Incorporating West Coast Groundfish Survey Data into the Offshore Component of the Pacific Northwest Coast Ecoregional Assessment

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SAVING THE LAST GREAT PLACES ON EARTH

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Introduction

The Nature Conservancy (TNC) has been among those at the forefront in the development of new approaches to systematic regional planning (Groves 2000, 2002, Beck 2003). Though varied, the methods and applicable information for marine ecoregional planning are improving rapidly. World Wildlife Fund recently completed plans for the Sula-Sulawesi Seas, the Meso-American Reef, and Nova Scotian Shelf. The Nature Conservancy has completed assessments for most of the North American marine ecoregions including northern Gulf of Mexico, Floridian, Carolinian, and Southern and Northern California (Figure 1). In response to marine conservation issues in the Pacific Northwest, TNC has developed methods for analyzing the nearshore marine environment in the ecoregions comprising Puget Trough – Georgia Basin as well as the Northwest Coast including the outer coasts of Oregon, Washington and Vancouver Island in British Columbia. Results of these marine assessments were integrated with terrestrial and freshwater analyses.

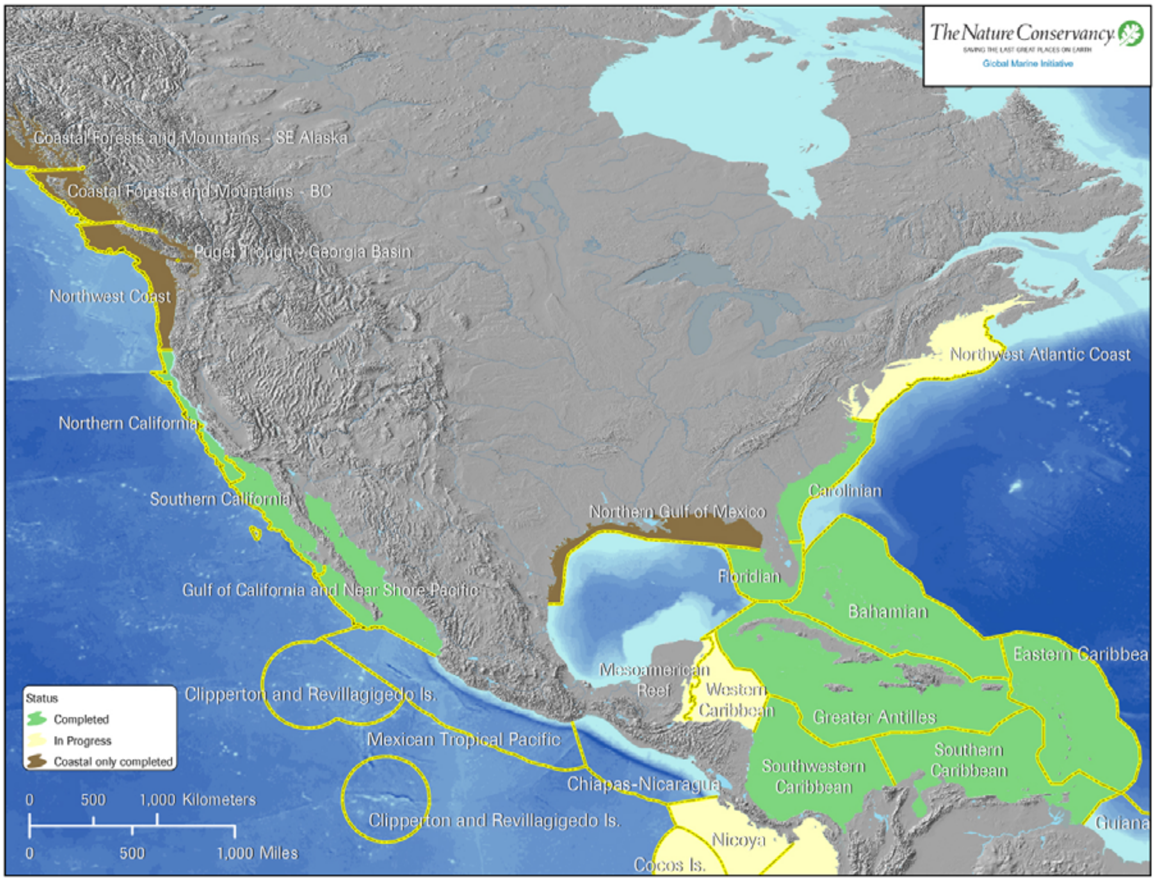


Figure 1: Status of marine ecoregional assessments conducted by The Nature Conservancy as of July 2006

The basic approach to ecoregional assessments is to: identify objectives, i.e., to represent a full range of the region’s biodiversity for conservation; select targets to represent this biodiversity and be the focus of conservation efforts; identify goals for the amount of the targets required to meet objectives; identify suitability factors likely to affect either the cost of conservation, the viability of targets in any area, or the suitability of a specific area for conservation; develop a spatial database from all the reasonably available regional-scale data on the targets and suitability factors; select priority conservation areas to achieve the stated goals and objectives.

The purpose of a marine ecoregional assessment is to bring an enhanced focus to marine conservation and management in a region. Often this results in a first comprehensive assessment of the region's marine biological diversity. To achieve this purpose, three products are developed: a spatial database of the region's biodiversity and the factors that affect it, a decision-support framework to evaluate conservation and management alternatives, and a set of conservation areas that represent the region's biodiversity. The identification of high priority areas for marine conservation makes no presumption about the best strategies for conservation at individual sites. However, the results of an assessment make clear that there are promising opportunities for conservation throughout the ecoregion.

Objectives of this study

Although TNC has been involved in marine ecoregional conservation assessment in the Pacific Northwest since 2001 (Ferdaña et. al., 2006), most of the existing work has focused on the coastal and nearshore environment. TNC would like to expand these assessments to include offshore areas. TNC's overall objectives for this work are to:

1. Create a planning process with fisheries data and benthic habitat characterization that is repeatable,
2. Develop a core database of benthic modeling and fisheries data to be used for a variety of conservation planning applications,
3. Develop an initial set of offshore conservation priorities, and
4. research the applicability of species-habitat associations using benthic modeling and fisheries data

Specifically, for this small project, we focused on reviewing and assessing the utility of the existing groundfish trawl survey data from the National Marine Fisheries Service for use in the Nature Conservancy's spatially-explicit marine ecoregional planning process. The primary data sets available to characterize groundfish species in a comprehensive manner throughout the Pacific Northwest ecoregion are the National Marine Fisheries Service's (NMFS) trawl surveys, conducted by the Alaska Fisheries Science Center (AFSC) and the Northwest Fisheries Science Center (NWFSC). The primary purpose of these surveys has been to collect long-term distribution and abundance information to support management of commercially-harvested, managed groundfish species. However, trawl surveys have also been used to investigate groundfish species diversity, community structure and geographic patterns (Logerwell et. al. 2005, Williams and Ralston 2002).

These surveys have been conducted off the west coast (Washington, Oregon, and California) since 1977 in water depths ranging from 55-meters to 1280-meters. For this project, we received data from the following surveys: AFSC's Triennial (continental shelf) survey, AFSC's slope survey, NWFSC's slope survey and slope/shelf combination survey, for 30 survey-years:

Triennial Survey – 1977, 1980, 1983, 1986, 1989, 1992, 1995, 1998, 2001

AFSC Slope Survey – 1984, 1988, 1990–1993, 1995–1997, 1999–2001
NWFSC Slope Survey – 1999–2001
NWFSC Slope and Shelf Combination Survey – 2002–2006

Specifics about survey methods and results have been reported in a series of NOAA Technical Memorandums, (for example, Keller et. al. 2006, Weinberg et. al. 2002, or Lauth 2002).

Target Species

The Nature Conservancy has developed, in consultation with regional experts, a preliminary list of 58 marine fish species of interest. This list of target species was compared to the species list from the NMFS surveys. 47 of TNC’s target fish species were found during at least one of the 8349 trawl survey hauls (Table 1). Out of these 47 species, speckled sanddab and brown rockfish are not found in the study area, leaving 45 of the target species that occur in the trawl surveys with the Pacific Northwest ecoregion. 17 target species occurred in at least 10% of all hauls. (See Table 1).

Table 1: TNC Target Species Occurrence in NMFS Trawl Surveys (1977 – 2004)

Common Name	Scientific Name	Haul Count	Percent of Hauls	Element Code
Dover sole	Microstomus pacificus	7034	84.2%	AFCTB14010
sablefish	Anoplopoma fimbria	6272	75.1%	AFC4C01010
Pacific hake	Merluccius productus	6138	73.5%	AFCMA10020
rex sole	Glyptocephalus zachirus	6064	72.6%	AFCTB21010
English sole	Parophrys vetulus	3279	39.3%	AFCTB16100
spotted ratfish	Hydrolagus colliei	3176	38.0%	AFDAA01010
lingcod	Ophiodon elongatus	2404	28.8%	AFC4D02010
Pacific sanddab	Citharichthys sordidus	2394	28.7%	AFCTA01080
darkblotched rockfish	Sebastes crameri	2347	28.1%	AFC4A06150
greenstriped rockfish	Sebastes elongatus	2272	27.2%	AFC4A06180
Pacific ocean perch	Sebastes alutus	1485	17.8%	AFC4A06020
Pacific herring	Clupea pallasi	1456	17.4%	AFCFA07030
eulachon	Thaleichthys pacificus	1401	16.8%	AFCHB04010
canary rockfish	Sebastes pinniger	1204	14.4%	AFC4A06460
yellowtail rockfish	Sebastes flavidus	1171	14.0%	AFC4A06240
Pacific cod	Gadus macrocephalus	922	11.0%	AFCMA08010
bocaccio	Sebastes paucispinis	836	10.0%	AFC4A06440
widow rockfish	Sebastes entomelas	675	8.1%	AFC4A06210
plainfin midshipman	Porichthys notatus	632	7.6%	AFCWA02010/AFCWA02020
redstripe rockfish	Sebastes proriger	545	6.5%	AFC4A06480
jack mackerel	Trachurus symmetricus	501	6.0%	AFCQZ13020
big skate	Raja binoculata	470	5.6%	AFDFD01020
walleye pollock	Theragra chalcogramma	448	5.4%	AFCMA14010
chub mackerel	Scomber japonicus	443	5.3%	AFCS307010
yelloweye rockfish	Sebastes ruberrimus	279	3.3%	AFC4A06530
Pacific sardine	Sardinops sagax	214	2.6%	AFCFA10010
whitebait smelt	Allosmerus elongatus	174	2.1%	AFCHB05010
northern anchovy	Engraulis mordax	171	2.0%	AFCFB04020
southern rock sole	Lepidopsetta bilineata	130	1.6%	AFCTB16080
Pacific hagfish	Eptatretus stouti	127	1.5%	AFABA01020
Pacific lamprey	Lampetra tridentata	45	0.5%	AFBAA02100
quillback rockfish	Sebastes maliger	42	0.5%	AFC4A06330
copper rockfish	Sebastes caurinus	40	0.5%	AFC4A06100
surf smelt	Hypomesus pretiosus	36	0.4%	AFCHB01030
black rockfish	Sebastes melanops	34	0.4%	AFC4A06350
brown rockfish	Sebastes auriculatus	31	0.4%	AFC4A06040
soupfin shark	Galeorhinus galeus	25	0.3%	AFDDG02020
sixgill shark	Hexanchus griseus	19	0.2%	AFDBB01010
tiger rockfish	Sebastes nigrocinctus	15	0.2%	AFC4A06420
blue rockfish	Sebastes mystinus	6	0.1%	AFC4A06400
green sturgeon	Acipenser medirostris	5	0.1%	AFCAA01030
blue shark	Prionace glauca	5	0.1%	AFDDG05010
thresher shark	Alopias vulpinus	4	< 0.1%	AFDDC01020
Pacific sand lance	Ammodytes hexapterus	4	< 0.1%	AFCS601030
cabezon	Scorpaenichthys marmoratus	3	< 0.1%	AFC4E13010
speckled sanddab	Citharichthys stigmaeus	1	< 0.1%	AFCTA01090
Pacific sandfish	Trichodon trichodon	1	< 0.1%	AFCRW02010
Basking shark	Cetorhinus maximus	0	0.0%	AFDDD01010
White sturgeon	Acipenser transmontanus	0	0.0%	AFCAA01051
China rockfish	Sebastes nebulosus	0	0.0%	AFC4A06410
Longfin smelt	Spirinchus thaleichthys	0	0.0%	AFCHB03010
Great white shark	Carcharodon carcharias	0	0.0%	AFDDE01010
School shark or tope shark	Galeothinus galeus	0	0.0%	???
Salmon shark	Lamna ditropis	0	0.0%	AFDDE04010
Broadnose sevengill shark	Notorynchus cepedianus	0	0.0%	AFDBB02010
Black & yellow rockfish	Sebastes chrysomelas	0	0.0%	AFC4A06120
Bay pipefish	Syngnathus leptorhynchus	0	0.0%	AFCPB010D0
Topsmelt	Atherinops affinis	0	0.0%	AFCND04010

Spatial Characteristics and Spatial Aggregation of Trawl Survey Data

Within the Northwest ecoregion, which includes the waters offshore from Washington and Oregon, there have been 5,489 NMFS survey hauls from 1977 to 2004. Although survey methods have been modified over time, the sample design has generally been a stratified-random design based on depth and latitude (Keller et. al. 2006, Weinberg et. al. 2002, Lauth 2002). The shallowest hauls are approximately 50-m depth and generally occur 5-10 km from the shore, whereas the deepest hauls occur at approximately 1280-m depth, and vary from 40-100 km from shore, depending on the width of the continental slope. The average tow length across all surveys is 2.3 km. Figure 2 shows the distribution of the hauls within the Pacific Northwest ecoregion boundary. The data tend to be spatially clustered, and the average nearest neighbor distance between haul start positions is 1 km.

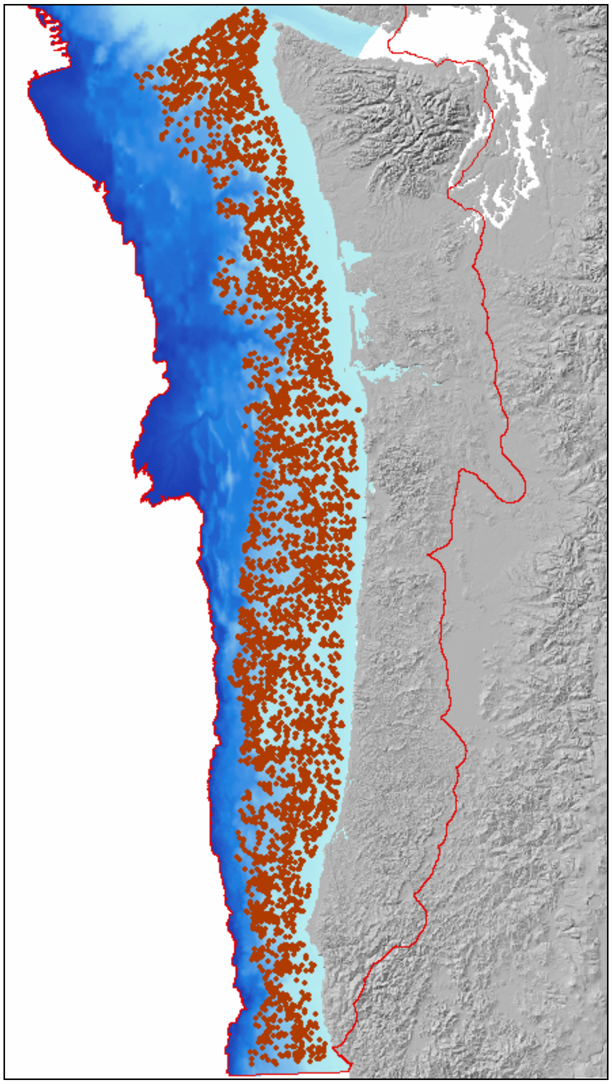


Figure 2: NMFS trawl survey locations (red dots) within the Pacific Northwest ecoregion (red outline)

For use in MARXAN, (a modeling tool used by TNC for conservation planning), the trawl data need to be spatially aggregated and summarized for each spatial unit. The mean nearest neighbor distance of 1 km and average haul length of 2.3 km provided a starting point for determining appropriate spatial summary units. The choice of spatial summary unit requires some tradeoffs – the units should be small enough to show distinctions between different locations and correctly capture the spatial distribution of the hauls, yet be large enough to include an adequate number of samples (hauls) for quantitative summaries. A wide range of square cell sizes were tested: 25–400, and 2500 km^2, corresponding to 5–20, and 50 kilometers on a side, respectively. A sample of cell sizes is illustrated in Figure 3.

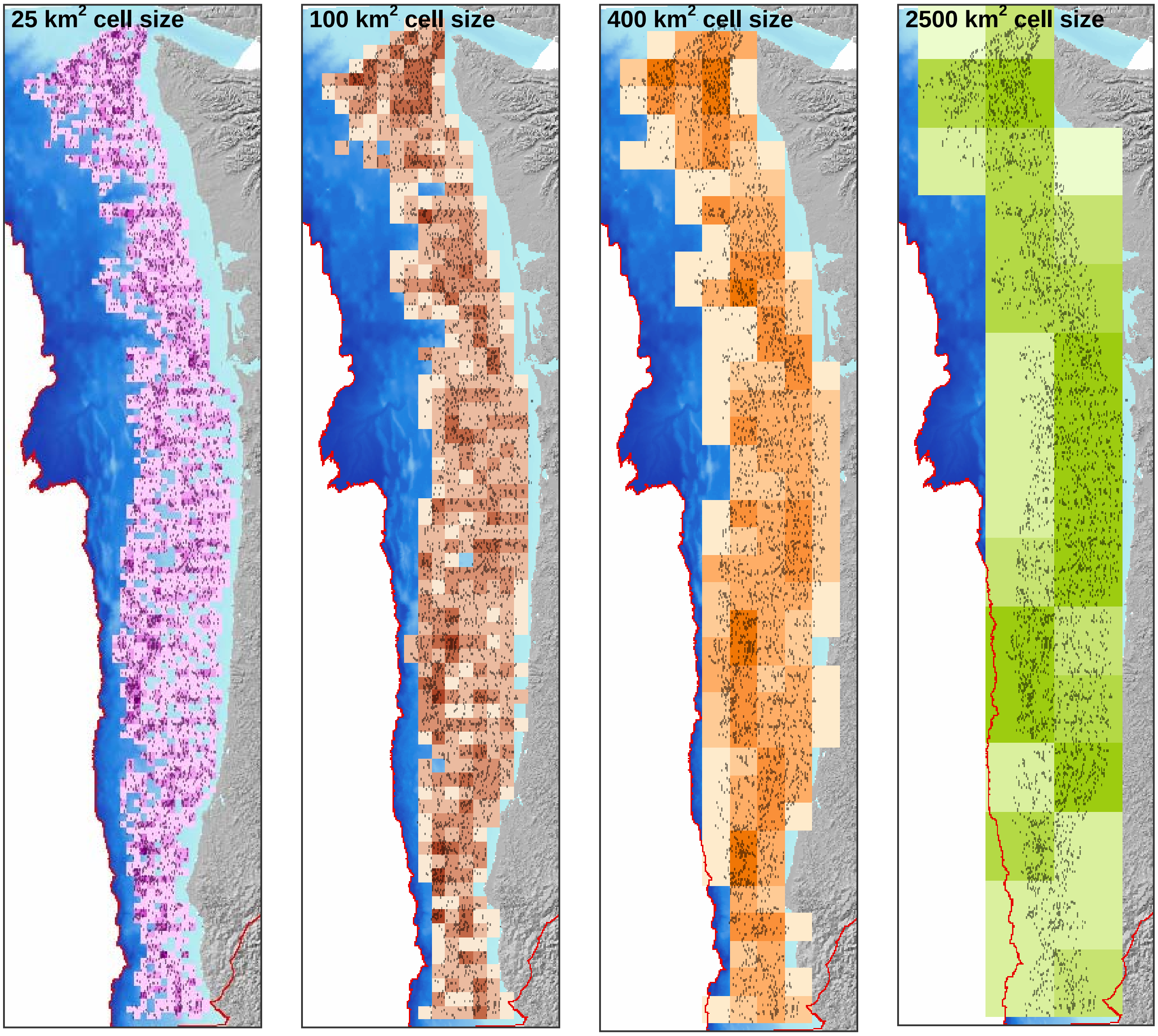


Figure 3: Number of hauls per cell for four cell sizes tested for summarizing trawl survey data. From left to right: 25, 100, 400, and 2500 km^2. Small black dots indicate start position for survey hauls. Shading indicates the relative number of hauls per cell – lighter = fewer hauls, darker = more hauls.

As one approach for selecting an optimal cell size, NMFS scientists recommended calculating mean and variance values of species richness per cell, and plot variance versus cell size. If there is a point of inflection where background variance increases precipitously, the cell size closest to this inflection point would be a good spatial summary unit. Sixteen cell sizes, ranging from 5 x 5 km to 20 x 20 km cells, were used to perform this comparison, and our analysis showed no such inflection point. Therefore, we used the reasoning described below to select our spatial summary units.

The two largest cell sizes, 400 km^2 and 2500 km^2 , are clearly too large to accurately capture the spatial extent of the trawl survey. Overall, there are too few cells, and the cells on the edge include too much area that was not surveyed, so those cells would be over representing the data.

The 100 km^2 cell size adequately captures the spatial distribution of the haul positions with a minimum of over representation. The number of samples per cell is appropriate for quantitative data summaries. Out of the 488 cells containing at least one haul, only 73 (15%) have fewer than 4 hauls and 26 cells (5%) contain only one haul. The maximum number of hauls per cell is 42. These cells provide good coverage within the trawl survey area and create a nearly continuous surface of species occurrence and abundance information. However, from a species/habitat perspective, these cells may be a bit too large and contain too many different habitat types. For example, the upper continental slope (approximately 180 – 550 m depth as defined by NMFS' survey strata), contains a community of species that are distinct from the adjacent continental shelf and lower continental slope. The upper continental slope is generally quite steep and in some places it is only three kilometers across.

The smallest cell size (25 km^2) captures the spatial distribution of hauls quite well. However, there are quite a few cells within the general coverage area of the survey that contain no hauls. These areas may be outside of the designated depth limits or they may be non-trawlable areas within the survey depth limits. These "holes" are valid data gaps, but may cause difficulty if a continuous surface of data values is needed for the MARXAN analysis. The number of hauls per cell is generally quite low – out of the 1484 cells containing at least one haul, 919 cells (62%) have fewer than 4 hauls and 366 cells (25%) contain only one haul. The maximum number of hauls per cell is 22. From a species/habitat perspective, these cell sizes are better suited for depicting distinct habitat areas than the larger cell sizes.

Ferdaña (2005) discusses the use of abstract versus natural units for use in conservation planning. The previous section describes our rationale for selection of an appropriate size for an abstract unit. The natural unit for summarizing the trawl survey data would be the depth and latitude strata used for the trawl survey sampling design. These two factors, along with benthic substrate type, are understood to be the most important characteristics determining groundfish species distribution along the west coast of the U.S. (Williams and Ralston, 2002 and Yoklavich et. al. 2000).

The depth strata used for the NMFS trawl surveys have been modified slightly over time, and differ by survey. However, in general, three depth strata are used:

Continental shelf: 30 – 100 fathom (55 – 183 meters)
Upper continental slope: 100 – 300 fathoms (183 – 550 meters)
Lower continental slope: 300 – 700 fathoms (550 – 1280 meters)

In order to more accurately depict natural species distribution patterns, a hybrid abstract/natural planning unit approach was tested. The square cells were combined with the three depth strata polygons and haul data were summarized within these polygons (Figure 4). Once again, the depth strata polygons combined with smaller, 5 x 5 km, cells may be more consistent with natural habitat patch sizes, but the larger cell size (10 x 10 km) allows for more complete coverage of the survey area, while incorporating depth-based habitat boundaries.

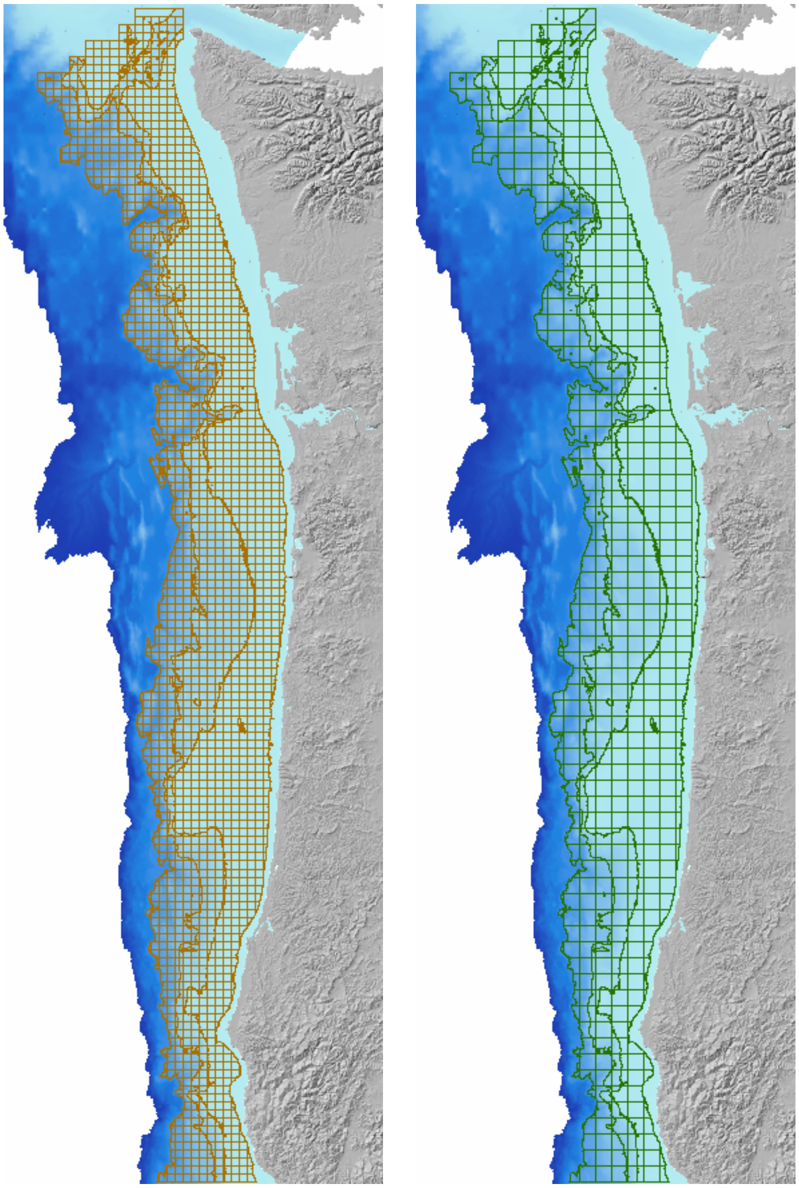


Figure 4: Square cells combined with three depth strata: 55-183 m, 183-550 m, 550-1300 m. On left: 5 x 5 km cells with depth strata. On right: 10 x 10 km cells with depth strata

Summaries of the trawl survey data are provided for four spatial summary units: 5 x 5 km cells, 10 x 10 km cells, 5 x 5 km cells combined with three depth strata, and 10 x 10 km cells combined with three depth strata. The larger cells offer the advantage of more complete coverage and more robust metrics, with the disadvantage of potential over-extrapolation of the information. The smaller cells offer the advantage of more site-specific information, with the disadvantage of many cells with no information (Table 2). The cells combined with the depth strata are enhanced by addition of some habitat-specific natural boundaries. Table 2 summarizes haul count by the various spatial summary units. The final choice of spatial summary unit from these four options will depend upon the relative importance of a continuous surface of information versus the need for site-specific information. If natural units are appropriate for the analysis, the hybrid cells combined with depth zones are preferable to the square cells.

Table 2: Summary of NMFS haul information by spatial summary unit

Spatial Unit	# polygons in study area	% polygons with >= 1 haul	% polygons with > 3 hauls
5 x 5 km	2063	73%	29%
5 x 5 km w/depth	2657	62%	22%
10 x 10 km	553	88%	76%
10 x 10 km w/depth	817	79%	59%

Quantitative Measures or Indices for Groundfish Species

After selecting an appropriate spatial unit, we focused on evaluating various ways to summarize groundfish occurrence or abundance within each of these units. Because we are interested in general geographic patterns, rather than trends over time, we pooled data from all surveys and years together. We used the haul's start position to assign the corresponding cell or polygon identifier to each haul. The following measures and indices were investigated: species richness, presence/absence, and catch per unit effort (CPUE).

Species Richness

For species richness, we counted the number of unique species that occurred in each cell. Species richness was calculated for two species groups: (1) target species only, and (2) all fish species found during the surveys. Species richness for the target species shows a fairly strong spatial gradient, with more species occurring in shallower waters than deeper waters (Figure 5b). In addition, species richness for target species is not strongly correlated with the number of hauls per cell (Figure 6). In contrast, species richness for all fish species do not show a strong spatial pattern (Figure 5c) and the number of species per cell is more highly correlated with the number of hauls (Figure 7). Although there is generally a positive relationship between sample size and species richness, the correlation between target species richness and number of hauls is not strong, and therefore the pattern of target species distribution, which primarily occur in shallower waters, is obvious in Figure 5b, rather than being simply a spatial pattern depicting sample size. This result indicates that species richness for the target species is a reasonable metric for inclusion in the MARXAN analysis, whereas overall fish species richness is not necessarily an informative metric.

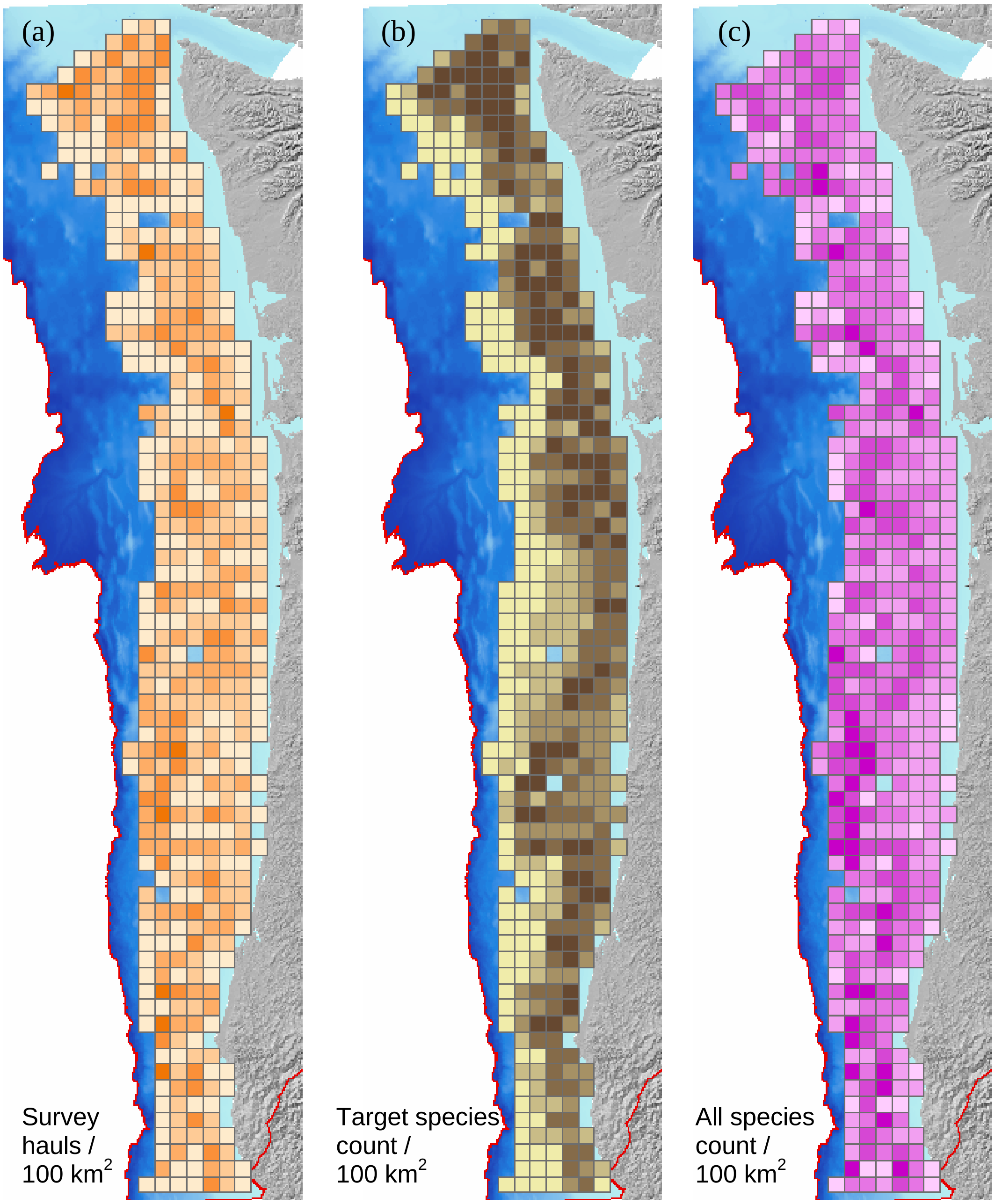


Figure 5: (a) Number of survey hauls per 100 km^2 cell, (b) species richness for target species, (c) species richness for all species.

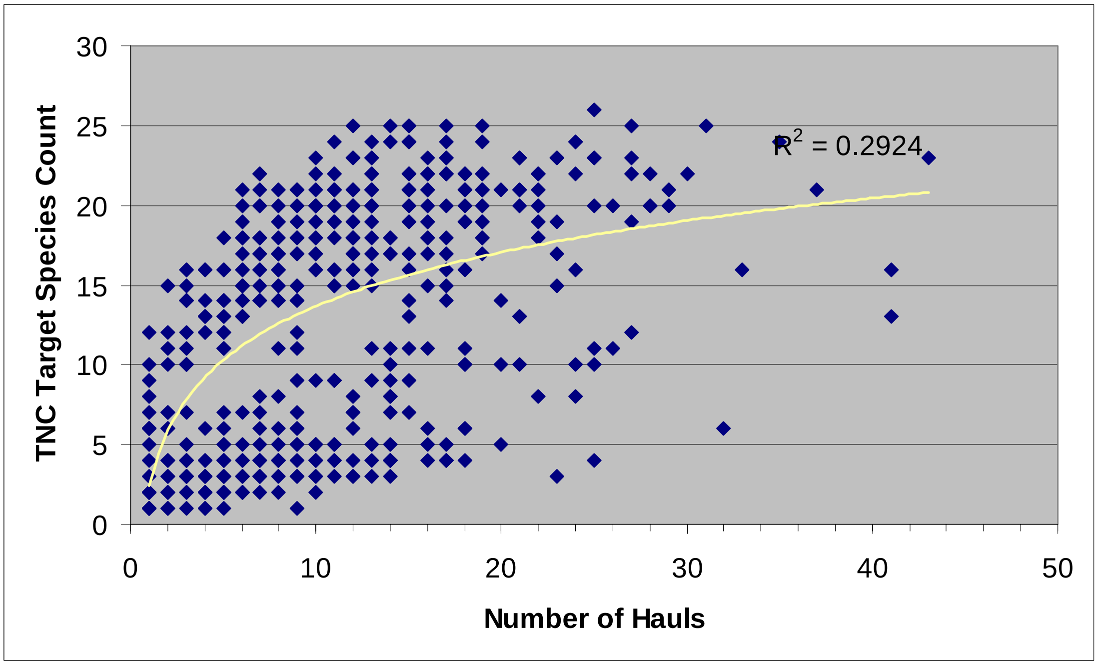


Figure 6: Relationship between the number of hauls per 100 km^2 cell and target species richness.

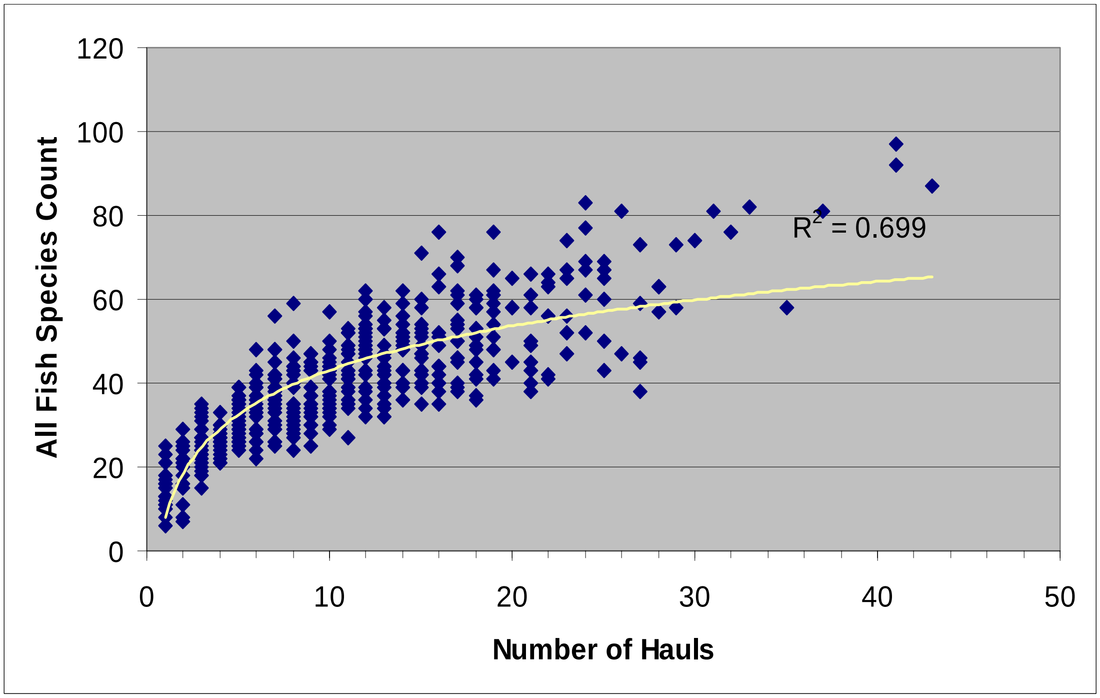


Figure 7: Relationship between the number of hauls per 100 km^2 cell and all fish species richness.

An additional metric that could be investigated is one proposed by Jennings et. al. (2006) that describes "compositional representativeness." This new metric indicates the extent to which areas are compositionally similar or distinct from each other based on the proportion of species that they have in common. This metric is an improvement over species richness because it incorporates species composition, not just species counts.

Presence/Absence

For many species, simple presence/absence information may be the most appropriate metric, especially when the species are not common enough for reliable measures of relative abundance. This approach has been used for modeling groundfish species associations with latitude and depth based on the trawl survey data (NMFS, 2005). Some of the target species are not well represented by the NMFS trawl survey because they prefer rocky, shallow, and/or mid-water habitats. However, lacking other information describing their locations, presence/absence information from the trawl survey is better than no information about their occurrence. Figure 8 shows a sample of presence/absence maps for four species: bocaccio, Dover sole, darkblotched rockfish, and Pacific cod. Appendix B includes a map of all TNC's target species occurring in the NMFS trawl survey.

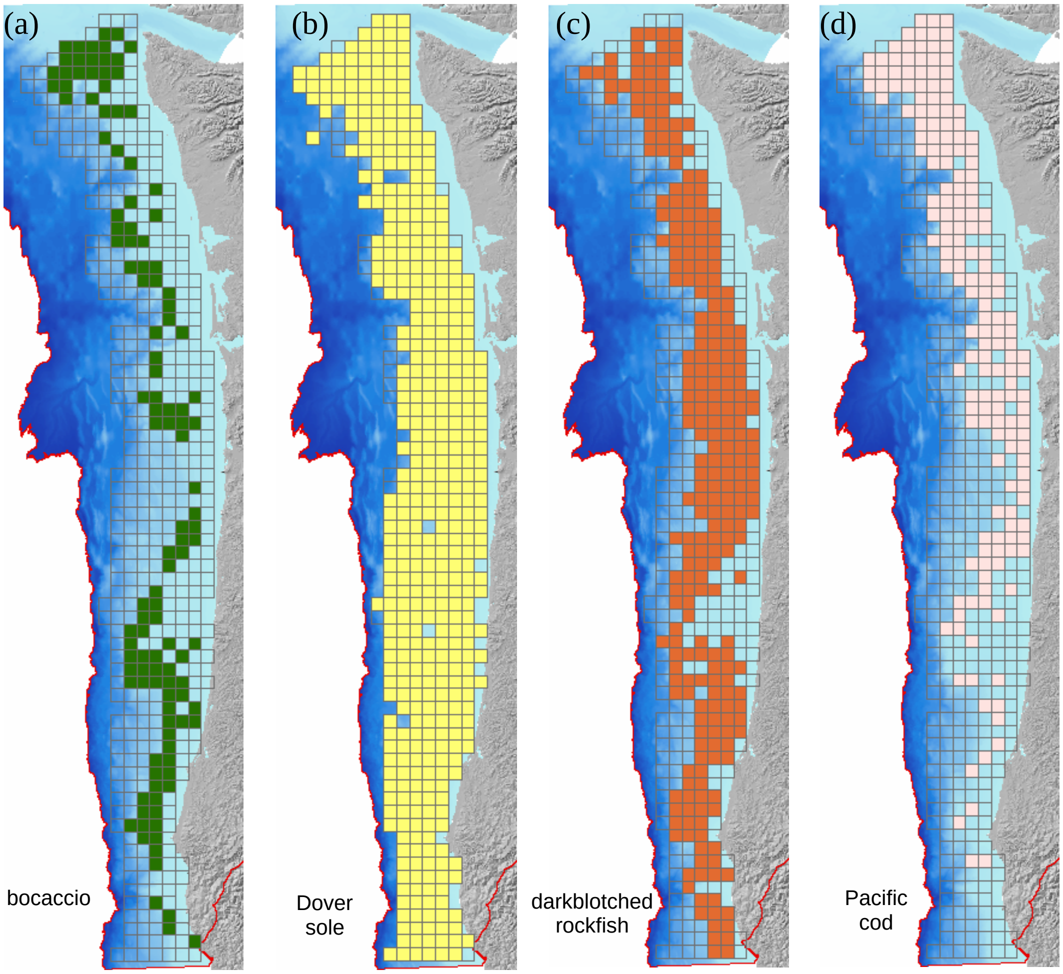


Figure 8: Sample presence/absence maps for four target species: (a) bocaccio, (b) Dover sole, (c) darkblotched rockfish, and (d) Pacific cod.

Catch Per Unit Effort (CPUE)

The standard measure of abundance used for the trawl surveys is catch per unit effort (CPUE) (Keller et. al. 2006, Weinberg et. al. 2002, Lauth 2002). CPUE is calculated as the species weight (in kg), divided by the area swept by the trawl (in hectares). The trawl area swept is the product of the net width and the distance towed. For the CPUE calculations, we chose to work only with species that are well represented within the surveys. As a first cut, a species had to occur in at least 10% of all survey hauls (Table 1) in order to be included in this analysis. We removed three species (eulachon, Pacific herring, and whiting) from this list because they are pelagic species which are not well sampled by bottom trawl gear. After additional assessment by NMFS, NWFSC scientists, Pacific cod and Pacific sanddab were also excluded from the CPUE metrics, however redstriped rockfish and southern rock sole were added. Therefore, only 14 species were included for CPUE calculations.

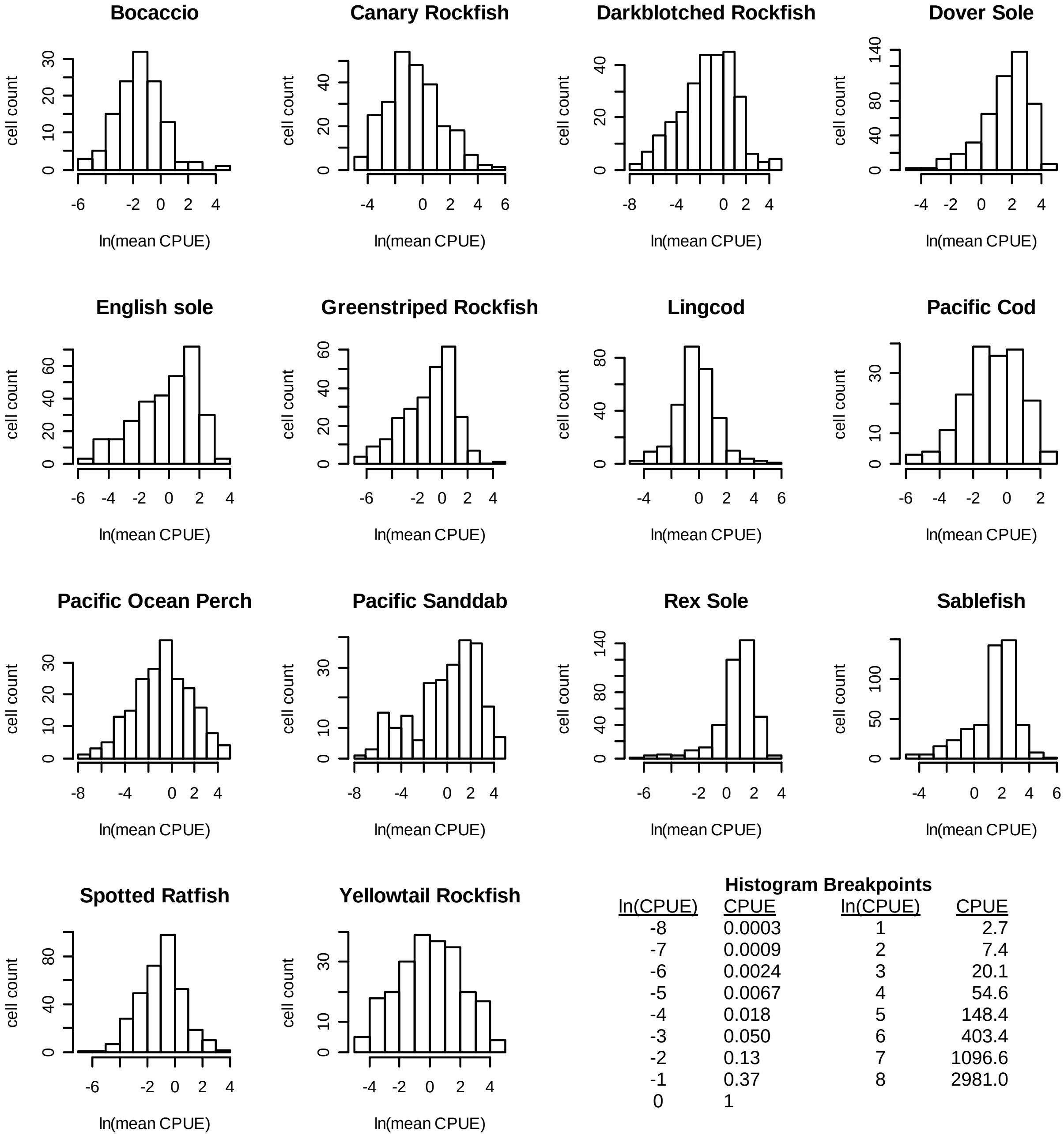
Similar to the analyses performed by Logerwell et. al. (2005) and Cook and Auster (2005), we calculated, for each species, the mean CPUE of all hauls within each summary unit The caveats discussed by Logerwell et. al. (2005) – “Because of this temporal pooling, the CPUE figures should be considered as relative measures only.” – are relevant to our analysis as well. The mean CPUE values give a relative index of the abundance of that species when comparing various locations within the study area. CPUE values cannot be used to compare between species because of differences in average body weights, overall abundances, and the ability of the trawl to sample different species (catchability).

As a further exploration of the distribution of the CPUE data, we plotted histograms of species mean CPUE by 100 km^2 cell (Figure 9). The mean CPUE values have been log-transformed to allow better visualization of the distributions.

If it is desirable to group CPUE values into bins indicating relative abundance (high, medium, low), we can use a quantile approach on the log-transformed means. Although choosing boundaries for these bins is inherently subjective, it is worthwhile to test different binning approaches within MARXAN to assess the sensitivity of the output. We recommend three binning strategies: one that highlights extremely low and extremely high CPUE values (< 10%,10-90%,> 90%), one that splits the CPUE values into three equal bins (< 33.3%,33.3-66.7%,> 67.7%), and one that highlights moderately high and moderately low CPUE values (< 25%, 25-50%, > 50%).

For a similar study in the Northeast (Cook and Auster, 2005), the authors summed the mean CPUE values and set a goal (in MARXAN) of a certain percentage (10%, 20%, 30%) of the cumulative total. This approach is appropriate for application to our Pacific Northwest data set as well. In addition, for increased reliability of the metrics, we recommend eliminating summary units that contain fewer than 4 hauls (Cook and Auster, 2005).

When using the binning approach in MARXAN, cells representing all ranges of CPUE values are expected be included in the final output. This may help address concerns that, due to anthropogenic impacts, low species abundance does not necessarily correspond to low habitat value. The percentage of cumulative CPUE sum approach will favor selection of the higher mean CPUE values because fewer cells will be required to meet the specified percentage goal. However, other data delineating habitats will be used in the ecoregional planning process, and therefore habitat will be considered as an additional input.



Histogram Breakpoints

ln(CPUE)	CPUE	ln(CPUE)	CPUE
-8	0.0003	1	2.7
-7	0.0009	2	7.4
-6	0.0024	3	20.1
-5	0.0067	4	54.6
-4	0.018	5	148.4
-3	0.050	6	403.4
-2	0.13	7	1096.6
-1	0.37	8	2981.0
0	1		

Figure 9: Natural log-transformed distributions of mean CPUE by 100 km^2 cell for 14 species.

Conclusions

This study has shown that with relatively little effort fisheries data can be processed and included in a conservation or other planning application. It is our hope that these methods will be refined for the next iteration of the Pacific Northwest Coast marine ecoregional assessment and adopted by other planning teams. These methods, as well as those to construct benthic habitat types, were designed to be flexible and simple using limited available data. We anticipate that many other geographies will have even less available data, or available at even coarser scales. Therefore any output from these models needs extensive expert review in order to validate and ground-truth them for accuracy and credibility. Nonetheless we think these data form a critical component in classifying and mapping the offshore marine environment at regional scales and provide a baseline database for more examination.

Recommendations

For a spatial summary unit, either the 25 km^2 or 100 km^2 cell sizes are acceptable, depending on the relative importance of complete coverage versus site-specific information. If natural units are included, the hybrid cell/depth zone spatial units offer the advantage of limiting the extent of spatial extrapolation of haul information to areas within a particular depth strata. Including the depth strata allows more fidelity to the original survey design, as well as the factors that determine groundfish distribution (Williams and Ralston 2002, Logerwell et. al. 2005, NMFS 2005). Overall, the 100 km^2 cells combined with the depth strata provide the best combination of characteristics – robust metrics, good spatial coverage, and some habitat-specific boundaries to limit spatial over-extrapolation.

Target species richness and presence/absence are reasonable and robust metrics to include in further analysis with MARXAN. We could potentially expand the diversity metrics by incorporating the new species composition metric proposed by Jennings et. al. (2006). For CPUE, we recommend testing the three binning groupings as well as the approach to select a certain percentage of the cumulative mean abundance for each of the 14 species. In addition, similar to Cook and Auster (2005), we recommend removing summary units with fewer than 4 hauls.

These methods for summarizing the trawl survey data have a number of limitations. First, because species are not uniformly distributed, but are habitat–specific, the spatial summary unit clearly overestimates of the area of influence of the group of associated hauls. Second, the trawl surveys do not completely cover the area of interest for the Pacific Northwest ecoregional planning process. These factors will have to be considered carefully as we design the MARXAN conservation planning framework.

Next Steps

As an alternative or supplement to these analyses, we could use the output of the Essential Fish Habitat (EFH) Bayesian network model (NMFS, 2005) as input to the MARXAN analysis. The EFH model uses information about groundfish species association with depth, latitude, and bottom-type to produce ‘habitat suitability probability’ (HSP) values, ranging from zero to one, which indicate the probability that a habitat is suitable for a particular species. Because the output is linked to GIS data depicting latitude, depth zones, and bottom type, we have a spatially-explicit model of groundfish habitat. The HSP data have previously been used in by TNC in a MARXAN analysis off the central coast of California (Matt Merrifield, pers. comm. 2005), so we could consult with this group for their experience with the data and the metrics they used. These data could also be used to verify the results of this current study, where HSP values could be compared with output from the benthic habitat characterization and processed fisheries data. We would like to explore this relationship between trawl survey data and benthic habitat types, giving an initial indication of species-habitat associations as developed through the HSP process.

In regard to the larger objectives of TNC for offshore conservation planning, we would like to use these data in a MARXAN analysis in order to develop an initial set of conservation priorities in the offshore component of the Pacific Northwest Coast ecoregion.

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Appendix A

Summary of Deliverables and Data-Specific Considerations

Deliverables

As a product of the analysis and data synthesis, a final ArcGIS 9.2 geodatabase was created and delivered to The Nature Conservancy in November 2007. The data tables contained in this geodatabase (**wc_trawlsurveys.mdb**) are summarized below:

Table/Feature Name	Type	Description	Source
btsvy5x5_dat	polygon	5 x 5 minute latitude/longitude cells with trawl data species summaries	TNC/Sound GIS
catch	table	Species catch data for NWFSC and AFSC combined survey data	NMFS/Sound GIS
catch_afsc	table	Species catch data for AFSC Slope and Triennial trawl surveys	NMFS, AFSC
catch_nwfsc	table	Species catch data for NWFSC Slope trawl surveys	NMFS, NWFSC
cell5x5min	polygon	5 x 5 minute latitude/longitude cells	TNC/Sound GIS
haul	table	Haul data for NWFSC and AFSC combined survey data	NMFS/Sound GIS
haul_afsc	table	Haul data for AFSC Slope and Triennial trawl surveys	NMFS, AFSC
haul_cellid	point	Vessel start locations and associated haul data for NWFSC and AFSC combined survey data with 5 x 5 minute blockid	NMFS/Sound GIS
haul_nwfsc	table	Haul data for NWFSC Slope trawl survey	NMFS, NWFSC
PERFORMANCE	table	Master list of haul performance codes	NMFS, AFSC
qtl_10_80_10	table	Species-specific quantile ranking of the natural log-transformed CPUE for quantile ranges: 0-10 (low), 10-90 (mid), 90-100 (high)	TNC/Sound GIS
qtl_25_50_25	table	Species-specific quantile ranking of the natural log-transformed CPUE for quantile ranges: 0-25 (low), 25-75 (mid), 75-100 (high)	TNC/Sound GIS
qlt_33_33_33	table	Species-specific quantile ranking of the natural log-transformed CPUE for quantile ranges: 0-33.3 (low), 33.3-66.7 (mid), 66.7-100 (high)	TNC/Sound GIS
species_afsc	table	Master list of species codes for all AFSC trawl surveys	NMFS, AFSC
species_nwfsc	table	List of species data provided by NWFSC for this project	NMFS, NWFSC
TNC_cpue_species	table	List of TNC target species used for CPUE summaries	TNC/Sound GIS
TNC_MarFish_Targets	table	List of TNC's target marine fish species	TNC
TNCspp_cpue	table	Catch per unit effort (CPUE) in kilograms per hectare for each species by haul	TNC/Sound GIS

Recent Data Modifications

Most of the analyses regarding optimal cell size and source data characteristics and metrics were conducted with a preliminary version of the source trawl survey data and prior to formal initiation of the offshore ecoregional planning process. Therefore, several key components of the geodatabase will differ from the discussion in the body of this document. These changes do not affect the analyses and recommendations, simply some of the implementation details. The changes include modifications to the final summary cell size and the updated source data provided by NWFSC, Groundfish Survey Database.

Cell Size

The cell size for the summary of trawl survey data was changed to a 5 by 5 minute latitude/longitude block in order to match the cell size used by Pacific States Marine Fisheries Commission to summarize data on commercial trawl fishing effort. This cell size is in between the 5 km and 10 km block sizes, so it is a reasonable size for summarizing the survey data.

Source Data

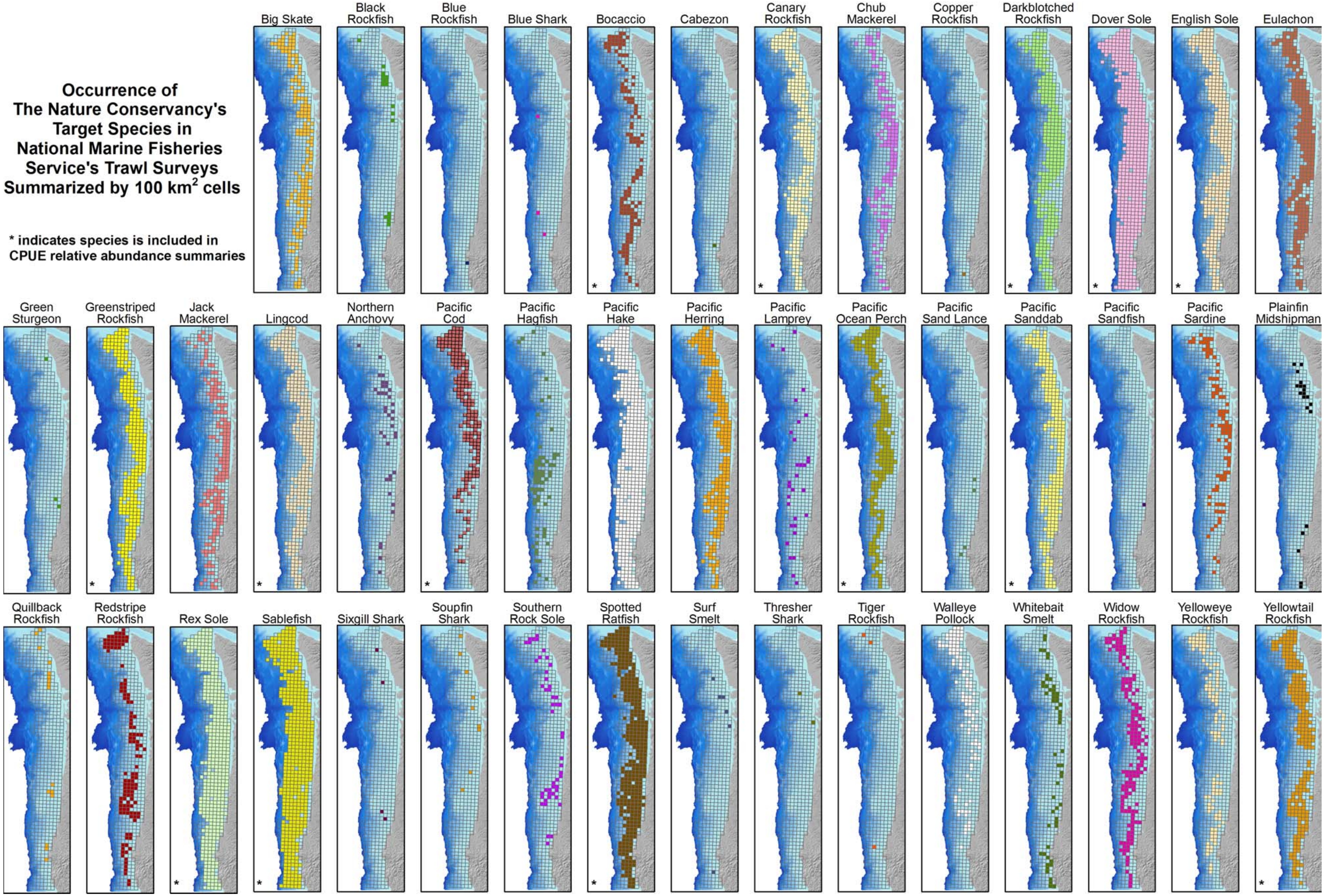
After review of our preliminary analyses, NWFSC provided updated data from the Groundfish Survey Database to expand the spatial coverage into California and to remove data elements that may not be necessary for our final product. Specifically, they provided data only for those species known to be representatively captured by the West Coast Groundfish Survey. For species that are on TNC’s target species list, but not on NWFSC species list, any presence/absence data will rely upon data from the older AFSC surveys (1977 – 2001). Further details about the NWFSC source data are provided in the spreadsheet, nwfsc_groundfishsurvey_metadata.xls.

List of species included in NWFSC data

Scientific_Name	**Common_Name**
Atheresthes stomias	arrowtooth flounder
Sebastes aurora	aurora rockfish
Sebastes melanostomus	blackgill rockfish
Sebastes paucispinis	bocaccio
Sebastes pinniger	canary rockfish
Sebastes goodei	chilipepper
Pleuronichthys decurrens	curlfin sole
Sebastes crameri	darkblotched rockfish
Microstomus pacificus	Dover sole
Parophrys vetulus	English sole
Hippoglossoides elassodon	flathead sole
Sebastes chlorostictus	greenspotted rockfish
Sebastes elongatus	greenstriped rockfish
Sebastes semicinctus	halfbanded rockfish
Ophiodon elongatus	lingcod
Raja rhina	longnose skate
Sebastolobus altivelis	longspine thornyhead
Antimora microlepis	Pacific flatnose
Merluccius productus	Pacific hake
Sebastes alutus	Pacific ocean perch
Eopsetta jordani	petrale sole
Sebastes babcocki	redbanded rockfish
Sebastes proriger	redstripe rockfish
Glyptocephalus zachirus	rex sole
Sebastes helvomaculatus	rosethorn rockfish
Anoplopoma fimbria	sablefish
Psettichthys melanostictus	sand sole
Sebastes zacentrus	sharpchin rockfish
Sebastes jordani	shortbelly rockfish
Sebastolobus alascanus	shortspine thornyhead
Sebastes brevispinis	silvergray rockfish
Lepidopsetta bilineata	southern rock sole
Squalus acanthias	spiny dogfish
Sebastes diploproa	splitnose rockfish
Hydrolagus colliei	spotted ratfish
Sebastes saxicola	stripetail rockfish
Scyliorhinidae	Unspecified Cat Shark
Macrouridae	Unspecified Grenadier
Citharichthys sp.	Unspecified Sanddab
Sebastes reedi	yellowmouth rockfish
Sebastes flavidus	yellowtail rockfish

Appendix B

Maps of Occurrence of The Nature Conservancy's Target Species in National Marine Fisheries Service Trawl Surveys



Occurrence of
The Nature Conservancy's
Target Species in
National Marine Fisheries
Service's Trawl Surveys
Summarized by 100 km^2 cells

*** indicates species is included in CPUE relative abundance summaries**

Occurrence of The Nature Conservancy's Target Species in National Marine Fisheries Service's Trawl Surveys Summarized by 100 km^2 cells combined with three depth strata (50-183m, 183m-550m, 550-1300m)

*** indicates species is included in CPUE relative abundance summaries**