The Trophic Interactions Program: Improving Multispecies Models Using a Data-based Approach

by Patricia Livingston

In 1976, the ecosystem modelling task force at the Alaska Fisheries Science Center (AFSC) began to build large-scale ecosystem models that focused on the dynamics of upper trophic level animals. The data demands of the models were quite extensive, requiring estimates of growth, natural mortality, fishing mortality, migration rates, temperature preferences, food preferences, size distribution, and biomass of all the major fish species in the Bering Sea, Gulf of Alaska, and Washington-Oregon-California coastal region. The models were designed with the hope that they could improve our understanding of ecosystem interactions for multispecies fisheries management.

Although the Center was building multispecies models of fish interactions in the North Pacific Ocean, the ability to provide the necessary data was limited. The Center initiated regular standardized groundfish trawl surveys in the North Pacific in 1979, making little data available on the levels of natural variability for these populations. In some cases, parameters from closely-related fish species in the Atlantic Ocean or other geographic areas were used. Only one Bering Sea stock, walleye pollock (*Theragra chalcogramma*) provided sufficient data to perform a single-species-based virtual population analysis; remaining population estimates were based on a limited time series of information from trawl surveys with varying survey areas and gear configurations across years.

A sensitivity analysis of an equilibrium biomass flow model of groundfish, birds, and marine mammals in the Gulf of Alaska revealed that fish food composition parameters were important in multispecies models with predation as the main source of species interaction. Again, data for those parameters were limited. To address this need, the AFSC initiated the Trophic Interactions Program for field collection and laboratory analysis of groundfish stomach contents.

Collection and Laboratory Analysis

Stomach sampling began in 1983. Initial efforts focused on the eastern Bering Sea shelf area, and about 2,200 stomach samples were obtained from five species. In 1984, the Trophic Interactions Program defined a basic species list and began a field and laboratory program in multispecies groundfish food habits. Since that time, the program has continued to obtain annual samples from the Bering Sea and on a rotating triennial schedule from the Gulf of Alaska, Aleutian Islands waters, and Washington-Oregon-California coastal waters. In 1994 the number of stomach samples obtained was over 12,000.

The Trophic Interactions Program has relied on two sources for obtaining groundfish stomach samples—the Fisheries Observer Program and National Marine Fisheries Service (NMFS) surveys. Systematic collections were initiated in 1984, utilizing observers on foreign fishery vessels in the eastern Bering Sea. Observers collected samples throughout the year, providing coverage that the Trophic Interactions Program was unable to achieve through standard NMFS surveys. At the height of activity in 1987, observers on foreign vessels collected 4,300 samples and completed a total of 6,400 qualitative stomach scans on Bering Sea groundfish in the field. As the groundfish fishery in the eastern Bering Sea became domestic during the early 1990s, observers were given greater responsibilities, the fishing seasons shortened, and the number of samples contributed by the observers declined. The primary source of samples for the program became NMFS surveys, with collection efforts increasing from covering one-half of the hauls in the annual Bering Sea crab and groundfish survey to covering all Bering Sea survey hauls, most of the triennial surveys of the Gulf of Alaska and Aleutian Islands region, hydroacoustic surveys, and small process-oriented studies.

The primary focus of the Trophic Interactions Program laboratory analysis has always been to identify commercially important fish and crab prey (Fig. 1). Established taxonomic references are used to identify prey species when prey are in suitable condition for identification and a key is available. However, because characteristics referred to in a key are often partially digested, the program employs alternative techniques for prey identification. An extensive prey reference collection, curated by members of the program since its inception, is used for comparative purposes. The program also utilizes techniques that allow identification of prey by hard or slowly digested parts. Cephalopod beaks and raduli are used for family or genus identification. Otoliths are used to help identify some prey fish to family, genus, or species level. An extensive gill raker reference collection is the primary source of prey fish identification when conventional taxonomic characters are not available (Fig. 2). Osteological characters such as vertebral count, size, and shape are also used. Pollock prey size information is augmented by utilizing the linear relationship between otolith size and body length to estimate pollock length when whole pollock from stomach contents are not measurable but the otoliths are.

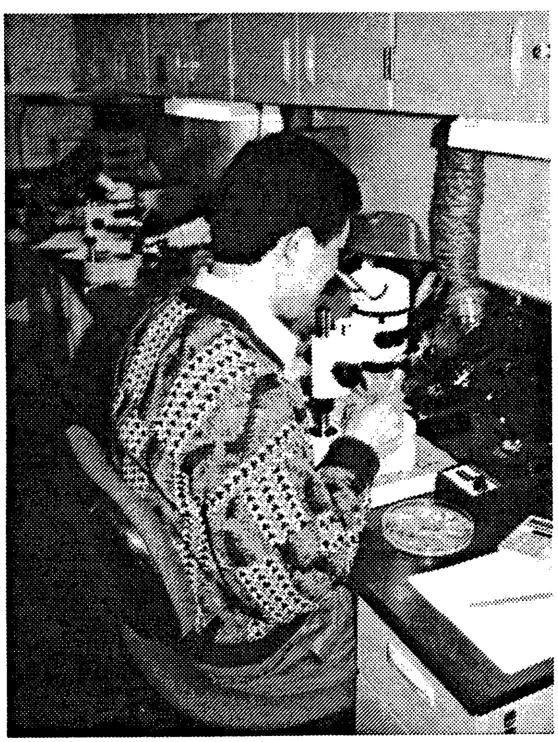

Figure 1. Biologists in the Trophic Interactions Program use laboratory analysis of stomach contents to identify commercially important prey of North Pacific groundfish.

The Trophic Interactions Program is continually broadening the scope of its taxonomic identification of prey. The level of taxonomic identification of pteropods, fish eggs, and polychaetes has improved. The polychaete work drew upon various sources, including taxonomic literature, reference collections, and experts at the AFSC and the Fisheries Research Institute at the University of Washington. One result of the polychaete work is an in-house guide to polychaetes commonly found as prey of eastern Bering Sea groundfish, which has greatly increased the ability to identify these ecologically important prey.

Laboratory analysis procedures have evolved over the years to efficiently analyze the large number of stomach samples that have been collected. At the inception of the program, laboratory analysis consisted of a rigorous quantitative procedure that involved sorting, weighing, and enumerating each prey taxon. This high level of detail was necessary for initial dietary description but was extremely time-consuming. Once a baseline database had been established, a more qualitative procedure was used, which eliminated the enumeration, weighing, and sorting of most prey taxa and relied upon estimates of percent composition of stomach contents. The current procedure includes exact counts, weights, and size measurements of all fishes and commercially important crab prey. This streamlined process retains the most important data—stomach content weight and fish and crab information—but decreases the time spent on sorting all noncommercially important prey while increasing the time spent on stomach sample analysis. Quantitative analysis is still done on samples collected from new areas, or of new species, or from process-oriented studies.

Data Analysis

The initial goal of the Trophic Interactions Program was establishment of standardized data collection procedures and the creation of a database on fish food habits. The intended use of these data was the determination of improved food composition parameters for the existing energy flow models. The data also have been used to define the factors influencing diet composition and to quantify groundfish predation removals of commercially important species. It is hoped that a better understanding of the predation process will be gained by examining changes in predation rates along with changes in prey abundance and distribution. Models would be improved by providing better parameter esti-

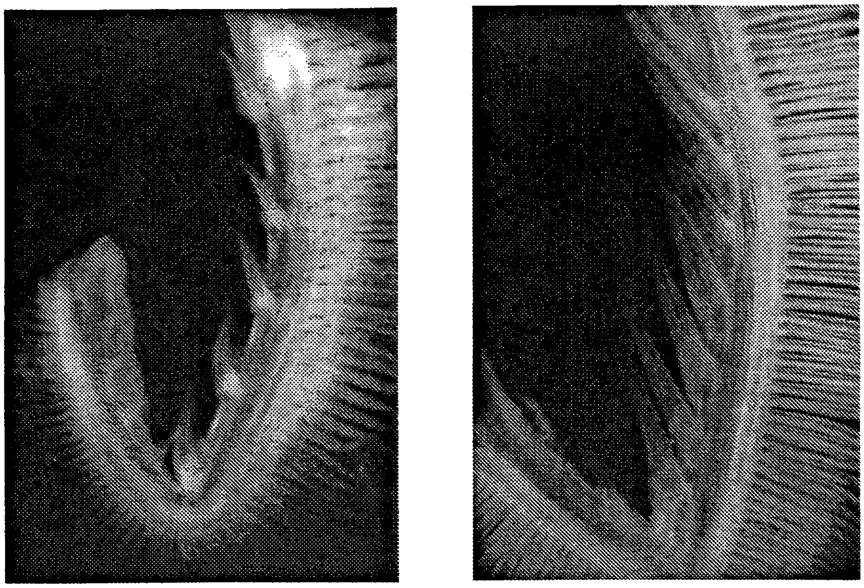

Figure 2. The AFSC's gill raker reference collection is a valuable source for prey identification. Pictured above are gill arches of two flatfish species: (left) rock sole (*Pleuronectes bilineatus*) and (right) Bering flounder (*Hippoglossoides robustus*).

mates and by enhancing knowledge on the functional forms of predation relationships.

Selected Program Research Results

In its early years, the Trophic Interactions Program produced basic diet and daily ration information on sampled groundfish predators. The program addressed questions on size-related changes in diet and the degree of diet overlap of major groundfish species in the eastern Bering Sea. Consumption rates were estimated in the form of daily rations, using field estimates of stomach content weight and laboratory-derived estimates of gastric evacuation rates. With these parameters, it was possible to estimate total amount of prey consumed by each predator population. The importance of groundfish consumption in the eastern Bering Sea ecosystem was highlighted when groundfish consumption estimates were compared with consumption estimates for birds and marine mammals in the early 1980s (Fig. 3). Mortality of walleye pollock, for example, was primarily due to groundfish predation. In terms of weight, bird, mammal, and fishery removals combined were less than half the amount of groundfish removals. Also, when pollock removals were partitioned by size of pollock removed, it became evident that groundfish, birds, and mammals primarily removed juvenile fish, while fisheries took mature pollock (Fig. 4). Furthermore, estimates showed that over 90% of the groundfish-induced mortality of juvenile pollock for the years 1985-89 was due to adult pollock cannibalism. These results suggested that the short-term effect of the pollock fishery was to enhance juvenile pollock prey resources of mammals and birds by removing a competitor for juvenile pollock prey.

As the time series of data expanded, it became evident that interannual variation in diet composition appeared to be important, particularly regarding amounts and locations of commercially important prey such as crabs and fishes. Spatial distribution for some prey species changed from year to year, perhaps due to changing environmental conditions. Prey species' spatial overlap with a given predator and predation-induced mortality also varied across time. Ideally, independent estimates of prey abundance were needed to calculate predation mortality rates at age. Unfortunately, the juvenile fish and crab prey of groundfish are inadequately sampled by the trawl gear, so age-specific estimates of the number of a prey species consumed by known major predators were used to reconstruct prey number-at-age and to estimate predation mortality-at-age for the years 1985-89. By examining trends in preda-

Eastern Bering Sea Pollock Food Web

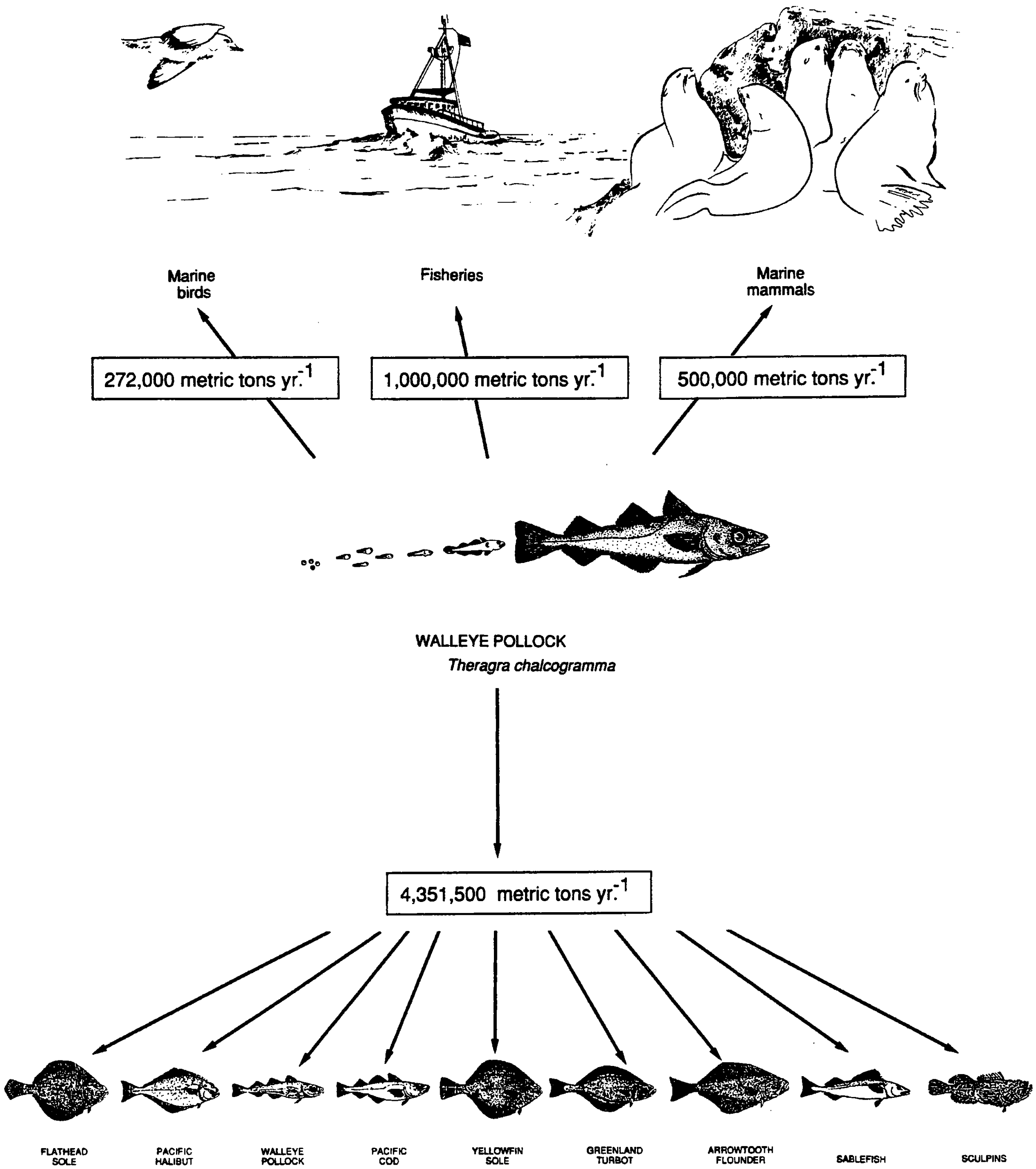

Figure 3. Estimates of walleye pollock removals in metric tons by marine mammals, birds, fishery, and groundfish in the eastern Bering Sea around the mid-1980s.

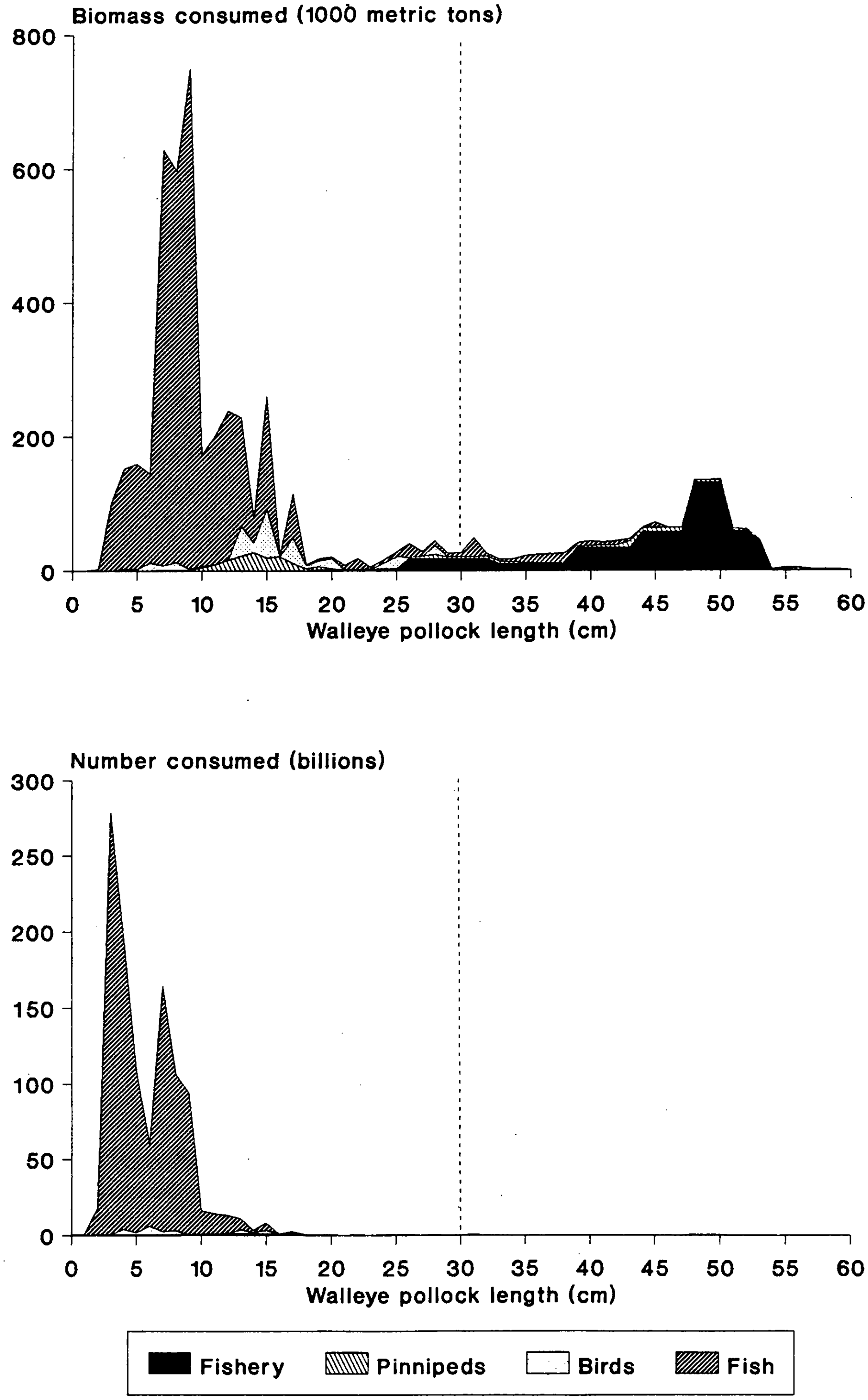

Figure 4. Estimated removals of walleye pollock in terms of biomass and number by size by groundfish, mammals, birds, and fishery in the eastern Bering Sea during 1985.

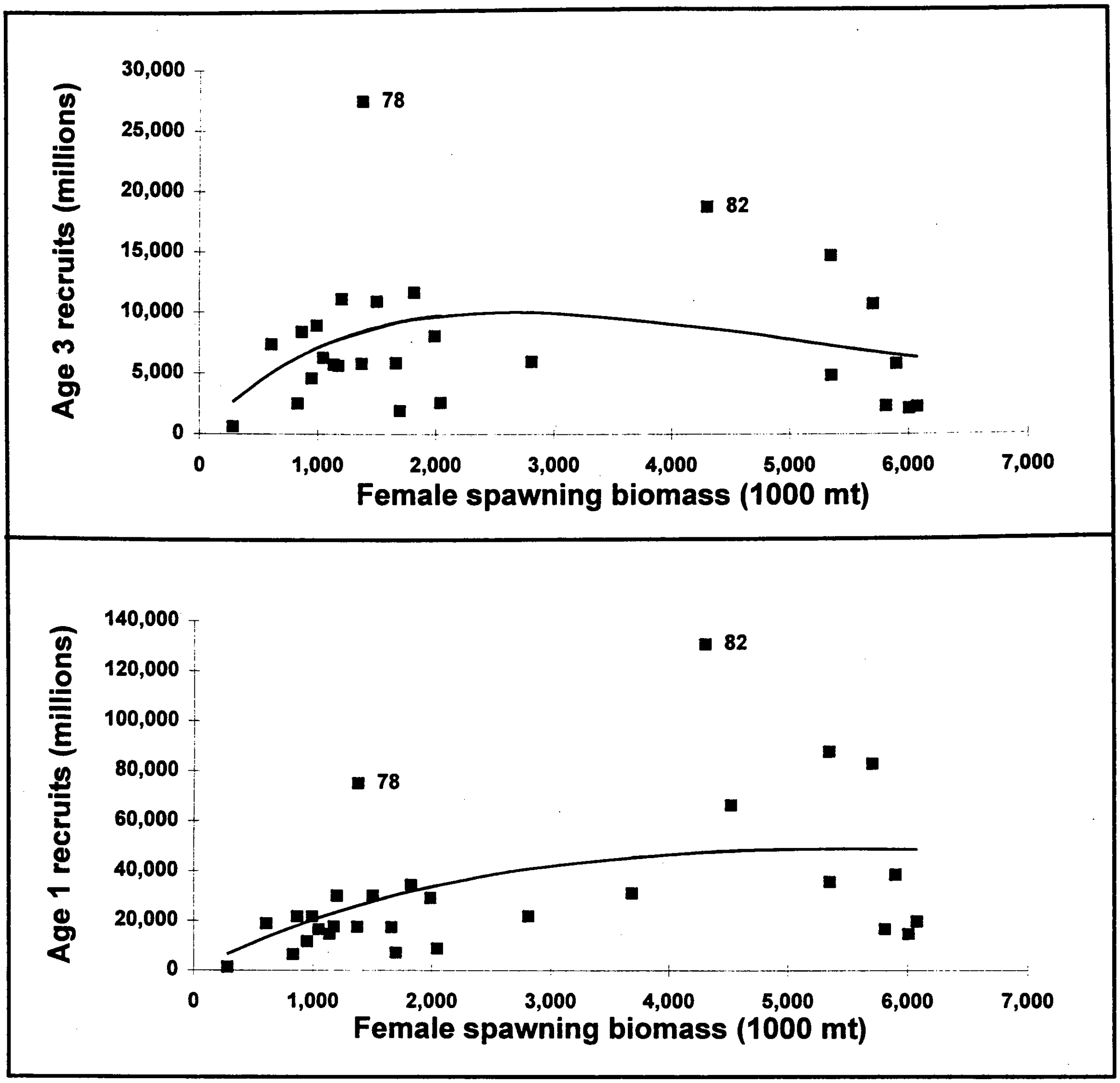

Figure 5. Synthesis model estimates of age-3 recruits (upper) and age-1 recruits (lower) versus female spawning biomass for the model with predators.

tion mortality-at-age, it was discovered that density dependent predation mortality could be occurring and that predators might be switching to abundant year classes of prey. This switching process would tend to dampen the size of those year classes before their recruitment into the fishery.

Predation data from the Trophic Interactions Program are now being incorporated into an integrated single species catch-at-age model called Synthesis. This type of model, which uses a maximum likelihood strategy to bring together diverse sources of information, allows comparison of the fit of predation data with other more traditional data sources used for assessing population size. Adding predation into these models does not appear to change the current assessment of the size of exploitable stock, but it does provide information about factors affecting recruitment into the fishery (Fig. 5) and should enhance prediction capabilities.

The AFSC's current energy flow model of the Bering Sea incorporates new data collected from the Trophic Interactions Program and uses better parameter estimates regarding food composition and ration and more extensive knowledge of the dynamics of predation. It is hoped that this research will improve the understanding of how human actions influence ecosystem processes and further the understanding of how to modify those actions to maintain ecosystem integrity and health.