Exxon Valdez Oil Spill
Gulf Ecosystem Monitoring Research Project Final Report

Alaskan Groundfish Feeding Ecology: An OBIS Information System

Gulf Ecosystem Monitoring Research Project 040710
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Dale A. Kiefer[1]

Vardis M. Tsontos[2]

[1] System Science Applications
P.O. Box 1589, Pacific Palisades, CA 90272
(213) 740-5814
kiefer@usc.edu

[2] Department of Biological Sciences, University of Southern California
3616 Trousdale Parkway, Los Angeles, CA 90089-0371
(213) 740-1810
tsontos@usc.edu

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tsontos@usc.edu

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Abstract
During the course of this project we have developed an information system useful for characterizing the distribution, dynamics and feeding ecology of Alaskan groundfish in relation to environmental parameters. Functioning as a form of electronic fisheries and biogeographic atlas, this system archives and provide a means to analyze and access via the Internet data on the spatial and temporal distribution of a large number of groundfish and associated prey species sampled in the Gulf of Alaska and Bering Sea by NMFS Alaska Fisheries Science Center (AFSC). Environmental observations from surveys and remotely sensed datasets are also included providing a characterizations of the habitats of species, such that the resulting information system and application provides a detailed account of both interspecific and environmental interactions. The system also provides advanced GIS tools to explore trophic interactions and taxonomic relationships between species, while also ensuring interoperability with OBIS protocols and facilitating Web-based, access to the resulting GIS application. Approaches, data and tools successfully developed under this project have since been ported and extended for the development of the Alaskan Marine Information System (AMIS) portal at the NPRB.

Key Words
Alaska, Biogeography, Fisheries, trophic, AFSC, online data, GIS, EASy, Netviewer, OBIS, Gulf of Alaska, Bering Sea

Citation
Kiefer, D.A.& V.M. Tsontos. Alaskan Groundfish Feeding Ecology: An OBIS Information System. EVOS Final Report xxx, 17 p.

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Study Chronology

System Science Applications (SSA) submitted a funding application entitled "Alaskan Groundfish Feeding Ecology: An OBIS Information System" to EVOS under its FY04 BAA. The period of performance of the resulting EVOS project (# 040710) was February 2004 to June 2005.

Interim progress reports by SSA were submitted by Kiefer to EVOS on June 2004 and April 2005. This final project report provides a synthesis of project achievements overall, focusing on deliverables produced in particular.

Introduction

As is the case for other coastal states and nations, Alaska needs to better monitor, communicate and understand ecological conditions and human activities in the coastal zone and their management implications for natural resources. Despite the growing number of both historical and real-time Alaskan marine environmental and biogeographic databases, typically these are the product of various initiatives and maintained by multiple agencies using disparate informatics frameworks. The highly distributed and diverse nature of oceanographic data makes data access, integration, and delivery of value-added products to end-users for use in management applications issues of critical importance.

This work resulted from a proposal submission in response to FY2004 EVOS BAA. Efforts have focused on developing a prototype information system useful for characterizing the distribution, dynamics and feeding ecology of Alaskan groundfish in relation to environmental parameters using established tools and protocols for Web-based access to biogeographic datasets. The resulting information system archives and provide a means to analyze and distribute via the Internet information on the spatial and temporal distribution of a large number of groundfish and associated prey species sampled in the Gulf of Alaska, Aleutian Island waters, and the Bering Sea by NMFS Alaska Fisheries Science Center (AFSC). This biogeographic information system includes data on the gut contents of specimens as well as environmental information characterizing the habitats of the species. These datasets provide a biogeographic description of groundfish distribution and dynamics in relation to habitat structure and environmental variability. They also provide a detailed account of interspecific and environmental interactions that are integral to ecosystem-based fisheries assessment and management approaches. The information system integrates multivariate fisheries oceanographic datasets collected over a range of spatio-temporal scales, including series of satellite imagery. It also provides advanced GIS tools to explore trophic interactions and taxonomic relationships between surveyed species while facilitating interactive, Web-based, access to the resulting GIS application. Our goal has been to develop a system that will not only augment OBIS, but also provide a model of how the integration of environmental information can aid in the assessment of marine resources given ongoing initiatives at NPRB and elsewhere in the region to develop an Alaskan Marine Information System (AMIS) and real-time Alaskan Ocean Observing System (AOOS).

Objectives
The main objectives/deliverables undertaken by SSA are described briefly below:

- Identify and assemble databases consisting of satellite imagery as well as fisheries and oceanographic survey data for inclusion together with associated metadata, focusing principally on NOAA-AFSC catch survey, gut contents/trophic and physical oceanographic datasets.
- Assimilate datasets within EASy and develop a GIS application that provides thematic organization of content.
- Develop software tools within EASy-GIS that allow users to explore generic "parent-child" data objects relationships such as predator-prey interactions and taxonomic relationships between surveyed species and visualize these relationships both spatially and temporally.
- Develop EASy software interfaces supporting OBIS (DiGIR) data search and mapping protocols and additional tools for assimilating satellite imagery.
- Internet-enable the developed GIS application using EASy's Netviewer technology, and deploy the Web-GIS system both on USC and AFSC servers.
- Document the application and technical system (online help).
- Train NOAA-AFSC personnel on the use and further development of the system.
- Attend project and EVOS symposium meetings, and conduct outreach on the project.
- Integrate and extend the resulting fisheries information system with the complementary efforts at the North Pacific Research Board (NPRB) for the development of a prototype Alaskan Marine Information System (AMIS), interoperable with OBIS and functioning as a GIS portal to Alaskan oceanographic data.

Methods
This section summarizes the basic approach to implementation of the various work-package components by contractor.

1. Identify and assemble datasets for inclusion in the information system together with associated metadata.

Various contacts at NOAA-AFSC that hold biological and oceanographic datasets for the Alaskan region were approached as potential data providers and arrangements for data access made. Specific datasets acquired are described in the Results section below. Metadata, providing a high level description of all compiled datasets, has been summarized according to FGDS standard using the Metalite software package.

2. All compiled datasets were assimilated into EASy using the software's in-built data connectivity and remote data polling tools. Development of the AFSC GIS application entailed amongst other things defining specific plotting modalities of data, temporal handling of datasets, and Scenes (thematically organized, pre-packaged views of data that allow end users to effortlessly explore available datasets and that

serve as ideal points of entry for the novice and for users interested in rapidly viewing thematically structured content). A detailed description of the application is available at: http://netviewer.usc.edu/afsctrophic/afsctrophicintro.html. As discussed in further detail below, AFSC fisheries catch survey datasets have since been assimilated in the AMIS (the Alaskan Marine Information System) hosted at NPRB where they can be seen in relation to a broader suite of environmental information. Details on AMIS are available via the NPRB website or the AMIS-GIS mirror site at: http://netviewer.usc.edu/amis/amisintro.htm.

3. Considerable effort was dedicated to developing and testing new capability in EASy for handling hierarchical "parent-child" data structures in a generic fashion and thus allowing for the visualization of trophic interactions and taxonomic relationships between surveyed species in space and time via the GIS.

4. Software development was also undertaken to ensure connectivity to all relevant satellite imagery data providers (NASA Po.DAAC) and that interfaces to DiGIR were operational (EASy OBIS query capability and EASy OBIS portal mapping service).

5. EASy's Netviewer GIS Webserver technology was employed to deploy the developed AFSC GIS applications via the Internet and the USC mirror. This entailed provision of AFSC collaborators with installation CD's and associated documentation, in addition to periodic updates of software and applications, and technical support.

6. Considerable effort was made to document the application in detail and provide a comprehensive online help system for both the EASy desktop software and Netviewer system.

7. An EASy/Netviewer training workshop by Kiefer was held at AFSC in January 2004 that was attended by project collaborators. This two-day workshop covered all aspects of software usage and application development. Subsequent training sessions focusing exclusively on the Netviewer Interface and AFSC Web-based application were undertaken over the phone.

8. Kiefer attended several EVOS & NPRB symposium meetings to present the AFSC application and conduct outreach on the project. Both he and Tsontos supported several project meetings and teleconferences held with AFSC collaborators and NPRB for project planning purposes.

9. The concepts and work done on the prototype fisheries information system done this project were successfully leveraged in a funding proposal to NPRB for the development the Alaskan Marine Information System. AMIS has inherited both tools and data developed under this project, and further extended the application to include a large suite of complementary physical and optical oceanographic datasets for the region and once again interface with OBIS. The application, into which the AFSC datasets have been fully integrated with associated GIS tools, can be viewed via the NPRB website at: http://www.nprb.org.

Results

This section summarizes the key outputs of the various work-package components undertaken.

1. Identify, assemble and assimilate databases consisting of satellite imagery as well as fisheries and oceanographic survey data for inclusion in the GIS application together with associated metadata.

The datasets assembled are such that AFSC GIS applications essentially serves as an interactive electronic fisheries, biogeographic atlas. In addition to topographical information for the region, the system combines:

- historical NMFS groundfish survey databases from the NOAA Alaska Fisheries Science Center (AFSC) for the Bering Sea spanning the period 1982-2004 and that include a complementary series of physical observations (surface/bottom temperatures at sampled stations).
- the AFSC trophic interactions database containing detailed observations on groundfish gut contents from subsampled individual fish over the period 1981-2002.
- an extensive series of AVHRR SST satellite imagery from NASA.

Tables 1 and 2 below provide a detailed description of data sources and sets used.

Table 1. Summary of datasets used by AFSC-GIS

Observation Type	Temporal Coverage/Frequency
NMFS-AFSC Bering Sea Groundfish survey catch data by species/taxa including top 5 predators	May 1982 - July 2004, Annual summer cruises (46)
NMFS-AFSC Bering Sea Groundfish Trophic (gut contents) database	April 1981 - September 2004, Annual summer cruises
Temperature (surface/bottom at NMFS tow stations)	May 1982 - July 2004, Annual summer cruises (46)
SST imagery (AVHRR) Regional Alaskan, 4km resolution, monthly series	January 1985 - December 2004, monthly

Table 2. Summary of overlay and multimedia content in AFSC-GIS

Type	Description
Website links	NMFS-AFSC, NASA-PoDAAC

Overlay	Description
Coastline	World Coastline
Bathymetry	GEBCO97 Bathymetry for N.Pacific
	(Depth Intervals: 50,100,200,1000,2000,3000,4000, 5000,6000m)

2. Development of an AFSC GIS application using EASy that provides thematic organization of content as Scenes.

The following provides a brief overview of the Scenes developed for the AFSC application, whereas table 3 below describes scene configuration aspects in detail:

- **Default** - entry view showing only overlays of coastline and regional bathymetric contours.

- **SamplingStations** - view the position of sampling stations and the evolution of sampling effort over time annually over the period 1981- 2004 for the various fisheries catch survey and trophic databases comprising the application.
- **Predator_CPUE** - simulate through time (1981-2004) in annual increments to see how spatial abundance distribution patterns of 5 key predator species (depicted as bubble pie plots) evolve and vary in relation to bottom topography (presented as bathymetric contours). The 5 species/taxe are: Pacific Cod, Arrowtooth Flounder, Walleye Pollock, Pacific Halibut and Skates.
- **PacificCod_Prey** - examine the dynamics of Pacific Cod (*Gadus macrocephalus*) spatial foraging behaviour as resolved from AFSC annual surveys and gut contents analyses over the period 1982-2002. Biomass data series for the top 30 by frequency prey items are represented as bubble pie plots.
- **PacificHalibut_Prey** - examine the dynamics of Pacific Halibut (*Hippoglossus stenolepis*) spatial foraging behaviour as resolved from AFSC annual surveys and gut contents analyses over the period 1982-2002. Biomass data series for the top 30 by frequency prey items are represented as bubble pie plots.
- **ArrowtoothFlounder_Prey** - examine the dynamics of Arrowtooth Flounder (*Atherestes stomias*) spatial foraging behaviour as resolved from AFSC annual surveys and gut contents analyses over the period 1982-2002. Biomass data series for the top 30 by frequency prey items are represented as bubble pie plots.
- **WalleyePollock_Prey** - examine the dynamics of Walleye Pollock (*Theragra chalcogramma*) spatial foraging behaviour as resolved from AFSC annual surveys and gut contents analyses over the period 1982-2002. Biomass data series for the top 30 by frequency prey items are represented as bubble pie plots.
- **Skates_Prey** - examine the dynamics of Skates as an aggregate group (*8 species/taxa: Bathyraja aleutica, Bathyraja binoculata, Bathyraja interrupta, Bathyraja maculata, Bathyraja parmifera, Bathyraja sp., Bathyraja tarantetzi, Bathyraja trachura, Rajidae*) spatial foraging behaviour as resolved from AFSC annual surveys and gut contents analyses over the period 1982-2002. Biomass data series for the top 30 by frequency prey items are represented as bubble pie plots.
- **WalleyePollock_BottomTemperature** - simulate through time (1981-2004) in annual increments to see how spatial patterns in Walleye pollock abundance (depicted as bubble plots) evolve and vary in relation to bottom temperatures (shown as computed false color fields) and bottom topography (presented as bathymetric contours).

- **PacificCod_WalleyePollock** - simulate through time (1981-2004) in annual increments to compare spatial abundance distribution patterns of Pacific Cod (depicted as bubble plots) and Walleye pollock (shown as computed false color fields).
- **SST_AVHRR_MonthlySeries** - simulate through the series of available monthly, 4km resolution, regional Alaskan coverage AVHRR SST imagery for the period 1985-2004.

Table 3. Detailed configuration settings of scenes developed in the AFSC-GIS application

Scene	Temporal Coverage / Step Interval	Spatial Focus/Coverage	Pre-Configured Plots / Parameters *Spatial Extents* Bubble	*Images* False Colour	*XY plots* Vector	*XY plots* Time Series	*XY plots* Profiles
Default	1/1/1981-12/31/2004, 12 months	N67.29, W166.00	-	-	-	-	-
Sampling Stations	1/1/1981-12/31/2004, 12 months	N67.29, W166.00	Active Stations	-	-	-	-
Predator_CPUE	1/1/1981-12/31/2004, 12 months	N67.29, W166.00	Theragra chalcogramma Gadus macrocephalus Atherestes stomias Hippoglossus stenolepis Rajidae	-	-	-	-
PacificCod_Prey	1/1/1982 -12/31/2002, 12 months	N67.29, W166.00	Top 30 by frequency prey species	-	-	-	-
PacificHalibut_Prey	1/1/1982 -12/31/2002, 12 months	N67.29, W166.00	Top 30 by frequency prey species	-	-	-	-
ArrowtoothFlounder_Prey	1/1/1982 -12/31/2002, 12 months	N67.29, W166.00	Top 30 by frequency prey species	-	-	-	-
WalleyePollock_Prey	1/1/1982 -12/31/2002, 12 months	N67.29, W166.00	Top 30 by frequency prey species	-	-	-	-
Skates_Prey	1/1/1982 -12/31/2002, 12 months	N67.29, W166.00	Top 30 by frequency prey species	-	-	-	-
WalleyePollock_BottomTemperature	1/1/1981-12/31/2004, 12 months	N67.29, W166.00	Theragra chalcogramma	Temperature Bottom	-	-	-
PacificCod_WalleyePollock	1/1/1981-12/31/2004, 12 months	N67.29, W166.00	Gadus macrocephalus	Theragra chalcogramma	-	-	-
SST_AVHRR_MonthlySeries	1/1/1985 -12/1/2004, 1 month	N67.29, W166.00	-	AVHRR_SST(1m)	-	-	-

Setting up an application in EASy to a large extent entails configuring plotting options and defining how specific data types will be viewed. These settings are summarized in table 4 below. Configured plot types form the basis of thematically related views of data that are packaged using EASy's Scenes capability described previously.

Table 4. Detailed configuration of views and plots by data type in the AFSC-GIS application

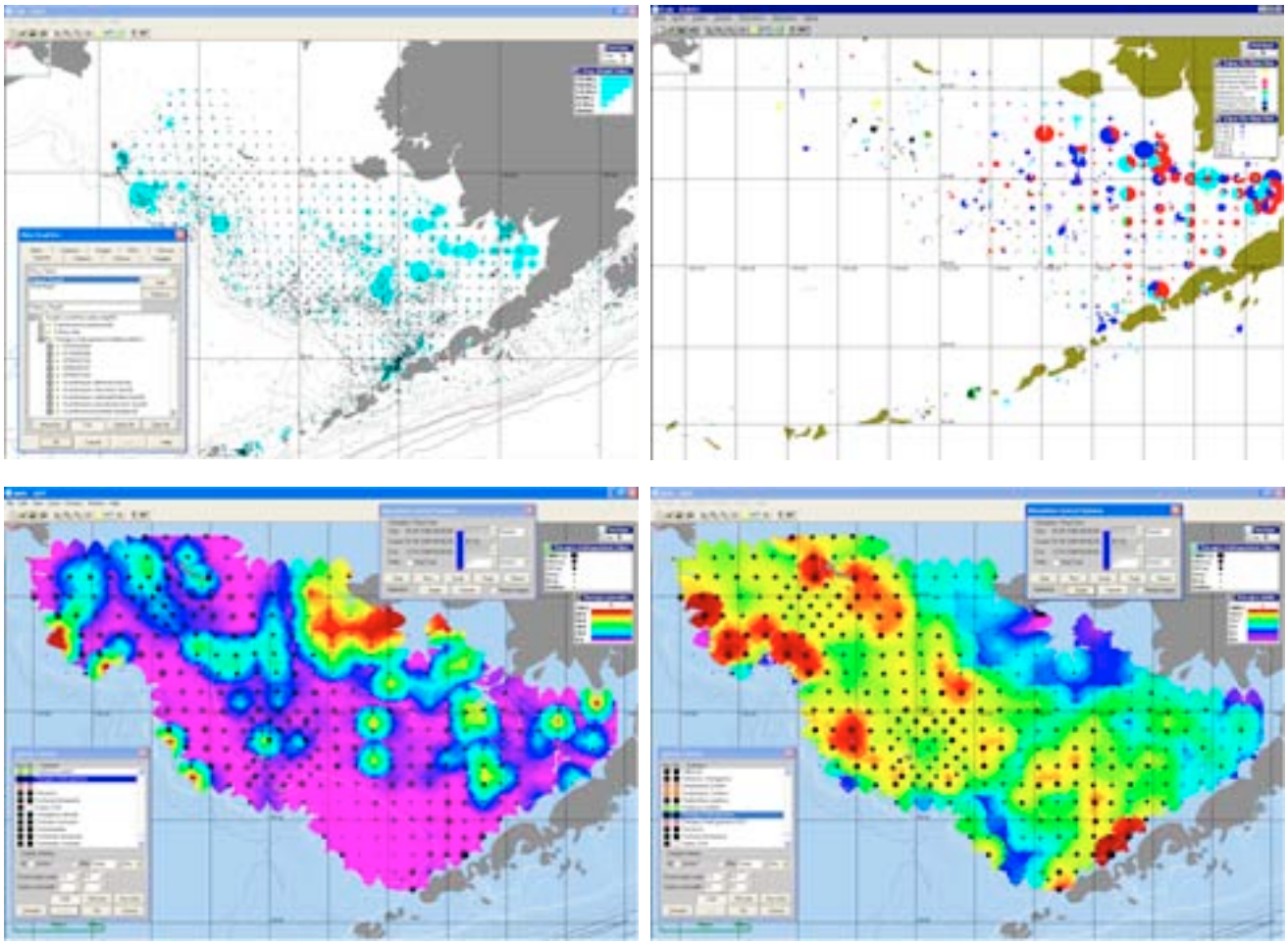
EASy Measurement Name	*View Category* / Configured Plot Types: *Spatial Extents* Bubble	*Images* False Colour	*XY plots* Vector	*XY plots* Contour	*XY plots* Transect Vertical Contour	*XY plots* Vertical Profiles	*XY plots* Time Series
Scientific prey species name (150 species, top 30 in frequency by predator out of a total 729 prey species)	●	—	—	—	—	—	—
Atherestes stomias (Arrowtooth flounder)	●	●	—	—	—	—	—
Gadus macrocephalus (Pacific cod)	●	●	—	—	—	—	—
Hippoglossus stenolepis (Pacific Halibut)	●	●	—	—	—	—	—
Rajidae (skates - 8 species/taxa)	●	●	—	—	—	—	—
Theragra chalcogramma (Walleye Pollock)	●	●	—	—	—	—	—
Temperature_Surface , Temperature_Bottom	●	●	—	—	—	—	—
SST_AVHRR(1m)	—	●	—	—	—	—	—

Note: where depth ranges are not specified, plots based on depth integrated, average values should be assumed.

3 & 4. Software development:

Software development work during this project focused largely on implementing a generic approach to handling and visualizing hierarchical "parent-child" associations in data. In the context of the AFSC datasets and application, this advanced capability allows one to flexibly explore trophic interactions and taxonomic relationships between surveyed species spatially and temporally via the GIS. Some of this functionality is illustrated in Figure 1 below:

Figure 1. Outputs of spatial trophic interactions resolved from AFSC datasets using EASy's hierarchical data analysis ("parent-child") capability. Panels: A) dialog box from which hierachcial associations between data elements can be explored and selected for visualization B) bubble pie plot outputs illustrating the distribution of principal pollock prey items. C & D) Pollock spatial abundance distributions at different point in time from AFSC catch survey data illustrated as false color imagery in EASy.



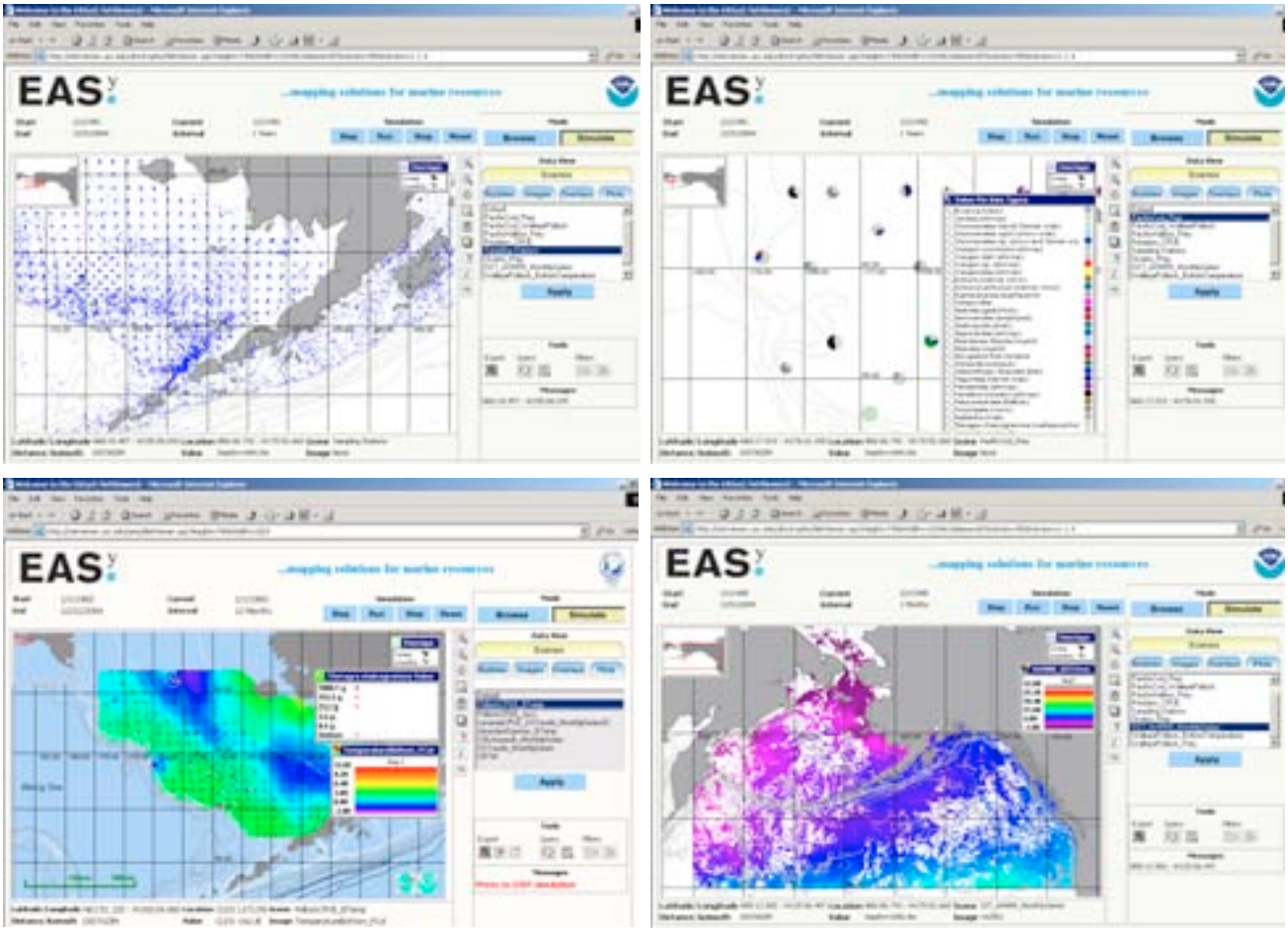
Software development undertaken also included developing the necessary interfaces in EASy to connect to new sources of satellite imagery data (NASA Po.DAAC). In addition, SSA ensured the operation of interfaces previously implemented in EASy allowing interoperability with DiGIR and the OBIS portal. This interoperability with OBIS has been achieved at two levels consistent with the requirements of the project: 1) EASy/Netviewer functions as a Web-mapping service for OBIS; that is for any species query initiated at the OBIS portal (http://www.iobis.org) Netviewer can be selected to map the resulting recordset as mapping web-service. 2) The second mode of connectivity to OBIS occurs via the Netviewer GUI itself; by clicking the OBIS button, a dialog appears that allows the user to specify a species search term at which time EASy conducts a distributed search of OBIS servers for data on that species and then maps it. Thus via both these complementary mechanisms EASy provides OBIS connectivity and mapping capabilities.

5. EASy's Netviewer component has been used to deploy the AFSC Web-GIS system and application. The system is currently hosted on the USC server but the AFSC survey data has also been integrated within the AMIS application on the NPRB website (http://amis.nprb.org). Arrangements have been made to port the AFSC Web-GIS application to a server at NOAA-AFSC as from 2006. An introductory page that describes the application and provides users with basic instructions on usage of the Netviewer graphical user interface has been developed (http://netviewer.usc.edu/afsc/afsctrophicnto.html) as entry point to the GIS application on the AFSC site as well (Figure 2).

Figure 2. Descriptive info page for the AFSC application providing a point of entry into the Web-GIS.

Figure 3 shows a collage of outputs for a selected number of scenes from the AFSC GIS application that was developed. Detailed descriptions are provided in the figure caption, but essentially one sees the range of datasets encompassed, the various utilities available for viewing and overlaying the multivariate data, and Netviewer capabilities and tools for stepping through data temporally, filtering/subsetting datasets, undertaking spatial queries and exporting datasets as synthetic raster images or raw station data.

Figure 3. Netviewer GUI and tools showing outputs of selected scenes from the AFSC GIS application. Panels: A) outputs from the "SamplingEffort" scene showing time integrated view of the distribution of sampling stations for the various AFSC GIS datasets. B) bubble pie plot outputs showing the distrbution of Pacific cod top 30 prey items from the AFSC gut contents analysis/trophic database . C) overlay of Pollock abundances and computed false color imagery bottom temperature data from the AFSC trawl survey database available as a simulation via the "WalleyePollock_BottomTemperature" scene. D) Simulation of monthly AVHRR SST composite imagery series for Alaska from NASA Po.DAAC.



6. Documentation.

Much of the documentation for the AFSC GIS application has been presented above (Tables 1-4 and Figure 2F). In addition, a comprehensive online help system for Netviewer (Figure 4) was developed during the course of this project that complements the basic instructions on usage of the system available via the application introduction page.

Figure 4. Comprehensive Netviewer online help system integrated in AFSC GIS

7. Integration of the AFSC application with AMIS

The Alaskan Marine Information System (AMIS), hosted at NPRB and available online at http://www.nprb.org has served as a more permanent home for both tools and data developed under this project (Figure 5). Significantly, this work has been leveraged to attract additional funds for development of the information system and further grow the application to include a large range of complementary physical and optical oceanographic datasets for the Alaska and further develop technical capabilities, potentially ultimately in support of AOOS.

Figure 5. Integration of AFSC Web-GIS application within the NPRB and AMIS Website.

Discussion

At the conclusion of this project, a comprehensive electronic biogrographic atlas of Alaskan fisheries resources has been developed based on historical survey databases compiled by the NOAA-AFSC. Comprised of detailed biological observations on the quantitative distribution of fish species and associated prey items in addition to physical water column observations, the resulting system provides positive proof of concept for web-based access to marine data, value added products, data integration and analysis tools. The system provides a web-based GIS tools that allow the integration and visualization of multivariate oceanographic and biogeographic datasets interactively by end-users across the Internet in accordance with OBIS and other standard data connectivity/transfer protocols. The system is inherently scalable, and has already been extended and ported for implementation of the Alaskan Marine Information System hosted by the NPRB. It could ultimately also serve as a model approach for future development of AOOS.

Publications

At present there are no publications resulting from this project.

Outreach

Dale Kiefer visited for 2 days the Alaska Fishery Science Center in April 2004 to identify datasets used for this project. The visit also involved demonstrations of EASy GIS with Pat Livingston's groundfish ecology team.

Kiefer presented our work at the January 2005 Alaska Marine Science Symposium in Anchorage. In addition he demonstrated the software during the poster sessions, and he met with collaborators. Directly afterward, Kiefer visited for 3 days the Alaska Fishery Science Center to meet with collaborators and discuss progress. The visit also included a 2-day training workshop on the use of the EASy GIS with both the Bering Sea Groundfish survey group that is under the direction of Gary Walters and the groundfish ecology team.

Alaska Training workshop at NPRB planned for the first quarter of 2006.

Acknowledgments

We would like to acknowledge the funding support of EVOS for this project. We would also like to thank all collaborators at NOAA-AFSC who have contributed data: Pat Livingston, Gary Walters, and Geoff Lang for the fisheries catch survey and trophic/gut contents datasets. Thanks also to colleagues at NPRB (Igor Katrayev & Clarence Pautzke) who have facilitated augmentation of this application and integration with the Alaskan Marine Information System (AMIS).

Literature Cited

None