Dynamic Habitat Mapping of Pelagic Tuna and Shark Species for Improved Fisheries Management

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Improving Fisheries Management

Stock Assessment / By-catch

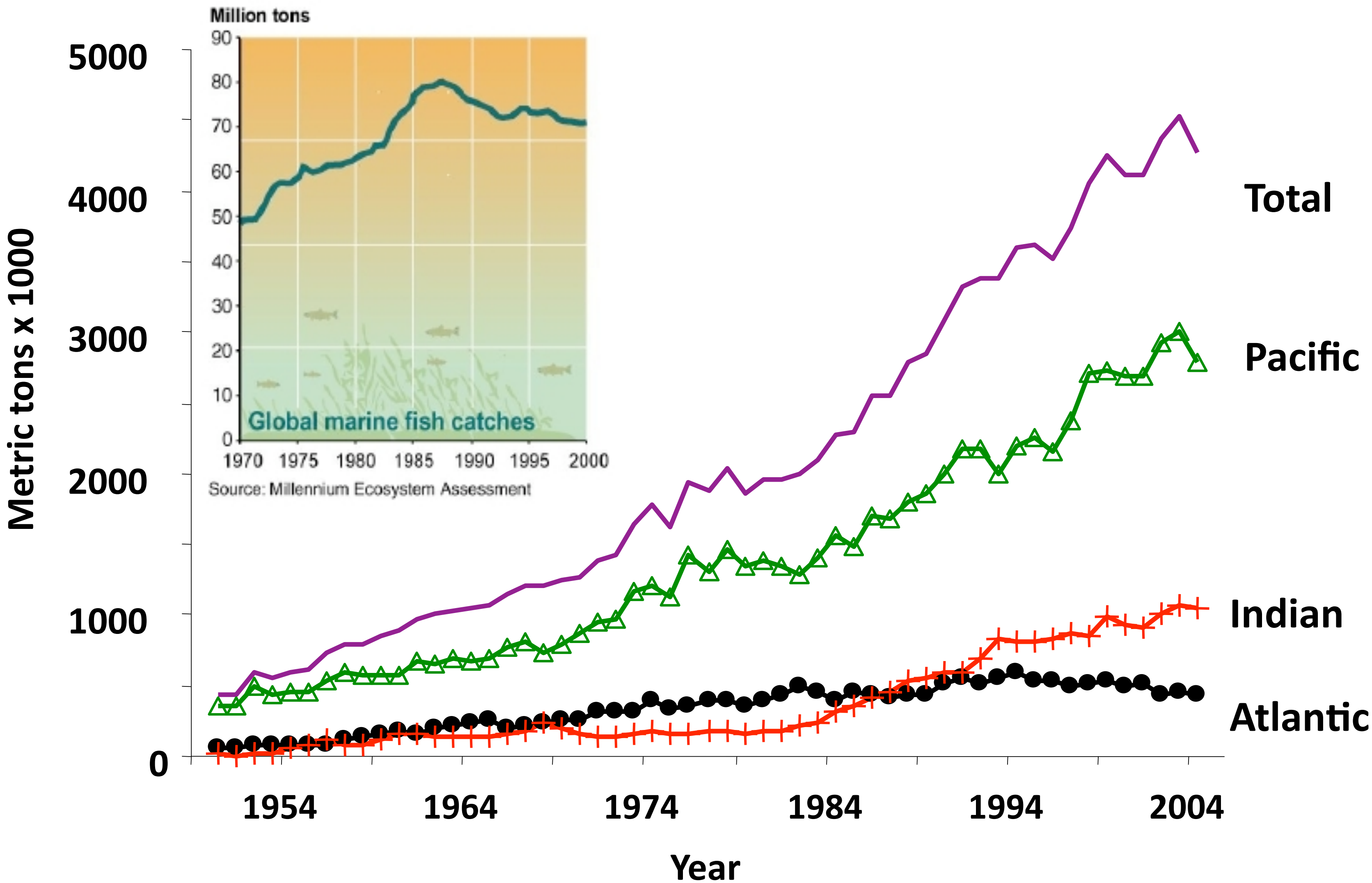
Tuna of the Eastern Pacific Ocean

- Important Commercial Species (Big Eye, Yellow Fin, Skip Jack)
- Stock assessment models only provide a reliable estimate recruitment several years after the fact
- Very little (if any) environmental data used in stock assessment models
- Need to manage by-catch of threatened species of sharks, dolphins, & turtles
- Is current sampling reflective of entire stock?

Sharks of the California Current

- Stock assessment model for Thresher Sharks
- By-catch Management – Where does habitat overlap commercial fishing
- Distribution of pregnant females

Tuna catch by Ocean



Recent Value of Tuna Fishery is \$6-\$8 Billion per annum

CIAT IATTC

Definitions

Species distribution is the location of a species' population in space and time. For example the distribution of a species can be defined by latitude, longitude, depth, and time at which individuals of a population are presence or absent. This distribution may differ seasonally because of the seasonal cycle of feeding and reproduction as well as between adult and immature stages.

Species habitat is the natural physical, chemical, and biological parameters that are required for the survival of a species. For example the habitat of a species may be defined by its required range in temperature, oxygen, and irradiance as well as its access to prey and tolerance of predators.

Obviously these two features of a species are linked. A species habitat will help determine its distribution, and alternatively information on a species distribution can help to define a species' habitat. The goal of PHAM is to provide the tools to reveal both aspects of this linkage, and to use this information to improve the management of marine pelagic species.

Habitat and Natural Selection during a Species Life Cycle

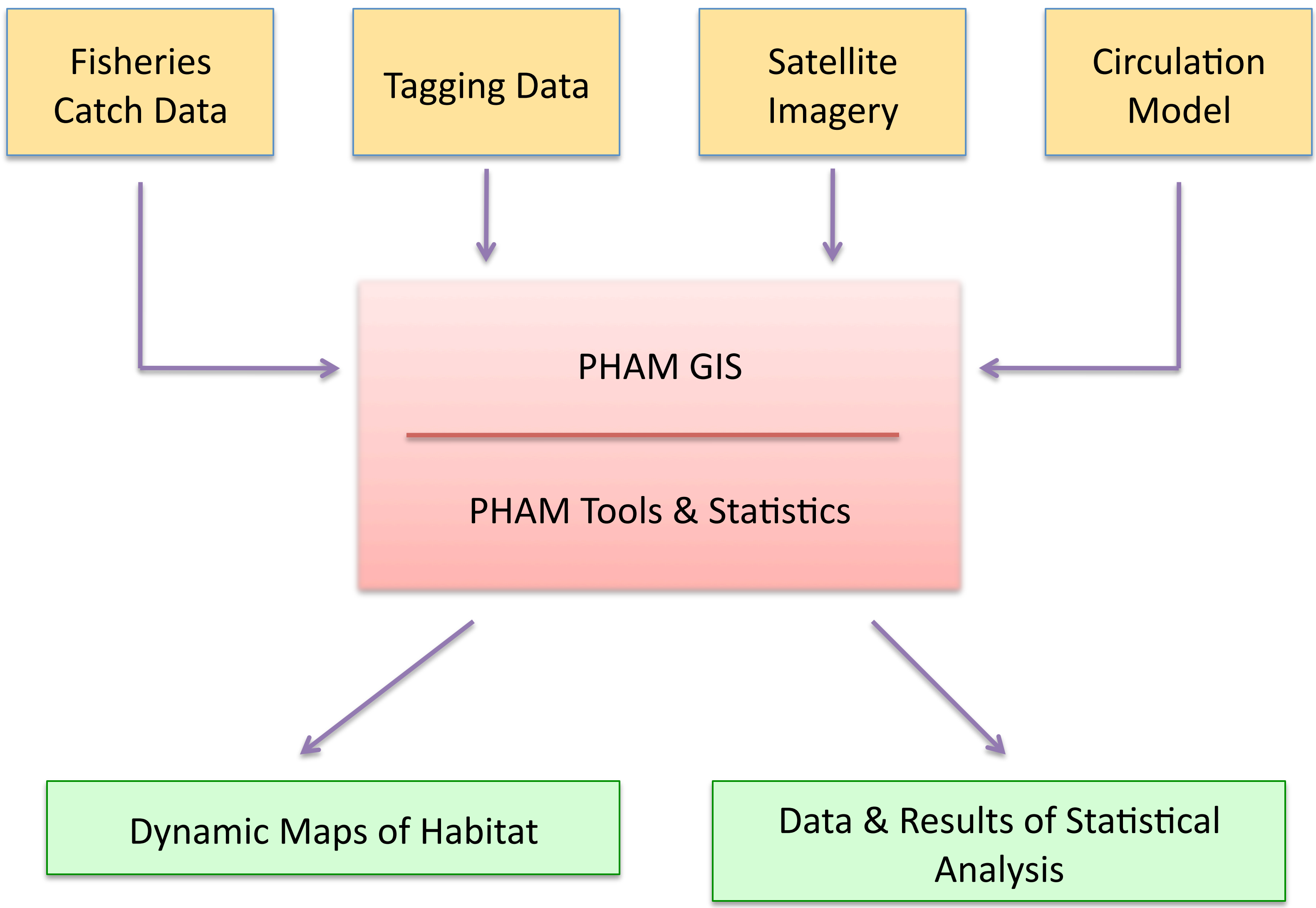
Survival Success: grow quickly by encountering prey and at the same time avoid predators

Immature Stages

Adult Stage

Reproduction Success: find mate(s), avoid predators, charged with gametes, in a habitat well suited for immature survival

Pelagic Habitat Analysis Module (PHAM)



Fisheries Data

- Survey Data
- Commercial Catch Data
- Vessel Logbook Data
- Recreational Fishing Data

Environmental Characteristics

Satellite Imagery

- Seawifs Chl
- Modis Chl
- Modis SST
- GHRSST
- AVHRR SST
- AVISO SSH
- QuikSCAT Winds
- NOAA Coastwatch Frontal Probability
- NASA JPL Frontal Probability
- ETOPO Bathymetry

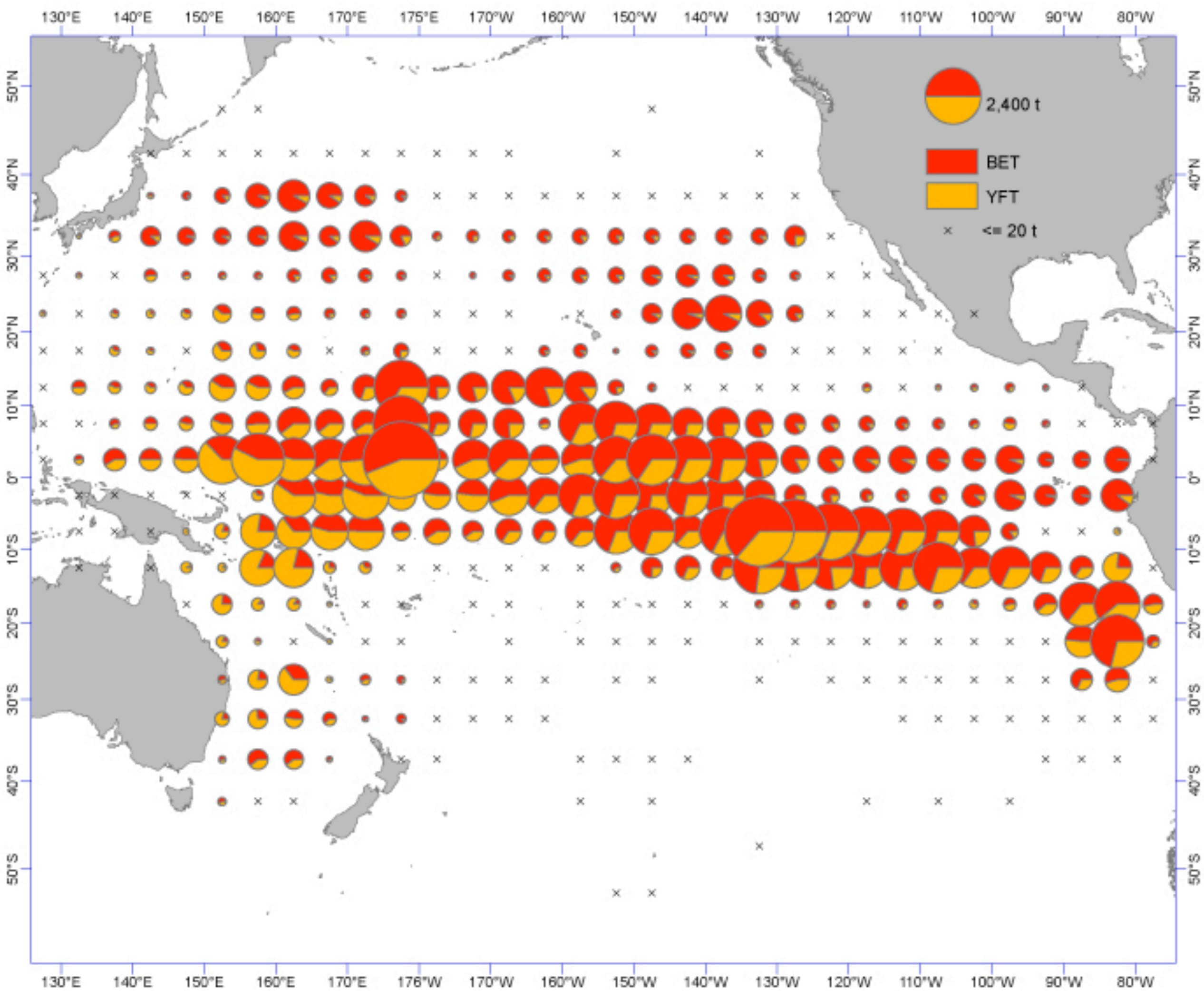
NASA ECCO 2 Model

- Mixed Layer Depth
- SST
- Temperature at Depth
- SSH
- Sea Surface Salinity
- Currents

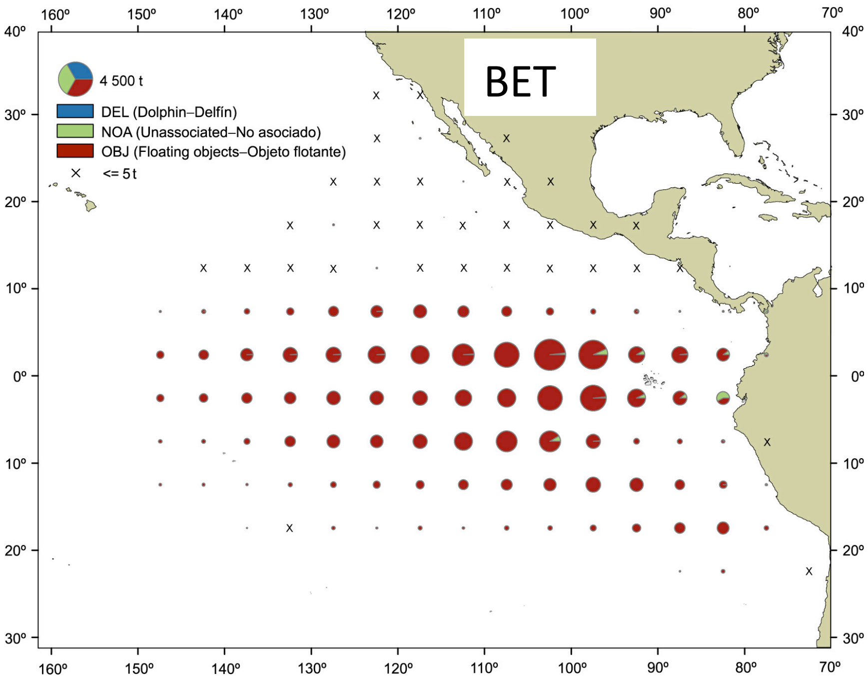
EASy Built In

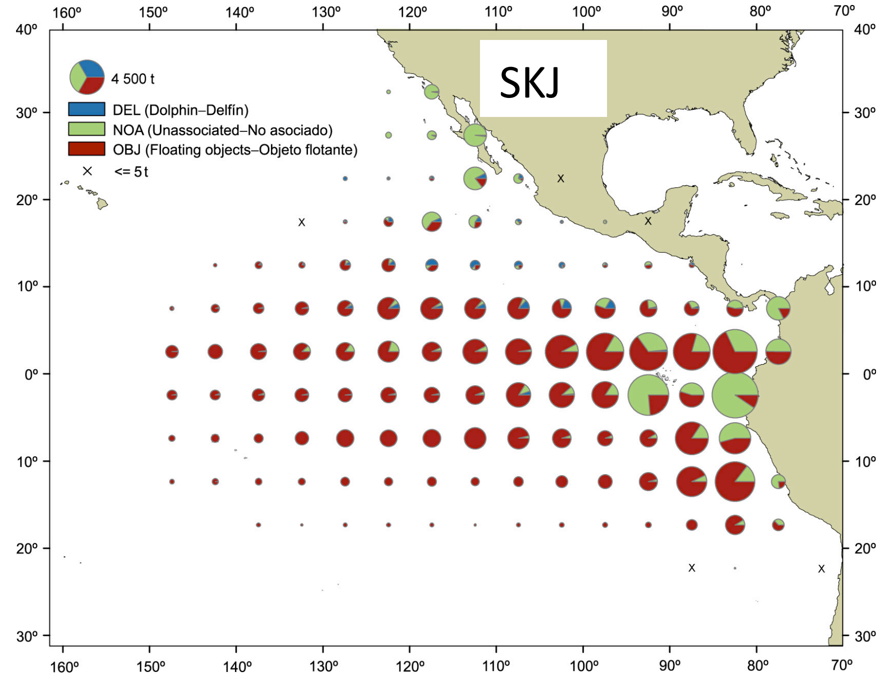
- Earth Magnetic Field
- Longitude
- Latitude
- Month

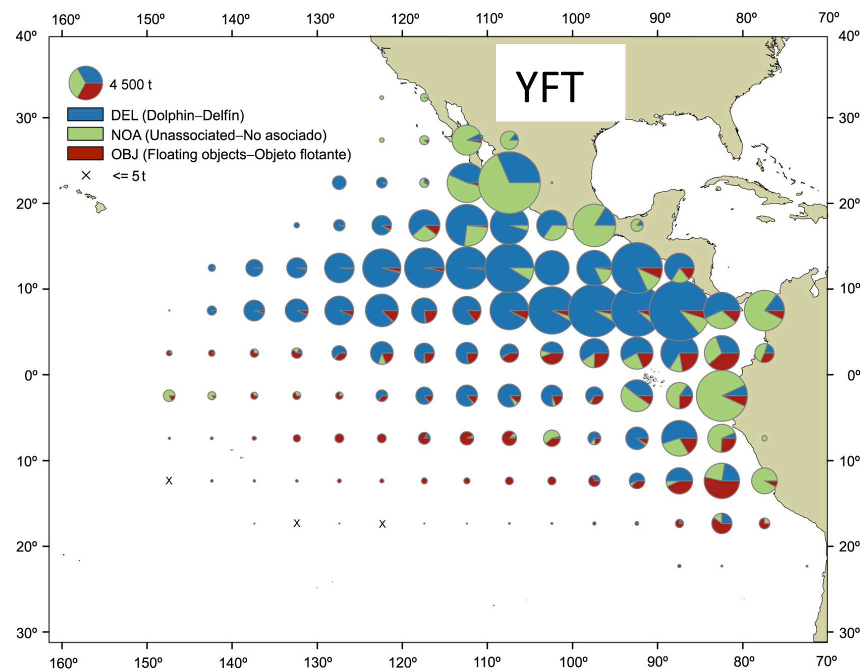
Distribution of longline catches of BET and YFT

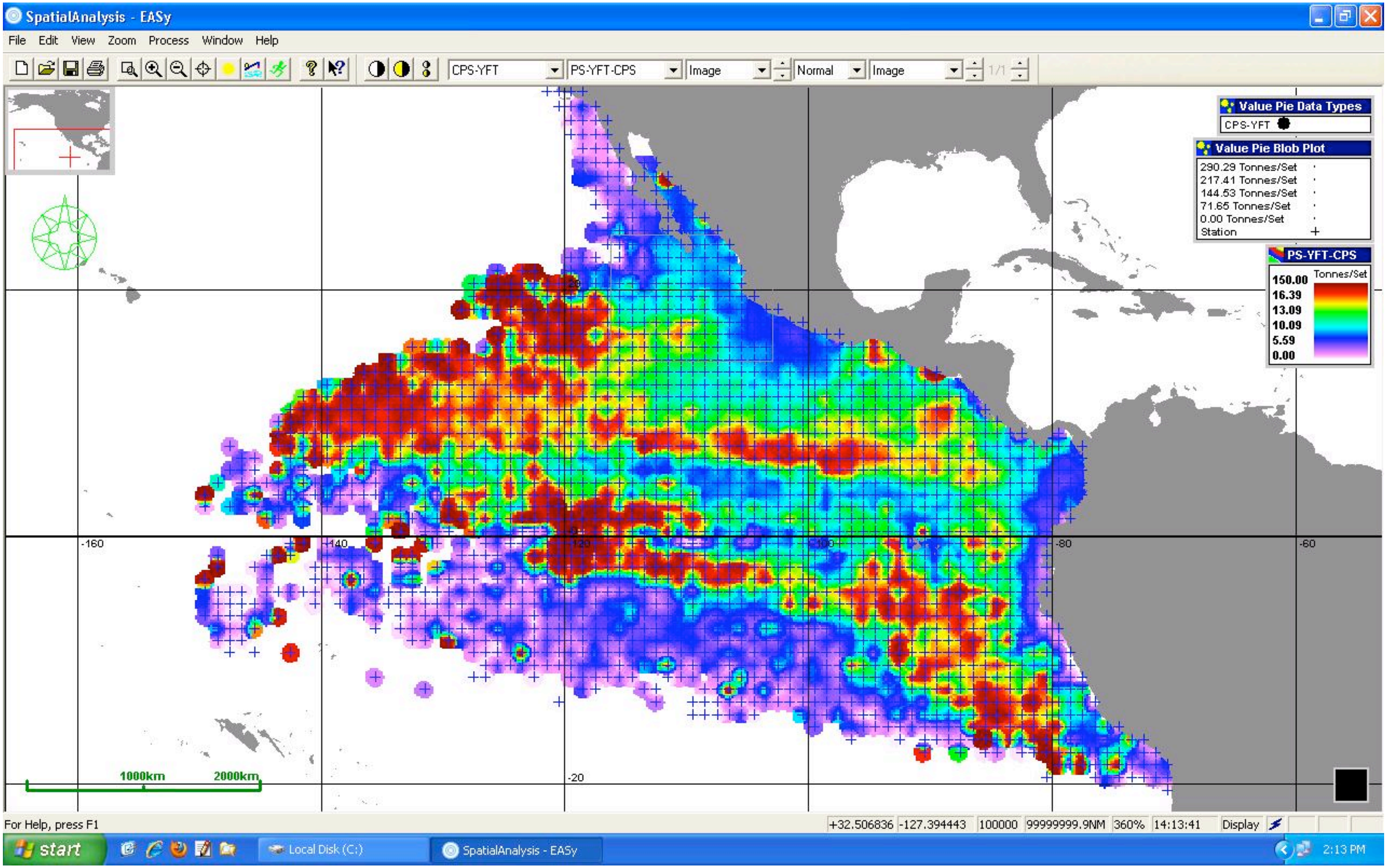


Distribution of purse seine catches

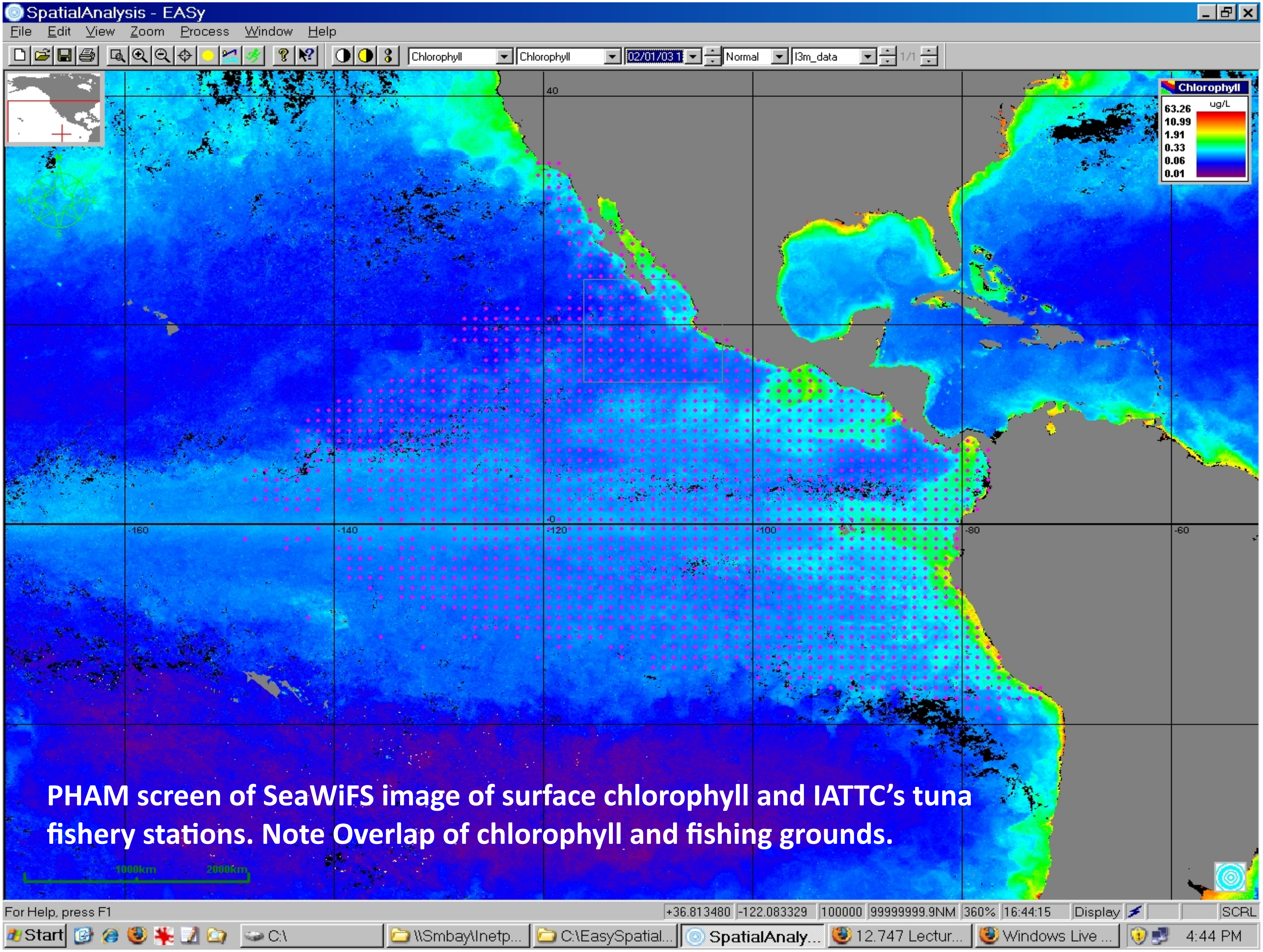




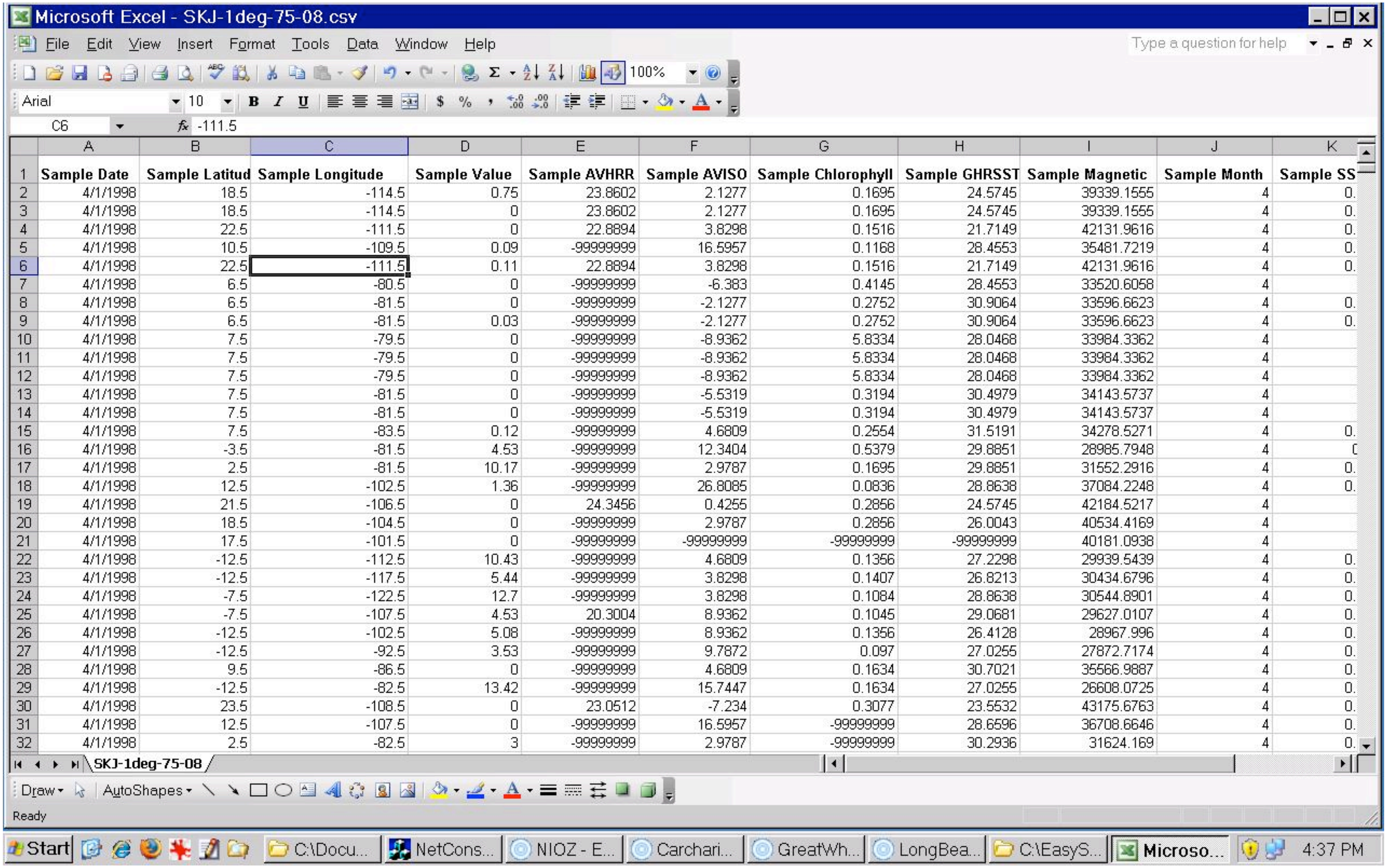




Average catch per set (Purse Seine) for Yellowfin Tuna, IATTC 35 Yr Timeseries

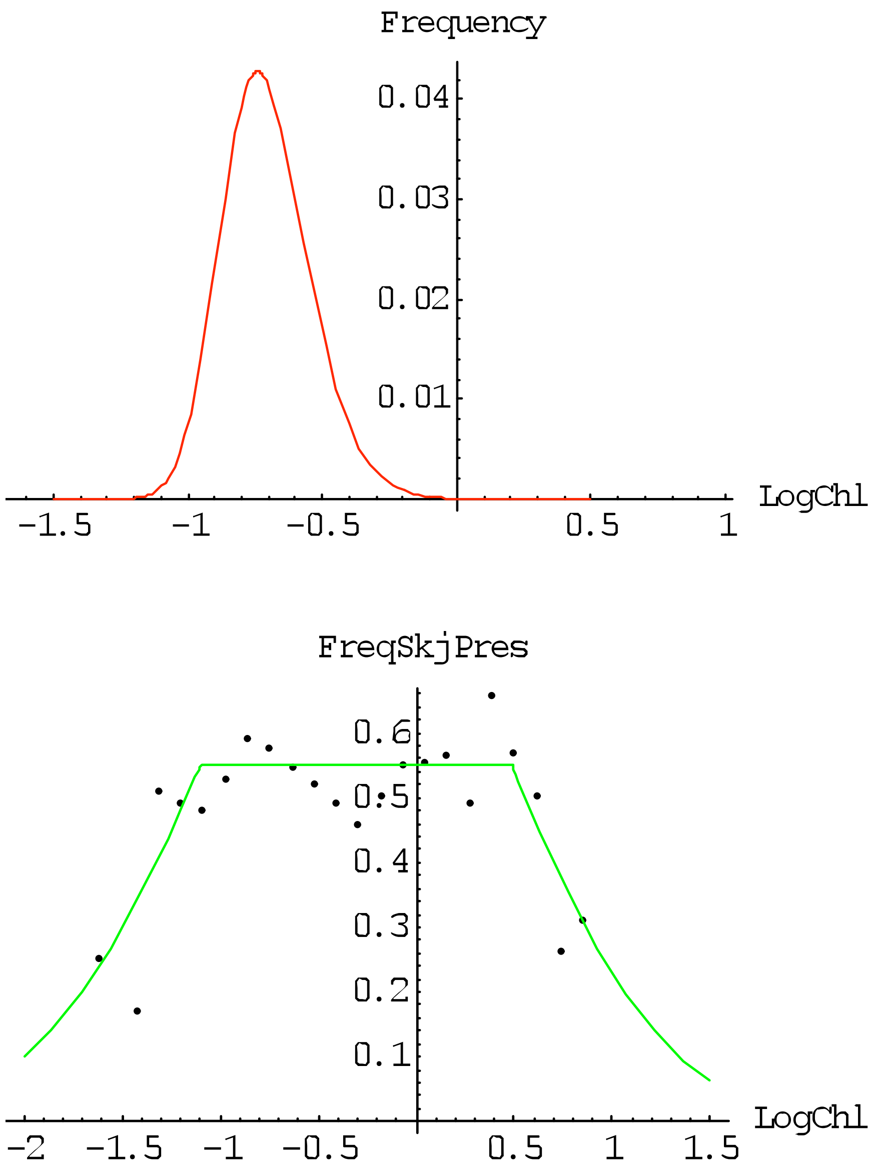


PHAM screen of SeaWiFS image of surface chlorophyll and IATTC's tuna fishery stations. Note Overlap of chlorophyll and fishing grounds.

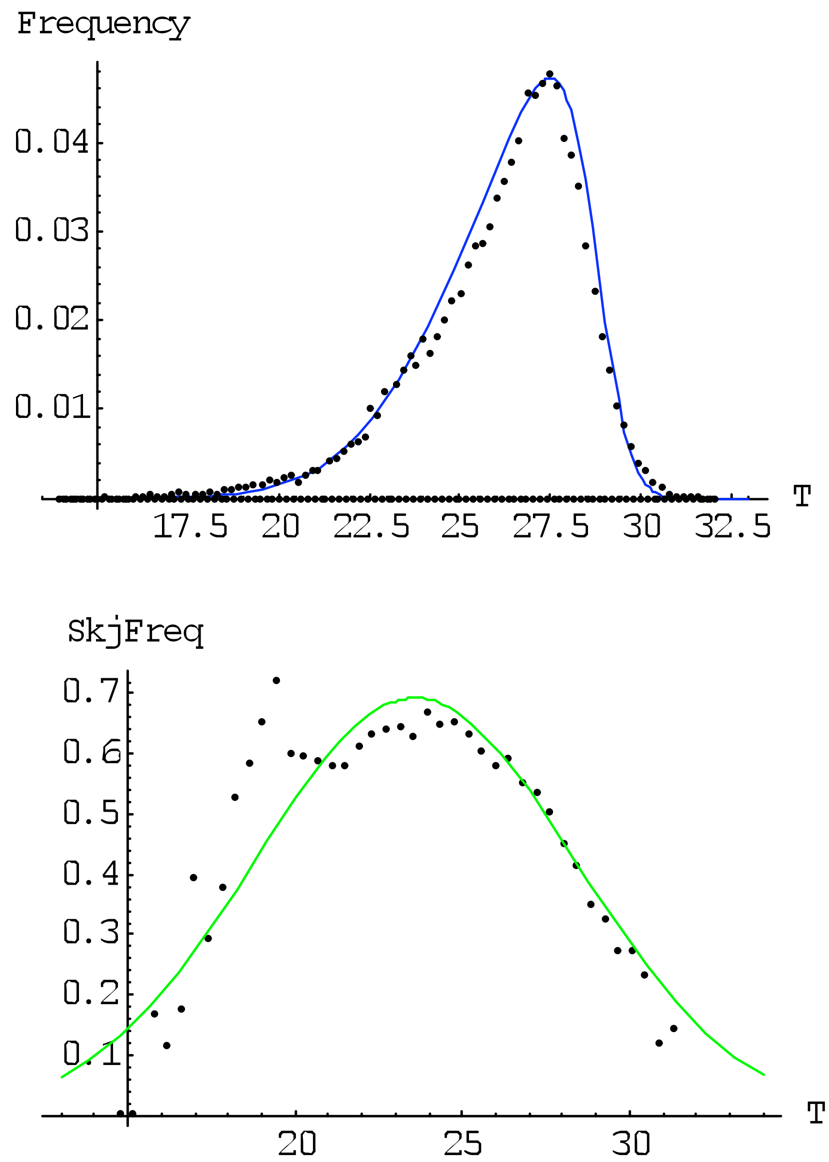


	A	B	C	D	E	F	G	H	I	J	K
1	Sample Date	Sample Latitud	Sample Longitude	Sample Value	Sample AVHRR	Sample AVISO	Sample Chlorophyll	Sample GHRSST	Sample Magnetic	Sample Month	Sample SS
2	4/1/1998	18.5	-114.5	0.75	23.8602	2.1277	0.1695	24.5745	39339.1555	4	0.
3	4/1/1998	18.5	-114.5	0	23.8602	2.1277	0.1695	24.5745	39339.1555	4	0.
4	4/1/1998	22.5	-111.5	0	22.8894	3.8298	0.1516	21.7149	42131.9616	4	0.
5	4/1/1998	10.5	-109.5	0.09	-99999999	16.5957	0.1168	28.4553	35481.7219	4	0.
6	4/1/1998	22.5	-111.5	0.11	22.8894	3.8298	0.1516	21.7149	42131.9616	4	0.
7	4/1/1998	6.5	-80.5	0	-99999999	-6.383	0.4145	28.4553	33520.6058	4	
8	4/1/1998	6.5	-81.5	0	-99999999	-2.1277	0.2752	30.9064	33596.6623	4	0.
9	4/1/1998	6.5	-81.5	0.03	-99999999	-2.1277	0.2752	30.9064	33596.6623	4	0.
10	4/1/1998	7.5	-79.5	0	-99999999	-8.9362	5.8334	28.0468	33984.3362	4	
11	4/1/1998	7.5	-79.5	0	-99999999	-8.9362	5.8334	28.0468	33984.3362	4	
12	4/1/1998	7.5	-79.5	0	-99999999	-8.9362	5.8334	28.0468	33984.3362	4	
13	4/1/1998	7.5	-81.5	0	-99999999	-5.5319	0.3194	30.4979	34143.5737	4	
14	4/1/1998	7.5	-81.5	0	-99999999	-5.5319	0.3194	30.4979	34143.5737	4	
15	4/1/1998	7.5	-83.5	0.12	-99999999	4.6809	0.2554	31.5191	34278.5271	4	0.
16	4/1/1998	-3.5	-81.5	4.53	-99999999	12.3404	0.5379	29.8851	28985.7948	4	[illegible]
17	4/1/1998	2.5	-81.5	10.17	-99999999	2.9787	0.1695	29.8851	31552.2916	4	0.
18	4/1/1998	12.5	-102.5	1.36	-99999999	26.8085	0.0836	28.8638	37084.2248	4	0.
19	4/1/1998	21.5	-106.5	0	24.3456	0.4255	0.2856	24.5745	42184.5217	4	
20	4/1/1998	18.5	-104.5	0	-99999999	2.9787	0.2856	26.0043	40534.4169	4	
21	4/1/1998	17.5	-101.5	0	-99999999	-99999999	-99999999	-99999999	40181.0938	4	
22	4/1/1998	-12.5	-112.5	10.43	-99999999	4.6809	0.1356	27.2298	29939.5439	4	0.
23	4/1/1998	-12.5	-117.5	5.44	-99999999	3.8298	0.1407	26.8213	30434.6796	4	0.
24	4/1/1998	-7.5	-122.5	12.7	-99999999	3.8298	0.1084	28.8638	30544.8901	4	0.
25	4/1/1998	-7.5	-107.5	4.53	20.3004	8.9362	0.1045	29.0681	29627.0107	4	0.
26	4/1/1998	-12.5	-102.5	5.08	-99999999	8.9362	0.1356	26.4128	28967.996	4	0.
27	4/1/1998	-12.5	-92.5	3.53	-99999999	9.7872	0.097	27.0255	27872.7174	4	0.
28	4/1/1998	9.5	-86.5	0	-99999999	4.6809	0.1634	30.7021	35566.9887	4	0.
29	4/1/1998	-12.5	-82.5	13.42	-99999999	15.7447	0.1634	27.0255	26608.0725	4	0.
30	4/1/1998	23.5	-108.5	0	23.0512	-7.234	0.3077	23.5532	43175.6763	4	0.
31	4/1/1998	12.5	-107.5	0	-99999999	16.5957	-99999999	28.6596	36708.6646	4	0.
32	4/1/1998	2.5	-82.5	3	-99999999	2.9787	-99999999	30.2936	31624.169	4	0.

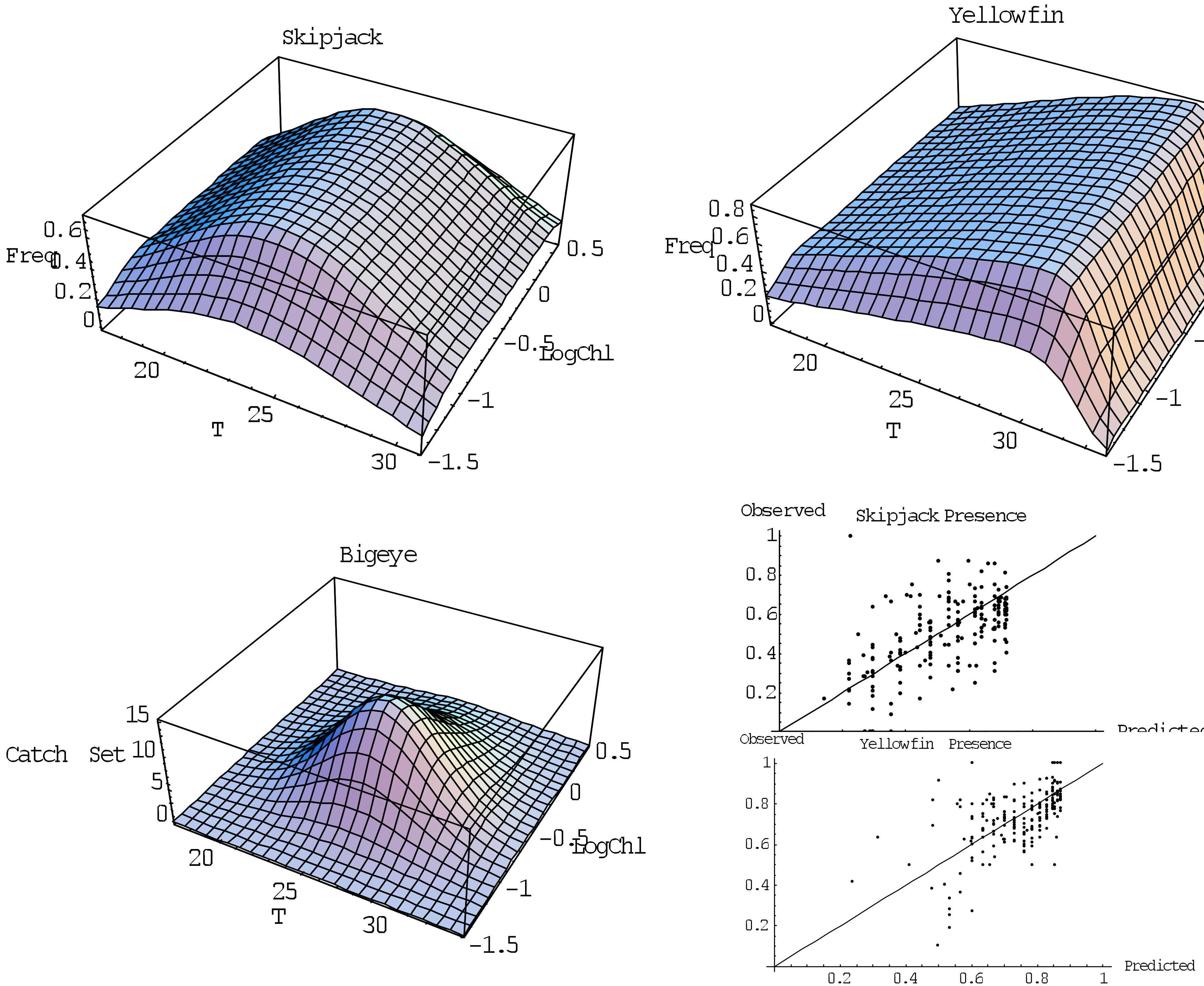
Data Matching Export from PHAM, Catch data & Characteristics



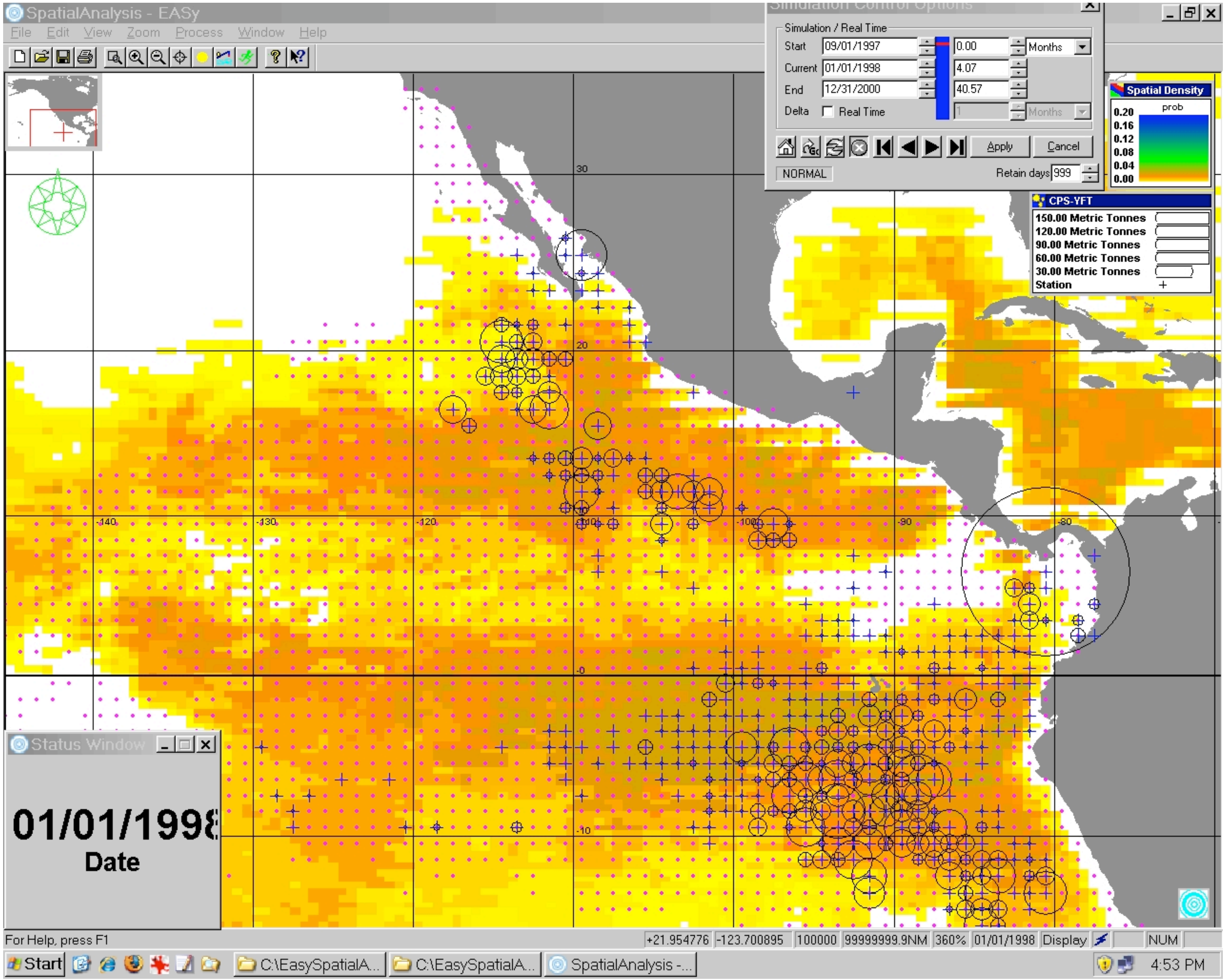
Skipjack Chlorophyll



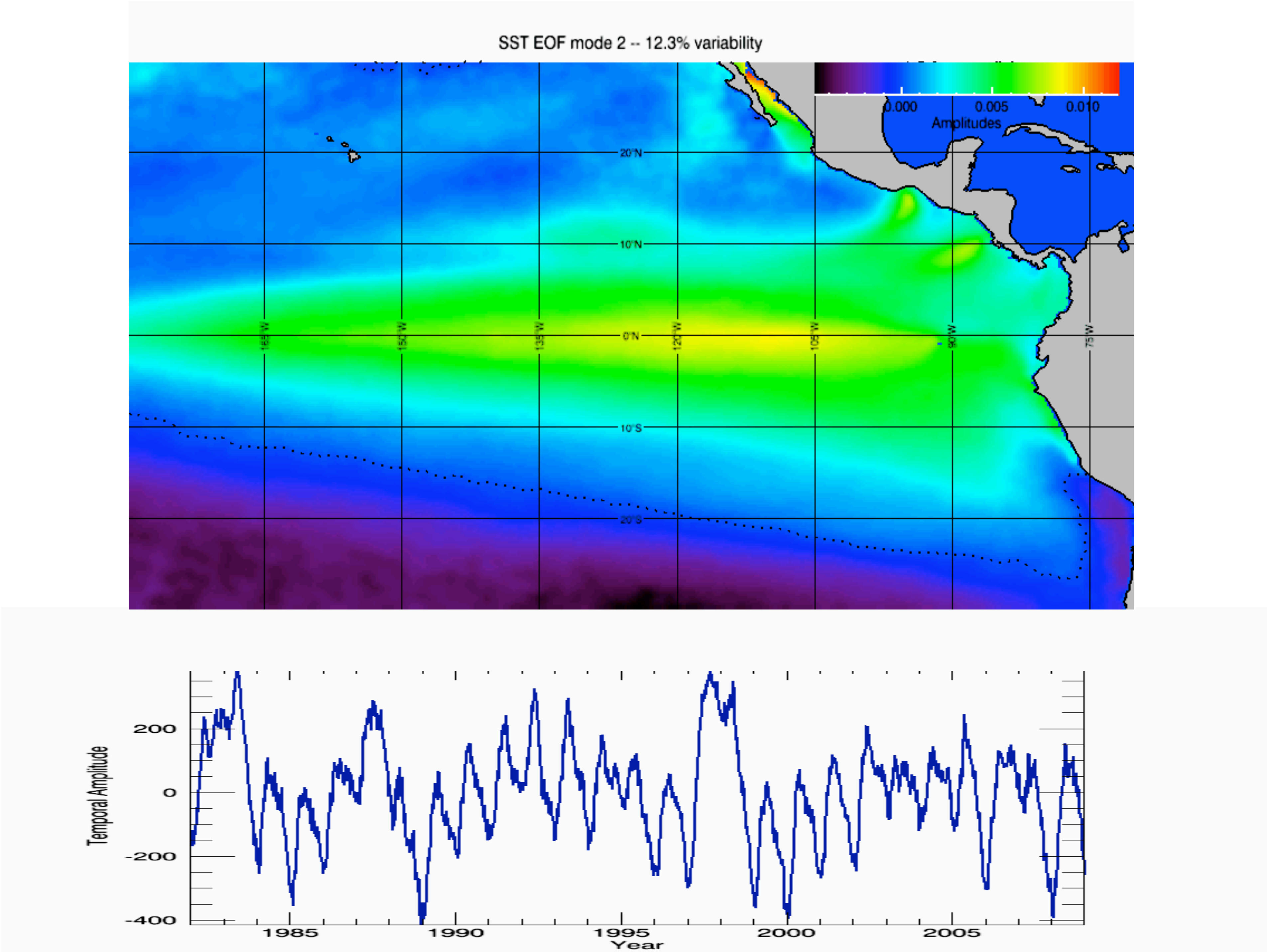
Skipjack GHRSST



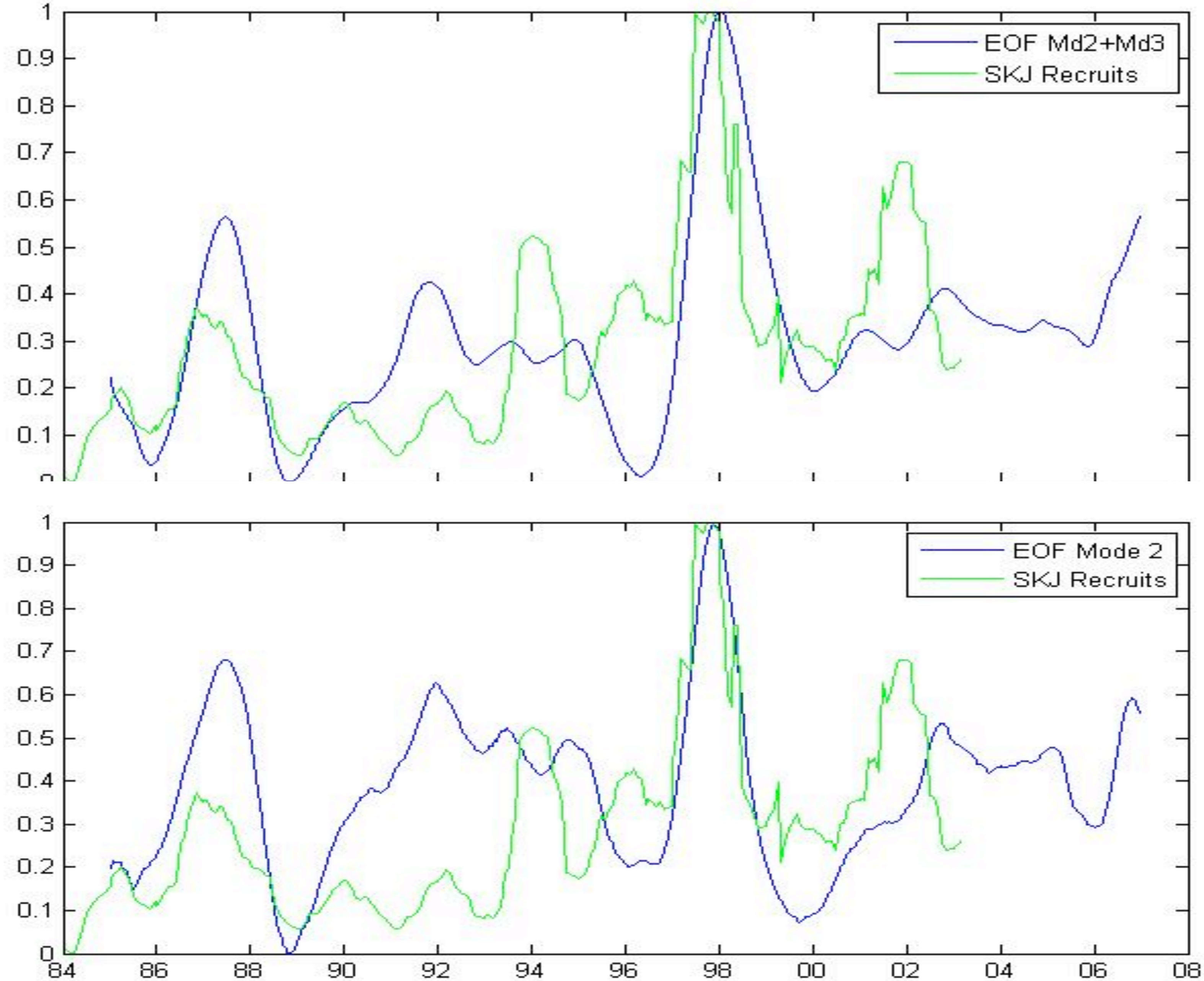
Skipjack
Freq
0.6
0.4
0.2
0
20
25
30
T
0.5
0
-0.5
-1
-1.5
LogChl
Yellowfin
Freq
0.8
0.6
0.4
0.2
0
20
25
30
T
0.5
0
-0.5
-1
-1.5
LogChl
Bigeye
Catch Set
15
10
5
0
20
25
30
T
0.5
0
-0.5
-1
-1.5
LogChl
Observed
Skipjack Presence
1
0.8
0.6
0.4
0.2
Observed
Yellowfin Presence
1
0.8
0.6
0.4
0.2
0.2
0.4
0.6
0.8
1
Predicted



PHAM screen of critical habitat of skipjack tuna as calculated from habitat analysis and current satellite imagery.



SST EOF mode 2 -- 12.3% variability
0.000
0.005
0.010
Amplitudes
20°N
10°N
0°N
10°S
20°S
165°W
150°W
135°W
120°W
105°W
90°W
75°W
Temporal Amplitude
200
0
-200
-400
1985
1990
1995
2000
2005
Year



References: Seapodym, Mid Ocean Production

Mako Shark (*Isurus oxyrhynchus*)

Blue Shark (*Prionace glauca*),

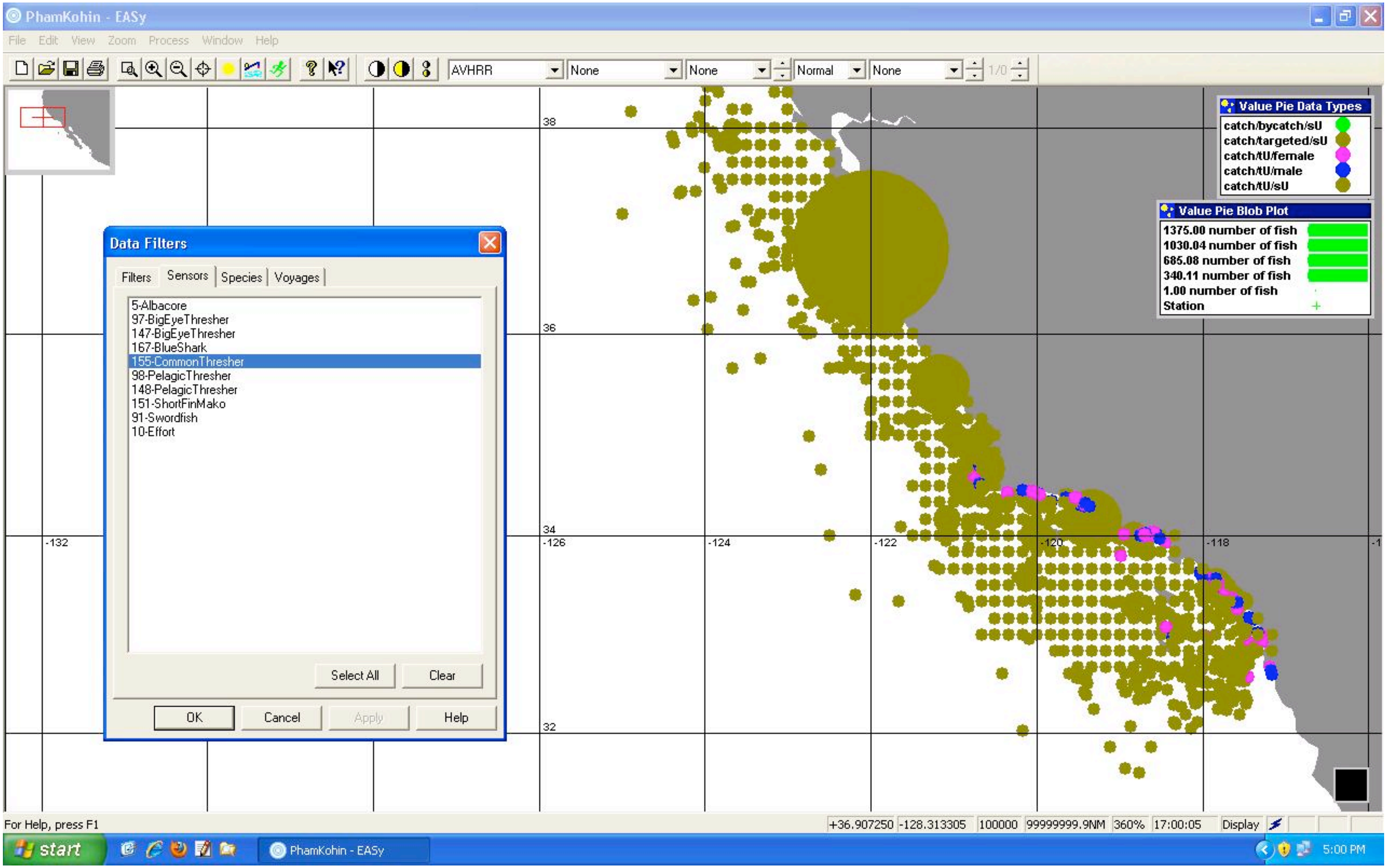
Common Thresher Shark (*Alopias vulpinus)*

Improving Fisheries Management

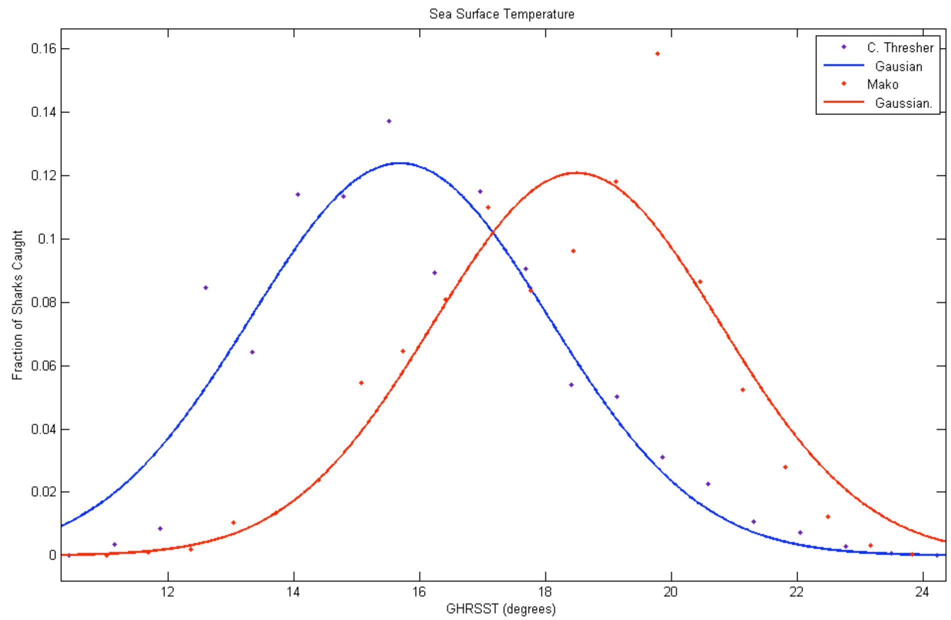
Decision Support for Stock Assessment / By-catch

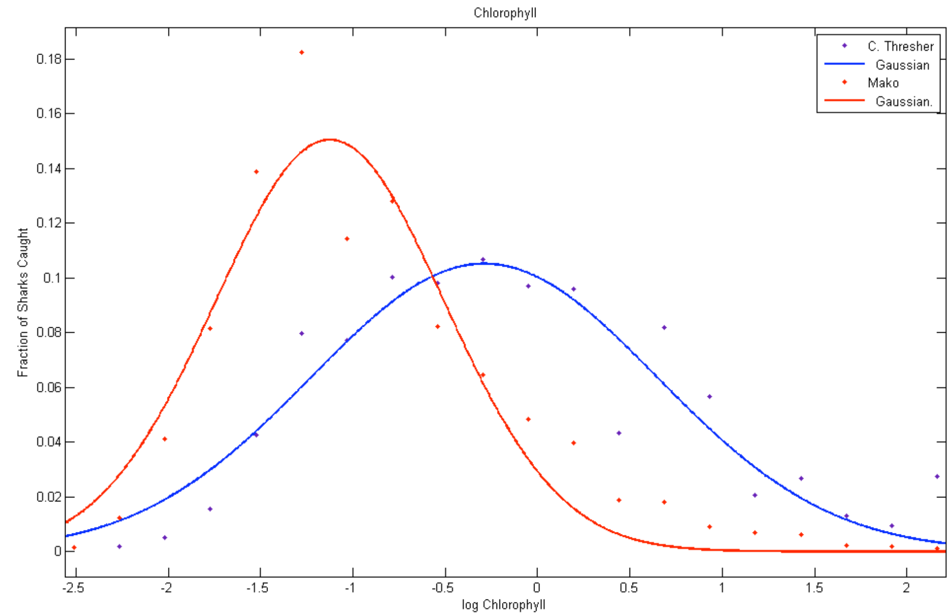
Sharks of the California Current

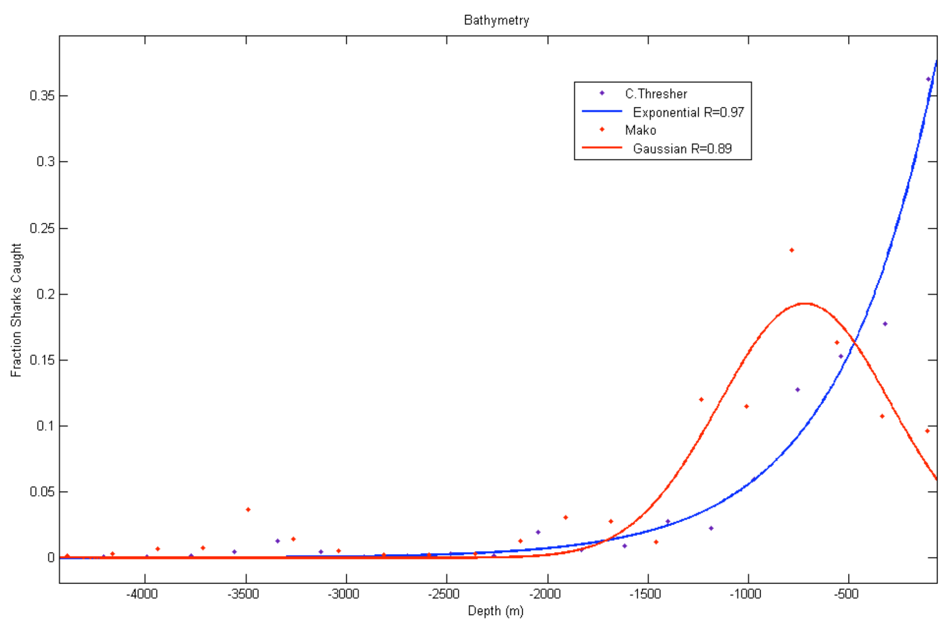
- Assist stock assessment model for Thresher Sharks
- Address research priorities to examine the habitat bounds, migratory behavior, and density distribution of pelagic shark species of the California Current
- By-catch Management – Where does habitat overlap commercially fished species, for example blue sharks are damaging to fishing nets so there is a desire to avoid high density areas of blue sharks
- Distribution of pregnant females – especially relevant to recreational fishery for thresher sharks

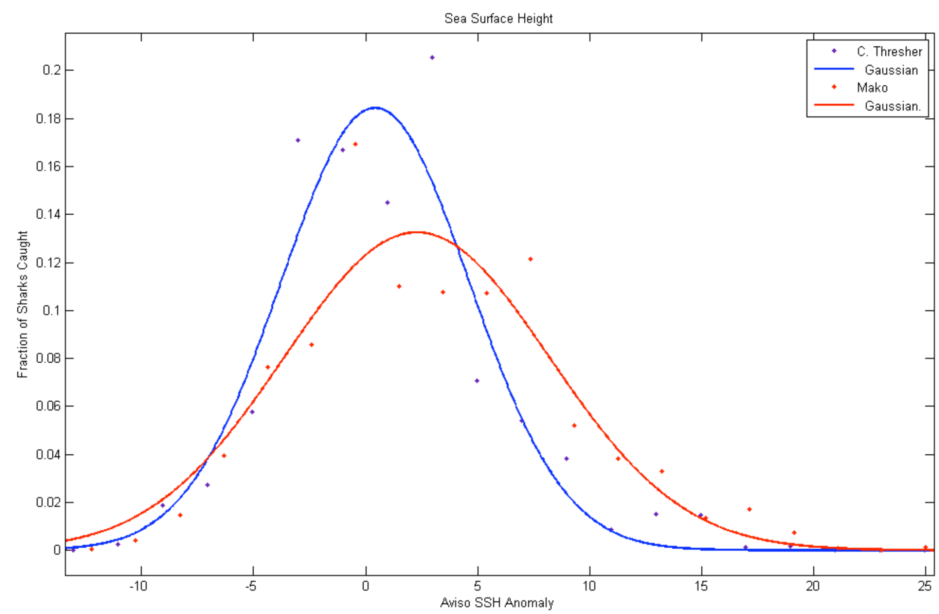


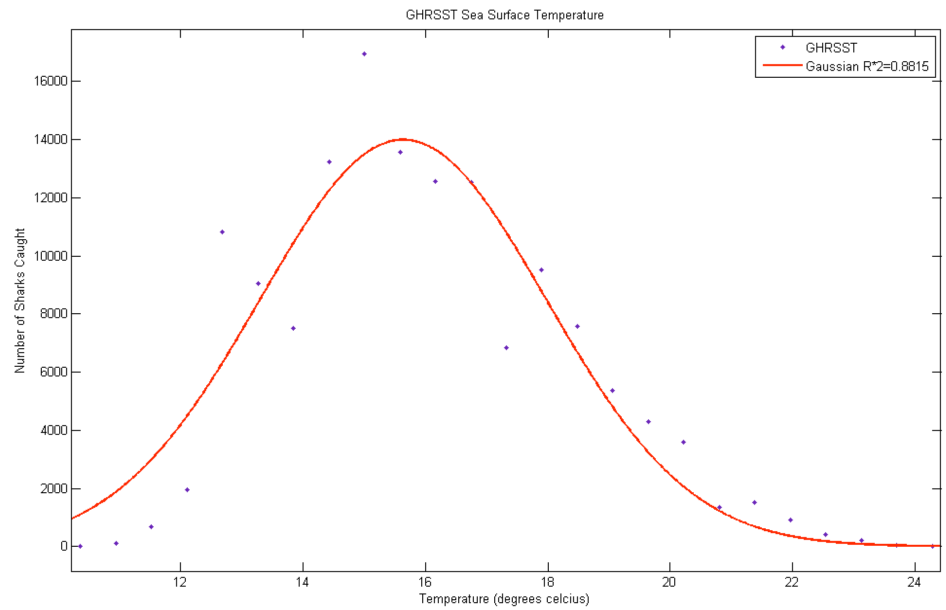
Average Catch Number by Sex – Common Thresher Shark, SWFSC

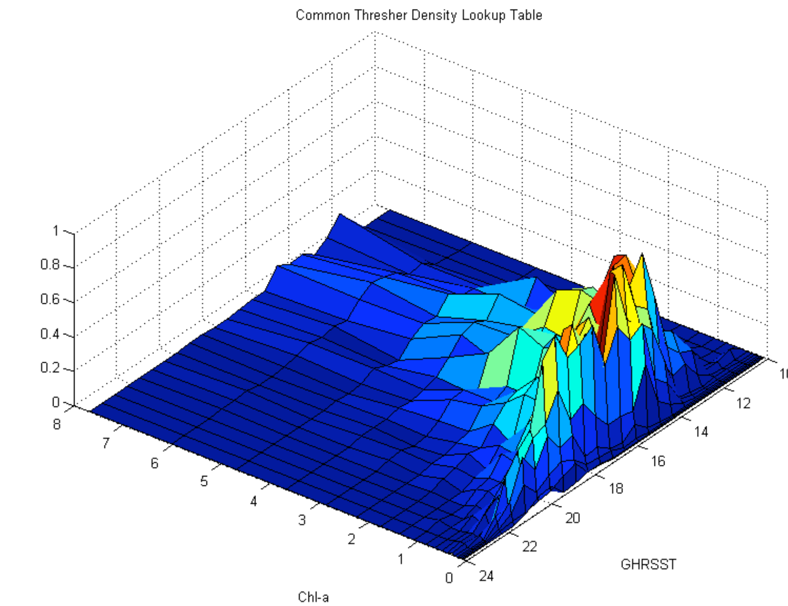

Sea Surface Temperature
C. Thresher
Gausian
Mako
Gaussian.
Fraction of Sharks Caught
GHRSST (degrees)

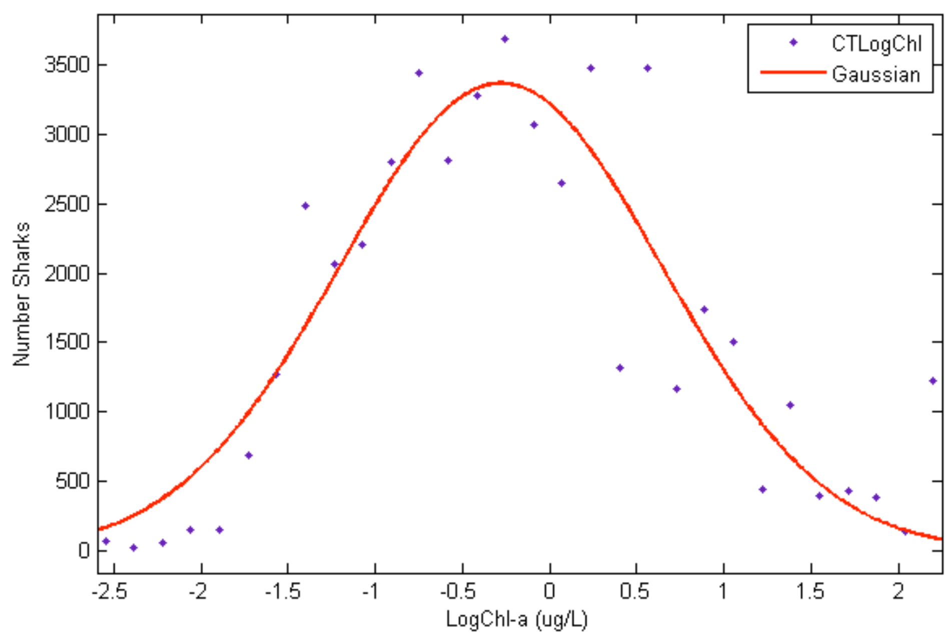

Chlorophyll
C. Thresher
Gaussian
Mako
Gaussian.
Fraction of Sharks Caught
log Chlorophyll

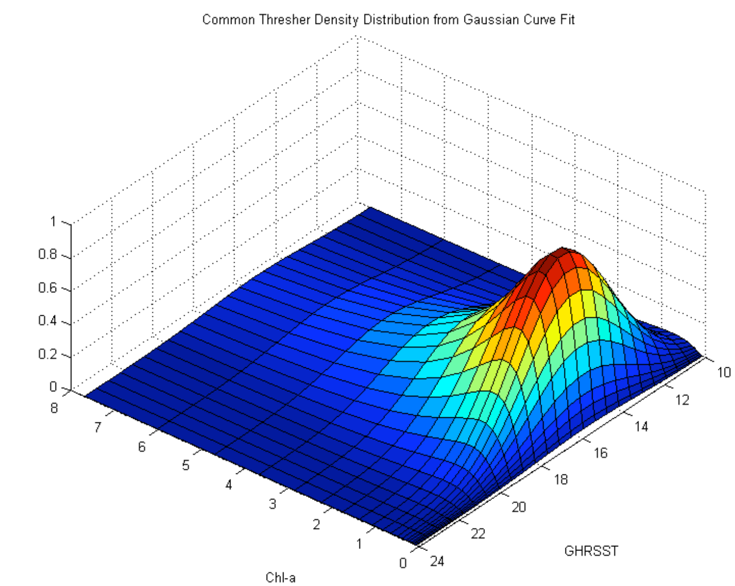

Bathymetry
C.Thresher
Exponential R=0.97
Mako
Gaussian R=0.89
Fraction Sharks Caught
Depth (m)

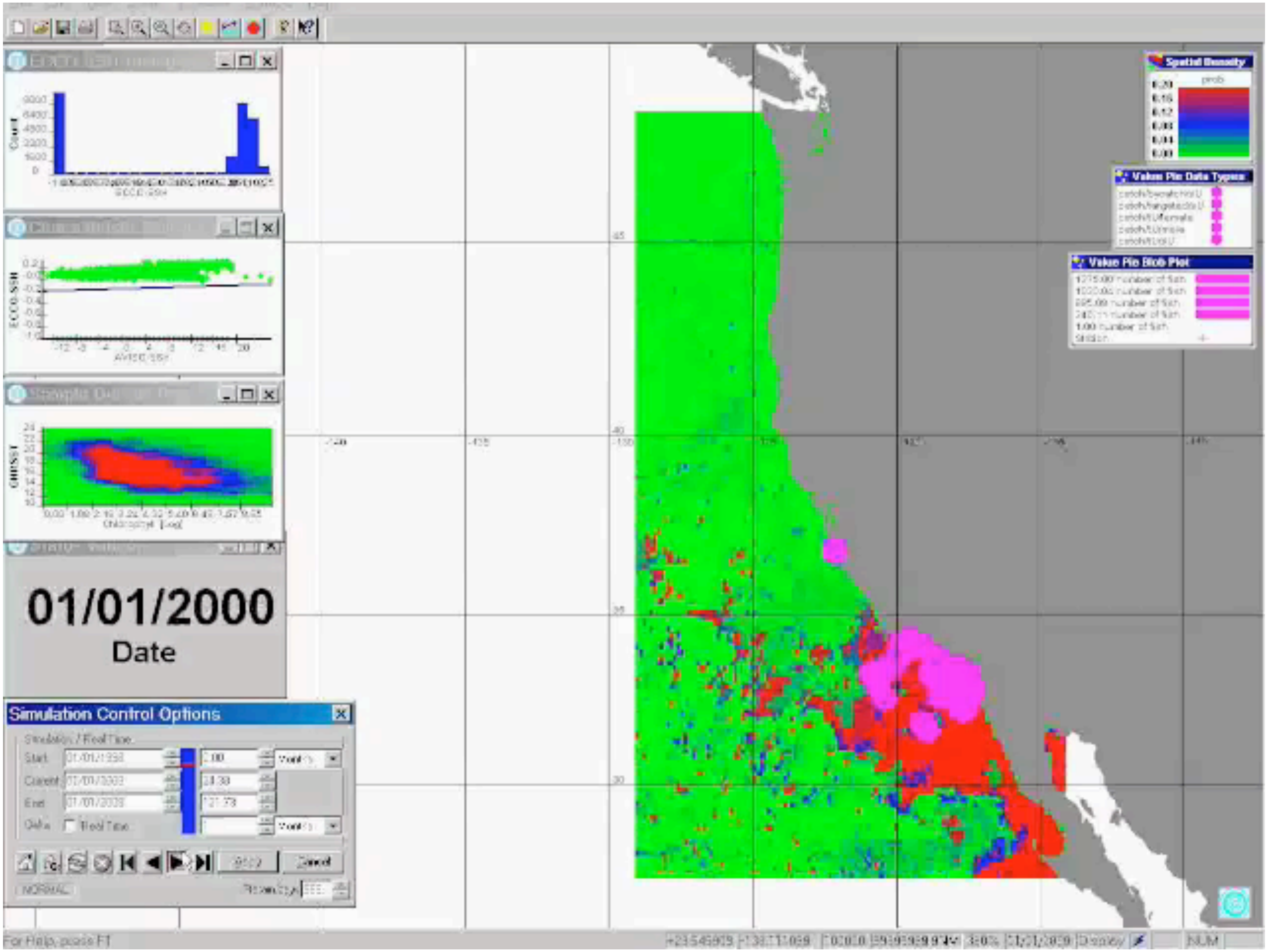

Sea Surface Height
C. Thresher
Gaussian
Mako
Gaussian.
Fraction of Sharks Caught
Aviso SSH Anomaly


GHRSST Sea Surface Temperature
GHRSST
Gaussian R^2=0.8815
Number of Sharks Caught
Temperature (degrees celcius)

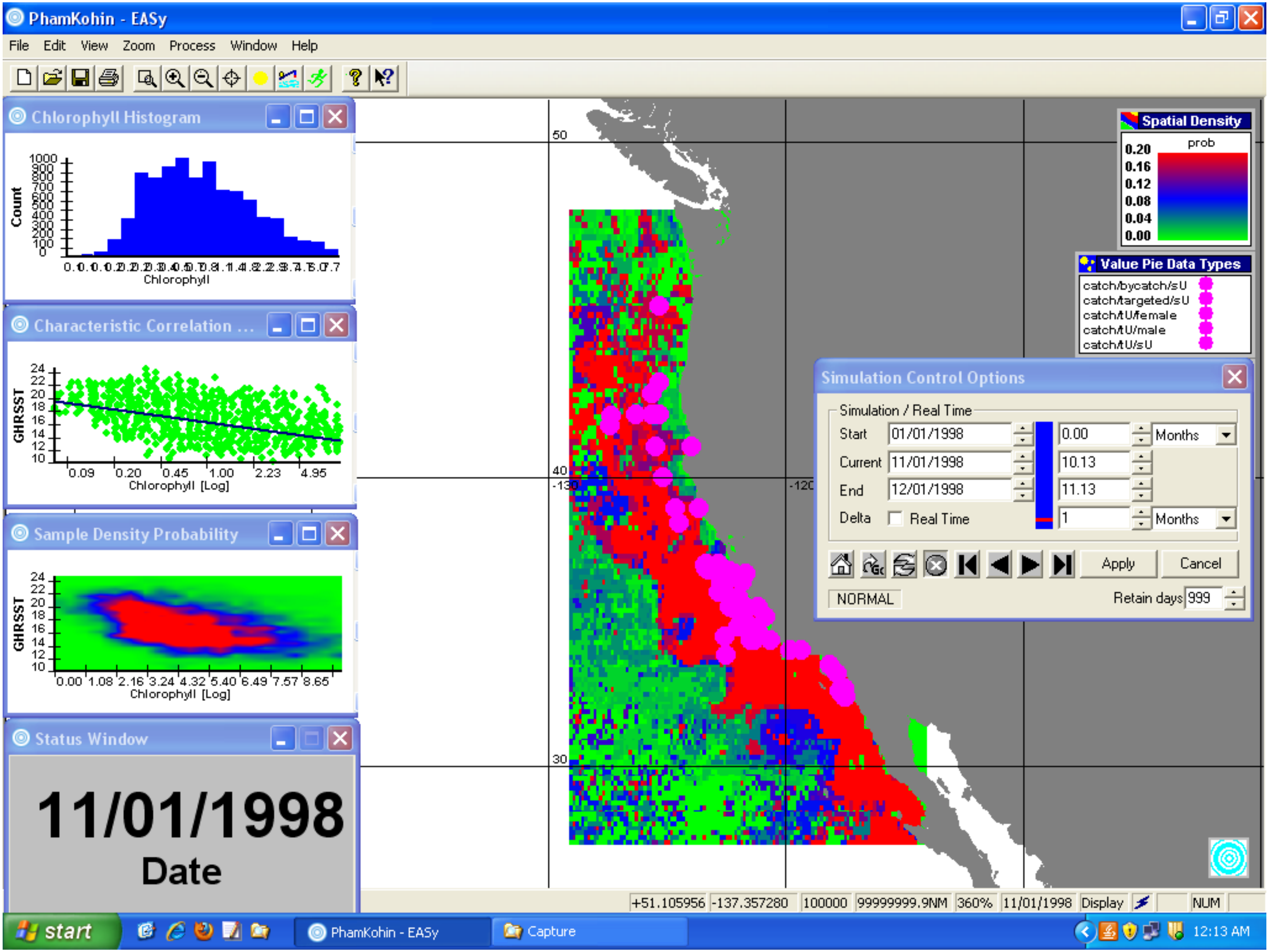

Common Thresher Density Lookup Table
Chl-a
GHRSST


CTLogChl
Gaussian
Number Sharks
LogChl-a (ug/L)


Common Thresher Density Distribution from Gaussian Curve Fit
Chl-a
GHRSST



Spatial Density
Value Pie Data Types
Value Pie Blob Plot
01/01/2000
Date
Simulation Control Options
For Help, press F1



PhamKohin - EASy
File Edit View Zoom Process Window Help
Chlorophyll Histogram
Count
Chlorophyll
Characteristic Correlation ...
GHRSST
0.09 0.20 0.45 1.00 2.23 4.95
Chlorophyll [Log]
Sample Density Probability
GHRSST
0.00 1.08 2.16 3.24 4.32 5.40 6.49 7.57 8.65
Chlorophyll [Log]
Status Window
11/01/1998
Date
50
40
30
-130
-120
Spatial Density
prob
0.20
0.16
0.12
0.08
0.04
0.00
Value Pie Data Types
catch/bycatch/sU
catch/targeted/sU
catch/tU/female
catch/tU/male
catch/tU/sU
Simulation Control Options
Simulation / Real Time
Start 01/01/1998 0.00 Months
Current 11/01/1998 10.13
End 12/01/1998 11.13
Delta Real Time 1 Months
Apply
Cancel
NORMAL
Retain days 999
+51.105956 -137.357280 100000 99999999.9NM 360% 11/01/1998 Display NUM
start
PhamKohin - EASy
Capture
12:13 AM

Conclusions

- We have assembled a system that integrates satellite and model data with fisheries data to investigate pelagic habitat based on environmental parameters
- Demonstrated the capacity to accurately map the dynamic habitat of Thresher Sharks including north / south migrations
- Tuna habitat maps look promising but require additional variables to provide a more accurate mapping
- EOF of ocean temperature shows tight coupling with SOI and offers a more detailed description of El Nino / La Nina events
- The time series of basin wide recruitment for all three species of tuna are similar and clearly respond to ENSO variability as revealed by EOF analysis
- Shown that habitat distribution can be examined and compared for multiple species to determine where environmental preferences are similar and where they differ
- Demonstrated the versatility of PHAM by extending the application from wide ranging tuna habitat of the EPO to sharks of the California current

What's Next?

- Dynamic habitat mapping for 2 species concurrently to examine habitat overlap, particularly between target and by-catch species
- Incorporation of tagging data to habitat model to add depth dimension
- Develop recruitment algorithm to examine environmental drivers in recruitment variability
- Statistical tests to identify the most important variables for each species, this will incorporate background analysis of environmental characteristics to determine the amount of “selection” shown for a particular characteristic
- Use of GLM & GAM to predict habitat allowing full use of all environmental variables for each species