Application of Combined Optical and Acoustic Technologies for Fisheries and Marine Mammal Research in Prince William Sound and Kodiak, Alaska

R.E. Thorne
Prince William Sound
Science Center
P.O. Box 705,
Cordova, Alaska 99574
thorne@pwssc.gen.ak.us

G.L. Thomas
Rosenstiel School of Marine &
Atmospheric Science
4600 Rickenbacker Causeway,
Miami, Florida 33124
gthomas@rsmas.miami.edu

M.B. Foster
Alaska Department of
Fish and Game
211 Mission Road
Kodiak, Alaska 99615
matt_foster@fishgame.state.ak.us

***Abstract*-For the past decade, the Prince William Sound Science Center has studied the role of herring in Alaskan ecosystems, including its vulnerability to damage from oil spills. The research techniques have centered on application of scientific acoustic technologies, but more recently have incorporated infrared scanners and underwater cameras. The combined techniques have provided a powerful suite of tools that have demonstrated the critical role of herring as forage for many marine birds and mammals, including the endangered western population of Steller sea lions**.

I. INTRODUCTION

The Prince William Sound Science Center (PWSSC) initiated an assessment of Pacific herring populations in Prince William Sound (PWS) in 1993 using scientific acoustic techniques [1]. The initial motivation was an evaluation of lingering impacts from the EXXON VALDEZ Oil Spill (EVOS). The assessment program has continued as part of an ecosystem monitoring program, and recently expanded to herring in the vicinity of Kodiak Island as part of a predator-prey study of herring and Steller sea lions in cooperation with the Alaska Department of Fish and Game (ADF&G) [2]. While the central technology has been fisheries acoustics, both underwater optical and infrared technologies have been incorporated to improve species identification and investigate predator-prey relationships.

II. ACOUSTIC TECHNOLOGY

Acoustic techniques have been used for assessment of pelagic fishes for decades [3,4,5]. Modern scientific digital echosounders are accurate and highly portable [6]. The assessment techniques for herring in PWS rely not only on these scientific echosounders, but also on modern scanning sonars and GPS-based navigation systems. The assessment is a four-stage process: (1) reconnaissance and location, (2) verification and mapping, (3) transects with scientific acoustics and (4) subsampling school groups for biological information. The initial survey stage, guided by historical observations, is conducted to identify the overall distribution of herring. The effort includes aerial surveys, sonar surveys and sentinel vessel observations including fishing vessels. Once an area of herring abundance is located, a sonar survey delineates the boundaries of the concentration. Then series of closely-spaced transects are run with the scientific acoustic assessment system (Fig. 1). Sonar monitoring continues at this stage to ensure that the survey covers the extent of the herring concentration. Lastly, net sampling using a commercial herring purse seine

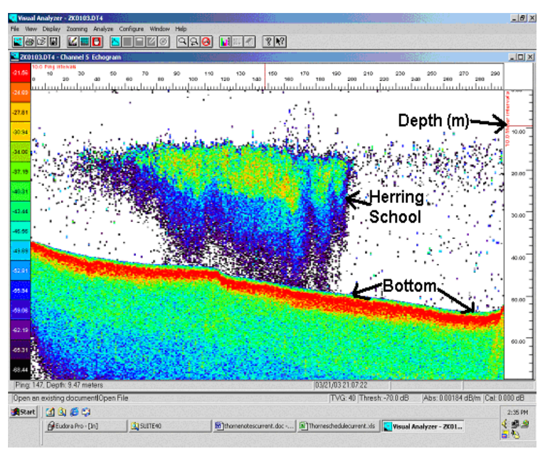

Fig. 1. Computer display from a BioSonics DT4000 digital transducer system showing a single transect across a herring school in Prince William Sound.

is directed toward the surveyed concentrations to obtain biological information, including size and species composition (Fig. 2).

Information from models used by ADF&G indicated that the herring population in PWS was over 100,000 metric tons in 1989 [7]. Between 1990 and 1992, 40,000 mt were harvested. However, in spring 1993 very few fish were found. This mystery led to the initiation of acoustic surveys in fall 1993. The acoustic survey confirmed that the herring population had collapsed to about 16,000 mt. Recently, correlations between the acoustic estimates and the aerial surveys of spawn (Fig. 3) were used to show that the actual population decline began in 1989, coincident with the EXXON VALDEZ Oil Spill, but the decline had not been detected by the models used by fisheries managers [2].

Fig. 2. Purse seiner making a set on herring in South Arm, Uganik Bay, Kodiak Island

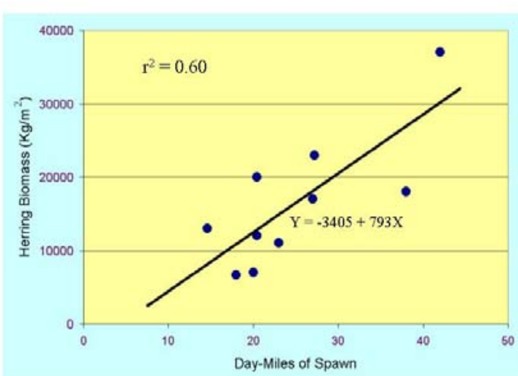

Fig. 3. Comparison of annual acoustic estimates of herring biomass and the day-miles index of herring spawn.

III. INFRARED TECHNOLOGY

The addition of infrared technology was serendipitous. We conduct our surveys of herring at night because the distributions are more amenable to acoustic assessment techniques during this period[1]. The fishing vessel chartered for the spring 2000 surveys was equipped with an infrared "Nightsight" scanner. The infrared scanner revealed intense night-time foraging activity by Steller sea lions, humpback whales and various marine birds, an observation reported in the journal NATURE[8]. Subsequently, infrared scanners have been routinely added to the herring surveys to document night-time feeding intensity, especially by the endangered Steller sea lions (Fig. 4). Surveys around Kodiak Island have shown that the infrared scanners could detect Steller sea lions on haul outs at night at distances over one mile (Fig. 5).

The research using the infrared scanners has shown that overwintering concentrations of herring are a critical food supply. Herring are so important that the numbers of Steller sea lions within Prince William Sound are a direct function of the biomass of the overwintering herring schools [2]. Linear correlation coefficients (r^2) between Steller sea lion counts and associated herring biomass typically exceed 0.9 (Fig. 6).

Fig. 4. Raytheon Model M100 NightSight Infrared Scanner

Fig. 5-Still image captured from infrared scanner video showing Steller sea lions hauled out at night near Gull Cape, Kodiak Island

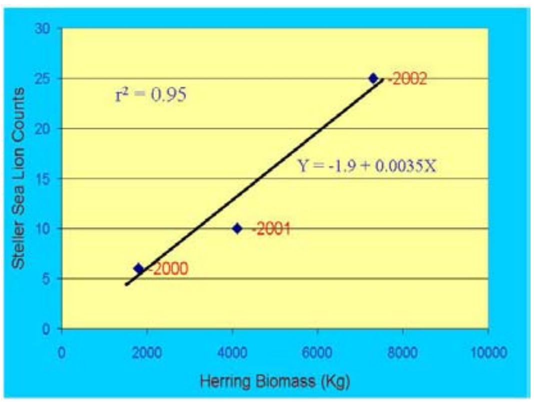

Fig. 6. Relation between Steller sea lion counts and herring biomass from annual surveys of the St. Mathews Bay herring population, 2000-2002.

The abundance of several bird species also depends on the herring abundance (Fig 7). Diving birds, such as cormorants, are highly correlated with herring abundance, while gulls are associated directly with the Steller sea lions. The foraging activity of the sea lions, which includes stunning the herring, apparently facilitates feeding by the gulls.

IV. UNDERWATER OPTICS

The last stage of the herring surveys, net sampling for biological information, is very costly and time consuming. Consequently, we

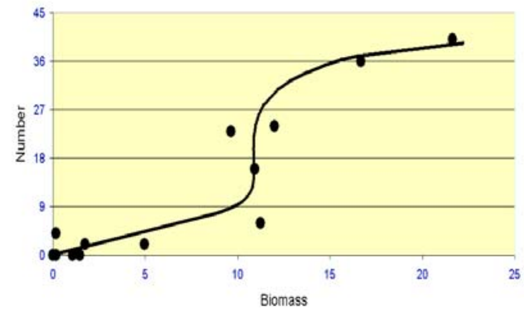

Fig. 7. Number of birds counted by the infrared scanner along night-time transects compared to the biomass (Kg/m^2) of herring below the vessel, from Rocky Bay, PWS, March 2000. The sigmoid curve is a classic threshold response.

explored the use of an underwater camera with infrared lighting as a tool to identify fish species. In most of our applications, the species are very limited, usually herring or pollock. We found that we could locate a school with the navigation sonar and echosounder, stop above the school to lower the camera, and usually identify the species within 5 minutes (Figs. 8-10).

While some biological information cannot be obtained with optics alone and require net sampling, the capability to rapidly identify species with the camera saves both time and expense.

Fig. 8. Still image captured from underwater camera video showing herring in South Arm, Uganik Bay

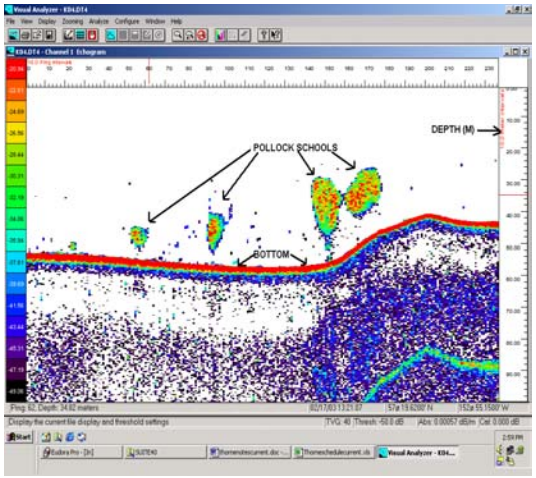

Fig.9. DT4000 visual display of pollock schools at Kiliuda Bay, Kodiak Island. The pollock schools in some cases show characteristics similar to herring schools

Fig. 10. Still image captured from underwater camera video showing pollock at Kiliuda Bay, Kodiak Island.

V. DISCUSSION AND CONCLUSIONS

Marine ecosystems are very complex. That complexity mandates the application of effective sampling tools. However, one or two planktivorous fishes often dominate arctic and sub arctic marine food webs[9]. The determination of the population abundance and distribution of these dominant planktivores is a prerequisite to understanding the fate of changing marine production and fluctuations in satellite predator populations. In many regions of Alaska, including Prince William Sound, the two dominant fish biomasses are herring and pollock. By focusing on these two fishes with effective sampling tools, we have been able to document their population trends in Prince William Sound over the past decade. We have seen that herring provide critical forage for many marine mammals and birds, while pollock are less available to surface feeding birds and animals. Further, pollock are voracious predators on other forage fish. We suspect that historic changes in the dominant role of these two fishes probably explain much of the variability in satellite populations, including the major decline of the western population of Steller sea lion that began in the 1970s.

The combination of acoustics (both scientific and commercial) with infrared and underwater optics has provided a powerful suite of tools in this research.

Acknowledgments

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