

**Herring Assessment Survey**  
For  
**Yaquina Bay, Newport, Oregon**

**February 18 – 20, 2002**

**Conducted by**  
**BioSonics, Inc**

For

**Yaquina Herring, Inc**

**Oregon Department of Fish & Wildlife**

## **Background**

BioSonics was contacted by Oregon Department of Fish and Wildlife (ODFW) in January of 2002 and asked to consider the potential for hydroacoustic assessment of herring biomass in Yaquina Bay Oregon. ODFW indicated that this would be a joint project, sponsored by ODFW and Yaquina Herring, Inc (YHI, a commercial fishing association). The survey was to (1) be of short duration, (2) provide an estimate of the “minimum biomass” of herring present in Yaquina Bay, and (3) provide a report of biomass to the sponsors immediately after the survey was completed.

The stated purpose of the survey was to establish a minimum sampled biomass estimate, which could be used for harvest planning purposes.

BioSonics suggested that such a survey and report were possible and that, upon approval of the project, they would conduct such an assessment.

Discussion and negotiations resulted in a project that would:

1. At a date to be determined by ODFW & YHI, based on abundance and gonadal stage of the herring, conduct a one to two day acoustic survey of herring schools in Yaquina Bay. ODFW and YHI would make arrangements for a suitable vessel and other needs for the survey.
2. BioSonics would provide scientist(s) and equipment necessary to conduct the survey.
3. BioSonics would provide an initial analysis and report to the sponsors upon completion of the survey. This initial (verbal) report would include, as the primary product, an estimate of the biomass of herring observed during the survey.
4. BioSonics would provide a written report (electronically) to ODFW and YHI, one week after completion of the survey. This report was to include methods, data summary, graphics, and recommendations for future hydroacoustic assessment work.

## **Methods**

Hydroacoustic assessment is an accepted methodology for presence, distribution, biomass, and behavior. Various methods for conducting and analysis of hydroacoustic surveys have been developed, based on the characteristics of the fish and the environment to be surveyed.

Although the states of Washington and Alaska, as well as several European countries, rely on hydroacoustics for assessment of herring stocks, we are unaware of the application of hydroacoustic technologies to the assessment of herring stocks in an environment as small and shallow as Yaquina Bay. Careful consideration of the acoustic and physical constraints necessitated development of methodology and sampling design to ensure completion of this survey.

The sample protocol was established as follows:

1. Acoustically sample as much of the Yaquina Bay environment as possible, between the Highway 101 Bridge and River Bend (Figure 1).
2. Concentrate acoustic efforts on herring schools, thereby achieving an estimate for the biomass of the fish observed.
3. Ensure that the survey included period(s) of suspected (according to YHI fishermen's' experience) peak schooling behavior of the fish, which was at slack (high and low) tide.
4. Attempt to get at least two surveys of the area completed, at slack (high and/or low) tide.
5. Attempt to collect side-looking acoustic measurements to help in establishing geographic distribution and size of individual herring schools.

Hydroacoustic equipment used for this project consisted of a BioSonics DT6000 scientific echosounder equipped with a 6-degree, 200 kHz split-beam transducer. The transducer was mounted to a pole, equipped with an adjustable mount for side-looking activity.

#### Integration analysis techniques

This involved measurement of the echo signal strength and analysis of that return relative to known echo strength measurements of the specific species and size of fish. For purposes of this project, due to time constraints, an echo integration value of  $-32$  dB (decibel) per kilogram, was taken from the literature and used as the value for determination of herring biomass. Final estimates were based on an echo integration value of  $133$  dB / kg, based on discussions with Washington Department of Fish and Wildlife personnel, better representing the fish found in this survey.

The acoustic sample, a transect through a school of herring, was expanded to estimate the biomass of the entire school sampled. This expansion was done by assuming that the school is cylindrical in shape, using the measurements of the transect length and of the detected school depth (from top of school to bottom of school) as parameters in the calculation of the volume of the sphere.

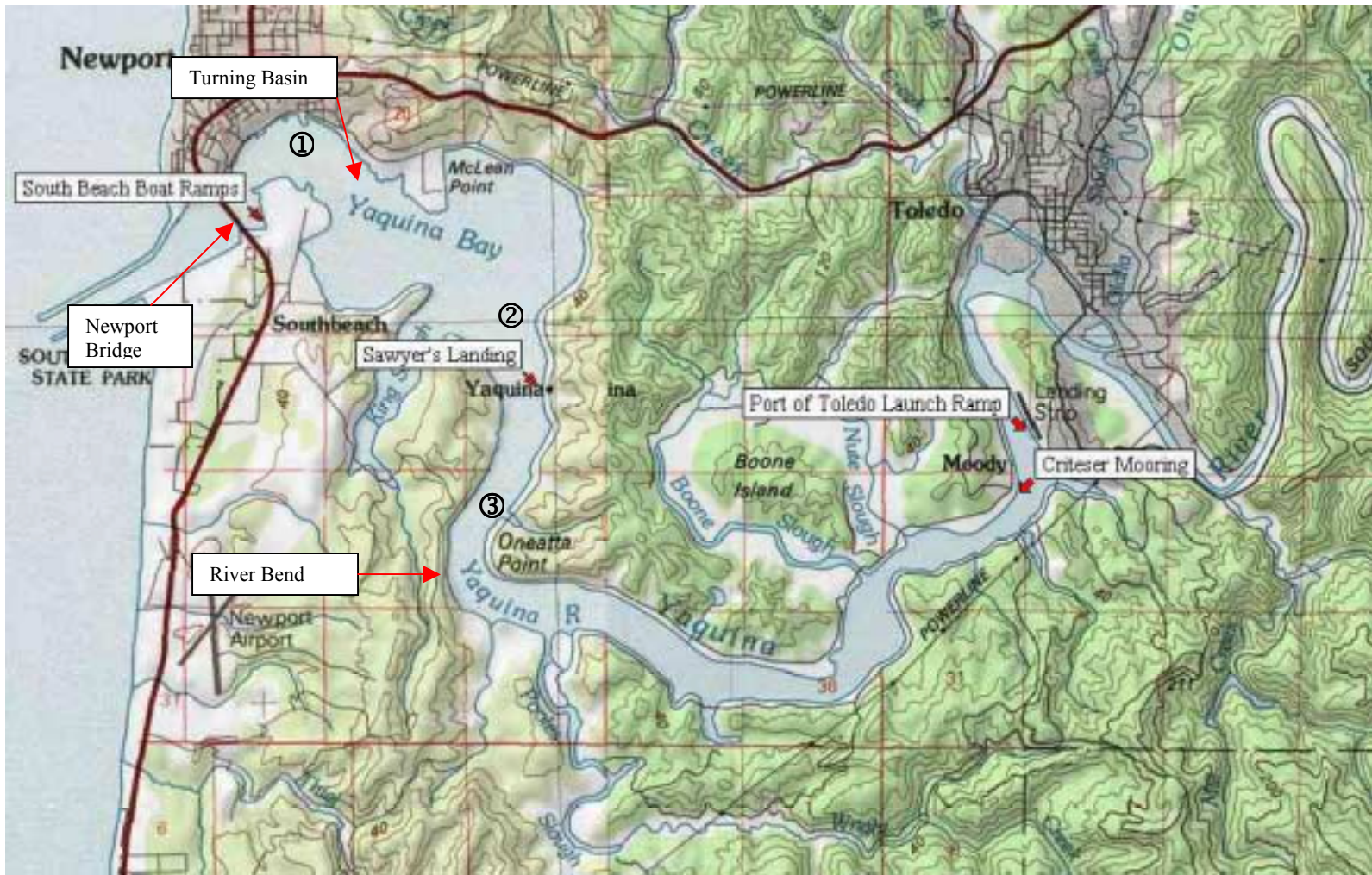


Figure 1. Yaquina Bay and vicinity. Key points of reference are indicated: Turning Basin, Sawyer's Landing, and River Bend. Herring survey conducted by BioSonics between the Newport Bridge and River Bend.

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Analysis of acoustic data for establishment of a biomass estimate (of sampled fish) was predicated on the following assumptions:

1. That a substantial portion of the larger herring schools present in Yaquina Bay (sample area) would be detected and sampled
2. That acoustic sampling through, or across, the schools would yield a density measurement (fish weight per cubic meter)
3. That acoustic information from the literature, indicating that an echo integration value of  $-32$  dB/kg, is appropriate for herring.

BioSonics personnel<sup>1</sup> arrived in Newport late the afternoon of February 18, 2002. At that time, they met with the representative for YHI<sup>2</sup> and began to prepare for the survey. This team visited the survey vessel, determined mounting and configuration requirements, and acquired and constructed necessary equipment and hardware for the project (Figure 2).



**Figure 2. Mr. Gene Law (Yaquina Herring, Inc) and Mr. Jim Dawson (BioSonics) construct hardware for use in the Yaquina Herring Study.**

On the morning of February 19, the team met at the survey vessel, the F/V Orca (Figure 3), and installed and tested the equipment (Figure 4). Upon completion of installation and testing, the vessel and crew began the survey.

The survey was initiated at 08:33, approximately three hours before low tide which occurred at 11:38. The survey was concluded at 18:46, approximately one hour after high tide, which occurred at 17:34 (Table 1).

<sup>1</sup> Mr. Jim Dawson, Senior Scientist and Mr. Bob McClure, Director for Marketing & Sales

<sup>2</sup> Mr. Gene Law

During the course of the survey, members of YHI on other vessels assisted in the survey by reporting observed (visual and acoustic) concentrations of herring. The survey vessel would visit those locations during the course of the survey. Once located, a school was traversed and acoustic data was recorded using BioSonics Acquisition software.



**Figure 3. The F/V Orca was used as the platform from which the Yaquina Bay Herring acoustic survey was conducted.**

The transducer was rotated approximately 90-degrees to the bottom (parallel to the surface of the water) in an attempt to collect information on a herring school inshore of the vessel. cursory analysis of the data proved inconclusive and this information was not used for this analysis.



**Figure 4. Installation of the hydroacoustic transducer mount aboard the F/V Orca.**

The survey was conducted in two stages. The first stage was conducted by proceeding from the downstream end of the area (Newport harbor) to the upriver end of the survey area (River Bend) in the morning, and returning to the downstream area by early afternoon. This coincided, roughly with the late falling and early rising tide of the day.

The second survey period followed the same geographic course, but did not proceed as far upriver as the first, due to the lack of herring concentrations from the other vessels. This survey generally corresponded to the late rising and early falling of the daily tide.

## Results

The F/V Orca proved to be a very good sampling platform and enabled the collection of a good quantity of high quality acoustic data. The BioSonics DT6000 echosounder worked well and resulted in the collection of high quality acoustic data over a large area of Yaquina Bay and River.

Herring schools were observed, and acoustic data were collected on herring school density, throughout the sampling area. However, larger herring schools were observed in three main regions within the sample area. These areas, as indicated in Figure 1, were: In the lower Yaquina Bay area ① (downriver of the turning basin), near the middle of the sampling area ② (Sawyer's Landing), and upriver ③ (in the morning only, near River Bend).

At several locations throughout the day, one of the fishermen aboard the F/V Orca, or another nearby vessel, successfully jigged for herring alongside our acoustic sampling location, confirming that the targets were, indeed, herring. At one point, a purse seine was set and a collection of 200 herring was made, by an accompanying vessel, to establish the roe to total weight ratio (for fishery planning purposes).

The analysis of the acoustic data was divided into three components:

1. Identification of larger herring schools from examination of the acoustic data. Only larger<sup>3</sup> schools were used in the calculation of biomass, as the time needed to process all data would have made reporting quickly impossible.

Acoustic data were reviewed using BioSonics Visual Analyzer, as displayed in Figure 5. This allowed recreation of the echogram (graphic) and identification and selection of larger herring schools. These schools were then selected (a feature of the software) and processed to determine their acoustic density. The result, based on the relationship measured acoustic density to weight per unit volume (based on Washington and Alaska herring data), yielded a weight per unit volume (in this case, pounds per cubic meter) for the sample.

2. Estimation of the volume of each sampled school.

The volume of the schools was initially calculated based on two assumptions: First, that each school was cylindrically shaped (on average), and secondly, that the measured acoustic transect through the school represented the diameter of the school. This method was used for the initial calculation of school volume.

Further consideration resulted in a modification of this methodology, based on the assumption that the transect length represented, not the diameter of the school, but represented instead the

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<sup>3</sup> The schools analyzed ranged from less than 100 lbs to well over 25 tons. The term "larger" here indicates that the dozens of very small aggregations recorded were not included in this analysis. The total weight of these disregarded aggregations is assumed to be very small.

average chord length of the circle (assumed to represent the diameter of the cylindrical school shape). This methodology is discussed in Appendix A.

3. Estimation of the biomass of each sampled school, based on the acoustic data and the estimated volume.

Applying the school-specific calculated sample density to the volume of the school produced an estimated biomass for each sampled school. The results for the 82 herring school transects which were analyzed are presented in Appendix B. Initial estimates were based on the diameter method of calculating school volume and using an echo integration value of  $-32$  dB / kg. Further review of the literature and communications with Washington Department of Fish & Wildlife personnel resulted in changing of the echo integration value (based on recent values and smaller fish size observed in Yaquina Bay) to  $-33$  dB/kg and changing of the method of calculating volume of the fish school (discussed above, and in Appendix A, final column of Table 2).

A total of 54 herring schools were analyzed from the morning survey. These schools ranged in an initial estimated biomass (diameter method of calculating volume and integration value of  $-32$  dB) ranging from 2 pounds to 24,374 pounds. Adjustment of the estimates, by utilizing average chord length and echo integration value to  $-33$  dB/kg, increased the range from a minimum of 4 pounds to a maximum of 49,724 pounds. A total of 28 herring school transects were collected during the afternoon survey. However, observations made during collection and analysis of the geographic coordinates of the acoustic data collected, indicated that four of the afternoon transects crossed the same school of herring (identified as schools 62, 63, 64, and 65 in Table 2). As a result, three of the transects were removed from the final estimate (school 62 was used). The schools observed in the afternoon survey ranged in initial estimated biomasses ranging from 155 pounds to 56,356 pounds. Adjustment of the estimates, by utilizing average chord length and echo integration value to  $-33$  dB/kg, increased the range from a minimum of 316 pounds to a maximum of 114,967 pounds.

The analysis was performed on the evening of February 19, by the BioSoncis staff and the preliminary report was written upon conclusion of that initial analysis. The resulting estimated minimum observed biomass of herring in Yaquina Bay was presented to the sponsors on the morning of February 20, as 375,000 lbs.

Review and reanalysis of the data and assumptions on returning to BioSonics, on February 21, resulted in use of mean chord length and a new value echo integration value of  $-33$  dB/kg, a new estimated minimum observed biomass estimate of 765,500 lbs was calculated.

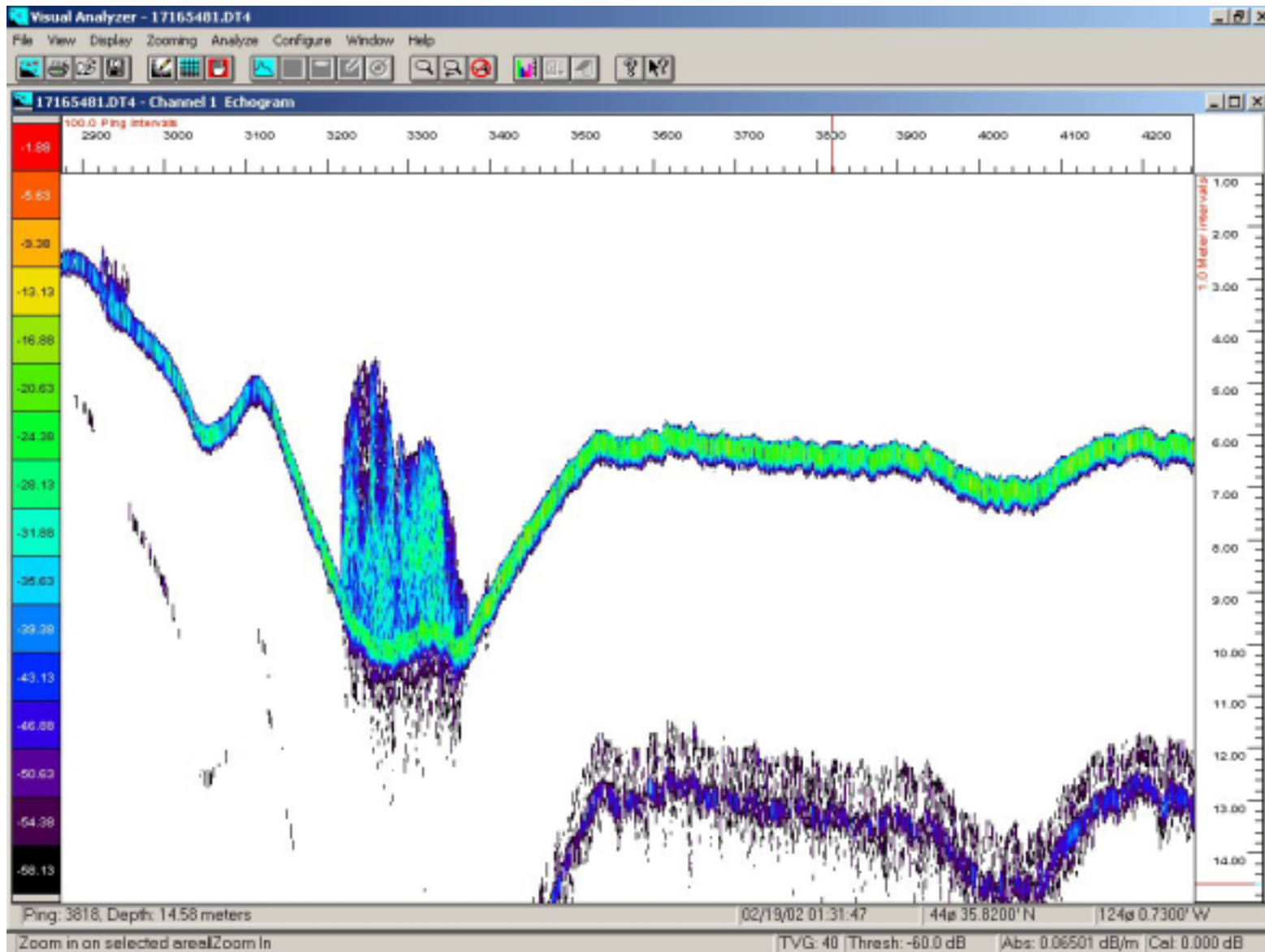


Figure 5. Screen capture from BioSonic Visual Analyzer software. The school of herring indicated by the arrow (school identified in data as # 63) had an estimated biomass of approximately 115,000 lbs.

## **Discussion**

This survey was conducted to provide an instantaneous estimate of a minimum biomass of herring present in Yaquina Bay at the time of the survey. The sample design was established through brief communications with the sponsors and based on a review of known (to BioSonics) acoustic herring work. Those references are listed in Appendix C.

The hydroacoustic data collected represented the best efforts of BioSonics and the project sponsors to locate and assess aggregations, or schools, of herring in Yaquina Bay on February 19, 2002.

BioSonics has confidence in the estimates provided, although the measurements made and the estimates generated were not subjected to statistical planning or analysis.

## **Recommendations**

- Prior to the 2003 herring assessment survey:
  - Parties (ODFW & YHI) should mutually agree on the following:
    - Areas to be surveyed
    - Temporal survey periods
    - Survey methodology (random vs. targeted)
    - Survey participants (number and type of vessels, partially determined by methodology)
    - Timeline for survey, analysis, reporting, management action
  - Parties (ODFW, YHI) and the contractor (BioSonics) should mutually agree on the following:
    - Analysis methodology (school size estimation & assumptions)
    - Report format and authorship

With the above issues pre-established, the acoustic survey of herring biomass can be conducted, much as it was this year, whenever the herring show up. It will also allow use of the resultant data in the manner intended, to establish harvest levels.



Table 1. Tide information for Yaquina Bay, and surrounding areas, for the Yaquina Bay Herring survey period. Data from US National Ocean Service, NOAA web site ( <http://co-ops.nos.noaa.gov/tides/westCC.html> ).

| Station                      | Time Diff.      |       | Hgt. Diff. |       | Ref. Station  |
|------------------------------|-----------------|-------|------------|-------|---------------|
|                              | High            | Low   | High       | Low   |               |
| <b>Yaquina Bay and River</b> | Bar at entrance |       |            |       |               |
|                              | +0 34           | +0 39 | *1.14      | *1.08 | Crescent City |
| Newport                      | +0 44           | +0 42 | *1.16      | *1.08 | Crescent City |
| Southbeach                   | +0 33           | +0 31 | *1.21      | *1.08 | Crescent City |
| Yaquina                      | +0 55           | +0 55 | *1.19      | *1.08 | Crescent City |
| Winant                       | +1 03           | +1 16 | *1.19      | *1.00 | Crescent City |
| Toledo                       | +1 29           | +1 39 | *1.17      | *0.92 | Crescent City |
| Taft, Siletz Bay             |                 |       |            |       |               |
|                              | +0 48           | +1 13 | *0.94      | *0.75 |               |

**Crescent City, California**

Tide Predictions (High and Low Waters)

February, 2002

NOAA, National Ocean Service

Standard Time

| Day   | Time    | Ht. | Time     | Ht. | Time    | Ht. | Time     | Ht. |
|-------|---------|-----|----------|-----|---------|-----|----------|-----|
| 16 Sa | 208am H | 6.4 | 805am L  | 2.3 | 152pm H | 5.9 | 807pm L  | 1.3 |
| 17 Su | 236am H | 6.4 | 850am L  | 2.1 | 238pm H | 5.4 | 837pm L  | 1.9 |
| 18 M  | 307am H | 6.4 | 942am L  | 2.0 | 335pm H | 4.9 | 909pm L  | 2.5 |
| 19 Tu | 343am H | 6.4 | 1043am L | 1.8 | 449pm H | 4.5 | 949pm L  | 3.0 |
| 20 W  | 426am H | 6.5 | 1151am L | 1.5 | 625pm H | 4.4 | 1044pm L | 3.5 |

**Calculated times for Yaquina Bay**

|    |          |  |          |         |          |
|----|----------|--|----------|---------|----------|
| 18 | 0351am H |  | 1024am L | 419pm H | 953pm    |
| 19 | 0427am H |  | 1125am L | 533pm H | 1031pm L |
| 20 | 0510am H |  | 1235pm L | -----   | -----    |

Table 2. Data collected and analyzed for Yaquina Bay Herring assessment study. Data collected using BioSonics DT6000 scientific Echosounder equipped with a six-degree, 200 kHz transducer.

| School ID # | lat       | lon      | time     | Start Range | Stop Range | Start Ping | Stop Ping | Absolute Density lbs/m3 | Estimated Surface Area (m2) | Original                |                          |                               |
|-------------|-----------|----------|----------|-------------|------------|------------|-----------|-------------------------|-----------------------------|-------------------------|--------------------------|-------------------------------|
|             |           |          |          |             |            |            |           |                         |                             | Estimated School Volume | Estimated School Biomass | Adjusted School Biomass (lbs) |
| 1           | 44.37.55  | 124.2.66 | 16:35:45 | 6.0         | 9.0        | 441        | 495       | 0.758                   | 192.61                      | 577.82                  | 438                      | 893                           |
| 2           | 44.37.53  | 124.2.61 | 16:36:17 | 5.4         | 8.4        | 610        | 650       | 2.743                   | 105.68                      | 317.05                  | 870                      | 1,774                         |
| 3           | 44.37.52  | 124.2.59 | 16:36:38 | 4.8         | 8.4        | 712        | 754       | 2.142                   | 116.52                      | 419.46                  | 898                      | 1,833                         |
| 4           | 44.37.51  | 124.2.57 | 16:36:56 | 5.2         | 8.1        | 781        | 844       | 0.680                   | 262.16                      | 762.89                  | 519                      | 1,059                         |
| 5           | 44.37.45  | 124.2.42 | 16:39:05 | 4.8         | 8.1        | 1471       | 1493      | 0.970                   | 31.97                       | 105.50                  | 102                      | 209                           |
| 6           | 44.37.447 | 124.2.41 | 16:39:09 | 5.4         | 7.0        | 1505       | 1510      | 0.702                   | 1.65                        | 2.58                    | 2                        | 4                             |
| 7           | 44.37.45  | 124.3.39 | 16:39:26 | 4.0         | 5.3        | 1587       | 1598      | 2.715                   | 7.99                        | 9.75                    | 26                       | 54                            |
| 8           | 44.37.45  | 124.2.39 | 16:39:29 | 8.3         | 9.8        | 1596       | 1611      | 3.110                   | 14.86                       | 21.70                   | 67                       | 138                           |
| 9           | 44.37.51  | 124.2.12 | 16:42:48 | 6.0         | 10.6       | 2586       | 2609      | 0.867                   | 34.94                       | 158.98                  | 138                      | 281                           |
| 10          | 44.37.50  | 124.2.01 | 16:43:56 | 3.4         | 7.2        | 2919       | 2949      | 2.233                   | 59.45                       | 223.52                  | 499                      | 1,018                         |
| 11          | 44.37.51  | 124.1.89 | 16:45:24 | 3.4         | 5.3        | 3383       | 3389      | 2.818                   | 2.38                        | 4.49                    | 13                       | 26                            |
| 12          | 44.36.27  | 124.0.68 | 17:16:19 | 5.9         | 8.0        | 3410       | 3652      | 1.089                   | 3868.27                     | 7891.27                 | 8,594                    | 17,531                        |
| 13          | 44.36.24  | 124.0.68 | 17:17:03 | 6.6         | 7.8        | 3811       | 3872      | 1.366                   | 245.78                      | 282.65                  | 386                      | 788                           |
| 14          | 44.36.19  | 124.0.67 | 17:18:03 | 3.9         | 8.3        | 4075       | 4174      | 0.825                   | 647.38                      | 2893.77                 | 2,387                    | 4,870                         |
| 15          | 44.36.14  | 124.0.66 | 17:18:57 | 6.7         | 9.2        | 4412       | 4446      | 1.873                   | 76.36                       | 188.60                  | 353                      | 721                           |
| 16          | 44.35.98  | 124.0.68 | 17:21:56 | 6.1         | 8.9        | 724        | 840       | 0.199                   | 888.80                      | 2488.63                 | 495                      | 1,010                         |
| 17          | 44.35.48  | 124.1.28 | 17:41:16 | 7.5         | 9.3        | 1952       | 2137      | 1.095                   | 2260.63                     | 4069.13                 | 4,456                    | 9,090                         |
| 18          | 44.35.42  | 124.1.32 | 17:42:26 | 6.5         | 9.5        | 2300       | 2488      | 3.476                   | 2334.54                     | 7003.62                 | 24,345                   | 49,663                        |
| 19          | 44.35.50  | 124.1.21 | 17:59:29 | 5.2         | 8.9        | 3063       | 3107      | 1.297                   | 127.88                      | 473.14                  | 614                      | 1,252                         |
| 20          | 44.35.53  | 124.1.17 | 18:00:18 | 4.6         | 8.4        | 3284       | 3349      | 2.407                   | 279.07                      | 1060.46                 | 2,553                    | 5,207                         |
| 21          | 44.35.46  | 124.1.24 | 18:07:08 | 4.5         | 7.0        | 707        | 791       | 2.206                   | 466.06                      | 1165.16                 | 2,570                    | 5,243                         |
| 22          | 44.35.51  | 124.1.21 | 18:10:25 | 4.0         | 8.9        | 1775       | 1885      | 2.601                   | 799.23                      | 3916.22                 | 10,186                   | 20,780                        |
| 23          | 44.35.52  | 124.1.19 | 18:11:19 | 5.2         | 8.1        | 2115       | 2153      | 1.146                   | 95.38                       | 276.60                  | 317                      | 647                           |
| 24          | 44.35.44  | 124.1.31 | 18:19:07 | 6.9         | 9.2        | 4399       | 4494      | 1.541                   | 596.12                      | 1371.07                 | 2,113                    | 4,310                         |
| 25          | 44.35.45  | 124.1.29 | 18:18:45 | 6.7         | 7.6        | 4378       | 4385      | 4.084                   | 3.24                        | 2.91                    | 12                       | 24                            |
| 26          | 44.35.44  | 124.1.31 | 18:19:12 | 7.2         | 9.4        | 1          | 24        | 2.698                   | 34.94                       | 76.87                   | 207                      | 423                           |
| 27          | 44.35.39  | 124.1.33 | 18:21:47 | 6.9         | 8.0        | 691        | 793       | 0.794                   | 687.20                      | 755.93                  | 600                      | 1,224                         |
| 28          | 44.35.39  | 124.1.32 | 18:22:11 | 4.9         | 8.4        | 847        | 915       | 1.594                   | 305.42                      | 1068.99                 | 1,704                    | 3,476                         |
| 29          | 44.35.41  | 124.1.30 | 18:23:21 | 4.8         | 8.0        | 1169       | 1240      | 1.934                   | 332.97                      | 1065.50                 | 2,061                    | 4,204                         |
| 30          | 44.35.42  | 124.1.28 | 18:24:33 | 4.3         | 7.2        | 1494       | 1626      | 1.602                   | 1150.89                     | 3337.58                 | 5,347                    | 10,907                        |
| 31          | 44.35.43  | 124.1.26 | 18.25.33 | 4.6         | 6.6        | 1713       | 1927      | 2.207                   | 3024.92                     | 6049.83                 | 13,352                   | 27,238                        |

Table 2. (Morning, Cont'd)

|    |          |          |          |     |      |      |      |       |         |         |               |         |         |
|----|----------|----------|----------|-----|------|------|------|-------|---------|---------|---------------|---------|---------|
| 32 | 44.35.44 | 124.1.24 | 18:26:47 | 5.1 | 6.4  | 2201 | 2291 | 0.943 | 535.02  | 695.53  | 656           | 1,338   |         |
| 33 | 44.36.04 | 124.0.67 | 19:29:04 | 8.4 | 9.6  | 1200 | 1421 | 0.682 | 3226.05 | 3871.25 | 2,639         | 5,383   |         |
| 34 | 44.36.13 | 124.0.71 | 19:30:14 | 7.1 | 8.9  | 1746 | 1771 | 2.405 | 41.28   | 74.31   | 179           | 365     |         |
| 35 | 44.36.08 | 124.0.64 | 19:32:38 | 5.1 | 7.7  | 2456 | 2489 | 2.897 | 71.93   | 187.02  | 542           | 1,105   |         |
| 36 | 44.36.15 | 124.0.67 | 19:33:41 | 6.4 | 9.3  | 2783 | 2799 | 1.500 | 16.91   | 49.04   | 74            | 150     |         |
| 37 | 44.36.21 | 124.0.68 | 19:35:48 | 5.9 | 8.2  | 3396 | 3438 | 1.855 | 116.52  | 267.99  | 497           | 1,014   |         |
| 38 | 44.36.21 | 124.0.66 | 19:36:03 | 6.2 | 8.2  | 3440 | 3514 | 1.856 | 361.70  | 723.40  | 1,343         | 2,739   |         |
| 39 | 44.36.20 | 124.0.66 | 19:36:19 | 3.3 | 8.0  | 3521 | 3593 | 2.696 | 342.41  | 1609.34 | 4,339         | 8,851   |         |
| 40 | 44.36.19 | 124.0.65 | 19:36:31 | 3.7 | 8.3  | 3624 | 3654 | 1.078 | 59.45   | 273.46  | 295           | 601     |         |
| 41 | 44.36.25 | 124.0.70 | 19:40:29 | 5.0 | 8.1  | 213  | 339  | 7.498 | 1048.64 | 3250.79 | 24,374        | 49,724  |         |
| 42 | 44.37.42 | 124.2.00 | 19:57:13 | 5.8 | 9.6  | 3210 | 3219 | 1.307 | 5.35    | 20.33   | 27            | 54      |         |
| 43 | 44.37.46 | 124.2.03 | 19:58:50 | 8.0 | 11.1 | 3688 | 3708 | 0.847 | 26.42   | 81.90   | 69            | 141     |         |
| 44 | 44.37.52 | 124.1.93 | 20:00:15 | 5.0 | 7.1  | 4100 | 4132 | 1.552 | 67.64   | 142.04  | 220           | 450     |         |
| 45 | 44.37.51 | 124.1.96 | 20:00:55 | 3.9 | 8.2  | 4266 | 4328 | 0.532 | 253.90  | 1091.79 | 581           | 1,185   |         |
| 46 | 44.37.49 | 124.1.99 | 20:01:41 | 5.8 | 7.5  | 4    | 53   | 0.886 | 158.59  | 269.60  | 239           | 487     |         |
| 47 | 44.37.51 | 124.2.05 | 20:02:41 | 5.6 | 10.2 | 203  | 349  | 1.379 | 1407.96 | 6476.63 | 8,931         | 18,220  |         |
| 48 | 44.37.51 | 124.2.07 | 20:02:58 | 8.5 | 10.4 | 349  | 440  | 0.646 | 546.98  | 1039.26 | 671           | 1,369   |         |
| 49 | 44.37.51 | 124.2.13 | 20:03:52 | 6.2 | 9.3  | 608  | 706  | 0.909 | 634.36  | 1966.53 | 1,788         | 3,647   |         |
| 50 | 44.37.51 | 124.2.14 | 20:04:28 | 6.1 | 7.8  | 794  | 888  | 1.557 | 583.64  | 992.18  | 1,545         | 3,151   |         |
| 51 | 44.37.49 | 124.2.13 | 20:06:32 | 4.6 | 10.6 | 1514 | 1559 | 1.666 | 133.76  | 802.53  | 1,337         | 2,728   |         |
| 52 | 44.37.49 | 124.2.09 | 20:07:02 | 7.9 | 11.2 | 1600 | 1656 | 2.503 | 207.14  | 683.56  | 1,711         | 3,490   |         |
| 53 | 44.37.48 | 124.2.03 | 20:07:41 | 8.4 | 10.6 | 1827 | 1852 | 0.726 | 41.28   | 90.82   | 66            | 134     |         |
| 54 | 44.37.66 | 124.2.70 | 20:40:05 | 3.4 | 7.0  | 2542 | 2573 | 4.470 | 63.48   | 228.51  | 1,021         | 2,084   |         |
|    |          |          |          |     |      |      |      |       |         |         | Morning Total | 139,367 | 284,308 |

Table 2 (cont'd) Data collected and analyzed for Yaquina Bay Herring assessment study. Data collected using BioSonics DT6000 scientific Echosounder equipped with a six-degree, 200 kHz transducer. Shaded cells indicated duplicate samples not used in th final estimate of biomass

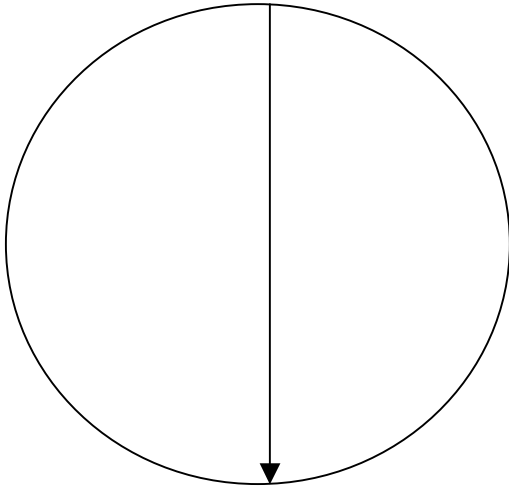
| School ID #     | lat      | lon      | time     | Start Range | Stop Range | Start Ping | Stop Ping | Absolute Density lbs/m3 | Estimated Surface Area (m2) | Original Estimated School Volume | Estimated School Biomass | Adjusted School Biomass (lbs) |
|-----------------|----------|----------|----------|-------------|------------|------------|-----------|-------------------------|-----------------------------|----------------------------------|--------------------------|-------------------------------|
| 55              | 44.37.58 | 124.2.89 | 23:37:00 | 5           | 7.5        | 1391       | 1565      | 0.8186                  | 1999.79                     | 4999.47                          | 4,093                    | 8,349                         |
| 56              | 44.37.63 | 124.2.97 | 23:40:35 | 11.4        | 13.2       | 2548       | 2636      | 1.379                   | 511.51                      | 920.71                           | 1,270                    | 2,590                         |
| 57              | 44.37.51 | 124.2.09 | 23:53:16 | 8.2         | 12.1       | 1867       | 1919      | 1.8496                  | 178.60                      | 696.56                           | 1,288                    | 2,628                         |
| 58              | 44.37.56 | 124.3.12 | 0:22:10  | 8.1         | 14.2       | 1540       | 1598      | 1.011                   | 222.20                      | 1355.41                          | 1,370                    | 2,795                         |
| 59              | 44.36.29 | 124.0.64 | 0:50:52  | 2.8         | 7.9        | 141        | 219       | 11.556                  | 401.86                      | 2049.49                          | 23,684                   | 48,315                        |
| 60              | 44.36.32 | 124.0.64 | 0:53:07  | 2.6         | 7.9        | 807        | 868       | 7.996                   | 245.78                      | 1302.63                          | 10,416                   | 21,248                        |
| 61              | 44.36.19 | 124.0.69 | 1:06:11  | 3.9         | 10.4       | 928        | 1090      | 4.355                   | 1733.47                     | 11267.54                         | 49,070                   | 100,103                       |
| 62              | 44.35.98 | 124.0.64 | 1:28:48  | 4.7         | 10.9       | 3217       | 3372      | 5.728                   | 1586.90                     | 9838.77                          | 56,356                   | 114,967                       |
| 63              | 44.35.99 | 124.0.62 | 1:34:10  | 4.8         | 9.5        | 349        | 481       | 2.731                   | 1150.89                     | 5409.18                          | 14,772                   | 30,136                        |
| 64              | 44.36.29 | 124.0.73 | 1:38:14  | 3.5         | 8.4        | 1566       | 1669      | 3.947                   | 700.75                      | 3433.65                          | 13,553                   | 27,647                        |
| 65              | 44.36.32 | 124.0.75 | 1:38:41  | 3.5         | 8.4        | 1670       | 1831      | 4.692                   | 1712.13                     | 8389.45                          | 39,363                   | 80,301                        |
| 66              | 44.37.53 | 124.2.64 | 2:06     | 6.4         | 9.3        | 1133       | 1160      | 4.213                   | 48.15                       | 139.64                           | 588                      | 1,200                         |
| 67              | 44.37.54 | 124.2.68 | 2:06:44  | 8.4         | 10.2       | 1231       | 1246      | 5.784                   | 14.86                       | 26.75                            | 155                      | 316                           |
| 68              | 44.37.51 | 124.3.23 | 2:11:20  | 4.5         | 7.8        | 2516       | 2628      | 0.0691                  | 828.56                      | 2734.24                          | 189                      | 385                           |
| 69              | 44.37.41 | 124.3.43 | 2:26:48  | 7.4         | 12.3       | 2545       | 2749      | 0.661                   | 2748.82                     | 13469.22                         | 8,903                    | 18,162                        |
| 70              | 44.37.46 | 124.3.39 | 2:27:37  | 6.9         | 11.7       | 2800       | 2999      | 0.457                   | 2615.72                     | 12555.48                         | 5,738                    | 11,705                        |
| 71              | 44.37.5  | 124.3.36 | 2:28:17  | 7.8         | 10.6       | 3000       | 3199      | 1.67                    | 2615.72                     | 7324.03                          | 12,231                   | 24,952                        |
| 72              | 44.37.55 | 124.3.34 | 2:28:57  | 8           | 11.2       | 3200       | 3399      | 1.114                   | 2615.72                     | 8370.32                          | 9,325                    | 19,022                        |
| 73              | 44.37.58 | 124.3.32 | 2:29:18  | 6.3         | 10.9       | 3400       | 3502      | 1.106                   | 687.20                      | 3161.14                          | 3,496                    | 7,132                         |
| 74              | 44.37.60 | 124.3.25 | 2:31:02  | 5.2         | 7.5        | 3947       | 4024      | 1.31                    | 391.62                      | 900.73                           | 1,180                    | 2,407                         |
| 75              | 44.37.54 | 124.3.33 | 2:32:09  | 8.6         | 11.5       | 4264       | 4359      | 1.272                   | 596.12                      | 1728.75                          | 2,199                    | 4,486                         |
| 76              | 44.37.51 | 124.3.5  | 2:32:32  | 8.1         | 11.6       | 4409       | 4474      | 1.497                   | 279.07                      | 976.74                           | 1,462                    | 2,983                         |
| 77              | 44.37.45 | 124.3.38 | 2:33:14  | 4.7         | 11.4       | 1          | 218       | 0.963                   | 3110.32                     | 20839.16                         | 20,068                   | 40,939                        |
| 78              | 44.37.37 | 124.3.46 | 2:34:25  | 8.4         | 10.8       | 511        | 556       | 2.139                   | 133.76                      | 321.01                           | 687                      | 1,401                         |
| 79              | 44.37.33 | 124.3.51 | 2:35:03  | 8           | 11.3       | 598        | 747       | 0.909                   | 1466.42                     | 4839.19                          | 4,399                    | 8,974                         |
| 80              | 44.37.45 | 124.3.35 | 2:40:47  | 7.9         | 11.8       | 2368       | 2470      | 1.347                   | 687.20                      | 2680.10                          | 3,610                    | 7,365                         |
| 81              | 44.37.46 | 124.3.25 | 2:42:08  | 4.6         | 11         | 2830       | 2869      | 1.787                   | 100.47                      | 642.98                           | 1,149                    | 2,344                         |
| 82              | 44.37.44 | 124.3.11 | 2:58:28  | 3           | 4.6        | 2996       | 3264      | 1.705                   | 4744.12                     | 7590.59                          | 12,942                   | 26,402                        |
| Afternoon Total |          |          |          |             |            |            |           |                         |                             |                                  | 235,868                  | 481,170                       |

## Appendix A. Estimation of the School Diameter and Volume

Our initial analysis assumed that the path of the survey boat through each school represented a path through the center of a circular school. Diameter was estimated from boat speed and length of time over the school. The area of the school was calculated as:

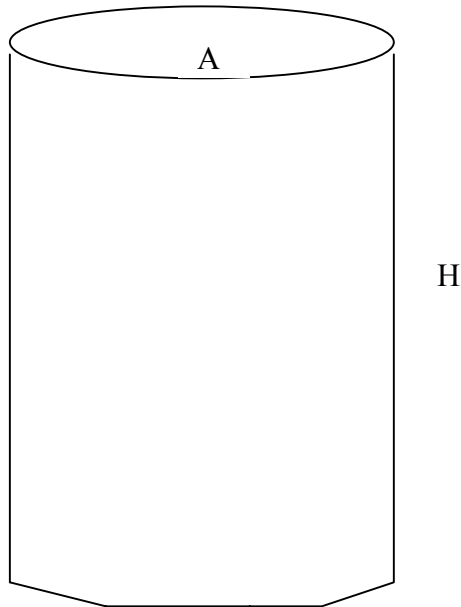
$$A = \pi * (D/2)^2, \text{ where}$$

A = area of circle,  
D = diameter of circle



And

The volume of a school was represented by a cylinder of Height H and Area A

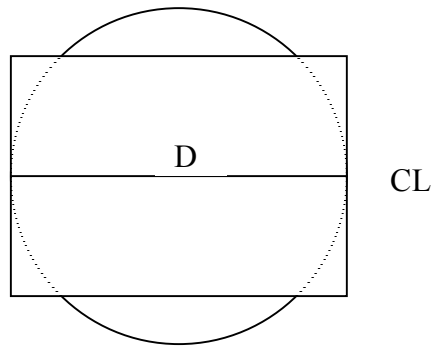


$$V = H * A.$$

This approach ignores the statistical probability that the boat will not always pass through the center of a fish school. If we consider that the path through each circle (school) is random, we see that sometimes we pass through the center of the school and other times through or near an edge of the circle. If we look at all possible path locations, the average path length is called the Average Chord Length. This value is a fixed proportion of the diameter. The relationship between Average Chord Length and Diameter is determined as follows:

Assume an infinite number of paths through a circle of Area A. The average length of all of these paths would describe a rectangle with width (D) equal to the circle diameter, and length (CL) unknown. However, the area of the circle should be equal to the area of the rectangle. Call the unknown rectangle side CL, and the known side D. Area of the rectangle is then  $CL * D$ . Area of the circle is  $\pi*(D/2)^2$ . Solving for CL, we get:

$$CL = D * \pi/4$$



CL represents the average path length through the circle, or the Average Chord Length.

As an example, assume that the school volume was calculated based on a diameter of 10 m and a cylinder height of 4 m. The school volume would then be 314.16 m<sup>3</sup>. If we had a density of 5 pounds per cubic meter inside the school, total biomass of the school would be 1571 pounds. In contrast, if we estimate school volume using the Mean Chord Length method, the Mean Chord Length is 10 m, the diameter is 12.73 m, volume is 509.3 m<sup>3</sup>, and total school biomass is 2546 pounds. By using this statistically correct method, all previous biomass abundance estimates would be increased by a factor of 1.621. We suggest that the Mean Chord Length method is more statistically correct than the assumption of all paths traveling through the center of the cylinder.

## REFERENCES

Washington herring

<http://www.wa.gov/wdfw/fish/forage/herring.htm>

Alaska herring:

[http://www.pwssc.gen.ak.us/sea/block/progop/cruise/plans/herring.survey\\_design.html](http://www.pwssc.gen.ak.us/sea/block/progop/cruise/plans/herring.survey_design.html)

Atlantic & North Sea herring:

<http://www.dfo-mpo.gc.ca/csas/csas/status/2000/b2-01e.pdf>

<http://www.clupea.de/research/AcousticSurveys/nseaacoustsurvey.html>

[http://www.cifar.uaf.edu/ssl\\_abstract01/thorne.html](http://www.cifar.uaf.edu/ssl_abstract01/thorne.html)

Related references:

Thorne, R.E. 1998. Review: experiences with shallow water acoustics. Fish. Res.35:137-141, Elsevier Science, Amsterdam

Thorne, R.E. and G.L. Thomas 1990. Acoustic observation of gas bubble release by Pacific herring. Can. J. Fish. Aquat. Sci. 47(10):1920-1928

## Equipment List



- DT 6000-00-085 Echosounder
- DT 200-615-0031 Transducer
- DTC 141-97-1146 Transducer Cable
- JRC Differential GPS (KD-61078)
- Honda Generator
- Adjustable Transducer Mount
- Misc. Mounting Mast
- Computer Control Unit