CHAPTER 9

94320-N Nekton and Plankton Acoustics

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ABSTRACT

The objectives of the Sound Ecosystem Assessment - Nearshore Fish (SEAFISH) program are to develop and apply technology to: (1) assess the macrozooplankton prey along the outmigration path of pink salmon fry in western Prince William Sound, (2) assess the nekton along the same outmigration path, (3) coordinate with ADF&G and UAF on other projects within the SEA program to complete these tasks, and (4) evaluate where bird/mammal interactions with fish may warrant further study.

Acoustic surveys conducted during the spring and summer of 1994 provided an assessment of the distribution, biomass, and numbers of nekton found in the outmigration path of pink salmon fry in western Prince William Sound. The surveys were conducted in nearshore and offshore strata that were predefined for this outmigration path.

To process acoustic samples by classification and to identify the species and size of the targets, net sampling of the targets is necessary. Net sampling for nekton was done by the Alaska Department of Fish and Game (ADF&G) and for plankton to the University of Alaska, Fairbanks (UAF). The first step in analyzing acoustic signals was to acquire net catch data and to match these data sets in time and space.

Measurement of the macrozooplankton prey along the migratory path was made throughout the outmigration season in the nearshore/offshore interface with 200 and 420 kHz echo sounders. Assessment of macrozooplankton prey density and distribution are being considered relative to the amount of plankton net data available to interpret results. Plankton net data are not available at this time. Measurement of macrozooplankton in the offshore strata was made using 120 kHz echo sounders, which limited assessment to large midwater layers. A 1 m tucker trawl was used by UAF to sample these layers.

Measurement of the nekton along the migratory path was made throughout the outmigration season in the nearshore/offshore interface with 120, 200 and 420 kHz echo sounders. As determined by the net samples provided by ADF&G, the dominant nekton species observed, pollock, squid, herring, and adult salmon, were identified as juvenile salmon predators. Our first and current decision was to estimate the walleye pollock population size along the outmigration path because this was clearly the dominant predator species observed on the survey.

Spin-offs from the SEAFISH project have been stock assessments of the fall biomass of PWS herring, the winter prespawn biomass of pollock, and population size of juvenile salmon in Coghill Lake. These stock assessments of adult herring and pollock are primarily funded by fishermen and agencies for harvest management information. These stock assessment techniques were not available in the region prior to the initiation of SEA.

INTRODUCTION

The SEAFISH program supplies the underwater acoustics for quantitative assessment of nekton and macrozooplankton. The program has been initiated during the past year. Much of the equipment and processing software require development time for acquisition and application. Acquisition time for new sonar has been running 12+ months and application development time normally runs 2-3 years. The payoff is that these tools offer the best opportunity for low cost, large scale monitoring in the future. The concern for this effort's success is exemplified by three multiple-day reviews of the program in its first year of operation. Peer reviewers at the November 1993 workshop estimated the development of new predictive tools for fish abundance would require 8-10 years.

Background - Sound Ecosystem Assessment (SEA)

Accurate prediction of abundance is a prerequisite to efficient restoration, rehabilitation or compensation of anthropogenic damages, such as oil spill damage, to key animal populations. For example, fisheries science has used hatchery practices on a widespread basis to restore, rehabilitate, and compensate for overfishing, habitat destruction and industrial damages (Benson 1970) with little knowledge of ecosystem impacts. Recently, hatchery practices have been critically reviewed and their benefits have become highly controversial (Thomas and Mathisen 1993). Similar controversies exist over shoreline oil cleanup practices, habitat modification programs, and animal rehabilitation and recovery centers. Restoration practices will remain controversial until our understanding of ecosystem level processes allow for the development of predictive models. Predictive models are the tool for determining the outcome of anthropogenic events (oil spills, habitat loss, etc.) and prediction and evaluation of damages.

The first step in developing tools for the prediction of population structure and change in Prince William Sound (PWS) is to develop a better understanding of the marine ecosystem. Unfortunately, the dynamics of marine ecosystems is poorly understood (GLOBEC 1991) making accurate predictions of change in marine animal populations impossible (Cullen 1989). The dynamics in composition and production of the plankton/nekton assemblage that resides in PWS is no exception, despite the intensive single population assessments after the *Exxon Valdez* oil spill (Wolfe et al. 1993). For instance, there are some long term databases on the harvests of key commercial fish populations (ADF&G 1994), yet little is known about how fluctuations of co-occurring populations (prey and predators) affect the abundance of the key populations, or how change in prey and predator populations are affected by climate-driven warming and cooling processes.

In response to the lack of ecosystem and species-specific knowledge, SEA (1993) advanced several ecosystem level hypotheses to explain the physical and biological dynamics of PWS and potential impact on previously identified sensitive populations, pink salmon and herring (Wolfe et al. 1993). The hypotheses emphasize the potential role of climate driven circulation patterns on the abundance and distribution of macrozooplankton food of juvenile fish (the lake river hypothesis), how changes in water circulation patterns may effect predator and prey dynamics (prey switching hypothesis) and the role of winter rearing habitat on the survival of juvenile herring (overwintering hypothesis). Evidence exists suggesting that climate driven events are important for understanding survival of many fish populations.

Pearcy (1992) has shown a positive correlation exists between the intensity and frequency of upwelling events (climate driven oceanographic and atmospheric processes) and salmon survival along the Oregon and Washington coast. Cooney (1986, 1987, 1993) has shown that the critical food sources for larval and juvenile fishes in PWS, the large oceanic calanoids, undergo annual and sesonal fluctuations in abundance, and proposed that climate-driven ocean currents cause major fluctuations in the calanoid abundance. Recently, low survival of salmon and herring has been attributed to shifts in predator populations into the La Perouse Bank during El Nino years (Ware, personal communication, British Columbia). Furthermore, the lunar nodal hypothesis suggests an 18.6 year cycle in climate driven warming and cooling of the eastern North Pacific (Royer 1993) that may affect prey and predator populations, which influence fish production (Thomas and Mathisen 1993). Thus, it is likely that climate driven fluctuations in ocean processes and its influence on prey and predator abundance and distribution affect salmon and herring survival in PWS.

Objectives

The objectives of this study are to develop and apply technology to: (1) assess the macrozooplankton prey found in the outmigration path of pink salmon fry in western Prince William Sound, (2) assess the nekton found in the same outmigration path, (3) coordinate with ADF&C and UAF on other SEA projects, and (4) evaluate where bird/mammal interactions with fish may warrant further study.

METHODS

Study Area

Prince William Sound (PWS) is a complex fjord/estuary (Schmidt 1977) located at the northern margin of the Gulf of Alaska (Figure 1). Prince William Sound covers an area of about 8800 square km with approximately 3200 km of shoreline (Grant and Higgins 1910). High mountain peaks in excess of 4000 m border the Sound and receive the brunt of the seasonally intense cyclonic storms from the Gulf of Alaska. Much of the shoreline is bordered by coastal rainforest which receives in excess of 7 m of rain annually. Freshwater input to the Sound occurs as runoff from glaciers, icefields and streams. Large scale surface currents are driven by the wind and buoyancy forcing. Depths exceeding 400 m occur in the western and central portions of the Sound where overwintering populations of oceanic copepods are supported.

Survey Design

The western corridor of PWS was stratified in north-south and nearshore-offshore directions.

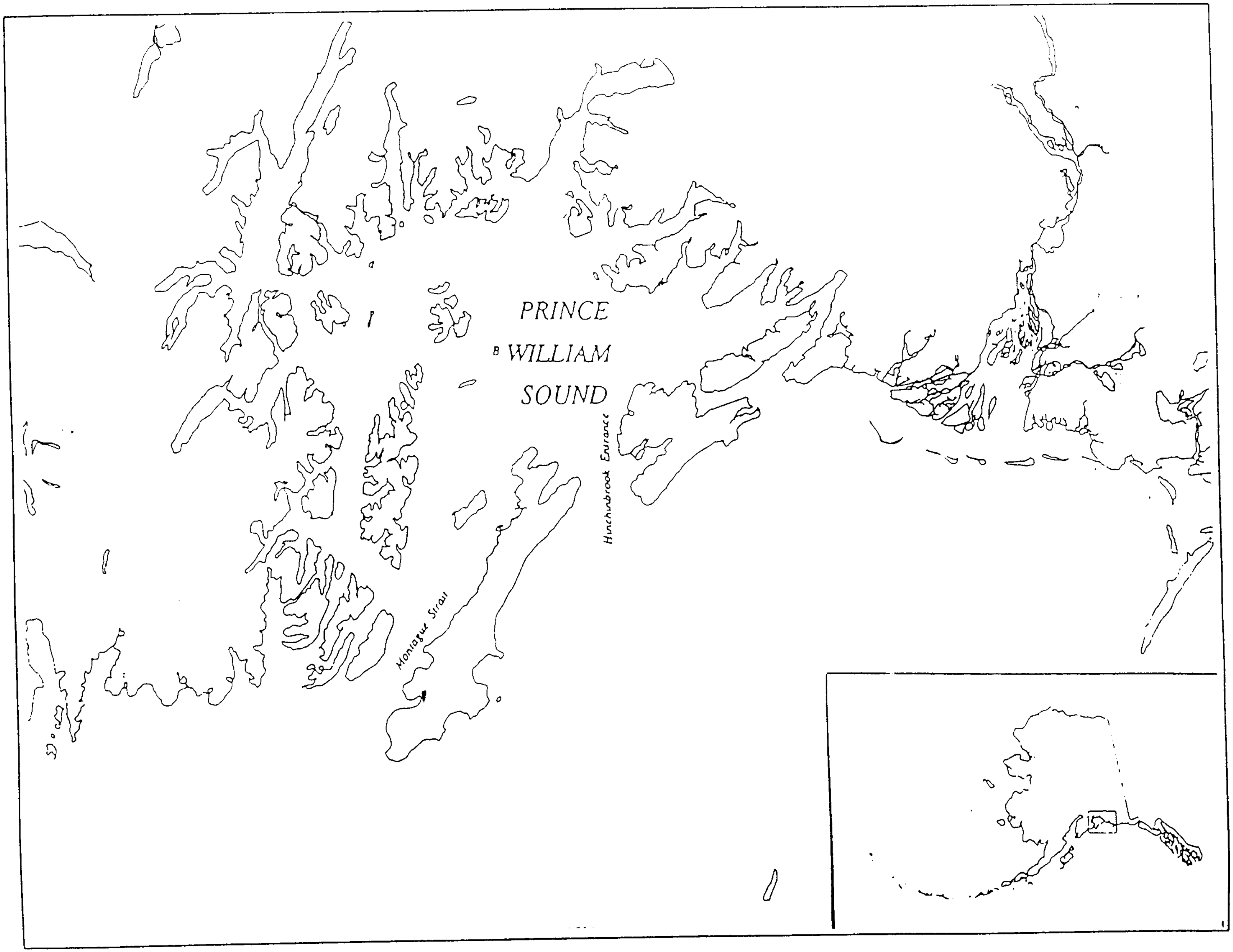


Figure 1. Location of Prince William Sound at the northern Margin of the Gulf of Alaska.

The Salmon Gulch, Cannery Creek and Ester Hatcheries released over 600 million salmon fry in northern PWS in 1994. Three northern strata were sampled early and four southern strata later in the outmigration season with the intent of following the juvenile salmon outmigration to the Gulf of Alaska (Figure 2,3).

There are several locations that require juvenile salmon to cross large expanses of open water. Schools of outmigrating juvenile salmon have been sampled in shoreline rearing areas since 1989 (Willette 1993). However, the portion of salmon fry using the offshore versus the shoreline for migration purposes is unknown, so a nearshore and offshore stata were established to determine predator fields along the migratory path. Figure 4 shows shoreline strata.

Acoustic transects

The offshore area was large, sampling was sparse, and the predator population unknown, so a systematic transect design was chosen over a random design to provide better representation of the north-south gradient in densities. As a result some precision was sacrificed for accuracy (Cochran 1977). Precision was estimated by assuming the transects to be independent samples and computing the weighted mean densities and biomass (Seber 1973). The offshore sampling was conducted on parallel transects that ran orthogonal to the passage being sampled (Figure 2,3).

For the nearshore areas, the dropoff is precipitous in most shoreline areas so transecting perpendicular to the shoreline was impractical. Parallel transects also were impractical since bottom depth and depth in the water column were known to be important characteristics of the nearshore predators. Threfore, a zig-zag transect design was adopted to sample nearshore fish and collect predator density information along extensive shorelines by bottom depth. Post-stratification of the shoreline by bottom depth was conducted to define near from offshore habitat and zigs were treated separately from the zags to establish independent units for computation of precision (Figure 5).

Transecting was conducted between 2 and 3 meters per second using Braincon and BioSonics towed bodies, which were towed off the side of the vessel at a depth of about 2 meters (offshore) and at a depth of 1 meter (nearshore). Boat speed was approximately 10 km/hour. Night-time navigation in shallow littoral areas was hazardous due to the presence of rocky pinnacles and large tidal fluctuations so some transects were modified for safety purposes.

Survey timing

Diel timing

Both trawling and purse seining are most efficient at night since lower visibility reduces fish avoidance. In general, acoustic surveys are also best conducted at night because the fish are more evenly distributed in the water column (Houser and Dunn 1967; Burczynski and Johnson 1986) which improves the precision of the estimates. However, due to latitude the night lengths and light levels were not optimal and several compromises were necessary. On the trawler, acoustic

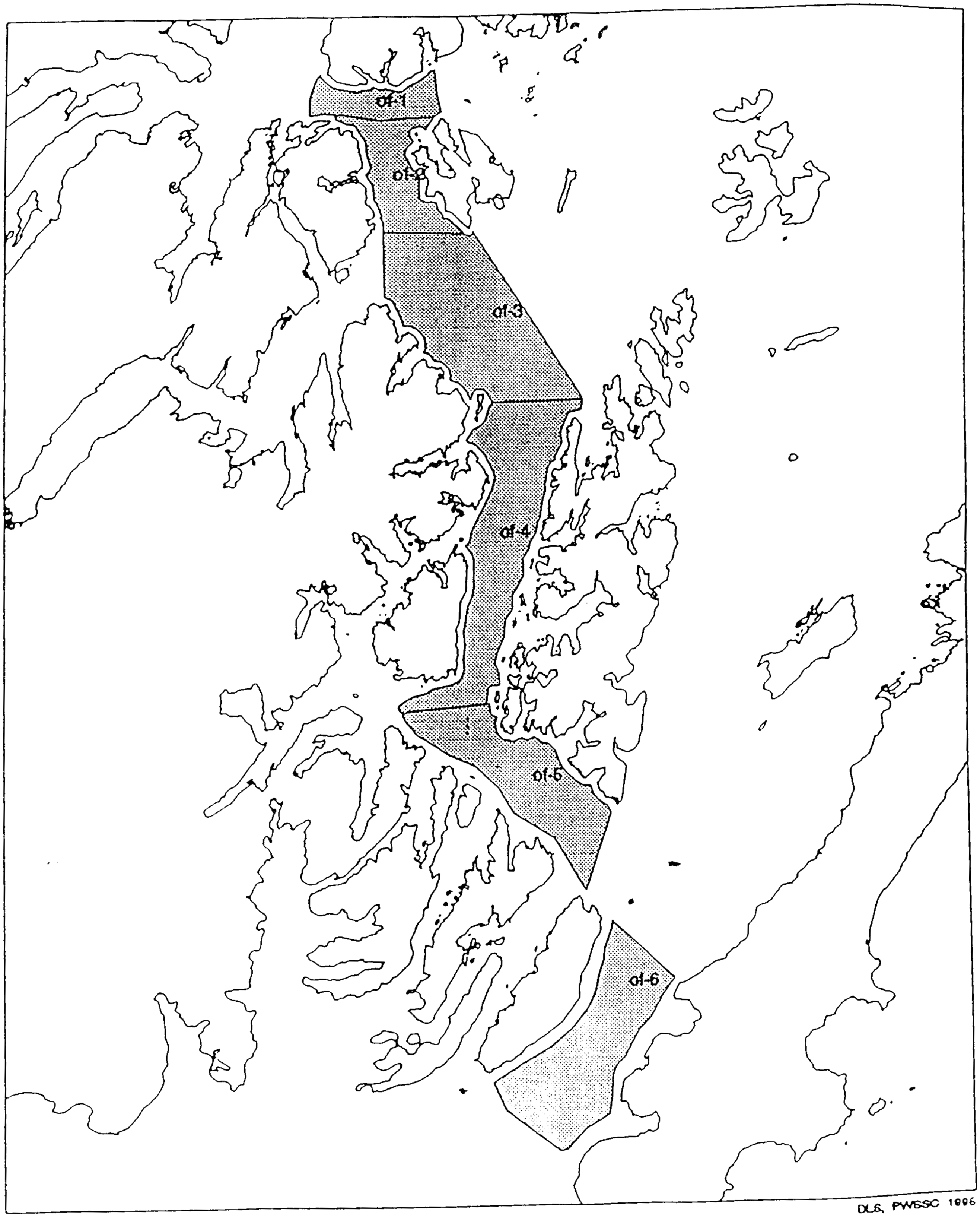
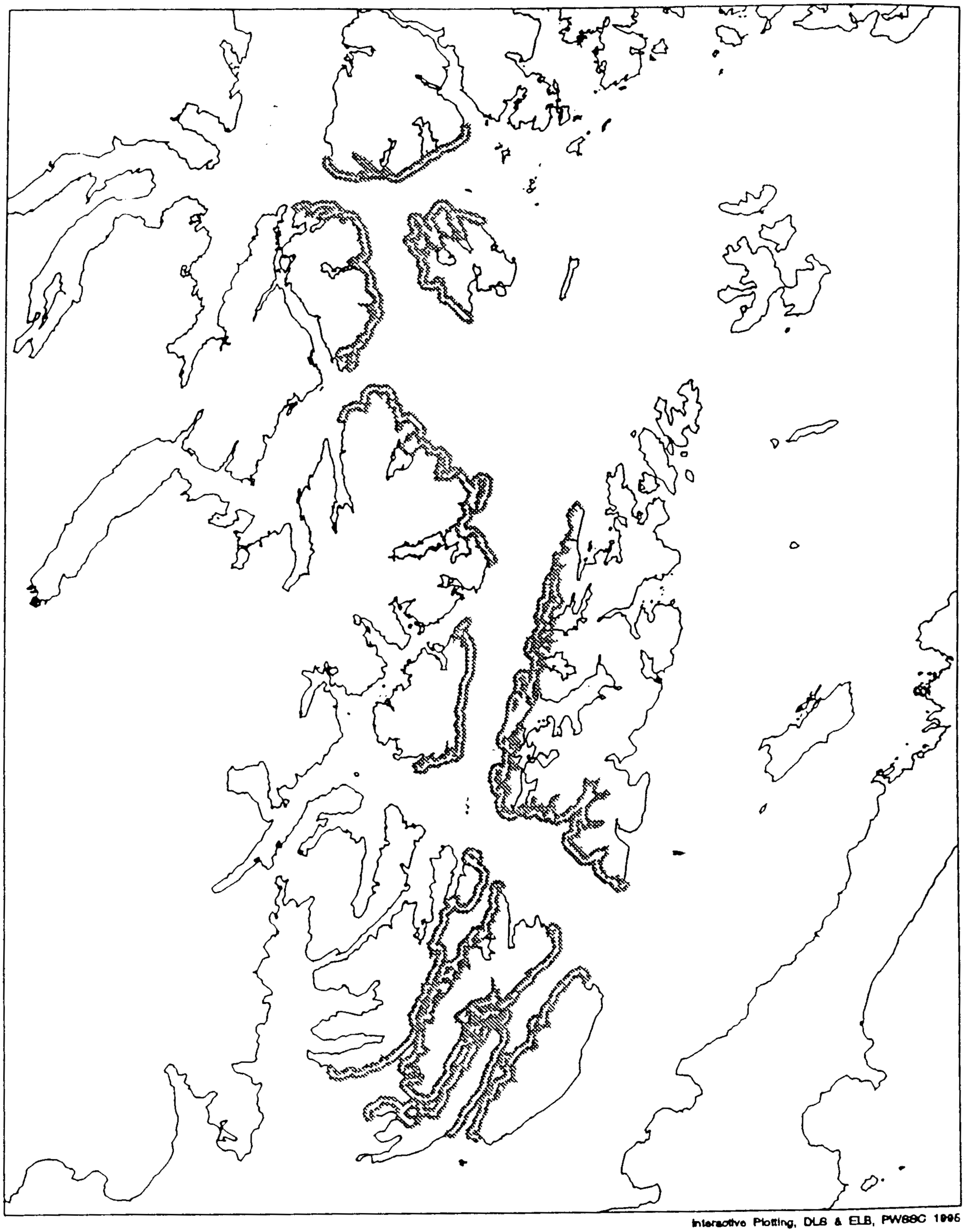


Figure 2. Offshore Survey Areas in Western Corridor of PWS
Northern Srata (of-1 to of-3). Southern Strata (of-4 to of-6).

DLS, PWSSC 1995

Figure 3. Offshore Survey Areas in Western Corridor of PWS Southern Strata (of-7).



Interactive Plotting, DLS & ELB, PWSSC 1995

Figure 4. Nearshore Survey Areas in Western Corridor of PWS.

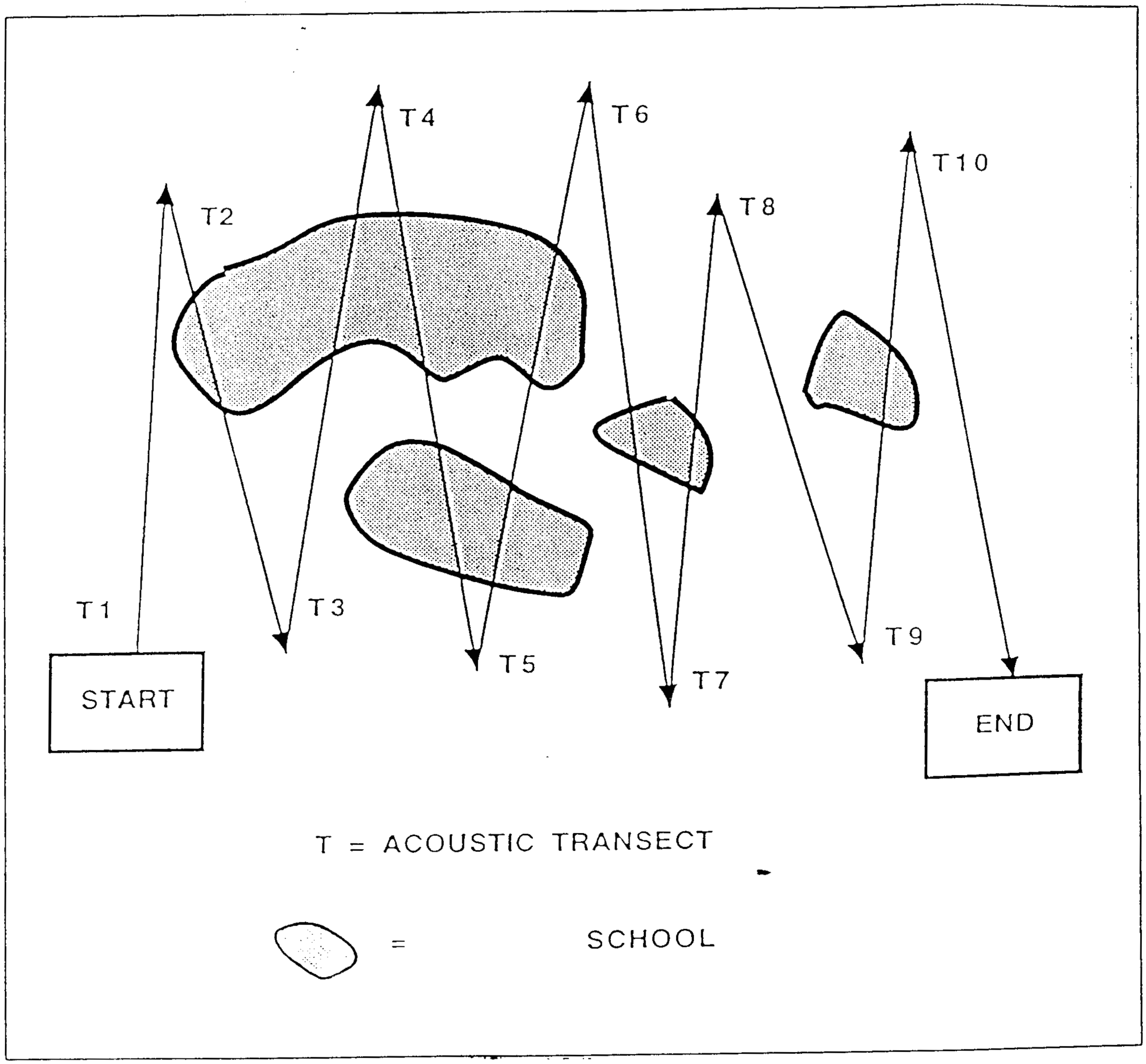


Figure 5. Zig-zag Transect Design for Nearshore Acoustics Transects.

surveying was conducted during the day and trawling was conducted at night. Acoustic sampling was also conducted during each trawl for signal classification purposes. In the nearshore strata, acoustic surveying was conducted independent of the purse seiners so both acoustic surveys and net sampling was conducted at night.

Seasonal timing

Three types of surveys were conducted six times (Leg I to VI) over the outmigration season. Two western PWS surveys to assess predator distributions along the length of the outmigration corridor were conducted with the trawler only on legs II and IV. Four north-western PWS surveys were conducted in the nearshore and offshore strata to assess early season predation at the beginning of the outmigration on legs I-IV. Two south-western surveys were conducted in the nearshore and offshore strata to assess late season predation at the end of the migratory corridor on legs V and VI. The later two surveys consisted of large scale acoustic and net sampling efforts to assess predator distributions, and a 24 hour diel survey to assess temporal trends in feeding behavior.

Acoustic equipment and processing

Geo-time coded acoustic data was collected using BioSonics 101-120 kHz and 102-200/420 kHz dual beam echosounders and processed in real time with ESP and BIOMAP software on a 486 laptop computer. Each sonar system was equipped with a Magellan DX5000 GPS receiver and external antenna to measure geographic position. Data were collected in 1 meter depth strata from 0-20 meters, 2 meter strata from 20-50 meters and in 5 meter strata below 50 meters for the offshore. For the nearshore, 2.5 meter strata were used from 20-98 meters. Sample process distances were established as every 45 pings in offshore strata and every 45 seconds on the inshore strata. Echo integration, dual-beam target strength and GPS data were stored on hard drives and backed up on optical or magnetic disks/tapes. Unprocessed data were stored on DAT recorders. A block diagram of the data acquisition system is shown in Figure 6.

Noise peaks at 100 meters were approximately 10 mV on the narrow and wide beams, respectively, with 40 log R amplification. A 33.2 mm tungsten-carbide ball was used as a standard target for dockside calibrations which produced a constant mean target strength of -41 dB with a SE of 0.3. Standard tungsten-carbide targets which are accurate within 1 dB (Foote and MacLennan 1992) were used for dockside calibrations. Dockside calibrations were made by collecting a large sample of positions in the beam by allowing the target to swing freely within the acoustic beam. Using the known TS of the sphere, the peak in the target strength distributions were used to calculate the combined source level and receiver gains (SL+RGn and SL+RGw). Subsequently, TS distributions are generated for possible values for the wide beam dropoff (w), and w is chosen from the distribution with the minimum variance. The determined calibration parameters are then set so that the expected TS value of the sphere can be obtained regardless of position in the beam. Ping-pong balls were used in the field on extended cruises to monitor for through-system changes in sensitivity (Foote and MacLennan). Important system parameters and calibration data are presented in Table 1.

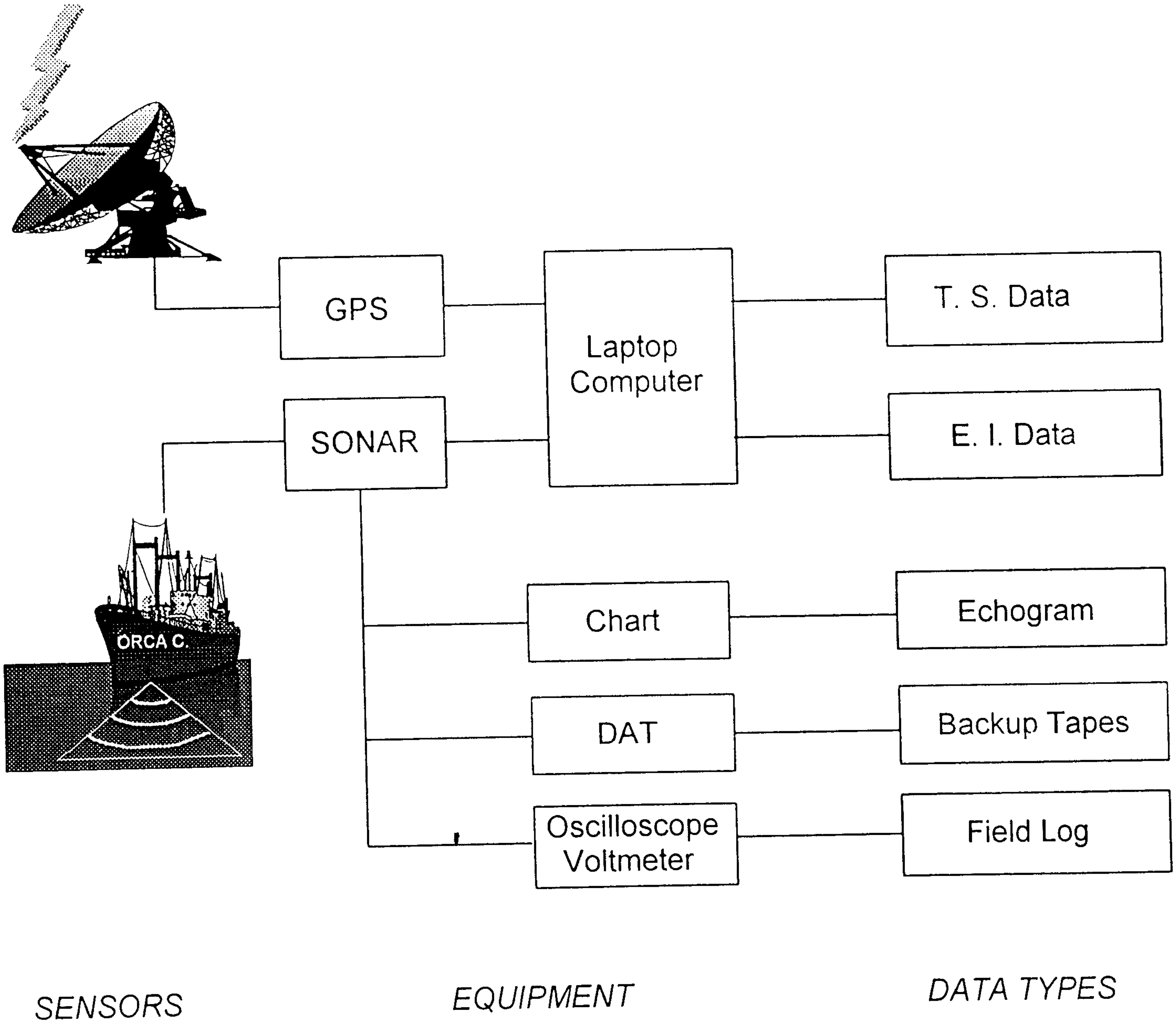


Figure 6. Block Diagram of the Data Acquisition System

Table 1

Parameters of the acoustic equipment used during the 1994 SEA surveys in Prince William Sound.

System	Frequency	Source level	System gain	Transducer	Pulse duration
BioSonics 101	120kHz	225.075dB	-165.264dB	.0010718	0.4 ms
BioSonics 102	200kHz	221.655dB	-179.779dB	.0006515	0.4 ms
	420kHz	220.257dB	-164.771dB	.0006515	0.4 ms

Reference voltages and TVG curves are systematically recorded at the beginning of every 2-hour DAT tape, measured on a digital voltmeter, and written in the field log book. This allows us to calibrate the tape playback output in the laboratory to match the echosounder's output from the field. This routine also allows for detecting changes in the receiver gain while in the field (amplifier drift and TVG curve).

Considerable post processing was necessary because equipment malfunctions in the field often interrupted real time processing. Post processing to collect missing target strength,echo integration and echogram data, and to correct for system parameter changes was conducted by playback of DAT tapes on personal computers and BioSonics processing equipment. All processing of echo-counting, echo-integration, target strength determination, and biomass estimation was done in accordance to standard techniques (Traynor and Ehrenberg 1979, Thorne 1983). Acoustic data for echo-integration was received on the narrow beam element only, and amplified by a 20 Log R time varied gain (TVG). Dual beam processing data were received on both wide and narrow elements of the transducer and amplified by a 40 log R TVG.

Batch processing of data to correct for real time measurement of temperature and salinity, bottom integration, classification and transformation of acoustic targets from dB to kg and numbers, estimation and visualization of biomass were conducted after transferring the data to a UNIX workstation. All data are stored in the appropriate format for post processing using ARCINFO, interactive data language (IDL), and automated visual systems (AVS) software. ARCINFO is the geographic information system software being used to store and process electronic map information. The Interactive Data Language (IDL) is an array-oriented programming environment which has been chosen for visualization, signal processing, and statistics. Advanced Visualization System software allows for 3D visualization, data I/O, and statistical functions.

Measured target strengths of individual fish were compared with length data of fish captured by the nets. A power function (Traynor and Ehrenberg, 1979) is currently used to simulate a transducer's beam pattern (ideally a Bessel function) so as to estimate TS. The target strengths are therefore compensated for off-axis location, and targets with angle greater than the mode in the angle distribution (usually about 3 degrees) are excluded so as to remove size bias (since off-axis targets require higher noise thresholds). The empiracle formula derived by Traynor (personal communication) for walleye pollock, 20 log L -66dB, was used to convert lengths of captured fish into predicted values of target strength.

Net sampling equipment and data acquisition (ADF&G)

Acoustic data analysis

Identification of targets is a problem in Prince William Sound because of the diversity of marine life. While pollock, salmon, and herring are the dominant fish species, other organisms including zooplankton, squid, and jelly plankton are plentiful and capable of reflecting sound. A first step in the identification of targets was to classify target types on the echogram: schools, layers, aggregations of large targets, large single targets (nekton<-60dB) and small single targets (plankton >-60dB). The second step was to code the appropriate echo integration cells and outline the targets in the processed electronic files with the type of classification or mix of classification that represent each. Third, the species composition for target classes was determined and applied to each of the coded integration cells. At this step, the lengths of the fish in the net catch was also compared to the target strength data from the dual beam analysis. Those cells which had mixed classifications received prorated estimates of composition. At this point the integration cells were assigned a species and size. In this case, cells containing walleye pollock were electronically tagged for biomass estimation. The target strength for the acoustic to biology transformation (dB to weight) was then chosen from the literature values, for the length of fish in the net catch. Weight of cells then were expanded to density per unit volume or surface area for vizualization and estimation of biomass. The area estimates of the strata used to expand density to biomass were derived from maps generated in ARCINFO. Weighted mean densities and their variances were computed and extrapolated to biomass and 95% confidence limits via the delta method (Seber 1973). Biomass estimates of predators were then combined with estimates of salmon fry predation by the same technique to estimate total fry consumption. A block diagram of data analysis is shown on Figure 7.

Two modes of sampling were chosen for collecting biological information on the fish: purse seining and midwater trawling. Purse seining was used along the shorelines and done in conjunction with the nearshore acoustic transects. Two 15 meter commercial purse seiners were chartered to deploy 250 by 30 m seines with 1.5 cm stretch mesh and a sink depth of 20 meters. Both round hauling and 20 minute hook set procedures were used. A midwater trawler of 25 m was chartered to fish a 40 by 28 m wing trawl with 1.5 cm mesh in the bunt. The trawl was equipped with a remote net sounder to determine depth to head rope and measure fish entering the mouth. Time of trawl ranged from 20 minutes to two hours dependent upon catch rates.

All fish in small catches were processed for species, length, weight, stomach contents, otoliths and external lesions. Large catches were systematically subsampled in accordance to Ricker (1975). Fish are caught to determine species, measure physical lengths (to compare to acoustic measurements), and to estimate food consumption rate and diet composition for each predator species. Processing of fish samples from each net set is outlined by Livingston (1989) and Dwyer et al. (1989). The age composition of the predators was estimated from otolith and analysis and length frequency data. Length modes are clearly separated for ages 1-3 among juvenile walleye pollock from the northwest Gulf of Alaska (Smith et al. 1984). A normal curve separation technique will be employed to assign length categories to age groups (MacDonald and Pitcher 1979).

Net survey design

The ADF & G conducted the net sampling primarily to collect fish stomach samples to identify predators. Specific sample sizes were the goal of the purse seiners in the nearshore areas and offshore for the trawler. Thus, sampling of acoustic targets was not always synoptic. For purse seining there were 447 sets: 26 were directed sets to sample known targets and 173 were in the same survey area at the same time as the acoustic surveys were done. These sets were used where appropriate to identify targets. The trawling was done at night, with acoustic surveying being conducted with the trawling. Separate acoustic surveys were also done in the offshore areas during the day.

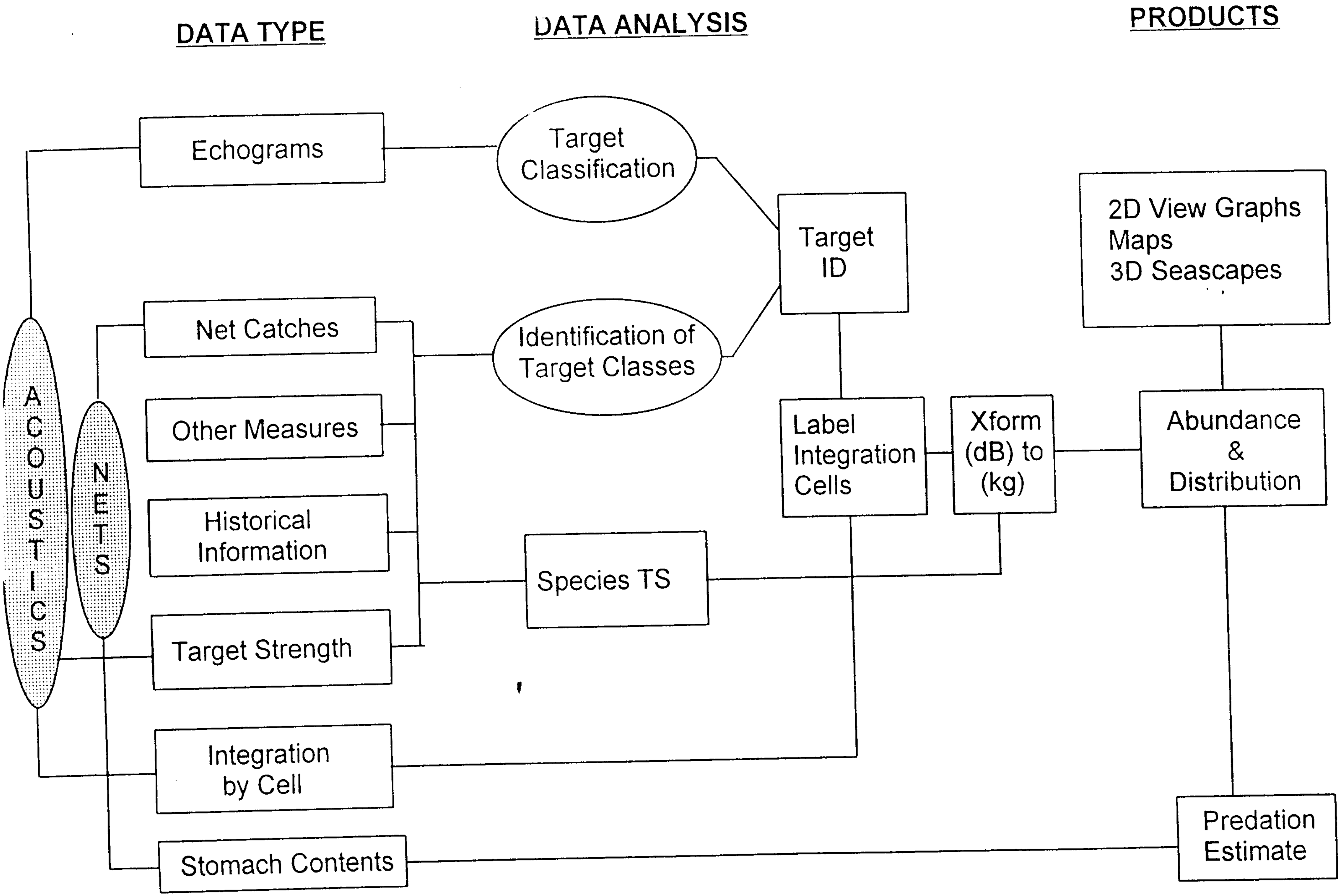


Figure 7. Block Diagram of Data Analysis

RESULTS AND DISCUSSION

The major goal of 1994 acoustic surveying was to estimate potential predator populations along the outmigration route. When it became apparent that the dominant predator was walleye pollock, the stock assessment survey on prespawn pollock (a joint study with the Alaska Draggers Association (ADA) and the Alaska Department of Fish and Game) gained relevance to the SEA objectives. Furthermore, in the absence of overwintering herring surveys, the stock assessment of fall herring biomass in 1993 and 1994 surveys (joint studies with Cordova Fishermen United (CDFU) and ADF&G) became important to SEA.

The principal nekton species observed in both offshore and nearshore surveys were pollock, squid, herring and adult salmon. The catch per unit effort (CPUE) for adult pollock, juvenile gadoids, squid and herring for the offshore trawl are given in Figure 8. Gelatinous plankton and macrozooplankton were also plentiful in the net catches and are also capable of reflecting sound (Figure 9). The dominant predator incurred along the outmigration route of the pink salmon fry was walleye pollock. This initial analysis focused on determining the distribution and biomass density of pollock populations. See accompanying Table 2.

Observations and data gathered in the 1994 field season on macrozooplankton, birds and mammals merit further study. Along the nearshore/offshore habitat interface, density layers of macrozooplankton were observed on the 420 kHz sonar. In certain locations, distinct boundaries existed (Figure 10). The 1995 nearshore sampling design has been modified to address these. Direct visual observations and echograms of marbeled murrelets feeding on pollock fry were also made (Figure 11). Kittiwakes and shorebirds were observed feeding on schools of salmon fry in Lake Bay and off the northern end of Prince of Wales Passage. Humpback whales feeding on a macrozooplankton layer in Knight Island Passage were also observed. For 1995, SEAFISH will collaborate with Dr. David Scheel's study on "estimating local avian predation rates on hatchery-released fry" to gather information on the distribution and abundance of birds and mammals relative to the distribution of fishes and macrozooplankton.

The long term goals of SEAFISH are critical in the development of restoration models. However, on the shorter term much of this is also pertinent to harvest management (Figure 12). Acoustic surveys on the number of herring spawners and the number of pollock spawners are providing knowledge of stock size from which harvest management decisions can be made. These data are derived from SEA spinoff projects. Furthermore, surveys providing assessment of the year class composition and the oversummer and overwinter survival will provide the harvest managers with additional information to better assess the harvest potential of those fisheries. Both fishermen and the management agencies are bearing much of the costs of these surveys.

Restoration of depressed populations (i.e. herring) is dependent upon understanding the effects of natural and anthropogenic events. SEA proposed, in accordance with GLOBEC, that ocean/trophic state survival models are needed for this assessment.

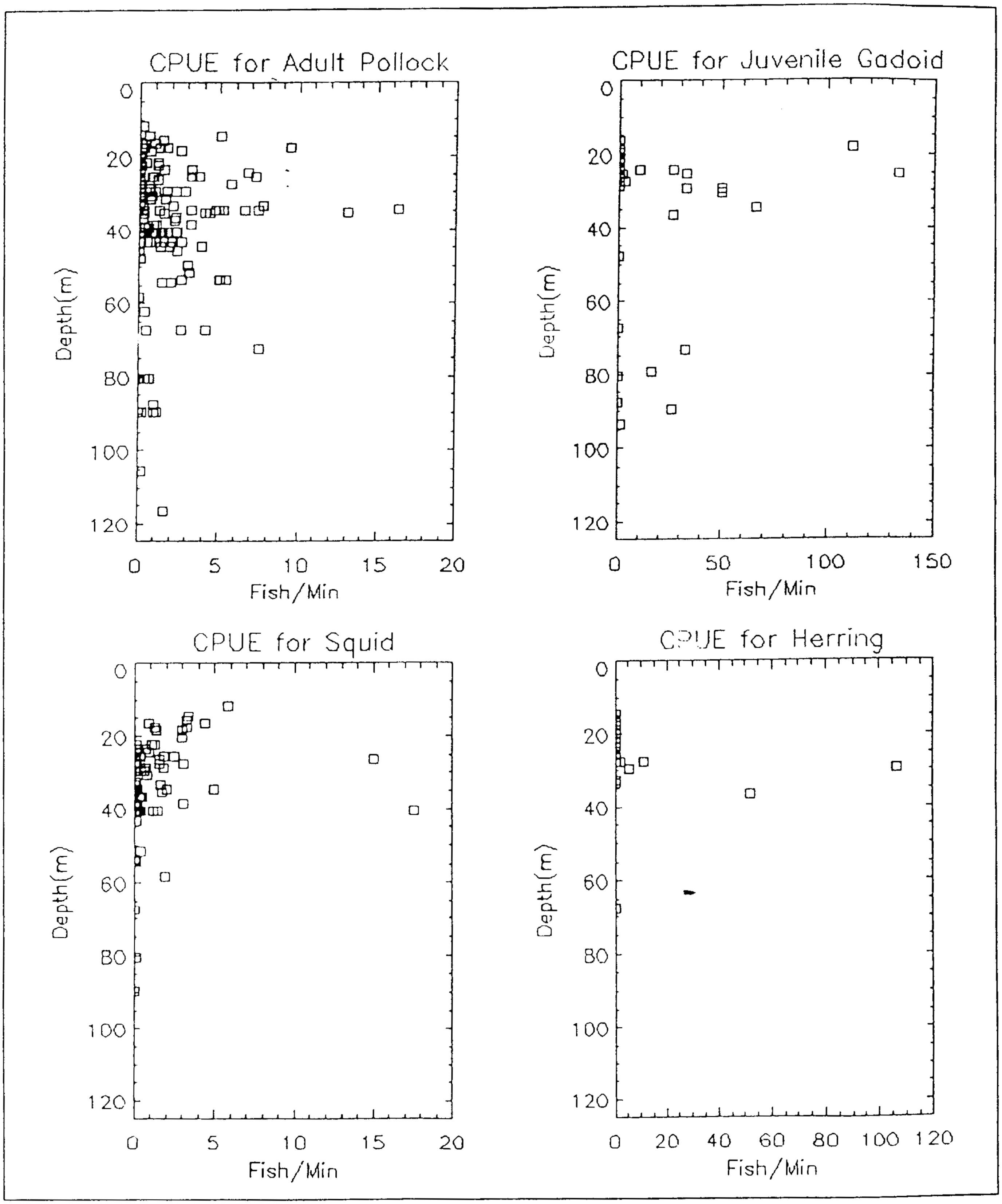


Figure 8. Catch Per Unit Effort (CPUE) for Adult Pollock, Juvenile Gadoids, Squid, and Herring for the offshore trawl.

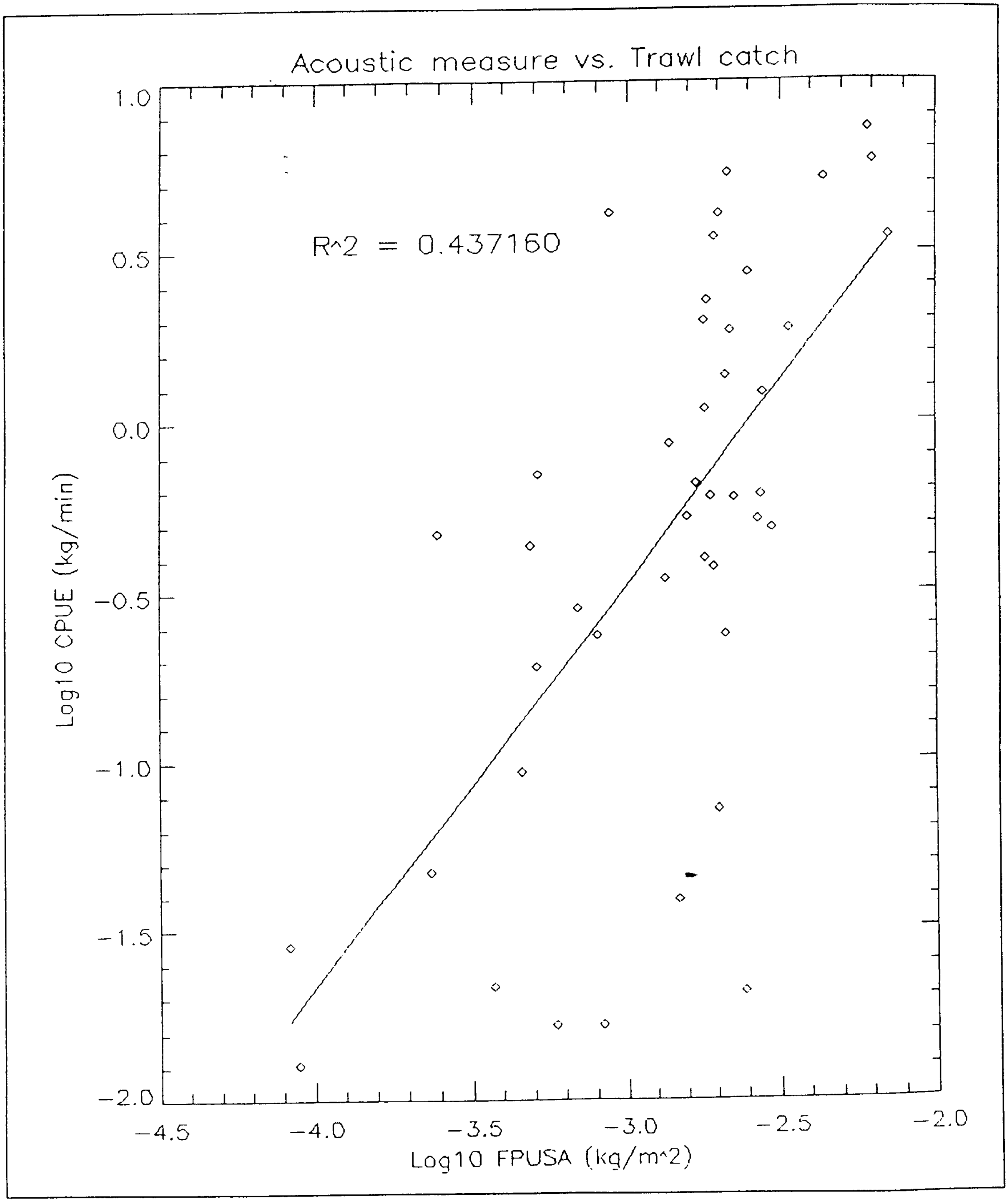


Figure 9. The acoustic measure vs. the offshore trawl catch.

Minutes trawled, by leg and area

\	1	2	3	4	5	6	T
13	387	566	775	762	0	119	2609
14	39	271	215	323	0	143	991
15	19	140	0	804	0	180	1143
16	0	0	0	0	570	385	955
17	0	0	0	30	377	394	802
18	0	30	0	0	240	390	660
19	0	30	0	38	59	393	520
T	445	1037	990	1957	1247	2005	7681

pollock caught in trawl

13	1278	1387	474	1855	0	31	5025
14	87	1019	240	378	0	11	1735
15	10	542	0	121	0	20	693
16	0	0	0	0	4	11	15
17	0	0	0	0	46	42	88
18	0	33	0	0	0	114	147
19	0	7	0	1	0	525	533
T	1375	2988	714	2355	50	754	8236

Avg weight (g) of pollock in trawl

13	848	792	830	792		505	808
14	822	759	789	742		633	761
15	1076	739		718		733	740
16					775	539	601
17					756	630	695
18		701				408	473
19		400		1229		274	277
T	848	769	816	780	757	344	750

Avg length (mm) of pollock in trawl

13	495	491	498	469		473	484
14	489	478	476	468		472	476
15	555	473		465		521	474
16					516	483	491
17					464	489	475
18		470				329	360
19		396		619		327	328
T	495	482	490	468	468	351	469

TS per weight, dB/Kg, as determined by net length (+Traynor TS) and weight

\	1	2	3	4	5	6	T
13	-31.3	-31.0	-31.1	-31.4		-29.5	-31.3
14	-31.3	-31.2	-31.3	-31.2		-30.5	-31.2
15	-31.4	-31.1		-31.1		-30.2	-31.0
16					-30.5	-29.6	-29.8
17					-31.3	-30.1	-30.8
18		-30.9				-31.7	-31.5
19		-30.0		-30.9		-30.0	-30.0
T	-31.3	-31.1	-31.2	-31.4	-31.2	-30.3	-31.3

TS per weight, dB/Kg, as determined by net length and Thorne curve

\	1	2	3	4	5	6	T
13	-34.5	-34.5	-34.5	-34.4		-34.4	-34.5
14	-34.5	-34.4	-34.4	-34.4		-34.4	-34.4
15	-34.8	-34.4		-34.4		-34.7	-34.4
16					-34.6	-34.5	-34.5
17					-34.4	-34.5	-34.5
18		-34.4				-33.5	-33.7
19		-33.9		-35.1		-33.5	-33.5
T	-34.5	-34.5	-34.5	-34.4	-34.4	-33.7	-34.4

Table 2. Distribution and biomass density of walleye pollock from the offshore trawl, by leg and area.

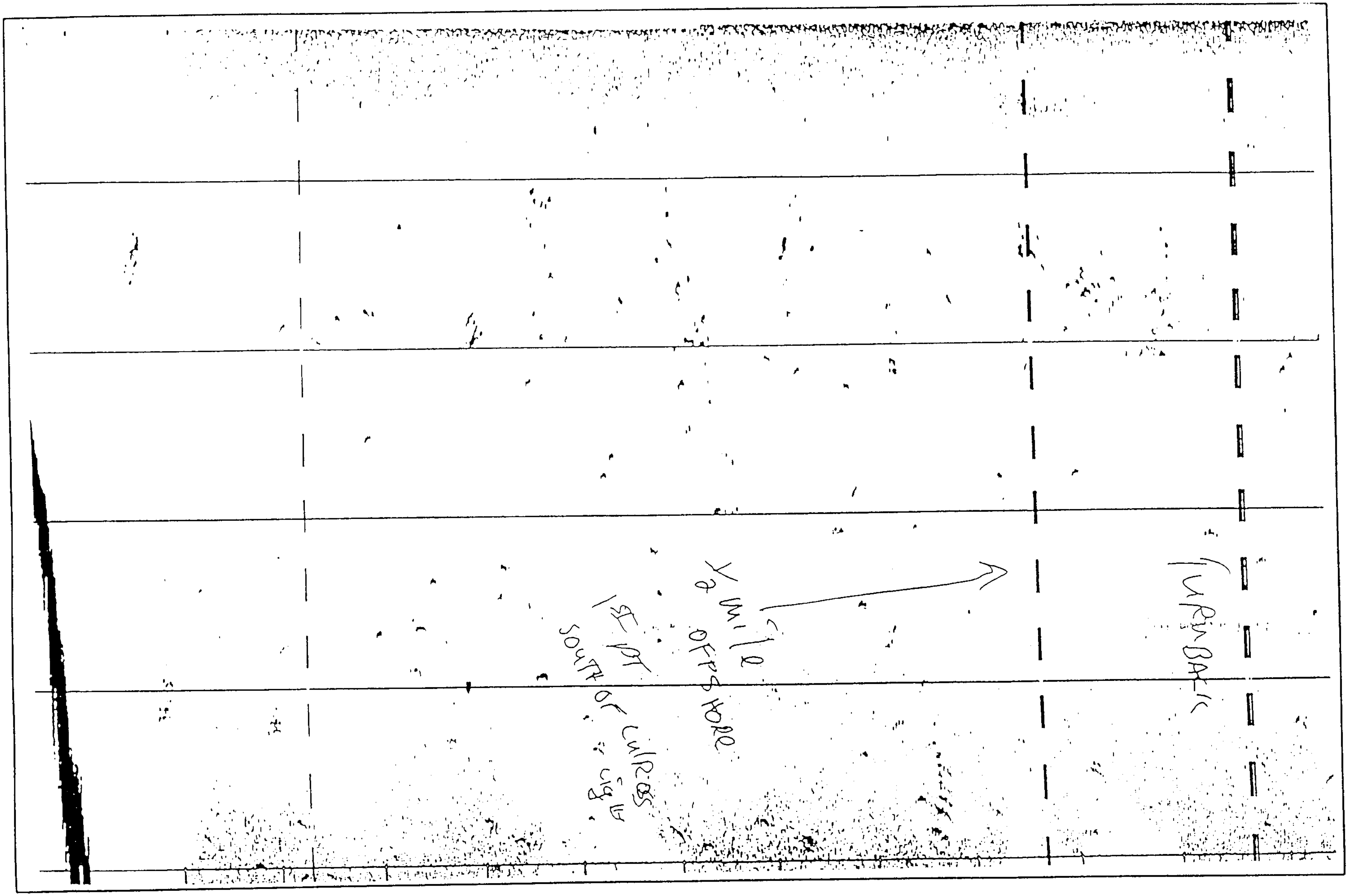


Figure 10. Echogram off first point south of Culross Light showing vertical anomally with pollock targets offshore of the anomally.

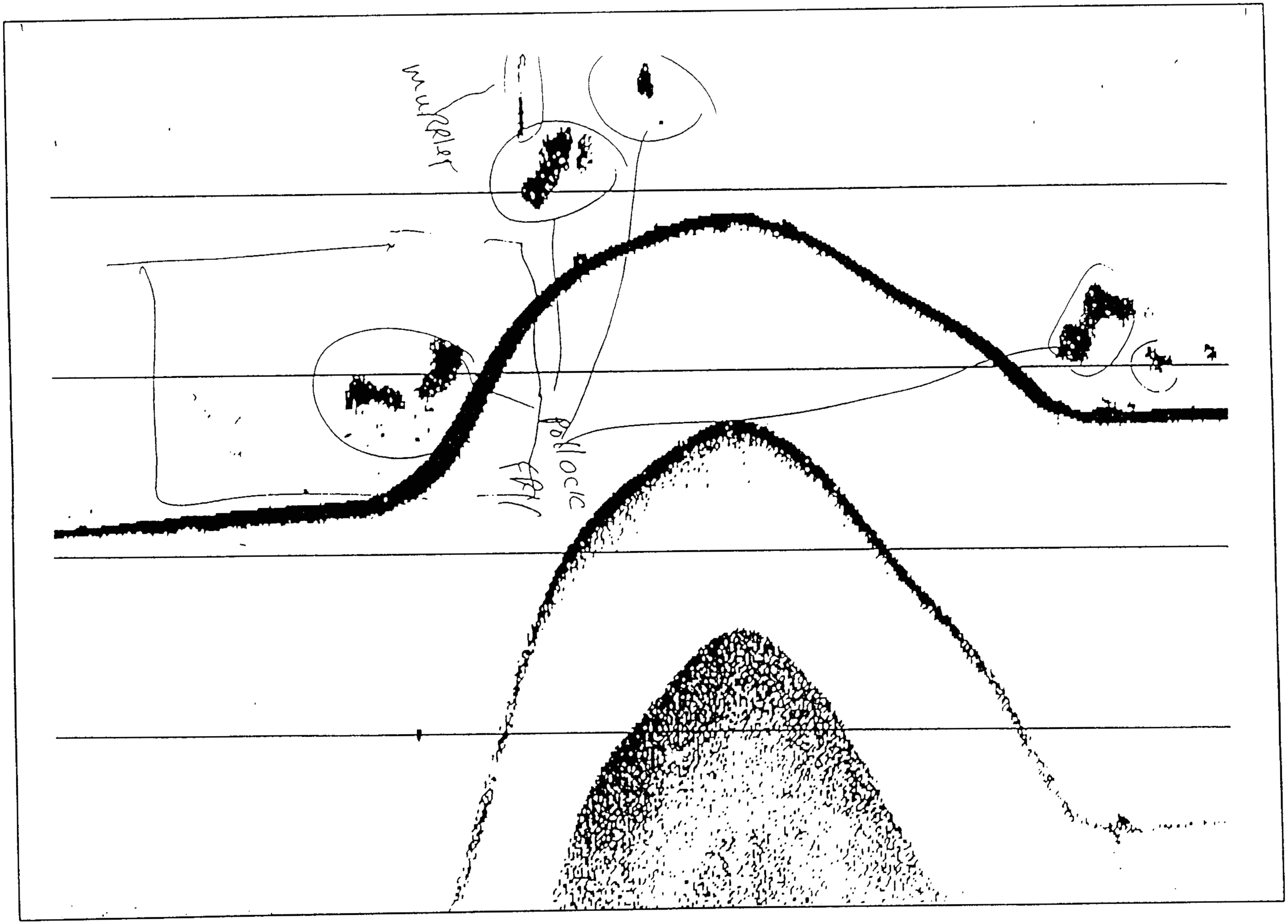


Figure 11. Echogram showing Marbeled Murrelet diving on pollock fry school in Fox Farm at the lower end of Elrington Island.

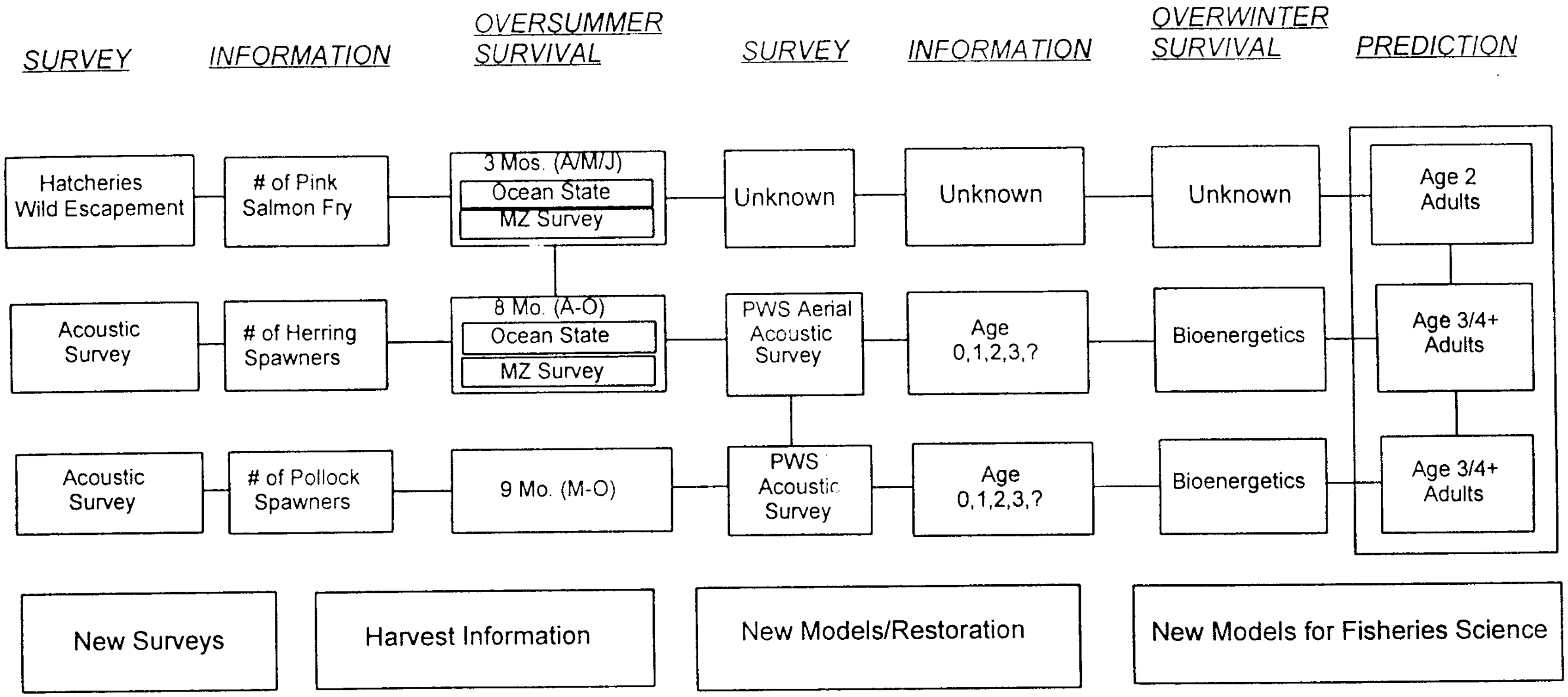


Figure 12. Block Diagram Depicting Development of Prediction Models.

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