48.35.988N 122.46.548W	Total Herring	93.1	28.6%	74
End Tow	48.35.805N 122.46.578W	Total Pollock	216.3	66.4%	103
Depth	head bar fished @ 52-60 feet	(Herring + Pollock)	309.4		
Time	set @ 23:37; pulled @ 23:52 / 15 minutes				
Tow #3	Northern Rosario (Cypress_Blakely)	Total Catch	584.0		
Start Tow	48.31.303N 122.46.432W	Total Herring	205.0	35.1%	191
End Tow	48.30.921N 122.45.680W	Total Pollock	83.0	14.2%	132
Depth	head bar fished @ 43-91 feet	(Herring + Pollock)	288.0		
Time	set @ 00:52; pulled @ 1:04 / 12 minutes				
12-Jun-08			(gms)	%	#
Tow #1	Burrows Bay				
Start Tow	48.27.970N 122.40.895W	Total Catch	183.5		
End Tow	48.28.960N 122.41.036W	Total Herring	10.0	5.4%	22
Depth	head bar fished @ 35-43 feet	Total Pollock	95.2	51.9%	61
Time	set @ 23:19; pulled @ 23:46 / 27 minutes	(Herring + Pollock)	105.2		
17-Jun-08			(gms)	%	#
Tow #1	Burrows Bay				
Start Tow	48.28.175N 122.41.031W	Total Catch	208.5		
End Tow	48.28.653N 122.41.057W	Total Herring	0.0	0.0%	
Depth	head bar fished @ 40-46 feet .	Total Pollock	208.5	100.0%	213
Time	set @ 20:24; pulled @ 20:39 / 15 minutes	(Herring + Pollock)	208.5		
Tow #2	Southern Rosario (W Burrows Isl, north to Fidalgo Head)				
Start Tow	48.28.554N 122.43.096W	Total Catch	49.9		
End Tow	48.28.919N 122.43.171W	Total Herring	1.1	2.2%	1
Depth	head bar fished @ 36-76 feet	Total Pollock	23.2	46.5%	11
Time	set @ 23:19; pulled @ 23:32 / 13 minutes	(Herring + Pollock)	24.3		
18-Jun-08			(gms)	%	#
Tow #3	Northern Rosario (E of Thatcher Pass, W to E off Blakely to Cypress)				
Start Tow	48.31.497N 122.46.546W	Total Catch	691.1		
End Tow	48.31.836N 122.46.175W	Total Herring	40.6	5.9%	33
Depth	head bar fished @ 110-119 feet	Total Pollock	633.4	91.7%	293
Time	set @ 00:28; pulled @ 00:50 / 22 minutes	(Herring + Pollock)	674.0		
18-Jun-08			(gms)	%	#
Tow #4	Northern Rosario (E of Thatcher Pass, off Lydia shoals)				
Start Tow	48.35.600N 122.46.675W	Total Catch	70.4		
End Tow	48.35.235N 122.47.311W	Total Herring	8.5	22.0%	9
Depth	head bar fished @ 38-80 feet	Total Pollock	50.7	68.3%	28
Time	set @ 01:58; pulled @ 02:18 / 20 minutes	(Herring + Pollock)	59.2		

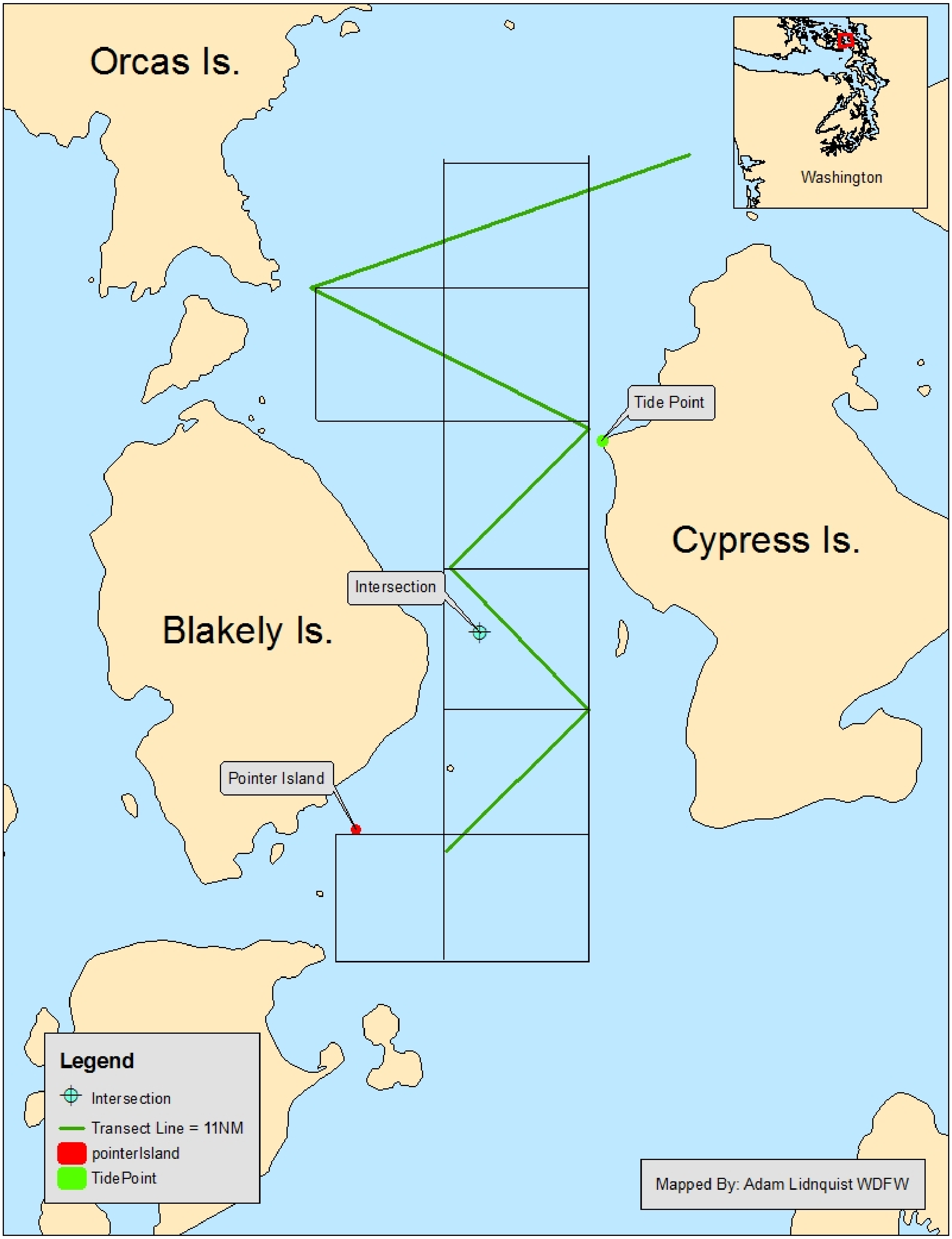

Figure 1. Northern Rosario Study Area.

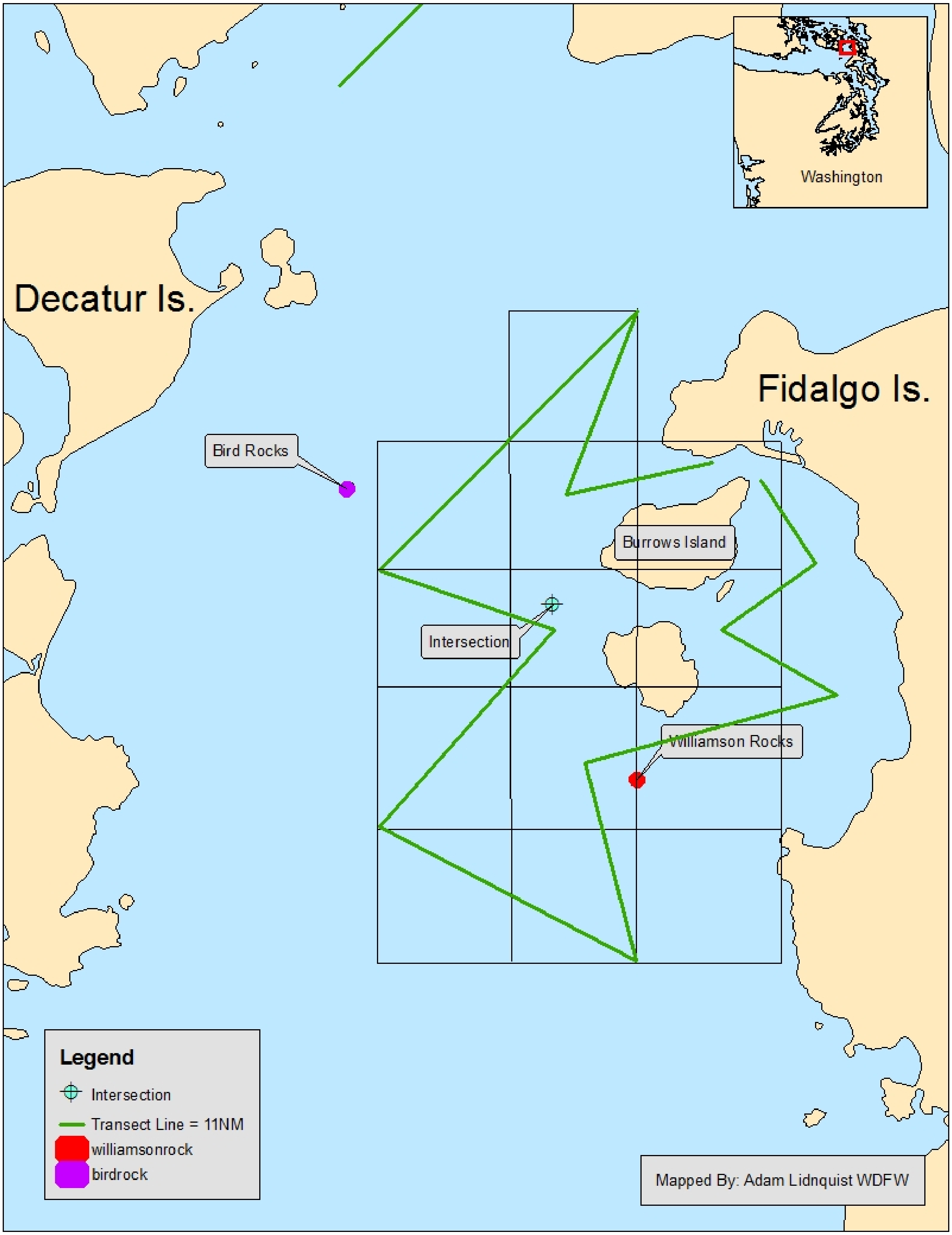

Figure 2. Southern Rosario Study Area.

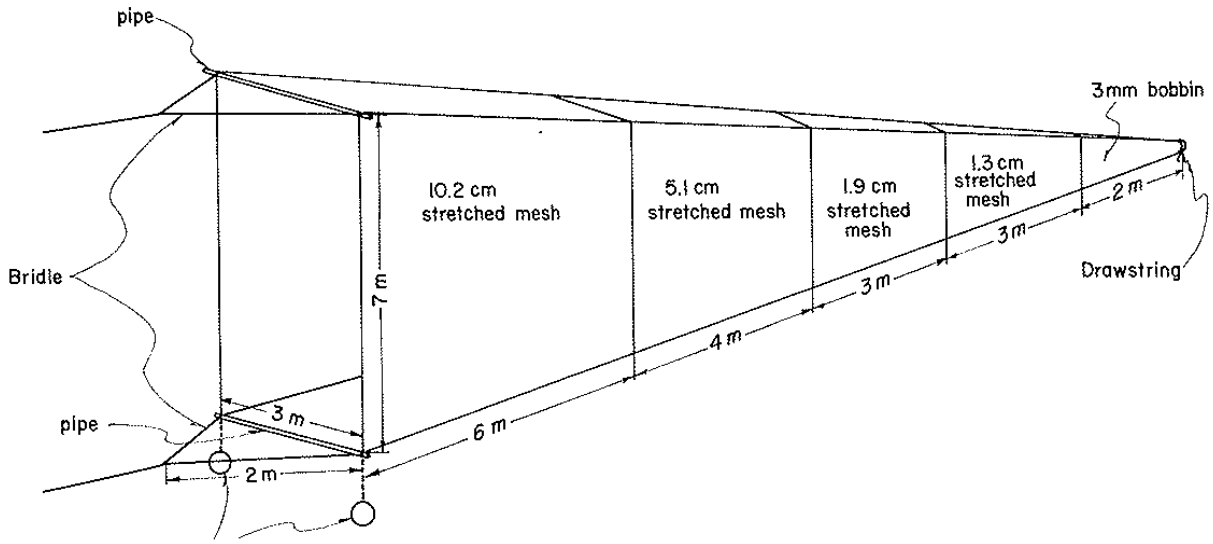

Figure 3. WDFW Pelagic HydroAcoustic Research Trawl.

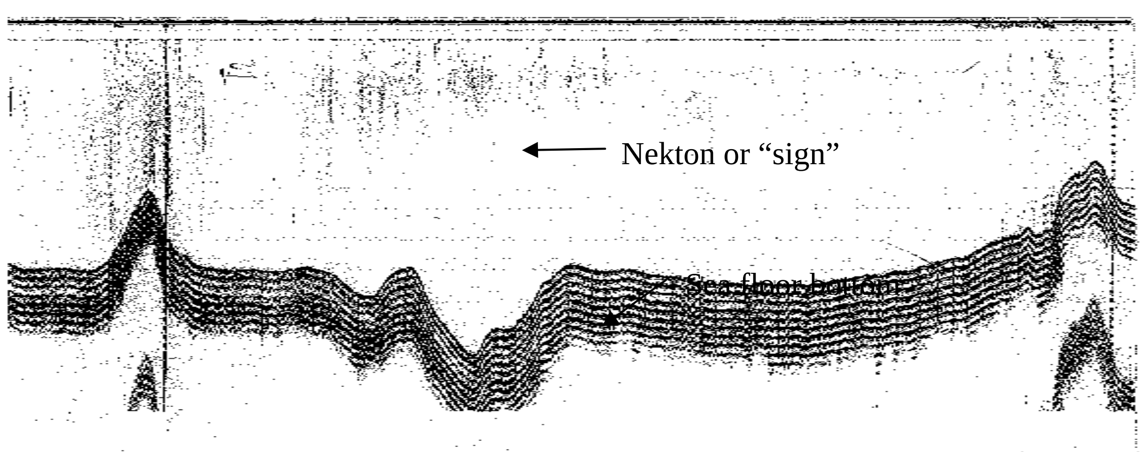

Figure 4. Example of Scatter.

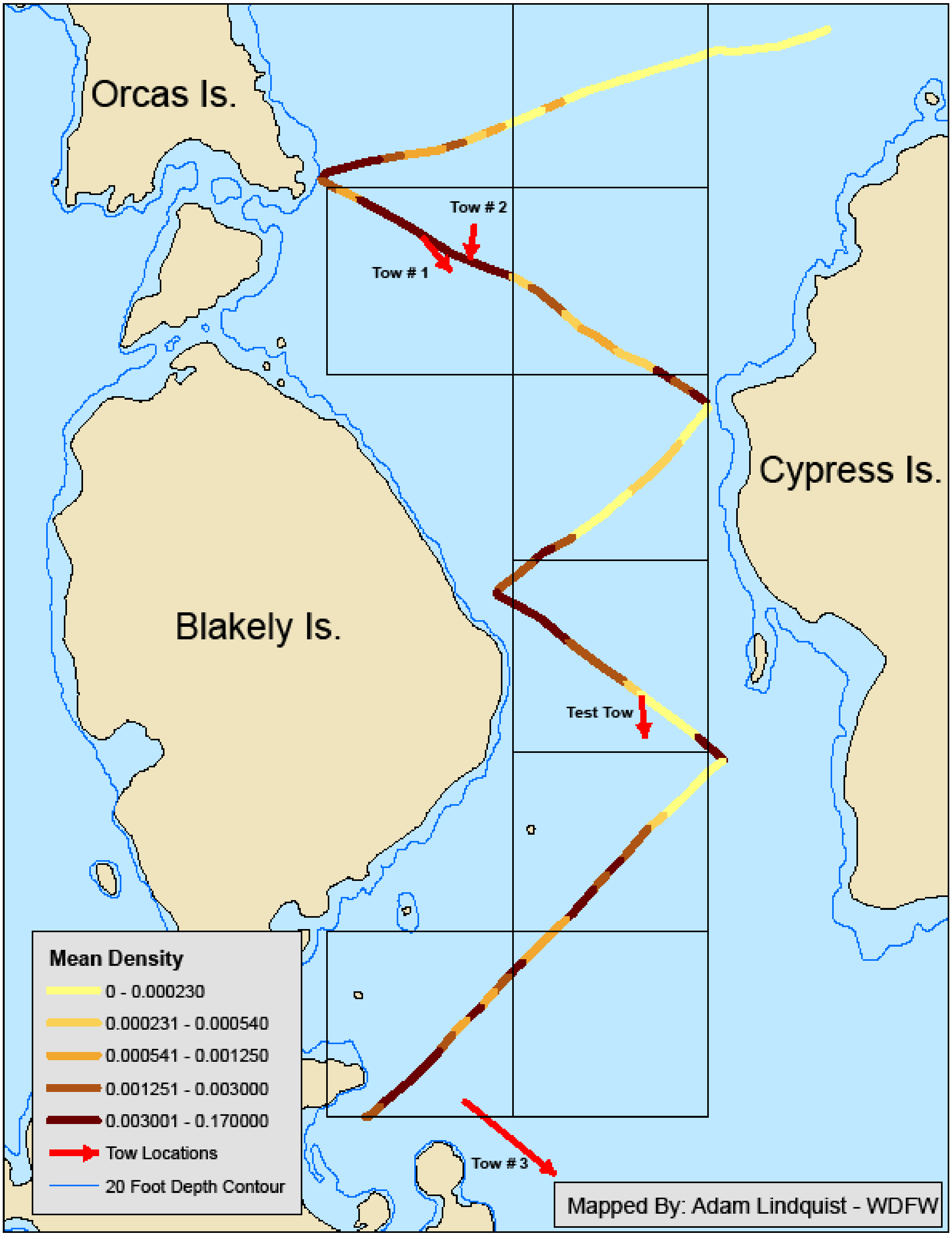

Figure 5. Northern Rosario 6/11.

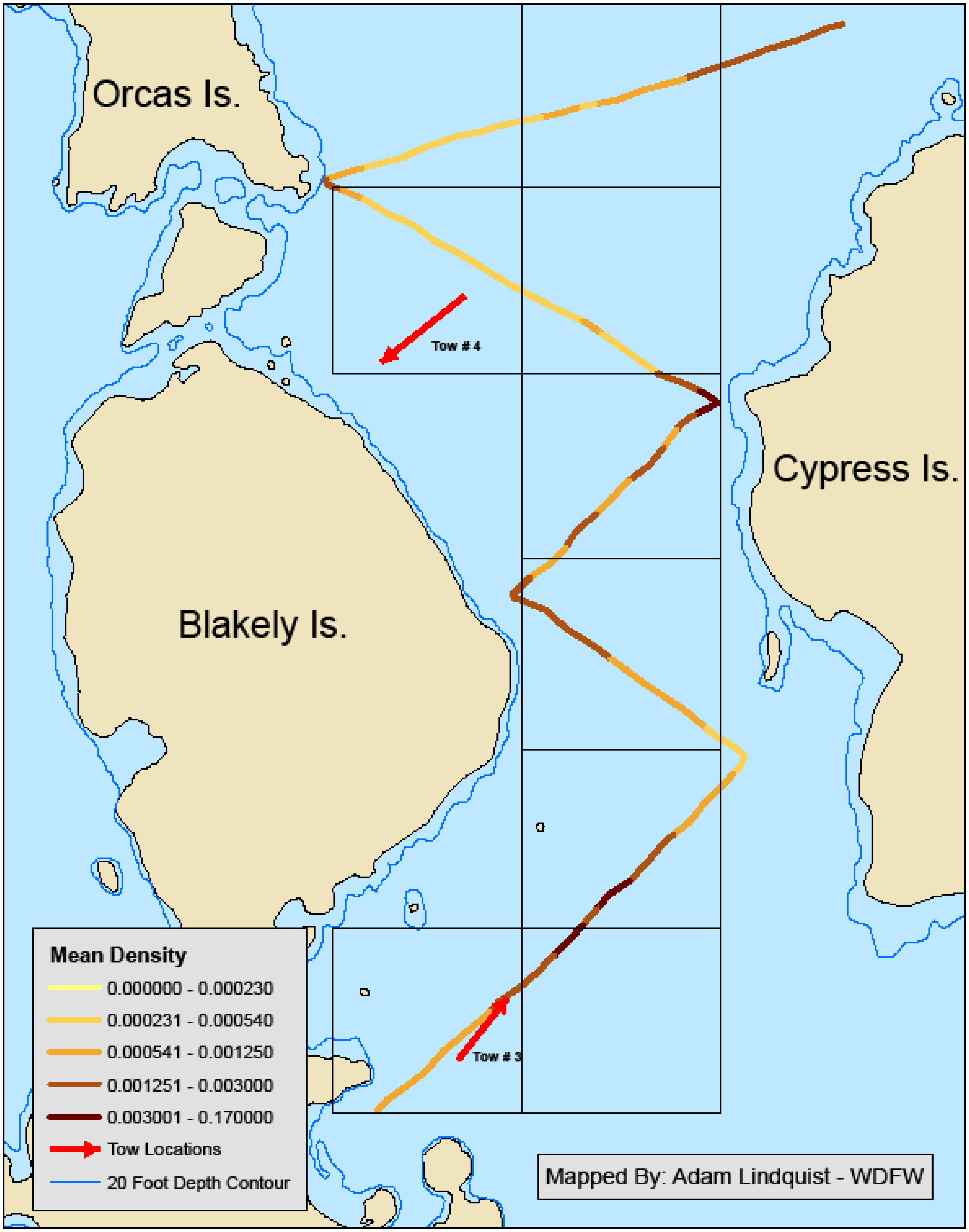

Figure 6. Northern Rosario 6/18.

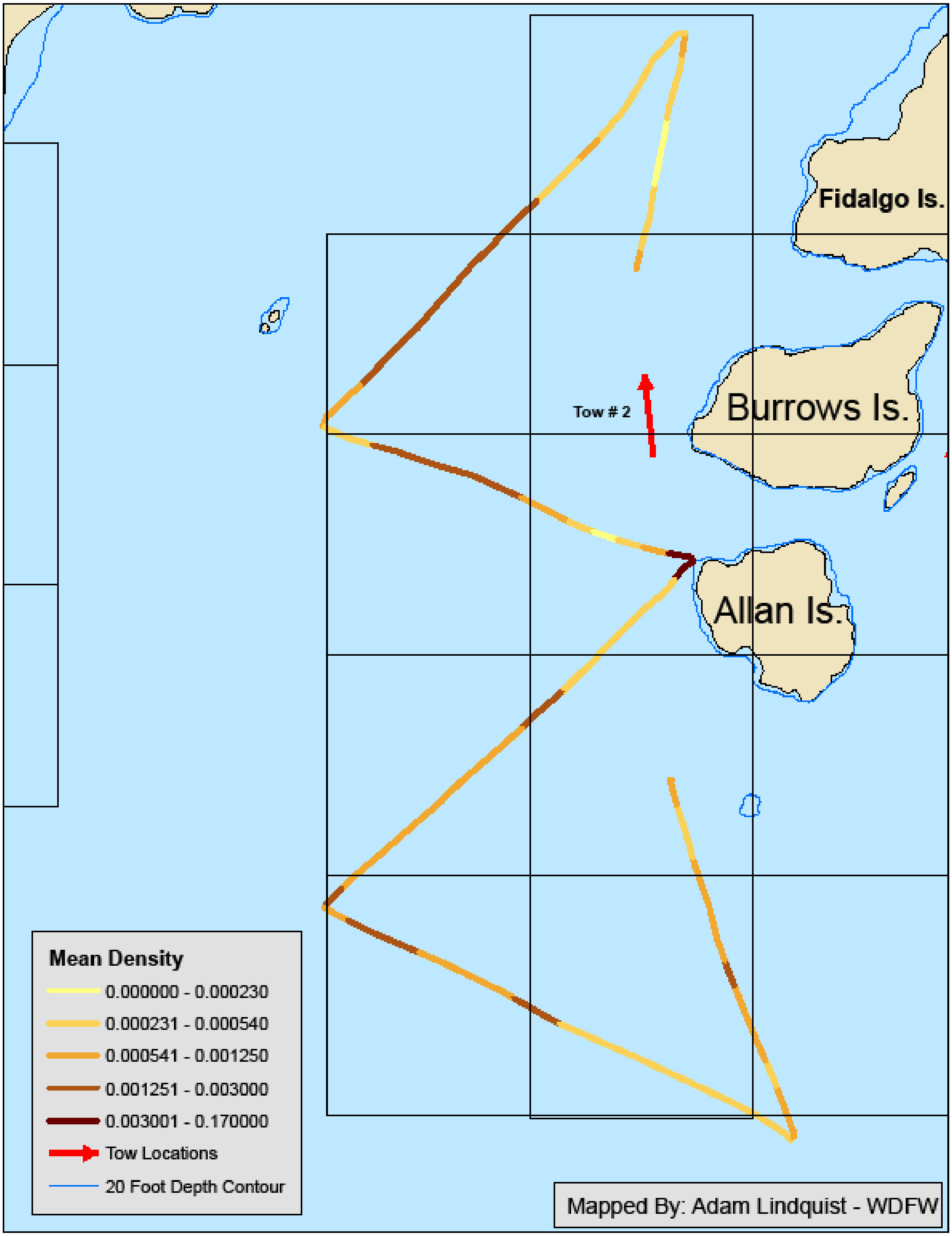

Figure 7. Southern Rosario 6/18.

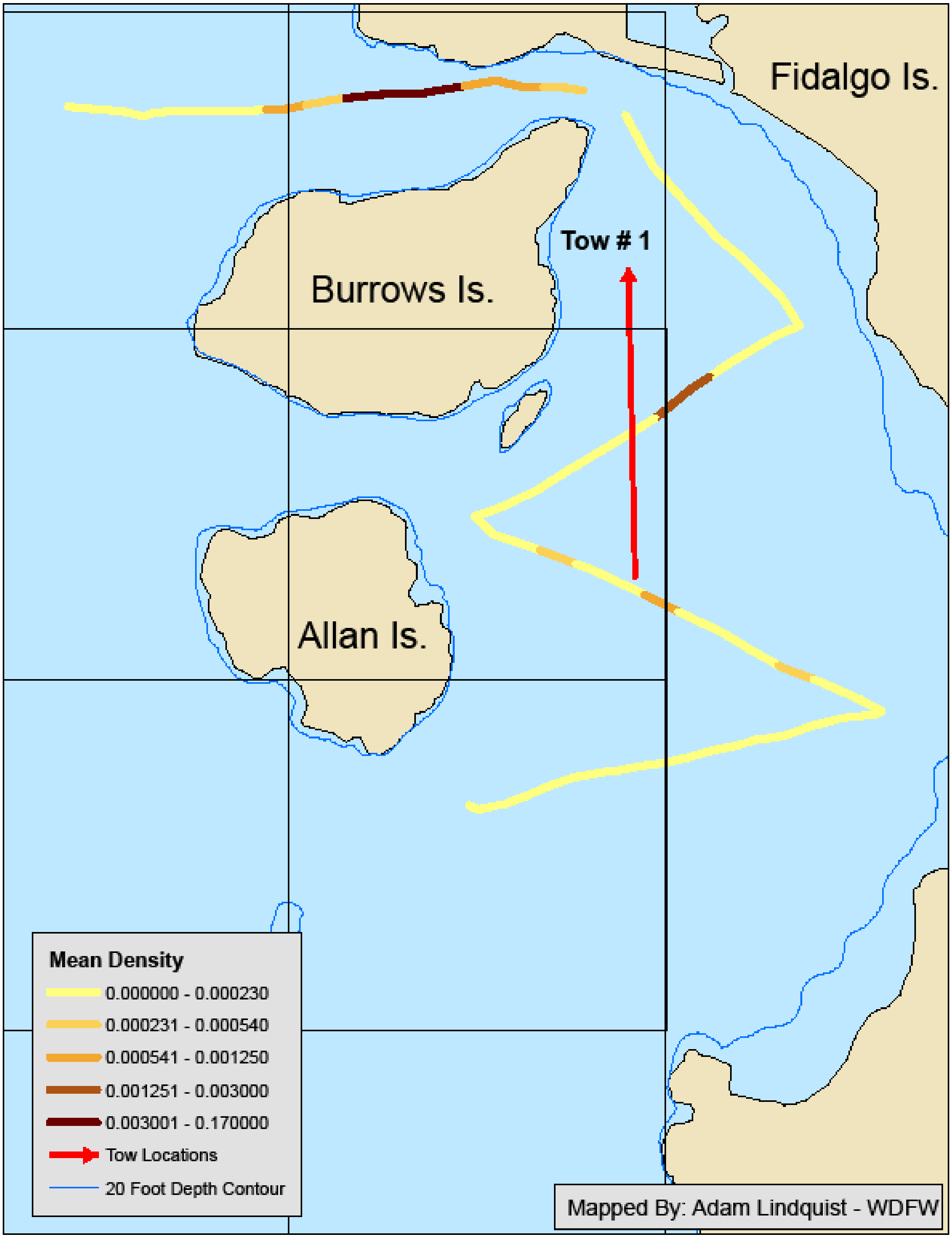

Figure 8. Burrows Bay 6/12.

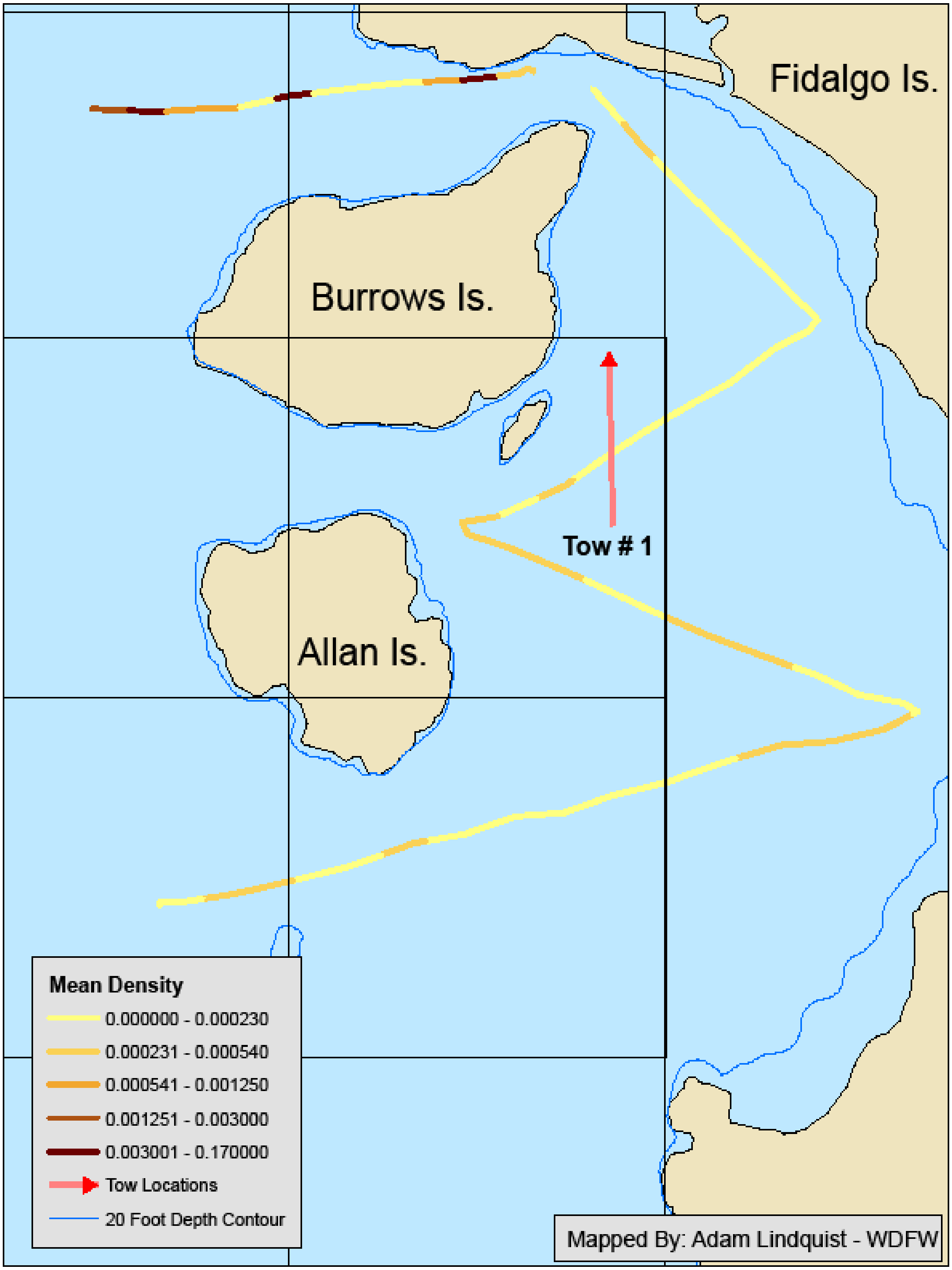

Figure 9. Burrows Bay 6/17.

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