Pacific Marine Conservation Council/Ecotrust

Groundfish Fleet Restructuring Information and Analysis Project

FINAL REPORT AND TECHNICAL DOCUMENTATION

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Executive summary

The West Coast groundfish fishery has changed dramatically over the last two decades. Following the halcyon days that attracted mariners from around the country to ports in Washington, Oregon and California, fishermen and marine ecosystems now struggle to adjust to continual management changes as well as ongoing and significant declines in many fish species and stocks. Since 1987, with the exception of the whiting fishery, landings of rockfish, flatfish and other types of groundfish have dropped dramatically. Nine of the 82 species managed by the Pacific Fishery Management Council (PFMC) have been listed as 'overfished' in just five years.

In response to dwindling fish populations and associated revenues, in 2000 the PFMC adopted a strategic plan entitled "Transition to Sustainability." The highest priority in this plan is to reduce fishing capacity by at least 50% in each fishery sector. Downsizing the fleet appears more urgent than ever in light of extensive 2002 fishing closures along the upper continental shelf, but without options for transitioning out of the fishery, many fishermen are facing the prospect of attrition and bankruptcy. Currently, a trawl vessel buyback program is the primary option being considered to attempt to accomplish capacity reduction.

It is clear that any reduction of the fleet, whether carefully designed or the result of regulatory or market forces, will have considerable economic and social impacts on coastal communities. Likewise, any change in the composition of the fishing fleet will have impacts on the marine environment. Recognizing the need for a port-by-port analysis of the fishery, and the necessary framework to assess these impacts, the Pacific Marine Conservation Council (PMCC) partnered with Ecotrust in 2001, and jointly initiated the *Groundfish Fleet Restructuring Information and Analysis Project* (GFR project).

The goals of this project were to:

1. Compile a comprehensive set of fishery data and information in a format that can be used by all who wish to explore fleet reduction options and other management measures;
2. Produce a set of analytical, publicly available, tools including:
    a) Fleet reduction scenarios that consider fleet composition, shore-based infrastructure, harvest history, spatial dynamics, and economic trends from the perspective of local fishing communities;
    b) A matrix or simulation to analyze potential social and economic effects of these scenarios; and,
    c) Case studies illustrating different port profiles, empirical information on fishing and processing businesses, market dynamics, and the potential effects of fleet buyout proposals and other management measures;
3. Prepare a set of policy options as well as an executive report to be presented to the Pacific Fishery Management Council and made available to all interested parties.

All existing and available data on the groundfish fishery from 1987 - 2000, combined with information on fishery infrastructure gathered through hundreds of personal interviews, were used to complete the GFR project. By using the analytical tools that have been developed in this project, a variety of scenarios for sustaining the fishery can be considered. For instance, we can demonstrate how fishing selectively and returning to the dock with a higher value product can increase fishing income, while extracting fewer fish from the ocean.

Thanks to invaluable assistance and cooperation from individuals, public and private institutions, agencies, and fishing groups along the coast, this project has been highly successful and has garnered national and international interest. In this report we discuss the GFR project and present all results in terms of the aggregate effects on the entire West Coast. Detailed results for dozens of communities are available on-line at www.ecotrust.org/gfr.

Groundfish fleet diversity varies considerably along the west coast. Ports differ both in absolute numbers of vessels which land groundfish, and in the fishing gear types used. During the time period that we reviewed, 1987-2000, more than 11,000 vessels participated in the groundfish fishery at one time or another. Almost 2,000 of those entered the fishery after 1994. According to the existing data, over 55% of the vessels participating in the fishery between 1995 and 2000 fished with only one gear-type, and 27% used two gear-types. This suggests that groundfish effort on the West Coast is fairly specialized.

Different fleet reduction scenarios have markedly different effects on different parts of the coast, and on fleet diversity. They also have different implications for the resulting redistribution of income to vessels that remain in the fishing industry. The GFR framework provides a means of viewing the effects of fleet diversity within various management scenarios, and allows communities and sectors of the fleet to evaluate how they will likely be affected. For example, we determined that:

- Reducing fleet capacity by 50% in each vessel size class in each sector achieves the same reduction of vessels, but at a smaller redistributive effect than selecting vessels at random or than reducing all excess capacity.
- Economic viability is an important consideration in designing capacity reduction measures.
- The catch made in the shelf closure areas may be small in absolute terms, yet account for a high proportion of groundfish landings in some ports.
- Analysis from this project suggests that estimates of the amount of income redistributed to the vessels remaining in the fishery could be viewed as an indicator of how much the vessels leaving would be willing to accept in compensation for leaving the fishery. This income redistribution information could serve as an indicator for the size of the fleet reduction that can be achieved with a buyback program that costs $37 - $75 million dollars.

Additional information can be layered with the GFR Project, including newly available habitat mapping and groundfish observer program data.

We are currently considering proactive options for development of additional tools to analyze the impacts of spatial, or area-based management measures.

PMCC and Ecotrust are confident that the tools developed through this innovative project will not only be useful to regional and national fishery managers in their difficult decision-making, but will help individual coastal communities evaluate their futures and options for fleet restructuring.

Introduction

This report contains the findings of the Ecotrust/Pacific Marine Conservation Council (PMCC) Groundfish Fleet Restructuring Information and Analysis Project—the GFR project for short. It details our analytical approach to addressing options for capacity reductions and related structural transitions of the West Coast groundfish fleet. In addition, we present the results from a suite of scenarios and simulations. The purpose of this report is to provide the West Coast fishing, scientific and management communities, and other interested parties, with our project results and its extensive documentation. This is an opportunity for them to consider the use of this spatial analytical approach in future fishery management and community planning.

The GFR project has two important dimensions. 1) The project was motivated by the Pacific Fishery Management Council (PFMC) decision in 2001 to reduce fleet capacity by at least 50% in every sector as a first step in transitioning the fleet to a long-term sustainable state. The results are intended as a contribution to policy discussions on how best to bring about this transition. 2) Work on the GFR project centered on an analysis of routinely collected and existing data pertinent to the fishery, which we integrated and standardized in a spatial framework. The GFR projects is also a proof-of-concept study of the use and usefulness of spatially integrated databases as called for in a recent National Academy of Sciences study (National Research Council 2002). Applications of analytical framework and database we developed for the GFR project extend far beyond the question of groundfish fleet restructuring, and have attracted the attention of state and federal marine resource management agencies, for example for the analysis of Essential Fish Habitat provisions of the Magnuson-Stevens Act.

Correspondingly, the report is organized in two parts. Part I deals with the GFR project proper. In it, we present our baseline analysis of 14 years of fishery-dependent and other data describing the West Coast groundfish fishery and results from four numerical and two policy-driven scenarios that we analyzed in terms of the likely implications for coastal communities. In the interest of preserving space, we discuss the project and present all results here in terms of the aggregate effects on the entire coast. Detailed results for dozens of West Coast communities are available on-line, at www.ecotrust.org/gfr. Part II contains the methods used and techniques developed in the GFR project, including the architecture of the geographic information system, computer code, and hardware issues, for this project. The technical documentation forms part of our deliverable to the Pacific States Marine Fisheries Commission (PSMFC), where the analytical processes and products are housed in the public domain. We hope that the kind of decision-support made possible by visual and geographically referenced information management systems such as the one we built for the groundfish fishery will become part of the toolkit for fishery management on the West Coast.

Work on this project was very much a team effort. The Ecotrust GFR team is managed by Ed Backus, and consists of Senior GIS Analyst Mike Mertens, Systems Engineer Debra Sohm, and GIS Technician Charles Steinback. Our project partner, PMCC, includes Executive Director Peter Huhtala, Science Director Jennifer Bloeser, Communications Director Caroline Gibson, and over 400 years of collective fishing knowledge and experience of the PMCC board of directors. The project has also benefited greatly from the participation of Marlene Bellman, who came to us as the 2001/2002 Oregon Sea Grant Research Fellow. The media and communications department at Ecotrust, especially Howard Silverman and Sam Beebe, provided valuable proofreading and production support for this report. Most importantly, over 60 fishermen, scientists, managers, and observers of West Coast fishery issues have given generously of their time and expertise in reviewing this and earlier drafts of the report. Their comments and suggestions have considerably improved the project and this report. The responsibility for all errors and omissions resides with the Principal Investigator, Dr. Astrid Scholz, to whom all correspondence and comments should be addressed: Ecotrust, PO Box 29189, San Francisco, CA 94129, ajscholz@ecotrust.org, Tel 415 561 2433.

Funding for the GFR project was provided, in order of proportion, by the David and Lucile Packard Foundation, the Pacific States Marine Fisheries Commission (PSMFC),[1] the Homeland Foundation, and Oregon Sea Grant.

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[1] Monies for a PSMFC contract for GFR completion funding come, in equal parts, from the Northwest Region of NMFS and the NOAA National Marine Protected Area Center.

PART 1 – GROUNDFISH FLEET RESTRUCTURING INFORMATION AND ANALYSIS PROJECT

1. Project Background

The groundfish fishery on the West Coast has undergone significant changes since the passing of the Magnuson-Stevens Fisheries Conservation and Management Act of 1976. After an initial period of expansion, allowable landings of groundfish and other species have generally declined over the past 20 years. Groundfish stock assessments have painted an increasingly troublesome picture of the health of fishery resources. Resultant management actions have become ever more stringent. In 2002, large areas of the upper continental shelf were, for the first time, closed to fishing. In response to dwindling stocks and associated revenues, the Pacific Fishery Management Council (PFMC) adopted a strategic plan in 2000, titled “Transition to Sustainability” (PFMC 2000), which prioritizes management options for ensuring the future of the fishery. The top priority was to reduce fishing capacity by at least 50% in each fishery sector. The goal of groundfish fleet reduction appears even more urgent in light of the recent and most restrictive harvest regulations in regional history, necessitated by plummeting populations of several rockfish species.

Any reduction of the fleet, whether carefully designed or the result of regulatory or market forces, cannot help but have considerable impacts on coastal communities. Social and economic impacts can vary considerably from community to community, depending on local fleet composition, traditional target species, transportation, processing facilities and other portside infrastructure, and other factors. Likewise, any change in the composition of the fishing fleet—and hence in the size, location, and timing of fishing activity and effort along the coast—has consequences on the marine environment and living resources. Recognizing the need for a comprehensive port-by-port analysis of the fishery, and the necessary analytical framework to assess these impacts, the Pacific Marine Conservation Council (PMCC) partnered with Ecotrust in 2001, and jointly initiated the *Groundfish Fleet Restructuring Information and Analysis Project* (GFR project).[2]

The goals of the project were to:

- Compile a comprehensive set of data and information in a format that can be used by all who wish to explore fleet reduction options and other management measures;
- Produce a set of analytical, publicly available, tools including:
    a) Fleet reduction scenarios that consider fleet composition, shore-based infrastructure, harvest history, spatial dynamics, and economic trends from the perspective of local communities;
    b) A matrix or simulation to analyze potential social and economic effects of these scenarios; and
    c) Case studies illustrating different port profiles, empirical information on fishing and processing businesses, market dynamics, and the potential effects of fleet buyout proposals and other management measures;
- Prepare a set of policy options as well as an executive report to be presented to the Pacific Fishery Management Council and made available to all interested parties.

With this document we report on the work towards these goals, and present the findings of the GFR project to our partners at PMCC, as well as to the Pacific Fishery Management Council, the fishing industry, the scientific community, and the public at large.

Results from an earlier draft of this report, which focused on methods and contained preliminary results from the numerical reduction scenarios, were presented to the Science and Statistical Committee (SSC) at the October/November 2002 meeting of the PFMC. We also presented preliminary results at the California and World

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[2] This was initially labeled the Groundfish Fleet Reduction Information and Analysis Project, motivated by the number one priority in the PFMC *Strategic Plan* (PFMC 2000). As Ecotrust and PMCC advocate and promote (economically, socially and ecologically) sustainable fisheries, the decision was subsequently made rename the project Groundfish Fleet Restructuring Information and Analysis Project, and more clearly signal our programmatic intent.

Oceans Conference, the Mote International Symposium, and the NOAA/USGS/ESA/AFS Symposium *Effects of fishing activities on benthic habitats* (Scholz, Mertens et al. forthcoming-a; Scholz, Mertens et al. forthcoming-b).

2. The geography and capacity of the groundfish fleet

The West Coast groundfish fishery takes place along the entire coast and varies considerably between regions—in terms of the vessels and gear used, the reliance of communities and business on groundfish and other species groups, and in terms of the environmental, weather, and physical conditions that shape fishing practices in different areas. Furthermore, the groundfish fishery is but one among many, and has historically been prosecuted as part of a mixed fishing "portfolio" consisting of salmon, crab, groundfish, and pelagic species. For the purposes of this project, we did not address any interactions with other fisheries and limited even the data acquisition to groundfish-related information. In this chapter we describe the groundfish fleet, first in terms of some pertinent statistics about the fishery and the fleet for the time period from 1987 to 2000 that comprises our analysis (section 2.1.), as well as in terms of its spatial extent and geographic idiosyncrasies (section 2.2.). In the third section of this chapter, 2.3., we describe our method for calculating the capacity of the groundfish fleet in the year 2000, which serves as the base year for the subsequent analysis of various reduction and other policy scenarios. These scenarios form the focus of chapters 3 and 4.

2.1. Baseline information

Because the PFMC strategic plan and two related documents on capacity utilization in the groundfish fishery are the points of departure for our analysis (PFMC 2000; SSC Economics Subcommittee 2000; Offices of Science and Technology and Sustainable Fisheries 2001), we chose 2000 as the baseline year. At the inception of the GFR project, 2000 was also the year for which data were most recently available. Since then, 2001 and 2002 logbook and fish ticket data have become available, and—together with subsequent years—could be incorporated into the database and analysis. Furthermore, the analysis could be conducted using a different base year. Given the worsening decline of groundfish landings and revenues in the past two years, and the pessimistic outlook for 2003 (Brinckman 2003), the project's 2000 baseline clearly should not be interpreted as a realistic, attainable level of fishing on the coast.

During the time period 1987-2000, more than 11,000 vessels participated in the groundfish fishery at one time or another. Almost 2,000 of those entered the fishery after 1994, and there were a total of 1824 vessels that recorded non-whiting groundfish landings in our baseline year, 2000. Of these, 40% (782 vessels) participated in the fishery in 1987. Our count includes vessels for which groundfish constitutes any fraction of their total catch, and thus may include vessels that primarily target other species. Our analysis therefore captures both targeted and incidental catch of groundfish, but we cannot distinguish between the two based on the data considered.[3]

For descriptive purposes, we organized all fishing gear used in the recorded landings of groundfish into five major groups associated with the groundfish fishery: any trawl, any pot or trap, any hook and line, longline, and "other" —which includes troll and various net gears. We also use a more detailed breakdown of gears to make the habitat and depth associations used in the spatial analysis of fishing activity, which forms part of our contribution to the Northwest Region's Essential Fish Habitat Environmental Impact Statement (Sustainable Fisheries Division 2001). For a complete list of gears assigned to each, see Appendix A.

In considering the effects of fleet reductions, we were interested in degree of internal diversification of the groundfish fleet, i.e., whether vessels use one or multiple gear-types to target groundfish. Gear choice can be interpreted as an indicator for fishing areas, since it is limited by bathymetric and substrate characteristics. According to the existing data, over half (55%) of the vessels participating in the fishery between 1995 and 2000 of fleet fished with only one gear-type, and over one quarter (27%) used two gear-types (see Figure 1). This suggests that groundfish effort is fairly specialized, although from the data it is not possible to conclude for how many vessels groundfish constitutes the only strategy. As previously noted, data on the other fisheries could be used to determine

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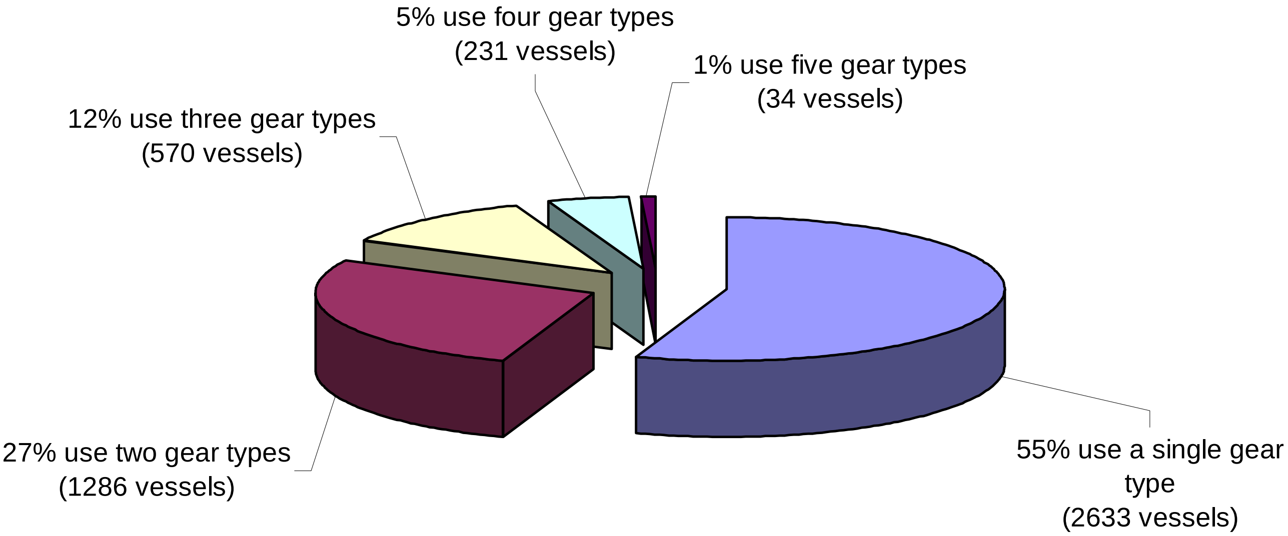
[3] To the extent that the GFR project serves as a prototype of a regional, spatially integrated database, it would be straightforward to incorporate the rest of PacFIN data about other fisheries into this framework, and to identify vessels according to the proportion of different fisheries prosecuted.

the degree of diversification of the fishery with other fisheries, notably salmon and crab.[4] Notice that vessels may make landings with more than one gear over the course of the fishing season, so the vessels counts below do not represent unique vessels, but rather the recorded instances of gear-combinations recorded in the fish tickets.

FIGURE 1: GEAR DIVERSITY IN THE GROUNDFISH FLEET, 1995-2000



The gear types are: trawl, pot & trap, hook and line, long line, and "other"

Over the period analyzed in the GFR project, 1987 to 2000, groundfish landings have declined considerably for most fishery sectors, gear types and species with the exception of the whiting fishery. Graphs similar to Figure 2 have accompanied PFMC documents for a number of years, and the current rebuilding plans and harvest regulations are based on widespread expectations that these declining trends will continue. In the GFR project, we consider the implications of these trends from the perspective of coastal communities, and the particular profile of fishing fleets and activities in various ports. A key consideration for assessing the impacts of a major restructuring that would accompany a capacity reduction program is how well the fleets in each port can adapt, which in turn is a function of diversification within and between fisheries and gear sectors, infrastructure, the overall economic health of a region, and new markets and other opportunities engendered by a more sustainable fishery.

For the purposes of the GFR project, we use fleet diversity <u>within</u> the groundfish fishery as a placeholder for this much bigger set of concerns. Fleet composition, however, is widely believed to have implications for how different ports will be affected by capacity reductions and other structural changes in the fishery. Figure 3 shows the fleet composition in port groups along the coast for the base year, 2000.

As is apparent from Figure 3, fleet diversity varies considerably along the coast. Ports differ both in absolute numbers of vessels that make groundfish landings and in the gear types used. Notice that in this instance we are considering landing ports and not homeports, so the numbers contain double counts of vessels making landings in different ports. In the next section we discuss the geographic idiosyncrasies in more detail.

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[4] In principle, this would be possible with data on all fisheries off the West Coast. For the purposes of the GFR project, we only requested groundfish data, so we only "see" vessels through their groundfish landings.

FIGURE 2: GROUNDFISH LANDINGS OVER TIME

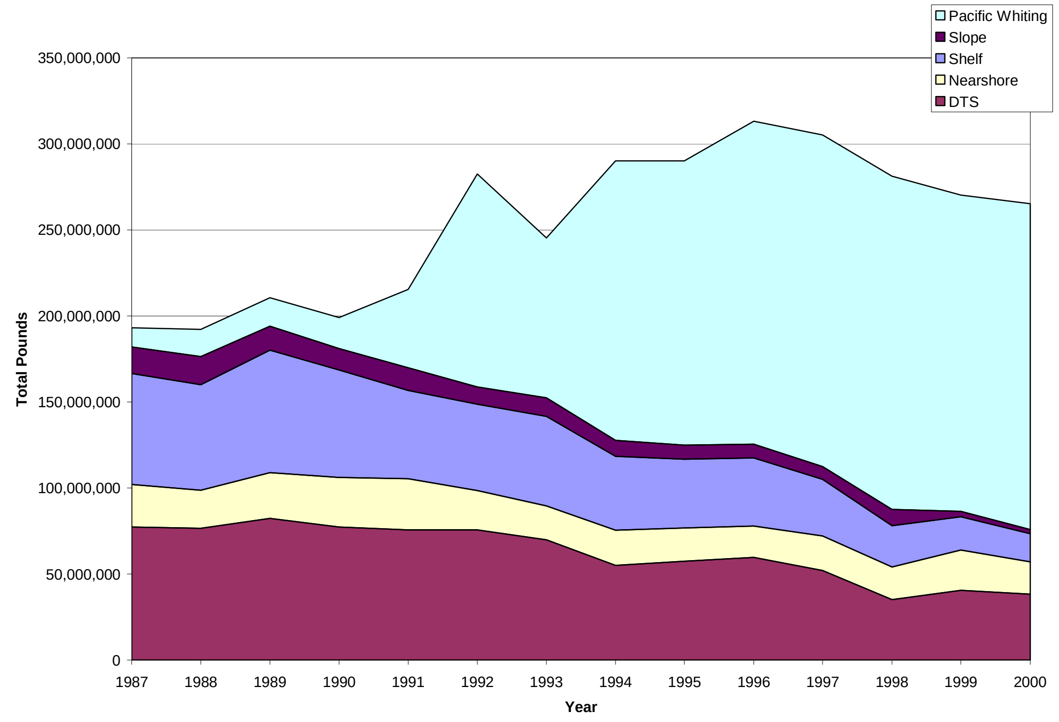
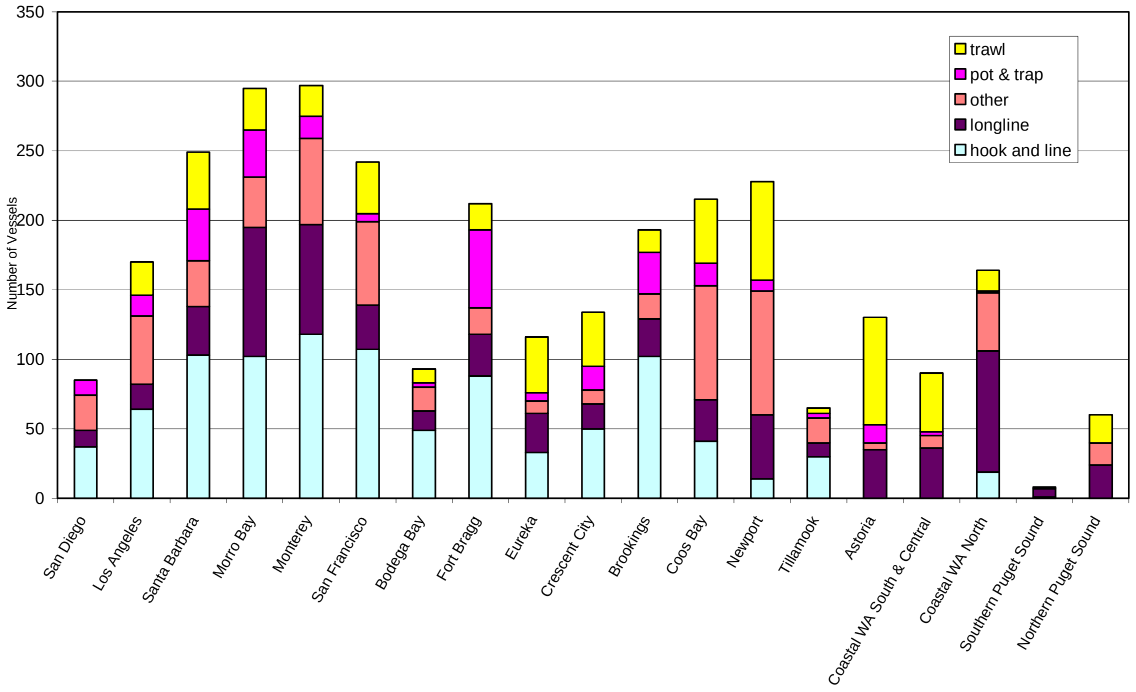


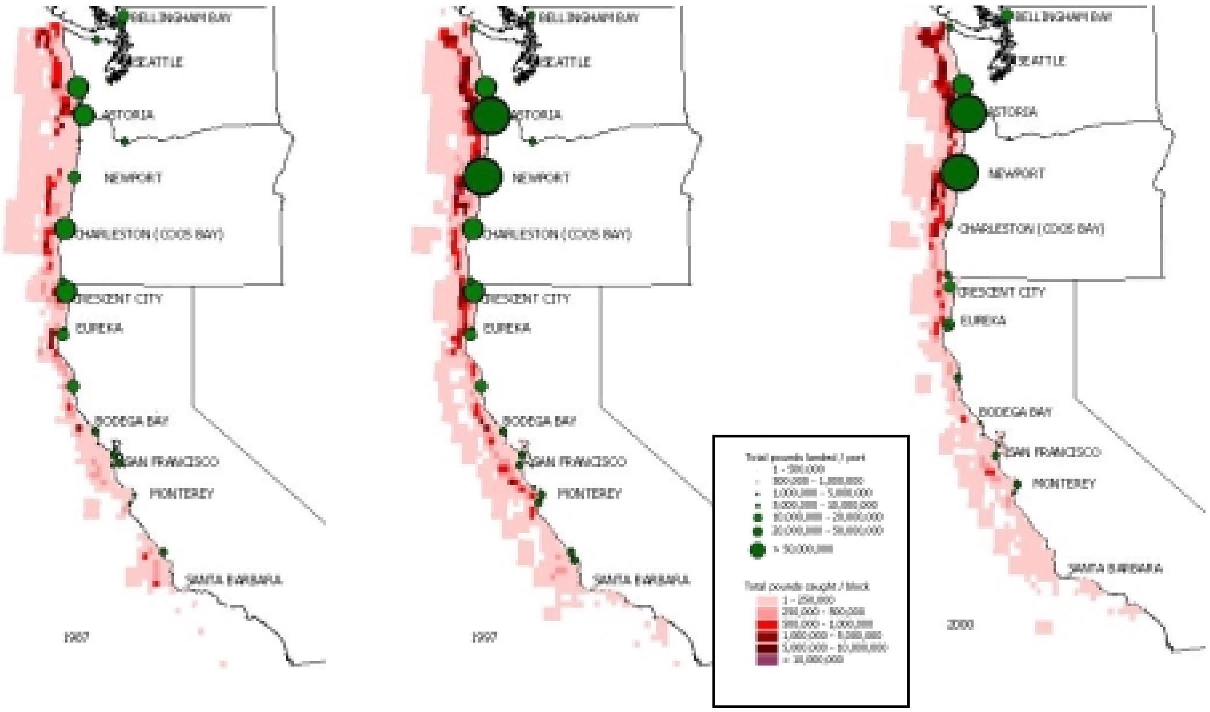
FIGURE 3: GEAR DIVERSITY BY LANDING PORT, 2000



2.2. Spatial description of the fleet, 1987-2000

One of the main goals of the GFR project is also the most difficult to convey on paper: the spatial extent of the groundfish fleet and its changes over time. We have developed techniques for spatially processing logbooks (trawl) and fish tickets (trawl and non-trawl),[5] which allow insights into the location and magnitude of fishing effort over the study period. For example, the trawl fleet has moved in and offshore at various times, as shown in the three panels of Figure 4.

FIGURE 4: COASTWIDE TRAWL CATCH AND LANDINGS FOR SELECT YEARS



We have chosen the first and last year of our time series, as well as the year (1997) after Magnuson Act reauthorization. To participants, managers and scientists familiar with the fishery, such spatial considerations may provide useful starting points for analytical or management assessments over and beyond the scenario analysis we undertook in this project. These three, or other intervals, can be examined in detail using the GFR database. The entire, animated, time series for the trawl fleet can be viewed at the GFR website, www.ecotrust.org/gfr, and corresponding maps for the non-trawl fleet are forthcoming.

Most of the approximately 1900 vessels catching groundfish on the West Coast make landings both in the principal port associated with them in PacFIN as well as in other ports. In addition to the aggregate "range" of the fishing fleet, or of non-trawl and trawl gear sectors, there are therefore also distinct "foraging areas" associated with various ports. One way to think about this is in terms of the number of landing ports associated with vessels from each homeport. The home ranges are also suggestive of constraints imposed on the fleet by the gear used, the species targeted and the habitats that support them, as well as weather, current and other environmental conditions that might act as constraints on fishing activities. The landing ports are also in no small part determined by the presence of processors and buyers, and thus the geographical signature of ports may be suggestive of underlying market signals. Over time, one would expect the expansions, contractions and other changes of the port foraging areas to reflect the changes in the processing sector. These, and other questions, remain objects for future inquiry.

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[5] For a description of these techniques, please see Part II of this report.

Another way of thinking about the forage areas associated with various ports is in terms of the effort exerted within them and the amount of landings associated with them. These considerations may be relevant for considering regionally explicit management or mitigation measures, or to avoid the inadvertent cutting off of particular fleets from locally constrained fishing grounds. For example, certain types of depth or area based management measures may effectively prevent particular sectors of the fleet (in terms of size and/or gear used) from reaching their "forage area". Pending the spatial processing of the fish tickets, it will be possible to analyze gear and/or size specific issues pertaining to depth and/or area-based management.

2.3. Fleet capacity

Fishing capacity is notoriously difficult to measure, since it is a combination of number and size of vessels, their technical efficiency and the time commitment of fishermen (Smith and Hanna 1990; Federal Fisheries Investment Task Force 1999; Gréboval 1999). Of these factors, only the number of vessels is well documented on the West Coast. While technical efficiency is generally assumed to have increased over time, estimating the physical capacity of the fleet is hampered by the absence of comprehensive data about vessel characteristics such as fish-hold capacity, horsepower, the volume of nets and other gears, and other variables. What we do know is almost entirely limited to fish tickets and log books, which record the amount of fish that are landed. This, in turn, is increasingly determined by market and regulatory factors, and is not an accurate reflection of the true capacity of the fleet—only of what it regulatory and market forces allow it to land NOAA's Fishing Capacity Task Force has proposed various practical measures of fishing capacity (Ward, Brainerd et al. 2001). The PFMC's SSC has used one of the techniques recommended for the task force to estimate the capacity utilization, i.e., the ratio of catch to capacity, of the West Coast groundfish fishery (SSC Economics Subcommittee 2000; Offices of Science and Technology and Sustainable Fisheries 2001). Comparing these figures to the allowed harvest, the SSC derived estimates for the "numbers of vessels needed" in each fishery sector to land the allowable catch, which form the basis for our analysis.

Before outlining the way in which we adapted the SSC estimates, it is useful to distinguish between latent capacity and over-capacity. **Latent capacity** are vessels that have the requisite permits to participate in the fishery but are not making any landings in a given year. Since the permits associated with these vessels are current, they could re-enter the fishery anytime. The PSMFC is in the process of consolidating the permit information from Washington, Oregon and California into one database, which will make it possible to assess the latent capacity in all coastal fisheries off the West Coast (Will Daspit, pers. comm., 9/11/2002). For the purposes of the GFR project, we only considered the limited entry (LE) permit data collected by PacFIN since the inception of the limited entry program in 1994. We compared the number of vessels possessing permits in each year with the number of vessels recording landings of groundfish designated as LE in the fish tickets database. Over the six year time period, there were a total of 257 vessels that had a permit but no landings for one or more years. Most vessels (157) had latent permits for only one year, 49 for two years, and the remaining 51 for three or more years.

Each year, between 65 and 100 vessels with LE permits did not record any landings, suggesting a latency rate of between 12-17% for the LE sector. Note that latent capacity occurs <u>in addition to</u> excess capacity, since it comprises vessels that could be joining the already larger than needed number of vessels participating in the fishery. Latent capacity is a concern for any capacity reduction program since it may dilute the effectiveness of, e.g., a buyback if the departure of some vessels brings latent ones back into the fishery. A future research need is to establish the degree of latent capacity in other fishery sectors, notably the open access fishery. In principle, it would be possible to identify vessels with latent permits and factor their removal or permanent retirement into a capacity reduction program, for example through the consideration of landing histories.

The primary concern with fishing capacity is the presence of **excess**, or **over-capacity**, i.e., more vessels participating in the fishery than the number "needed" to catch the allocations determined by stock assessments and harvest guidelines. Many of the groundfish fisheries target stocks that are depleted, such as several rockfish species. Other groundfish fisheries are constrained by measures designed to minimize the bycatch of depleted stocks. Thus, the issue of reducing excess capacity has become more urgent. It is this over, or excess, capacity that we consider in the GFR project.

To arrive at a baseline capacity for the fleet in 2000, we replicated the SSC analysis of capacity utilization in the West Coast groundfish fishery (SSC Economics Subcommittee 2000), which uses landings from earlier, less constrained periods together with current fleet sizes to infer the underlying capacity. The assumption is that vessels were fishing at or close to their capacity in earlier, relatively unconstrained time periods. In the case of the West Coast groundfish fishery, the distinction is typically made between pre and post 1994 fishing seasons, when LE was implemented and vessels either qualified for LE permits or remained in the open access (OA) fishery. Using the 1995-1998 participation in the fishery by fleet sectors and permit/endorsement status, i.e., open access, limited entry trawl, limited entry non-trawl/sablefish, and limited entry non-trawl/non-sablefish, vessels were assigned LE or OA status in earlier years. This assumes considerable temporal homogeneity of the fleet and basically codes vessels in earlier years by the fleet sector they participated in later. Considering the landing histories of each fleet sector prior to 1994, the SSC analysis then estimated the number of vessels needed in each of the earlier years to catch 2000 harvest targets defined for each sector. In other words, how many vessels fishing at relatively unconstrained capacities would have been needed to catch the allocations for each fleet sector in 2000. The SSC analysis found capacity utilization rates ranging from 6% in the open access to around 40% in the limited entry trawl fleet sectors (SSC, 2000; p. 46).[6]

We applied the same logic to the dataset to derive the number of vessels in each of the four fleet sectors in 2000. Since we are working with a somewhat different data set and were not able to replicate the SSC steps exactly (for example, we had no record of the 1984-1988 landing records vessels used to qualify for the limited entry permits), our estimates of the fleet size vary slightly from the SSC figures, but are of comparable magnitude.

Table 1 summarizes our and the SSC's findings, as well as the inferred number of vessels needed in each sector from the SSC study. In the open access and limited entry trawl fleets, we derived somewhat higher capacity utilization rates. These should not be read as an improvement of the capacity problem, but are rather a reflection of the incongruities between the two data sets. Also, we decided to use our 2000 figure for the number of distinct vessels in the open access (614) fleet rather than the 1995-1998 average (980, which was higher than the SSC's average of 910) because we believe that this reflects trends in the open access fleet better. Our capacity utilization rates for the limited entry non-trawl fleet are lower than those derived in the SSC study. We believe this is a function of our data: since PacFIN distributes catches of rockfish over vessels and areas, our annualized data do not allow for sufficient distinction between targeted and bycatch harvest strategies for sablefish and rockfish caught in the LE fixed gear fleet. Also, upon closer inspection we discovered a high degree of overlap between vessels in the LE non-trawl sector: most of these vessels appear to fish for both sablefish and rockfish, and only 16 vessels target sablefish exclusively. The SSC inferred a need for 40 non-trawl LE vessels total, of which 15 are needed to harvest the sablefish target. In our scenarios, therefore, we apply the reduction logic to the entire LE non-trawl sector, and treat the 16 "sablefish-only" vessels separately.

TABLE 1: SUMMARY OF GFR AND SSC CAPACITY CALCULATIONS

Fleet sector	GFR [No. of vessels]	GFR No. of distinct vessels[7]	SSC [No. of vessels]	SSC inferred number of vessels needed	SSC capacity utilization estimates	GFR capacity utilization estimates
OA (2000)	1524	--	--	--		
OA with groundfish landings > 0.25 MT (2000)	713	**614**	--	**50 (low)** **100 (high)**		**7% (low)** **14% (high)**
OA with groundfish landings > 0.25 MT (1996-98 average)	983	--	910	50 (low) 100 (high)	5.5% (low) 11% (high)	
LE trawl (2000)	452	**244**	274	**107**	39%	**45.5%**
LE non-trawl (2000)						
Non-sablefish	279	**177**	232	**40**	17.2%	**14.3%**
Sablefish	228	176	164	**15**	9.1%	6.6%
Sablefish exclusive		**16**				**100% (assumed)**

Note: the numbers in bold are used in the subsequent scenario analysis

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[6] These figures are currently being revised to reflect recent changes in harvest regulations (Jim Hastie, pers. comm., 9/25/2002). Since these have continuously decreased the allowable catch for each sector, the capacity utilization rates have likely decreased further.

[7] These vessels still contain double-counts of vessels that occur in more than one size category in information received from PacFIN. This is one of many factors that makes accurate counts of vessels challenging.

The number of vessels needed in each sector, thusly derived in the SSC, serves as the basis for our reduction scenarios in the following chapters 3 and 4. In other words, using the SSC estimates as a measure of how large the fleet should be to fish the harvest allocations, we then take the logical next step of asking how many would have to be removed (and how) to bring capacity into line with the resource available.

It is important to note that these numbers are not real vessels, but are more properly understood as an indication of the order of magnitude of reductions in each sector. This analysis of the fleet leads to a number of strange artifacts that result from idiosyncrasies of the database, at least in the annualized form of the data that we consider in this report. In this form, each vessel's catch made in a particular area using a particular gear are summarized. The analytical units we deal with, consequently, are instances of particular vessel-gear-area configurations, and are somewhat removed from actual vessels and fishing practices. For policy purposes, one would want to minimize the number of derivations data are put through for any one of these analytical steps. Also, our numerical scenarios (chapter 3) are silent on <u>how</u> vessels are chosen for removal from the fleet. In reality, the mechanism for this initial choice has significant implications for the kind of capacity reduction achieved. We consider one of these mechanisms in the permit stacking scenario for the trawl sector in chapter 4.

The reduction scenarios we discuss in the next two chapters all follow the same basic logic using these capacity estimates. In chapter 3 we discuss four different, numerical ways of removing excess capacity. <u>These should not as policy recommendations, but rather as illustrations of the effects of different kinds of fleet reduction</u>. In chapter 4 we discuss the effects of the 2002 in-season shelf closures and a permit-stacking scenario in the trawl fleet, as well as outline other potential policy applications of the GFR framework. The analysis is a static comparison to the 2000 base. In other words, in each scenario we remove vessels based on a set of criteria. The immediate effect on coastal communities is to diminish revenues and landings associated with those vessels. Since total landings are a function of allowable harvest limits, which we assume stay constant in our analysis, a redistribution of landings and revenues along the coast takes place. In other words, vessels remaining in the fleet get to harvest the difference between total harvest limits and what they landed before the reduction—essentially absorbing the landings formerly made by the exiting vessels. Correspondingly, the income and other community impacts associated with these landings shift from vessels and ports eliminated in each scenario to those remaining. In economic theory this is frequently referred to as a zero-sum game. There may also be gains from decreased costs due to less competition, and other effects. However, in the absence of well-specified models of the economic behavior of the fleet,[8] we opted for a conceptually rather simplistic analysis rather than introduce further assumptions.

The scenario results are first-order effects of a capacity reduction, and are derived using economic impact analysis that is routinely conducted in natural resource management, including fisheries. Economic impact analysis measures changes in income and employment resulting from management alternatives, <u>before</u> the system adjusts and mitigating effects come into force. In other words, it is only an approximation of what would happen, and only for the short term. Given the trends in the fishery, it stands to reason that over time the harvest limits would be reduced or increased (depending on the effectiveness of rebuilding measures). In the medium to long term, therefore, the "extra" landings accruing to the remainder of the fleet would likely fluctuate. The remaining vessels also stands to gain from reduced costs of competition, and from a comparatively larger share of the overall harvest allocation. Thus the immediate impacts are <u>not</u> the ultimate outcome a capacity reduction. They do, however, indicate the direction and quality of change in different communities.

Vessels remaining in the fleet are better off, since they compete with fewer boats for the total allowable catch. Their trip limits increase, and they bring in more landings and revenues into their port—presumably up to the total of coast-wide landings and revenues from groundfish in 2000. The difference between the "before" and "after" levels of landings and revenues, therefore, accrues to vessels remaining in the fleet. Indeed, to the extent that the remainder of the fleet is successfully managed to achieve stock rebuilding objectives, total allowable catches may even increase again. Those ports associated with vessels removed from the fleet, however, experience a corresponding decline in landings and revenues. For them the "after" effect of our various scenarios may be permanent, and can be interpreted as a cost associated with a fleet reduction measure. For all scenarios, we discuss before and after landings, revenues, and number and diversity of vessels remaining in each port afterwards, plus a number of considerations about community impacts.

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[8] Some very promising research on fleet behavior, including on where and when to fish, is being conducted by Mike Dalton at California State University, Monterey Bay.

3. Results from the numerical fleet reduction scenarios

In this chapter, we consider four hypothetical ways of reducing the groundfish fleet. These scenarios all follow the same, numerical, logic: various proportions of vessels in excess of those "needed" according to the capacity utilization estimates derived in chapter 2 above are eliminated from the distribution. Landings, ex vessel revenues, incomes, and fleet composition after each such reduction is then compared to the 2000 base year. The analysis is a static comparison of the 2000 "before" and the post-reduction "after" status of the fleet. It is important to note that these scenarios do not reflect any actual policy choices—we deliberately chose numerical ways of "slicing and dicing" the fleet to illustrate the GFR framework. Other scenarios could be developed for the purpose of evaluating different fleet reduction options, for example the proposed trawl buyback.

Several important caveats apply. Firstly, the analysis is static; in the absence of detailed behavioral models of how the fishing fleet reacts to fleet changes—or, for that matter, other determinants like weather, environmental change or the normal suite of regulations—it is impossible to predict any adaptive response. Secondly, therefore, these numerical scenarios are <u>not</u> intended as viable policy alternatives *per se*. Rather, they illustrate the kinds of questions that can be examined in the GFR framework. To the extent that stakeholders in the fishery can agree on first order approximations of their adaptive behavior, even the static model can be used to assess policy options. We illustrate this in the next chapter, where we simulate the effects of the 2002 in-season shelf closure and of a permit stacking scheme in the LE trawl fleet based on certain assumptions. By contrast, the numerical reductions do not hinge on any assumptions about behavior. They are properly interpreted as approximations of the effects of removing varying types and numbers of vessels from the fleet and illustrate the relative distributional effect from exiting vessels to those remaining. The coast-wide summary results we present indicate the order of magnitude of income foregone by vessels leaving the fleet, which is what would presumably serve as the basis for a policy debate about compensatory or mitigation measures. Given that the total allowable catch would not necessarily change, it—and the associated income—accrues to fewer vessels remaining after a reduction.

In the following section we describe the four numerical scenarios. In section 3.2 we discuss the framework we used for the economic analysis of the reduction scenarios, and describe how we integrate it with other considerations of community impacts. Section 3.3 contains the results from the four numerical scenarios, summarized for the entire coast; the final section, 3.4., illustrates the different effects these scenarios have on different communities, using the examples of Newport and Port Orford. Information on additional communities can be found on the project website, at www.ecotrust.org/gfr, or can be requested from the principal investigator.

3.1. Description of numerical reduction scenarios

Using the capacity estimates from chapter 2 above, we consider four numerical scenarios for reducing the 2000 fleet capacity:

a) by the total number of vessels in excess of those needed to harvest the 2000 allowable catch,
b) by 50% in each sector at random,
c) by 50% in each sector while preserving fleet diversity, and
d) by selecting vessels to remain in the fleet that meet minimum ex vessel revenue levels in each sector, respectively.

It is important to note that these numerical manipulations of the data are blind to the political and practical exigencies that would influence a capacity reduction measure in reality. Identifying vessels purely by the capacity estimates derived for each fleet sector is, in all likelihood, <u>not</u> how participants in the fishery and decision-makers would want to go about reducing the fleet, nor should the SSC capacity analysis be construed as suggesting such a course of action. We merely use the existing capacity analysis, adapted to the data available to our project, as a point of departure for our fleet reduction inquiry and to illustrate the GFR framework, which we submit may be useful for assessing any restructuring of the groundfish fleet and indeed other marine management measures.

What these "unrealistic" numerical scenarios illustrate, however, is that different reduction schemes have substantially different effects on different parts of the coast and on fleet diversity (defined here in terms of gear types and vessel size). The scenarios also have different implications for the overall amount of income that is effectively redistributed from those vessels exiting the fleet to those remaining in it,[9] and thus may be useful for

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[9] Again, absent any models or assumptions about who would buy out whom, or other redistribution mechanisms, the GFR analysis only generates estimates of the upper bound of the amount that would be redistributed, and remains silent on how this redistribution would occur.

considering mitigation and compensatory measures to facilitate the transition of coastal communities. More realistic reduction scenarios would consider other criteria for identifying boats to leave the fleet, notably their willingness and readiness to exit, past landings and/or revenues, the number and diversity of fisheries in which vessels participate, or some set of optimal characteristics desired for the remaining fleet—size, profitability, habitat impacts, and so on.

Using the SSC estimates of the number of vessels needed, we asked the question "given the number of vessels needed, what might a capacity reduction look like?" The four scenarios are our answers to that question, and are intended to illustrate the kinds of effects on the different fleet sectors one might expect under various management objectives. Given the number-of-vessels-needed benchmark, we devised four different ways of reducing capacity by selecting the vessels from the corresponding number of vessels <u>not needed</u> in each fleet sector and analyzing the effects of their removal. Again, the overall coast-wide effect of a capacity reduction is that the harvest targets are now caught by fewer boats, whose owners are presumably better off. This entails a redistribution of income along the coast, between vessels that exit and those that stay in the fishery. In other words, landings and ex vessel revenues decline initially by the amounts associated with the eliminated vessels. This has income impacts on each port affected, and also indicates the magnitude of the redistributive effect of a fleet restructuring. Other effects include changes in the fleet composition and the types of fishing gears used to target groundfish. There are also other effects that can only be intimated with the present analysis. For example, depending on the size of and gear types used by the remaining fishing vessels, fishing activity may center on different areas on the fishing grounds than before a reduction. These dynamic and adaptive effects are beyond the scope of the GFR project. Nonetheless, the comparative statics of the scenarios presented here may suggest useful avenues for further inquiry.

Scenario 1: Removing all excess capacity

The first is the most extreme scenario, and captures what would happen if <u>all</u> the unneeded vessels were removed from the fishery and capacity was perfectly matched to the harvest targets at year 2000 levels. In other words, only exactly as many boats remain in the fishery as the SSC analysis found necessary. This obviously exceeds the 50% capacity reduction targets adopted by the PFMC's *Strategic Plan*, and would entail substantially larger reductions in some fleet sectors. While perhaps not politically desirable, we thought it useful to depict this capacity benchmark. Depending on what causes are attributed to the present state of over-capacity in the fleet, the coast-wide effects of this scenario can be thought of an indication of what it would take to rectify past decisions that led to the *status quo*. We eliminated all but the highest producers up to the number of vessels needed in each fleet sector in order to achieve the reduction goal with the <u>minimum number of vessels necessary, given the 2000 harvest levels</u>. In case of the open access (OA) fishery, we follow the SSC report in considering a high and low case with 100 or 50 vessels remaining, respectively (SSC Economics Subcommittee 2000). Based on the overlap of vessels in the LE non-trawl sectors that target sablefish and/or rockfish, we identified 16 vessels that had both sablefish endorsements and appeared to be targeting sablefish exclusively. We assumed that these 16 vessels would fulfill the capacity needs for harvesting sablefish, and thus did not reduce this subsector of the fleet. In the other fishery sectors, this scenario required reductions between 55% (LE trawl) and 93% (OA, low capacity utilization case).

Scenario 2: Reducing capacity by 50% at random in each fleet sector

This scenario is an apolitical version of the PFMC goal articulated in the *Strategic Plan*. Since the PFMC has yet to identify the mechanism for removing 50% of the capacity in each sector, we picked vessels at random. Clearly the method for identifying vessels has repercussions on the composition of the remaining fleet, which the random choice ignores. Given the considerably different capacity utilization rates across the fleet, this has the effect of pegging the reduction to current capacity rather than to what is needed for harvesting the allowed catch. In the sablefish-exclusive subsector that we identified, for example, this scenario results in removing half of the vessels deemed needed. In this scenario, we assigned numbers to vessels and picked them at random (using computer software designed for this purpose) until the halfway mark in each sector was achieved.

Scenario 3: Removing 50% of vessels in each size class within each fleet sector

With this scenario we tried to approximate the goal articulated in the *Strategic Plan* of preserving fleet diversity. The idea is to have vessels of all sizes and gear types remain in the fishery in order to maintain a varied production base and different kinds of fishing activities along the coast. It is not clear how this will be accomplished in practice. As a first approximation to maintaining fleet diversity, we used vessel length as an indicator of diversity, since this seems to fit at least the colloquial interpretation of fleet diversity and the distinction people along the coast make between "big" and "small" boats. To the extent that the fleet sectors are characterized by different gear types, it would be equally possible to distinguish between the kinds of gears used, or a combination of factors. In this scenario, we removed 50% of all vessels in each fleet sector by removing the low producers in each size class up to half of that class. The remainder of the fleet thus represents the high producers in each vessel size class, and each fleet sector has the same proportion of large and small vessels as before the reduction exercise.

Scenario 4: Reducing capacity in each sector while preserving economic viability

In the fourth and final scenario, we consider a different kind of capacity reduction logic. Rather than using the capacity estimates for determining how many vessels exit the fleet, we explored another often-cited goal for capacity reductions: to make the remainder of the fleet more economically viable. This would suggest that vessels that currently manage to make a living in the fishery stay in, irrespective of whether they are needed or not in numerical terms. Essentially this presumes that people can make a living in the fishery regardless of whether capacity is matched to the harvest targets.

Arguably this is the most subjective of our scenarios, since the definition of "making a living" differs from person to person, and from vessel to vessel. From conversations with fishermen, however, it seems that there are shared notions about the level of landings or revenues that distinguishes fulltime fishermen from those making a part time or occasional effort. Certainly the adequate maintenance and upkeep of vessels requires a certain level of income. Lacking comprehensive cost-earnings data, it was not feasible to determine the appropriate levels of revenues for each fleet sector statistically. Instead, we made some educated guesses based on marked "kinks" in the distribution of ex vessel revenues in each fleet sector. The analysis could easily be rerun using other specifications.

We eliminated from the fleet all vessels that did not achieve a minimum level of revenues. These cut-off points were, respectively,

- Ex vessel revenues greater than $50,000 for vessels in the LE trawl sector;
- Greater than $10,000 in the LE non-trawl/non-sablefish sector;
- Greater than $20,000 in the sablefish-exclusive sector;
- And greater than $5,000 in the open access fishery.

In other words, for a vessel to remain in, e.g., the LE trawl sector, it had to have recorded at least $50,000 in groundfish ex vessel revenues in 2000. It is important to note that our data only contain groundfish landings, so we are not considering revenues generated from participating in other fisheries, e.g. crab or salmon. We are only considering groundfish-related revenues and use these four figures as benchmarks for "making a living" in each sector. Again, these values are *ad hoc* and could be changed to reflect other assumptions about the economic realities of the various fishery sectors.

Before presenting the results from these four numerical scenarios, we turn to the economic and community analysis we conducted in the GFR project.

3.2. Assessing the impacts on coastal communities

Whether planned or by attrition, any rationalization of the fleet will have both immediate and less immediate impacts on coastal communities. The Oregon Coastal Zone Management Association likens the groundfish transition to the structural changes affecting the logging industry since the late 1980s in the wake of environmental legislation and market forces (Oregon Coastal Zone Management Association 2002). While the transition will no doubt be painful, recent fishery management measures can lead towards recovery of depleted species, and deliberate planning may help mitigate the adverse effects of the fleet rationalization on communities. As a first step in anticipating the likely changes, we have compiled economic, demographic and other information about coastal communities that we hope will be useful in planning for the transition.

Before outlining the economic model used for assessing immediate income impacts of the fleet reduction scenarios considered in the GFR project, as well as the components of a broader community analysis, it is important to consider the context for community analysis. The law requires that the people and places that stand to be affected by policy measures be considered. In the case of fishery management, National Standard 8 of the Magnuson Stevens Fishery Conservation and Management Act of 1996 (a.k.a. The Sustainable Fisheries Act) requires that

> “Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to (A) provide for the sustained participation of such communities, and (B) to the extent practicable, minimize adverse economic impacts on such communities” (Sec. 301, Magnuson Stevens Act 1996).

Typically, community impacts enter into the regulatory process in the form of environmental impact statements, regulatory impact analysis and other assessments required under the Magnuson Stevens Act and other legislation. Various forms of quantitative and qualitative analysis are routinely used in this stage of policy making, ranging from a full-fledged cost-benefit analysis of policy alternatives to qualitative statements about expected effects (Pautzke 2000). A review of recent groundfish regulations suggests that the accepted format of community analysis mainly entails comparisons of gross ex vessel revenues and landings, occasionally augmented by considerations of income impacts using a regional economic impact model developed for the fishery management council (described in SSC Economics Subcommittee 1994).

We use the current version of PFMC’s Fishery Economic Assessment Model (FEAM), to derive income impacts of our reduction scenarios. The FEAM is described in more detail in the next section. Essentially it translates changes in landings due to regulatory measures into the concomitant changes in income for the various communities along the coast. Changes in harvesters’ and processors’ incomes, however, are only part of the picture of the impacts on coastal communities. In section 3.2.2. below, therefore, we describe some additional metrics of change in communities that we adapted for the purposes of the GFR project.

3.2.1. Economic impacts

The effect of fleet reductions is effectively a zero-sum game: the declines in landings and revenues in some ports are matched by increases in landings and revenues in other ports, depending on the distribution of the remaining fleet. In the GFR analysis, however, we focus our attention on an earlier stage—right after the removal of the excess vessels, before the remaining vessels have the opportunity to harvest the freed up allocation. Effectively, our scenarios consider the impacts on landing ports of a number of vessels disappearing, as if they had sunk: the initial, local effect is a loss in landings and concomitant revenues. These declines will translate in reduced fish sales to processors, and result in lower incomes for fishing families and processors, as well as—in a derivative effect—for marine suppliers and other fishing-related businesses. In addition to landings and ex vessel revenues, we focus on the income impacts in the presentation of the scenario results, since these give a first order estimate of the effects likely to be felt along the coast.

The FEAM provides a mechanism for estimating some of the income impacts associated with changes in groundfish landings. The FEAM belongs to a class of regional input-output models that treat the economic activity in a region as a set of interconnected sectors. It is routinely used on the coast to describe the income generated from various fishing activities (see for example the recent report by the Oregon Coastal Zone Management Association 2002). Each dollar generated in one sector has a “multiplier effect” because it generates economic activity in other sectors. For example, fish are landed and the vessel is paid a price per pound for its catch, generating the ex vessel revenue. Out of this revenue, crew shares, maintenance and moorage costs and other expenses are paid, which in turn generates personal income, and revenues for the port district and other marine-related businesses. The FEAM estimates these effects for the two primary sectors affected by fishing activity, i.e., harvesters (fishermen and their families) and processors. The currently available version of FEAM is based on a 1996 version of a national input-output model that generates lists of coefficients describing the relationships between various economic sectors. These have been adapted to a regional, fisheries-specific model, i.e. the FEAM, which is then used to generate a set of multipliers for various fisheries and their harvesting and processing sectors. These model outputs have been summarized in a set of spreadsheets available from the PFMC (Davis 1998), which can readily be integrated into the GFR framework.

We consider the economic impacts of each scenario for communities and the entire coast. Typically, for each pound in landings there are between $1 and $4 in income impacts (Davis 1998), depending on the value of species and the kind of processing they undergo. For example, higher value species like sablefish have a proportionately larger impact than low-value, high-volume species like whiting. The FEAM only considers a fraction of all groundfish species targeted and some regionally important market sectors, such as live rockfish, are not modeled at all. Since the FEAM only considers a subset of groundfish species ("sablefish", "thornyheads", "soles/flounders", "other rockfish and perch" and "whiting"), we reassigned the species contained in our landings data into the appropriate FEAM groups before applying the local impact multipliers derived in FEAM. We then estimated the impacts of each reduction scenario on each port (by port group).[10] The port impacts are then converted into statewide impacts, which in turn are converted into coast-wide impacts. In other words, each pound of groundfish landed in a port has local and coast-wide income impacts. Detailed results for all coastal communities can be found on the project website, www.ecotrust.org/gfr. In the interest of brevity, we only report the coast-wide results in section 3.3 below.

Distributional effects. Again, it is important to note that these immediate income impacts are not permanent but have differential effects, depending on whether the vessels in a port are among those removed or remaining in the fleet. In section 3.3 we compare the four scenarios in terms of their coast-wide economic impacts. Since the overall landings and associated income does not change under our assumption of constant harvest targets, the difference between the base and each scenario essentially constitutes the amount of income that will be reallocated from the vessels departing the fishery to those remaining in it. Each scenario is associated with a change in landings, and so applying the relevant multipliers to the amount of the change generates an initial estimate of the income impact. It is important to note that this impact analysis is static in nature, i.e. it compares a "before" state with an "after" state under the assumption that everything else remains equal, notably that fishing behavior does not change in response to regulatory changes. Clearly that assumption is only realistic in the very short term, before fishermen and processors adapt to management measures. In terms of the fleet restructuring precipitated by capacity reductions, the major response is that vessels remaining in the fleet harvest the allocations formerly harvested by the vessels exiting, up to the level of the coast-wide total. So in this sense, the income impacts give an initial indication of the order of magnitude of the groundfish related income that will be redistributed along the coast.

The dynamics of fleet restructuring over time are not modeled in this project. How individuals or businesses, communities and the whole coast will adjust to profound structural changes is as important to the sustainable transition of the fishery as it is elusive. Typically, these responses are approximated by postulating some likely responses and estimating their impacts. This method is routinely used in council processes, drawing upon the expertise of fishing industry representatives and aided by regional input-output models such as the FEAM, which in turn are widely used in regulatory analyses for natural resources management to gauge the immediate impact of a proposed policy measure. A longer-term research need is to improve our dynamic understanding of the fishery and how it relates to ecological, social and economic systems. One plausible direction might be to develop dynamic models for considering alternatives about the fleet size under a set of constraints such as maximizing income, minimizing habitat effects, or increasing ecological and social resilience (Lawson and Gooday 2001; Walker, Carpenter et al. 2002).

3.2.2. Community analysis

There is, of course, more to fishing communities than landings, revenues, and the associated income. The culture of fishing, for example, is clearly important to the social cohesion of coastal communities (The H. John Heinz III Center for Science Economics and the Environment 2000). Therefore a central aspect of the GFR project was the collection and integration of other socioeconomic data into the analysis. The ultimate goal is to develop a measure of community health and resilience in the face of changes in the fishery, potentially in a joint ecological-socioeconomic model we are exploring with academic partners. For the purposes of this project, however, we focused on identifying and integrating a variety of community-relevant data into the GFR framework. We approach this both through harvesting the fishery-dependent data in ways that we think are relevant for understanding how communities will make the transition, and through a range of other data from sources like the United States Census Bureau.

In terms of the fishery-dependent data, we are using length as an indicator of vessel size and, together with gear types used, of fleet diversity—the preservation of which is important to many people and organizations on the coast. Thus we consider the "before" and "after" make-up of the groundfish fleet in each port as well as coast-wide. Clearly, different reduction scenarios will have very different effects on the composition of the fleet, and this may be an important consideration in the design and implementation of fleet reduction measures. The GFR framework

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[10] Detailed results for each port or landing place reported on fish tickets is available in suitably aggregated formats. In fact, it is one of the goals of the GFR projects that communities use the information pertaining to them, which can be provided in a variety of database and GIS formats.

makes visible these effects on fleet diversity of different scenarios, and allows communities and sectors of the fleet to evaluate how they will likely be affected.

Ideally, we would consider the fleet not in terms of its landings and ex vessel revenues, but in terms of the income net of operating costs and other outlays to gain a measure of the profitability of the fleet or individual vessels. The FEAM estimates are based on fairly old cost-earnings information, which has furthermore not been replicated systematically along the entire coast. A recent cost-earnings survey of the groundfish fleet was completed by the PSMFC (2001), but it suffers from low return rates. This lack of up-to-date information on costs and earnings is one of the socioeconomic data shortfalls diagnosed by the PFMC in its *West Coast Economic Data Plan* (2000). Over the course of the GFR project, we collected a small, non-representative sample of cost, earnings, and operational information on different kinds of fishing vessels to gain a better understanding of the fishery, which we present in the community case studies in section 3.4 below. This remains an area for further research.

There are a number of efforts under way to assemble more comprehensive community information for the coast, notably the communities documents under preparation at the PFMC and PSMFC (PFMC 1999; Langdon-Pollock 2002), as well as the more comprehensive analysis made necessary by the EIS for the 2003 harvest measures (PFMC 2002). The GFR project database contains a literature section that catalogues these and other publications (for example, Gilden 1999; Radtke and Davis 2000; Gilden and Conway 2002; Oregon Coastal Zone Management Association 2002), which we cross-referenced with the ports and regions to which they pertain. Using a port ID, the GFR database can then be queried to generate all the literature linked to a particular port. We have also mined some of this information directly, adding it to the description of ports. Since this is again linked through data categories, it is possible to relate published information about ports with new information we have collected, and with the rest of the GFR database. This makes it convenient and, as we hope, useful to communities and others on the coast to tap into the collective research that has been conducted along the coast without having to undertake the literature review anew each time.

We also augmented the GFR framework with census and regional economic statistics available from federal agencies. These provide information on the demographic make-up of communities, and contain metrics of important community aspects such as educational attainment, county income, home ownership and so on. While it is at this stage not possible to link this information directly to the fishing fleet, it does allow comparisons, e.g., of the groundfish-related income in a port or group of ports to the overall income in the county where they are located. Similarly, while changes in census statistics cannot be linked to changes in the fishery, comparing data on, e.g., poverty, across different ports provides important context for considering fishery management measures. For example, reducing the fleet in a port with a higher rate of poverty or unemployment may have disproportionately larger effects than reducing the fleet in a well-diversified community. The GFR project barely begins to consider all the possible socioeconomic factors, but does combine and present them in one integrated framework that we hope will be of use for future analyses.

Ultimately the goal is to develop measures of community health and adaptability to change, such as an index of community resilience outlined in the PSMFC's community analysis (Langdon-Pollock 2002). Measurable aspects of location, demographics and economy such as commercial and marine infrastructure, distance from major cities or from other ports, number and diversity of local businesses could conceivably be constructed into one or more indices, appropriate levels of which may suggest communities more or less resilient to change. This remains an area for further research, and the community analysis presented here remains largely descriptive.

3.3. Summary of results from numerical scenarios

We now turn to the presentation of the results from the four numerical fleet reduction scenarios. To recapitulate, the four scenarios were:

1) Reducing all excess capacity—given the estimates of how many vessels are needed to harvest the 2000 harvest targets, we consider what the fishery would look like if only the highest producing vessels up to the level needed were harvesting;
2) Reducing capacity by 50% in each sector—this is the PFMC priority articulated in the *Strategic Plan*. Since there was no particular mechanism identified, we randomly selected half of the vessels in each sector;

3) Reducing capacity by 50% in each sector while preserving fleet diversity—this takes into consideration the *Strategic Plan* goal to preserve fleet diversity, which we interpret here as preserving the proportions of different vessel lengths present in each fleet sector in the base year, 2000; and
4) Reducing capacity in each sector while preserving economic viability—defined by the following minimum groundfish-related ex vessel revenue levels: LE trawl > $50,000; LE non-trawl/non-sable > $10,000; LE non-trawl/sable > $20,000; and OA > $5,000. In other words, for a vessel to remain in, e.g., the LE trawl sector, it had to have recorded at least $50,000 groundfish ex vessel revenues in the base year 2000.

The results of the four numeric reduction scenarios are summarized in Table 2 below. We focus on two central aspects of fleet reductions: 1) the landings, ex vessel revenues and associated income that are redistributed from the vessels exiting the fishery to the remainder of the fleet, and 2) the effects on overall size and composition of the fleet. Obviously there are many other issues that can be explored with the GFR framework, which we reserve for future research and presentation in order to keep this report to a manageable size. In particular, we only compare the coast-wide results of the scenarios. It is possible to explore the effects down to the level of individual ports with the GFR framework, which can be accessed on-line at www.ecotrust.org/gfr.

It is apparent that even at the coast-wide scale, different reduction schemes have substantially different effects on the fleet. There are three notable results. Firstly, the effects of removing all excess capacity and removing 50% of capacity are remarkably similar. Recall that scenario 1 removes the entire excess capacity, and only the numbers of vessels per fleet sector needed to harvest the 2000 targets remain in the fleet. The overall effect is comparable to that of a 50% capacity reduction, in terms of the initial reductions landings and revenues and the amount of income effectively redistributed from the exiting vessels to those remaining. Indeed, since scenario 1 selected for the highest producers, this occurs at a smaller initial decline in ex vessel revenues than in the random selection process of scenario 2. To the extent that income impacts can be thought of as the "cost" of capacity reduction,[11] a coast-wide reduction of fleet capacity can thus be achieved for between $70 and 75 million. Coast-wide, the effect on fleet composition is most pronounced when removing all excess capacity to the low level of only 50 distinct open access vessels. Not surprisingly, the share of the smallest vessels, i.e. those less than 35 feet in length (VS1) drops.

Secondly, selecting for a diverse remainder of the fleet imposes significantly lower costs (in terms of the income redistributed) on the coast. In other words, reducing fleet capacity by 50% in each vessel size class in each sector achieves the same reduction of vessels, but at a smaller redistributive effect. Also, consider the meaning of the multiplier: each pound landed has an income "footprint". The fleet remaining after scenario 3 has a larger income footprint than the other scenarios. In other words, each pound caught generates more income than the same pound caught in a differently configured fleet. The total amount of income redistributed from the vessels exiting to those remaining is around $50 million. Since the number and sizes of vessels remaining in the fleet have a different geographic distribution than in scenarios 1 and 2, the effects of this scenario are also distributed differently. In comparison to the random reduction of 50% in each fleet sector, the overall fleet composition remains the same, but with more vessel instances (1464 versus 1212) and thus with more associated income and jobs.

Finally, scenario 4 suggests that economic viability may be a useful consideration in designing capacity reduction measures. Recall that this scenario is based on some explicit and not entirely realistic assumptions about levels of ex vessel revenues derived from groundfish needed to "make a living". Since these economic constraints can be translated into vessels to select for removal from the fleet, there are clear effects on the size, composition and distribution of the remaining fleet. It would be interesting to examine the economic viability criterion in conjunction with numeric reduction targets. Interestingly, the particular set of economic viability criteria we chose had the effect of increasing the share of vessels in the 60 – 80 foot range (VS 3). This further illustrates the fleet composition effects of fleet reductions, which can be explicitly considered in the GFR framework.

The local implications of these scenarios differ along the coast. Figure 5 shows the amount of income generated by fishing in 2000 and in each of the four reduction scenarios, aggregated by port group from South to North. To the right of the base column for each port group are the income impacts of each scenario, i.e. the amount of harvester

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[11] Technically, income impacts cannot be considered the costs of a policy measures, although the two are often equated for convenience. Firstly, there are mitigating effects: the income generated by the fleet that has been removed, will, to a large extent, be replaced by the remaining fleet. One would have to compute the net change in consumer and producer surplus resulting from the measure—the net present value of this stream constitutes the actual cost of the fleet reduction. In the absence of fully specified supply and demand curves for West Coast fisheries and their products, it would be difficult to conduct a proper cost-benefit assessment of fleet reduction measures.

and processor income generated by the vessels remaining after the reduction. As is evident from the graph, some scenarios (notably the economic viability one) result in some ports maintaining income levels at pre-reduction levels, e.g. the Monterey Bay area or ports in the Eureka area. Also, the aggregate income effects suggest that economic viability concerns may be more important in some ports than others. For example, Eureka, Coos Bay and Newport areas fare better in terms of income associated from landings by the remainder of the fleet under the economic viability scenario than the fleet diversity one, whereas there is little difference for Astoria or the Northern Puget Sound area. Recall, however, that the economic viability criteria were set rather lower than realistic and are thus likely to retain too many vessels in the fleet.

TABLE 2: SUMMARY OF FLEET REDUCTION SCENARIOS

		Initial value of fleet remaining after capacity reduction				
	base (2000)	scenario 1 (with 50 OA remaining)	scenario 1 (with 100 OA remaining)	scenario 2 (random)	scenario 3 (diversity)	scenario 4 (viability)
coastwide landings (pounds)	272,390,187	123,131,582	123,772,655	132,480,150	153,934,597	181,145,380
change from base		-55%	-55%	-51%	-43%	-33%
Coastwide revenues	$62,141,810	$36,127,210	$37,274,029	$30,509,611	$43,664,904	$47,744,959
change from base		-42%	-40%	-51%	-30%	-23%
coastwide income impacts	$138,961,151	$63,832,802	$65,180,144	$68,244,427	$90,997,105	$101,667,573
Income redistributed (change from base)	$0	$75,128,349	$73,781,007	$70,716,723	$47,964,046	$37,293,578
income change	0%	-54%	-53%	-51%	-35%	-27%
implied multiplier ($/pound)	0.51	0.52	0.53	0.52	0.59	0.56
number of vessels*	2427	986	1011	1212	1464	1499
LE trawl	642	344	344	311	378	553
LE non-trawl, non sablefish	422	143	143	210	255	152
LE sablefish exclusive	25	25	25	11	17	21
Open Access	1339	174	499	680	814	773
fleet diversity (%) of total fleet						
VS1	39%	26%	37%	40%	39%	38%
VS2	37%	29%	27%	37%	36%	32%
VS3	18%	35%	28%	17%	17%	23%
VS4	5%	9%	7%	3%	6%	6%
VS5	0%	0%	0%	0%	0%	0%
VS6	1%	1%	1%	3%	2%	1%

* Note: Revenue, landings and income estimates are based on the unique vessels identified in the capacity calculation. Each vessel, however, has multiple instances as a function of making landings in multiple ports and using multiple gears over the course of a year. The numbers reported in this table report these per port “vessel-gear instances”. So in the base year, there were, for example, 642 gear-port combinations of the 244 vessels in the LE trawl sector.

It is also important to notice that our analysis assumes that the total possible harvest remains unchanged, i.e., that there is no net reduction in the harvest allocations in conjunction with a fleet reduction. Specifically, for our 2000 baseline this means that the remainder of the fleet is catching the same total poundage as the fleet prior to the reductions. In light of the increasingly more stringent measures made necessary by rebuilding plans and other considerations, there may be a concomitant reduction of the overall harvest. In that case, there would be income impacts in addition to the redistribution effect between exiting and remaining vessels we consider here.

FIGURE 5: SUMMARY OF SCENARIO INCOME IMPACTS ALONG THE COAST

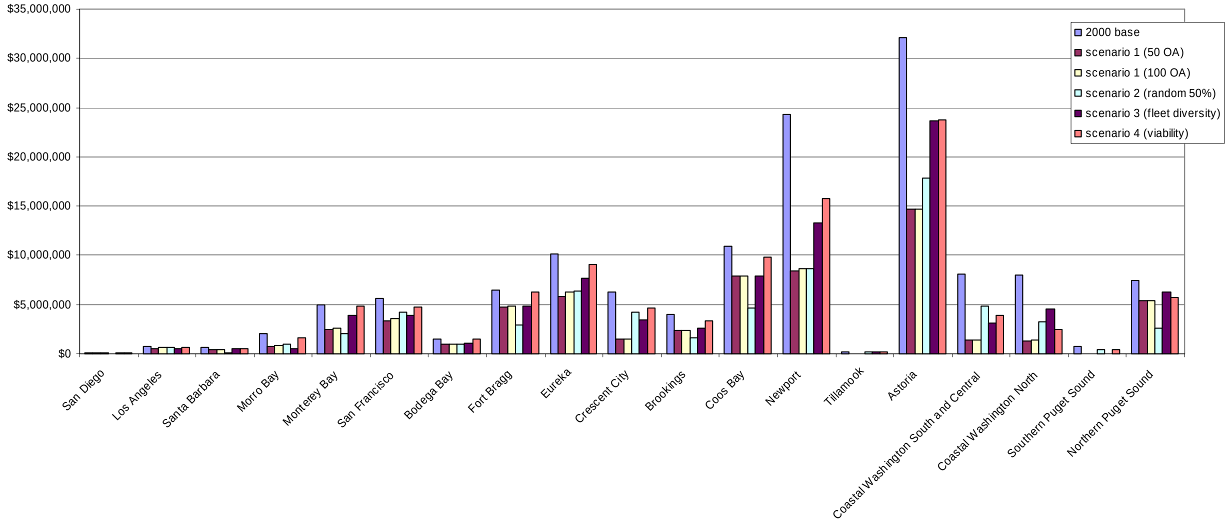


Figure 5 is properly interpreted as the level of income generated in each port group immediately after each reduction scenario is implemented, by the vessels that were making landings in those ports before. The dynamic response of the fishery to each scenario cannot be inferred. In particular, it is not clear how the landings formerly accruing to the vessels exiting the fishery would be allocated among the remainder of the fleet. This offsetting effect on port-reduction income levels could be approximated by making some assumptions about the remainder of the fleet. For example, one could reasonably assume that vessels remaining in the fleet would harvest the now "surplus" allocation according to the same proportions as they did before. Alternatively, one could impose some new allocation rules such as gear requirement on the remainder of the fleet.

It is also important to note that our analysis assumes that processors and prices would remain at 2000 levels. Both the processing sector's internal dynamics and its likely response to a fleet rationalization make it likely, however, that there would be changes that may offset some of the income effects observed in our scenarios.

The fleet composition effects summarized for the entire coast in Table 3 are considerably more pronounced at the local level, where some scenarios eliminate entire vessel size and gear classes in some ports. Results for individual ports are listed on the project website, at www.ecotrust.org/gfr.

3.4. Effects of fleet reductions on different communities: the example of Newport and Port Orford

In order to illustrate the effects of fleet reductions on different communities, we discuss in this section the outcome of the four numeric scenarios on Newport and Port Orford. In subsequent chapters, we will also frequently refer to these communities to illustrate additional results and applications of the GFR framework. Both are fishing communities located in Oregon, and illustrate some of the differential effects of fleet restructuring on different kinds of communities. Although both have prominent fishing fleets, neither relies on fishing for a significant share of income generated—at least not at the county level considered here. Newport is a larger city with a diversified economic base. Its fishing fleet includes all kinds of gear-types and vessel sizes, targets groundfish and the full complement of other commercially significant species on the West Coast. Furthermore, the fleet operates both in Oregon waters and as far away as Southern California, and a significant number of boats are part of the distant water fleet that operates seasonally in Alaska. By contrast, Port Orford is a small community with greater relative dependence on fishing. Its fleet is comparatively homogenous and consists of a moderate number of medium-sized vessels that mostly target rockfish and operate in day trips from port.

Not surprisingly, the different reduction scenarios we analyzed in the GFR project have markedly different effects on Newport and Port Orford. This illustrates the case for considering the effects of fleet reductions from different communities' perspectives, and for taking regional and community differences into account in the design of any fleet restructuring. In the following two sections, we discuss both the numerical results for the two ports, and give a synopsis of other statistics and qualitative information contained in the GFR database. While the scenario summaries for the remainder of West Coast ports are listed on the project website, www.ecotrust.org/gfr, similar narrative profiles for communities can be requested from the principal investigator.

Below we discuss some, but by no means all, of the fisheries and other features of both communities. In general, the data coverage is too thin to infer causal relationships between changes in the fishery and any of the social and economic characteristics. Considerably more research would be needed to address such linkages.

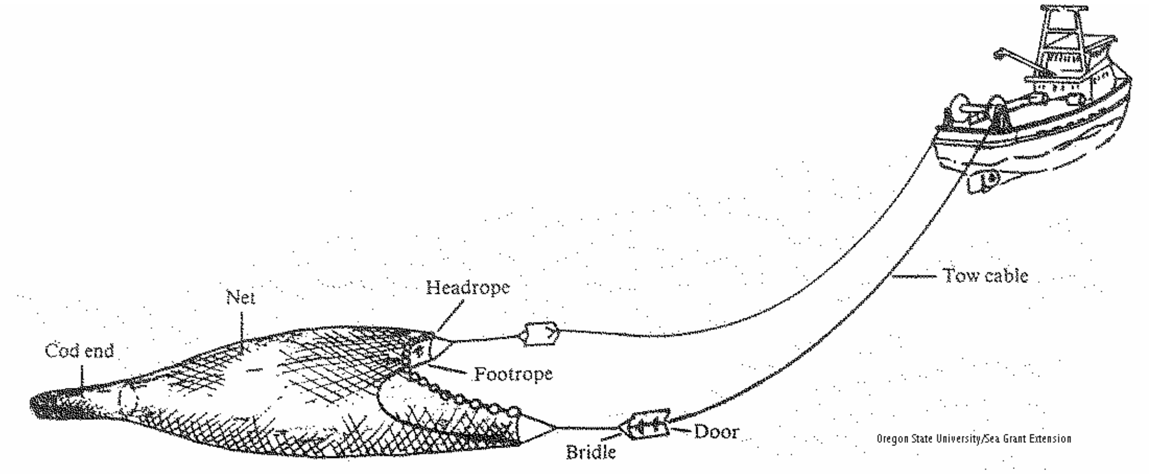
3.4.1. Newport

Newport is located in Lincoln County, and is one of the biggest fishing ports on the West Coast. It houses a large, diverse fleet comprising trawlers, shrimpers, salmon trollers and longliners. The fleet, especially larger vessels, operates both off the coast and in distant waters (Alaska). The distant water fleet is of considerable importance to the port, accounting for 10-15% of vessels and concomitant shares of moorage revenues, marine supplier business, and boat work (interview 45). Groundfish accounted for 9% of all fish landed in 2000 (Oregon Coastal Zone Management Association 2002, p. IV-9), or approximately 85 million pounds that generated $24 million in income for local harvesters and processors. Groundfish-related income accounted for almost 50% of total fishery income generated in the Newport area, and most of this was due to whiting (Stoebig and Carter 2001, p. 10). Total fishery income in Newport, in turn, was estimated at $45 million for the 2000-2001 fishing season (PFMC 2003, table 3.3-48, p. 3-160).

There is a significant amount of fishing-related infrastructure and businesses in Newport, including net makers, marine suppliers, boat yards, and cold storage. Many of these businesses have experienced considerable declines in revenues in recent years, or closed entirely (interviews 117, 126). A local net maker, for example, has experienced a drop decline in business and noted that 20% of clients are behind in their payments (interview 23). As of summer 2002, there were two full-time processors in town, with several other fish buyers operating seasonally (or focusing on other species, notably crab). A recent report by the OZCMA concluded that Newport appears well poised to weather the transition of the groundfish fishery (Oregon Coastal Zone Management Association 2002, p. IV-10), the recent experience of harvesters and processors notwithstanding.

According to census data, the population of Lincoln County increased from 38,889 to 44,479 between 1990 and 2000. During this time, the poverty rate has remained at around 14%, but at least one informant observed that the fishery as at the forefront of a local economic decline that is beginning to affect school services (interview 117). An often-cited study by Oregon Sea Grant found that 23 out of 81 groundfish vessels in Newport were at high risk of failure (Stoebig and Carter 2001, p.12), mostly due to limited opportunities for diversifying into other fisheries (as assessed by the number and types of permits associated with Oregon vessels).

FIGURE 6: BOTTOM TRAWLING



Oregon State University/Sea Grant Extension

In Newport, one common type of vessels used in the groundfish fishery are trawlers in the 60-80 foot range (see Figure 6). In addition to capital costs, operating costs are a key factor in determining the viability of a particular fishing business. Put simply, the amount of fish a vessel is allowed to land each year—as extrapolated from the trip limits set by the council and the average number of trips a vessel is likely to make—translates into revenues that at the least have to cover the costs of fishing before generating income for fishing families. Not surprisingly, these costs can be quite large for larger boats. For example,[12] a 70+' trawler might require $25-50,000 in annual maintenance—repairs to the hull and other structures, gear repairs or replacement, engine and electronic maintenance. In addition, moorage, taxes, insurance and licenses may cost another $30,000 per year, and fuel, ice and provisions each cost $18-25,000/year. In recent years, due to decreasing trip and cumulative limits trawlers have spent considerably fewer days at sea (approximately 120 compared to 165 in 1990), resulting in fewer days in which to catch enough to cover these costs and generate income for crew and skipper. A common coping strategy is to defer maintenance, and—as in the case of the $45,000 trawl nets that used to be replaced every 2-3 years—delay gear replacement (interview 23). Over the same time period, many trawlers have seen the value of their boats and permits decline by 50-80% (interview 11).

3.4.2. Port Orford

Port Orford is located in Curry County, on the Southern coast of Oregon. It is unique among ports on the Oregon coast in that it is not located on a river channel, but rather on an open bay. Vessels homeported there are limited in size, since they have to be hoisted in out of the water by two cranes located on the pier, the bigger of which has a capacity of 50,000 pounds (interview 121). Consequently, the majority of vessels are 36 feet or smaller—34 (77%) out of a 44 total making landings there in our base year, 2000. Groundfish accounted for 40% of total landings in 2000 (Oregon Coastal Zone Management Association 2002, p. IV-18), or approximately 550,000 pounds; other species include (roughly in order of importance) urchin, crab, tuna, and salmon. These groundfish landings generated approximately $670,000 in harvester and processor incomes—illustrating the higher per-pound value of the groundfish species landed here than in Newport. Most of the groundfish landed are sablefish and live rockfish. According to one interviewee, Port Orford accounted for 50% of the state urchin and 80% of live rockfish harvest (interview 41). There were three fish buyers in Port Orford, all of whom transport groundfish to Charleston for processing (interview 121).

There is little fishing related infrastructure in Port Orford. Apart from the pier and the two cranes, there is cold storage and ice to be had at one of the fish plants, and the port sells fuel (interview 41). Vessels tend to go to Brookings or Gold Beach for repairs. Other marine businesses include a tackle store, and there is interest from a dive operator to open a shop at the port (interview 121). The same nearshore reef complex that makes Port Orford a center for the live fish fishery (Oregon Coastal Zone Management Association 2002, p. IV-19), also attracts recreational fishermen and divers (interview 121). Prospects for fishing related tourism may improve with the passing of an ordinance that would allow overnight camping (interview 121).

Between 1990 and 2000, the population of Curry County increased from 19,327 to 21,137, and the poverty level stayed at 12%. Estimates of fishery-related employment vary considerable. According to a port official, there are approximately 325 fishing related jobs in Port Orford alone, or 30% of the population in the voting district (interview 121). By contrast, a recent PFMC document estimates the number of fishery-related jobs in the entire Brookings port group (which includes the larger ports of Brookings, as well as Gold Beach) as 400, with 171 of these dedicated to groundfish. Both the local and the PFMC estimate are considerably higher than comparable statistics from the Regional Economic Information System (Bureau of Economic Analysis (BEA) 2002), and illustrate the relative importance of the fishing for the economic base in Port Orford. Discrepancies such as the employment figures for Port Orford underscore the need for better, locally validated information on key socioeconomic parameters.

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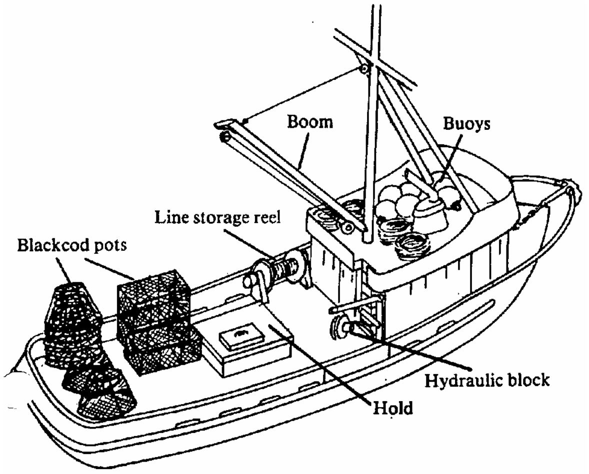
[12] Information is derived from an anonymous questionnaire (GFR 06.01) that a number of fishermen filled out for different groundfish vessels used on the West Coast.

FIGURE 7: FIXED GEAR VESSEL



The smaller, fixed gear vessels characteristic Port Orford are cheaper to maintain and tend to be well diversified—in addition to groundfish, many vessels also target crab, salmon and/or tuna (see Figure 7). For a 32' fixed gear boat, annual maintenance costs may run to almost $30,000. Moorage, taxes, insurance, and license fees may run to an additional $20,000. Fuel costs are approximately $9,000/year, and ice and bait may be close to $7,000 for a fishing season that might be as short as 90 days at sea. Most of those, due to the relatively small range of the Port Orford fleet, are day trips, and highly dependent on weather and current conditions. Recent declines of trip limits, coupled with the bad 2002 crab season, have led to declines of up to 40% in boat income (interview 40).

3.4.3. Comparing baseline information and scenario effects

The four reduction scenarios have somewhat different effects on Newport and Port Orford. This is not least a function of the considerable size difference of the groundfish fishery in both communities—Newport's landings are two orders of magnitude greater than landings made in Port Orford, and in absolute terms, the impacts from the various reduction scenarios are larger, too. Recall the four ways to reduce fleet capacity that we are considering so far:

1) removing <u>all</u> vessels in excess of those needed to harvest the 2000 allowable catch (with 50 and 100 OA vessels remaining, respectively);
2) removing 50% at random in each sector;
3) removing 50% in each sector while preserving fleet diversity, i.e., removing 50% of each size class; and
4) selecting vessels to remain in the fleet that meet minimum ex vessel revenue levels in each sector.

The results are summarized in Table 3 below, and reflect the different natures of the groundfish fishery in the two communities.

TABLE 3: SCENARIO SUMMARIES FOR NEWPORT AND PORT ORFORD

		Initial value of fleet remaining after capacity reduction				
	base (2000)	scenario 1 (with 50 OA remaining)	scenario 1 (with 100 OA remaining)	scenario 2 (random)	scenario 3 (diversity)	scenario 4 (viability)
NEWPORT						
landings (pounds)	85,045,486	42,445,617	42,445,617	22,348,783	43,100,767	52,223,255
change from base		-50%	-50%	-74%	-49%	-39%
revenues	$9,038,817	$6,212,111	$6,212,111	$3,829,695	$5,301,922	$6,174,593
change from base		-31%	-31%	-58%	-41%	-32%

local income	$24,350,948	$8,425,375	$8,621,629	$8,594,141	$13,314,706	$15,729,472
Income redistributed (change from base)		$15,925,573	$15,729,319	$15,756,806	$11,036,242	$8,621,476
income change		-65%	-65%	-65%	-45%	-35%
PORT ORFORD						
landings (pounds)	554,991	235,176	235,176	383,399	371,900	312,296
change from base		-58%	-58%	-31%	-33%	-44%
revenues	$846,066	$385,498	$385,498	$585,155	$603,271	$489,469
change from base		-54%	-54%	-31%	-29%	-42%
local income	$669,982	$250,484	$250,335	$569,094	$429,991	$344,471
Income redistributed (change from base)		$419,498	$419,647	$100,888	$239,991	$325,511
change from base		-63%	-63%	-15%	-36%	-49%

It is interesting to note that the scenario effects vary significantly depending on whether landings, revenues, or income are considered. For example, in Newport both variations of scenario 1 (the removal of all excess capacity) and the diversity scenario lead to 50% reductions in landings. Yet, despite impacting revenues more (41% as opposed to 31%), the diversity scenario results in higher post-reduction incomes to harvesters and processors. This is likely a function of more vessels targeting higher-value species remaining in the fleet in scenario 3. Designing fleet reductions to maintain diversity can therefore mitigate the income impacts. Another important consideration is the question of fleet viability. Even with our simplistic assumptions, treating viability as a fixed minimum level of ex vessel revenues, such considerations may well help identify a strategy that maintains—in this case the highest—pre-reduction levels of income in the community.

As in Newport, the most severe effects in Port Orford take place under the full-removal scenario, which may be an indication of things to come if the restructuring continues by attrition. The fleet does surprisingly well under the random scenario, in which 50% of each fleet sector are removed at random. This may be an artifact of having picked high-value vessels for remaining in the fleet. The next best scenario, in terms of having the least adverse effects on the community, is the diversity scenario, in which the fleet composition in the port is maintained to reflect pre-reduction levels of diversity.

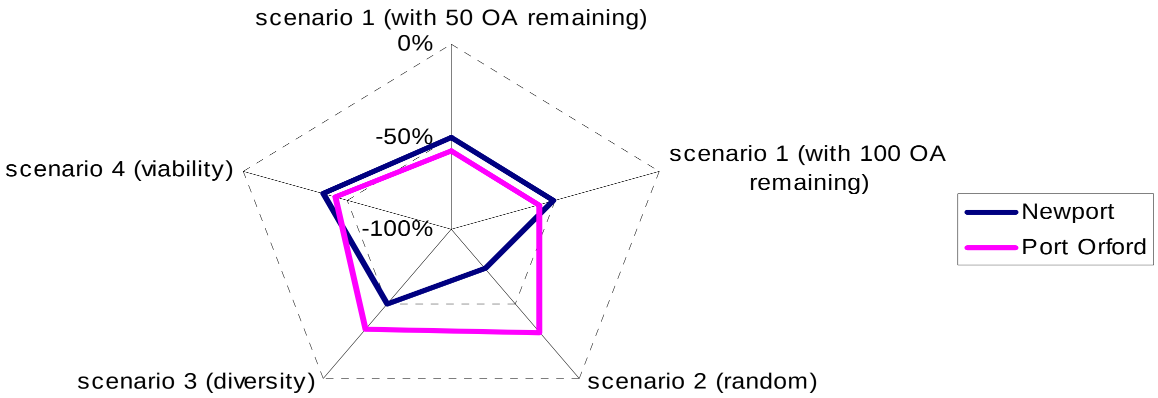
Fleet restructuring is a coast-wide undertaking, and the decision-making process will likely entail balancing the interests of many different communities and local fleets. It is therefore instructive to compare the relative impacts of the reduction scenarios on landings, revenues and income in Newport and Port Orford. What is good for one may not be good for the other, and expectations of relative community wealth post-reduction may be grounds for contention in the fleet restructuring process.

Figure 8 compares relative impacts for each of the three “community wealth” parameters—landings, revenues, and income—for Newport and Port Orford. The x-axis depicts the percentage change from the baseline figures, as summarized in Table 3 above. The closer the “spike” is to the outside of the graph, the smaller the change from the baseline, i.e. the lesser the adverse impacts, and the “better” the scenario.

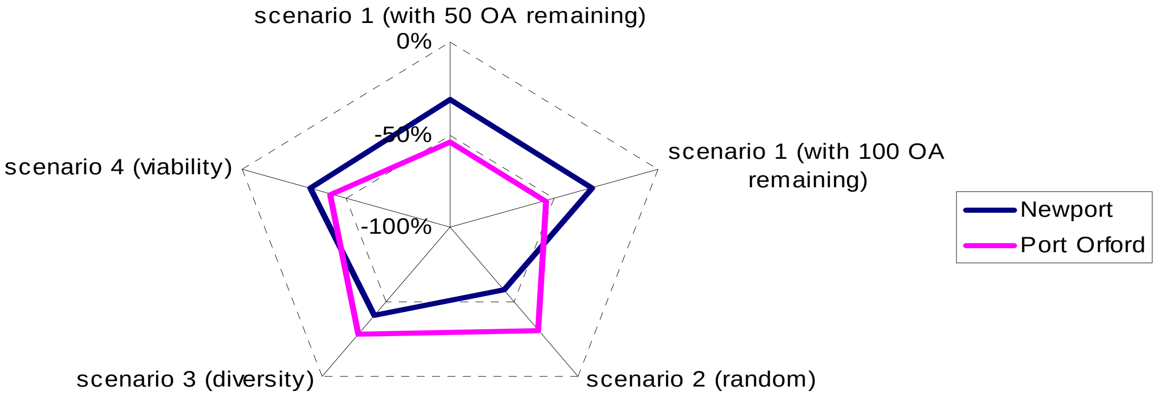
As should be apparent from these graphs, whether fishery participants from Newport and Port Orford can agree on a fleet restructuring scheme that benefits both of them, or at least mitigates impacts on both communities somewhat equitable, will depend on which of the three parameters is considered. For example, in terms of ex vessel revenues, the scenarios that are good for Port Orford (2 and 3) are not as good for Newport, which would tend to do better under the full-excess-capacity removal (scenario 1). If, however, landings are considered, the two ports are much more closely aligned, and scenarios 1 and 4 would appear to be likely candidates for mutual ground. The match is closed in terms of income, where scenario 1 is equally bad for both ports—while the scenario that is best for Port Orford (2) is one of the worst for Newport. If all of the scenarios were to be considered, e.g. in the context of an assessment of different policy alternatives for realizing fleet reductions on the West Coast, then something like the diversity scenario may be a compromise between what is best for Newport, in terms of income, (4) and for Port Orford (2).

FIGURE 8: COMPARATIVE EFFECTS IN NEWPORT AND PORT ORFORD

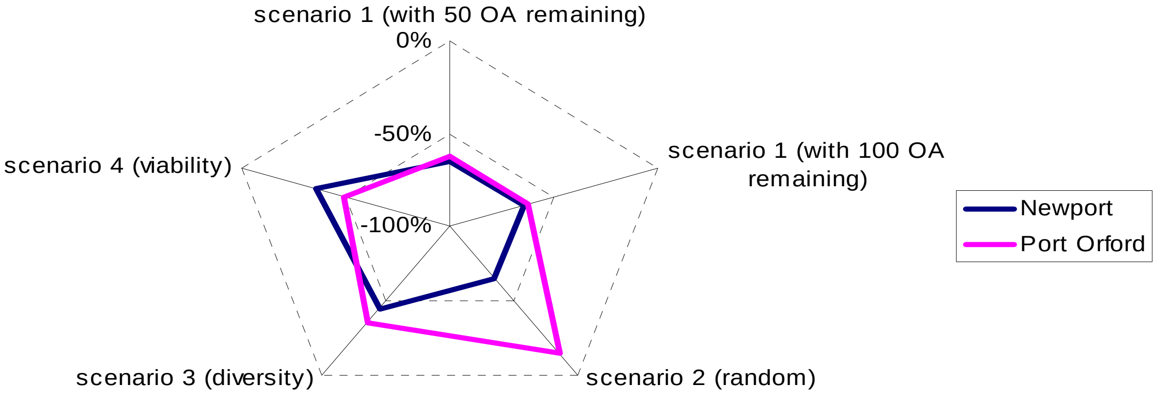
Comparative landings effects



Comparative revenue effects



Comparative income effects



It is important to note that the policy discussions around fleet restructuring have not progressed to the point of considering different alternatives. Instead, proposals such as the trawl buyback target one fishery sector in isolation. The framework developed here could be used to compare the effects of such a buyback on different parts of the coast, and to estimate the effects on various communities. To the extent that there are multiple design options for the buyback, which at least in its initial form focuses on an auction design that selects for viability (Leipzig 2001), parameters such as fleet diversity could be factored into any analysis.

4. Results from policy-oriented reduction scenarios

In this section, we consider some refinements of the basic approach for modeling fleet reductions. The four scenarios considered so far are premised on the numerical capacity estimates and various ways of reducing the number of vessels to the amount needed to harvest the 2000 allocations. In this chapter we turn to two more policy-oriented scenarios that also have the effect of reducing or restructuring the fleet.

The first of these is the 2002 in-season shelf closure, which is presumed to have resulted in the displacement or even cessation of some fishing effort. Actual fishery data for 2002 could be analyzed to see what actually happened to the various fleet sectors. Here, however, we use this case to illustrate a central feature of the GFR approach—the analysis of spatially or geographically circumscribed management measures. Beginning with the 2002 in-season measures, the PFMC is managing the fishery with reference to particular depth contours, making it necessary and desirable to analyze the impacts of such measures on coastal communities. The GFR framework provides a mechanism for this sort of analysis, and may serve as a useful prototype for spatially integrated databases that support fishery management in the future.

The second scenario we consider in this chapter is a permit stacking idea for the limited entry trawl sector that is currently under discussion at the council. Pending approval of a (partially) federally funded buy-back of vessels in one or more fishery sectors, such a permit-stacking scheme is a likely option for consideration. We conclude this chapter with a discussion of other policy-relevant scenarios that could be analyzed using the GFR framework, notably a vessel buy-back.

4.1. The 2002 in-season shelf closure

Partway through the 2002 fishing season, the PFMC responded to landings data signals and emerging stock information by closing parts of the continental shelf to targeted groundfish fisheries in order to protect fish populations at risk of being overfished. As of July 1, 2002, vessels were prohibited from targeting groundfish between 20 and 150 fathoms South of Cape Mendocino, and effective September 1, between 100 and 250 north of there. By preventing vessels from fishing in certain areas, such measures may lead to a geographic redistribution of the fleet. To the extent that vessels have no alternatives for the areas they are now prevented from fishing, area closures may also result in permanent fleet reductions.

Area and depth-based management measures such as the 2002 in-season closures are likely to continue to be part of fishery management in the foreseeable future.[13] Using the GFR framework, we used the depth delineations of the closure areas in a hypothetical scenario. The actual shelf closures went into effect partway through the season. Since we had only data on annual landings per vessel available for the whole coast, we made the simplifying assumption that the closures were in effect for the entire year. In this scenario, we asked what would have happened if the fleet (in the 2000 base year) had not been able to fish in the areas that were closed in 2002. As in the other scenarios, we excluded whiting from the analysis. Furthermore, we assumed that there were no substitutions of landings from catches made in other areas. In reality, vessels are likely to be able to relocate to other fishing areas for at least a portion of the catch foregone in the closure areas. The actual 2002 landing records could be used to determine the size and extent of this potential displacement effect, especially in comparison to catch locations in previous years. As a first estimate, however, the shelf closure scenario gives an idea of the order of magnitude of the impacts that area closures such as the 2002 in-season measures have on coastal communities.

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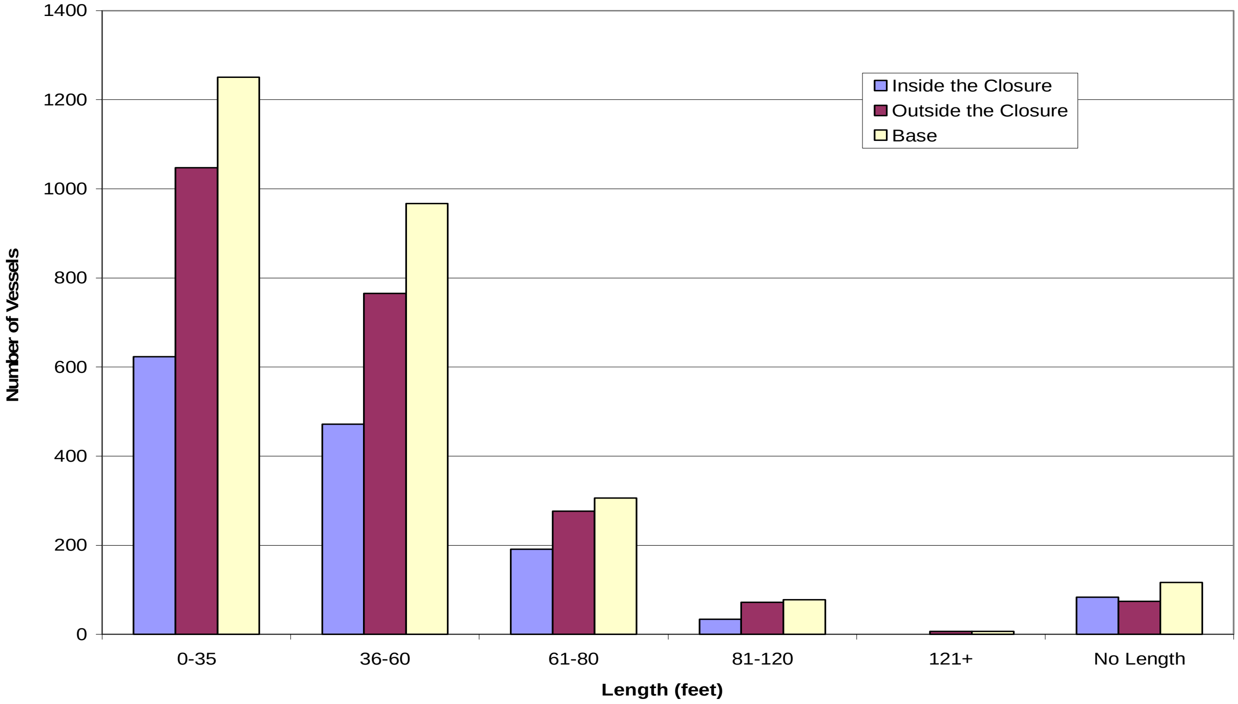
[13] The 2003 harvest measures maintain the 20, 100, 150 and 200 fathom lines, and add a number of seasonal and gear-specific variations. Using line item fish tickets, these could be analyzed for local and fleet specific effects and impacts.

Using the GFR framework, we can identify individual vessels and the areas where they fished. It is then possible to identify the vessels affected by the closures, and profile them in terms of size, landing ports, homeports, gear types and so on. Due to the uncertainty associated with the way actual fishing locations are recorded in the trawl logbooks or have to be inferred from the landing receipts, this is not a precise picture of the number of vessels affected by the closure. We can, however, infer from the past distribution of the fleet the vessel types and communities most likely to have been affected by the 2002 closures. This can further be tested using the actual landings data for the 2002 season as they become available.

In order to match the closure areas with our statistical 9km x 9km blocks, we weighted the percentage of each block falling within the closure area. We designated any block with 40% or more overlap as inside the closure area. Pending the release of waypoints used for enforcement, we are using the actual fathom lines to delineate the closure. Summarizing the information from these closed blocks, we can identity the vessels affected, and trace them and the associated impacts to the landing ports on the coast.

Of the around 2,750 different vessels (by size) catching groundfish in 2000, more reported landings from <u>outside</u> (82.3%) than inside (51.5%) the closure areas. Notice that the percentages do not add up because vessels may be fishing in both. The only vessel class that did not record any landings from inside the closed areas where vessels over 120 feet in length; these, however, account for less than 0.5% of the overall fleet. We did not investigate what, if any, vessels or vessel classes relied exclusively on the closure area for their groundfish landings, although it would be possible to do so in the GFR framework. Of those vessels for which length information is recorded in the fish tickets, between 44% and 62% made landings from inside the closed areas, suggesting that these areas are of varying importance for the various size and gear groups. Figure 9 summarizes this for the entire coast.

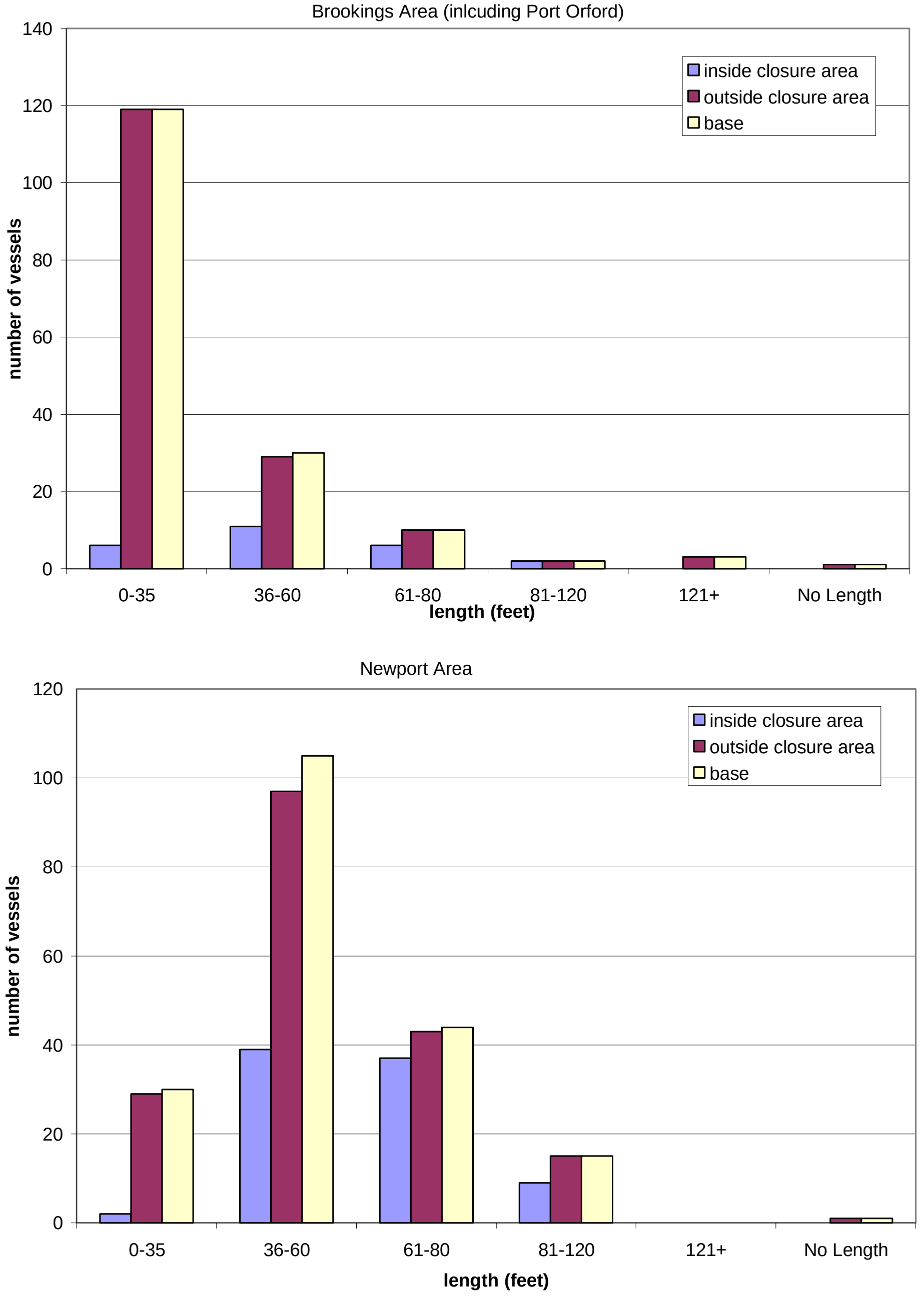
FIGURE 9: NUMBER OF VESSELS (BY LENGTH) FISHING INSIDE AND OUTSIDE CLOSURE AREAS, COMPARED TO TOTAL NUMBER OF VESSELS (BASE)



The example of Newport and Port Orford illustrate the geographical differences of the reliance of different vessel classes on the shelf closure areas. Focusing again on vessel size, Figure 10 shows the size distribution of vessels fishing inside and outside the closure area, compared to the base year number of vessels making landings in the port groups associated with the two ports. As expected, the use of the shelf closure area mirrors the pattern of the base distribution: vessels landing groundfish in the Brookings Area port group (which Port Orford belongs to) tend to be smaller than vessels in the Newport Area. Interestingly, the largest group of vessels—those in the under 35’ class—

in Port Orford appears to be the least affected by the closed areas, since most of them fish outside. While vessels in the 36-80’ range are roughly equally affected, accounting for around 37% of vessels making landings in each port group, there is a noticeably effect on the second largest vessel group in Newport, those between 61 and 80’ in size. Of those, almost 85% recorded landings from inside the closure areas in 2000, suggesting that this fleet sector would be most adversely affected.

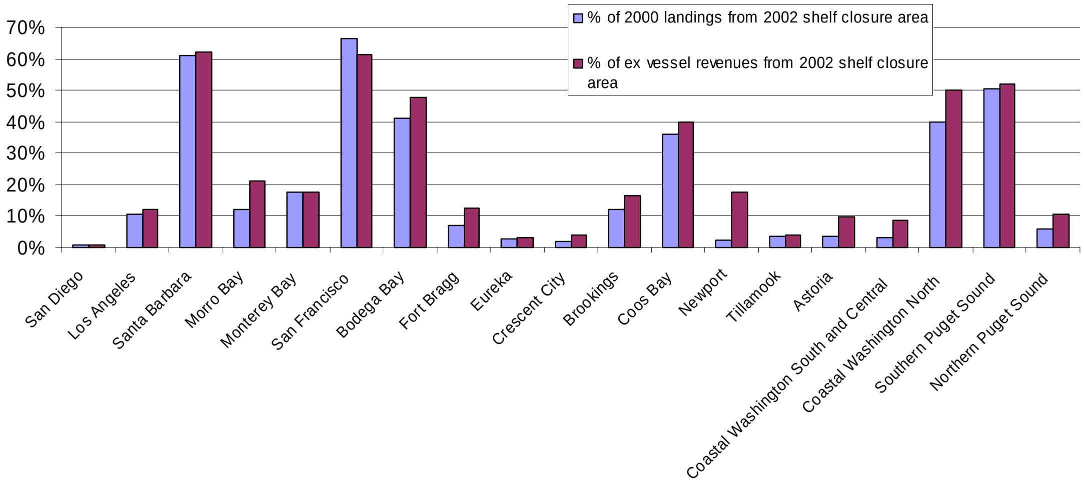
FIGURE 10: BROOKINGS AND NEWPORT PORT GROUP VESSELS (BY LENGTH GROUP) FISHING INSIDE/OUTSIDE THE SHELF CLOSURE AREAS, COMPARED TO BASE



In terms of the income impacts associated with spatial management measures, the basic logic of this scenario is that immediately upon the shelf closure, a number of vessels that typically fished in the closed areas were prevented from fishing there. The number of vessels, landings, and revenues displaced can be interpreted as an upper estimate of the effect of the closure. Many of the vessels are likely to adapt, and move farther offshore or closer inshore. In order to estimate the likely behavioral response, however, it is useful to know which gear types and size classes were fishing in the now closed areas, since their response will depend on factors such as size (which together with horsepower, fishing gear used and safety equipment constitutes the seaworthiness of a vessel, and thus determined how far offshore it can feasibly fish). The adaptive response could potentially be inferred using data for subsequent years, i.e., testing where vessels displaced in 2002 ended up fishing in 2003.

We consider the effect of the shelf closure in terms of the catch that would have been foregone had the same measure been in effect in 2000, and assuming that the entire annual catch from that area would have been affected. Landings from the shelf closure area accounted for 7% of total pounds landed coast-wide, and for 21% of ex vessel revenues.[14] Not surprisingly, perhaps, the share of landings and revenues from inside the 2002 closure areas differs considerably along the coast; see Figure 11.

FIGURE 11: LANDINGS AND REVENUES FROM INSIDE THE 2002 SHELF CLOSURE AREA



Clearly, some parts of the coast rely more heavily on the areas closed in 2002 than others. The catch made in the closure areas may be small in absolute terms (as indicated by the total overall income generated, see Figure 12), yet account for a high proportion of groundfish landings in a port, e.g., in Southern California. There is considerable uncertainty associated with these coast-wide estimates. In particular, we suspect that the high reliance on the shelf closure areas in parts of California is an artifact of our algorithm for spatially interpreting fish tickets. As explained in the methods section in Part II, this algorithm relies—among other things—on species distributions derived from trawl surveys periodically conducted by NMFS off the West Coast. These, however, are not conducted over the entire length of the coast. Another confounding factor is the bottom topography in parts of California. For example, groundfish fisheries in Santa Barbara and Bodega target the waters around the Channel Islands and Cordell Bank, respectively. These are comparatively small areas of lesser depth that likely fall inside 9km x 9km blocks used in our fish ticket analysis. In other words, we may be counting landings as coming from inside the closure area that in actuality come from adjacent shallower areas.

Area-based management measures such as the 2002 shelf closures are not capacity reductions *per se*. Unless they are placed such that they inadvertently displace an entire fleet sector from its home or foraging area, they are more likely to result in the relocation of effort. These dynamics remain an area for further research. In the short run, the shelf closure has the effect of "eliminating" vessels from a particular area and can be interpreted as an upper estimate of the potential impacts. Many vessels will likely relocate, but it is not clear where and how fast. The initial impact effect, therefore, gives again an upper bound of the cost associated with the shelf closure measures. In

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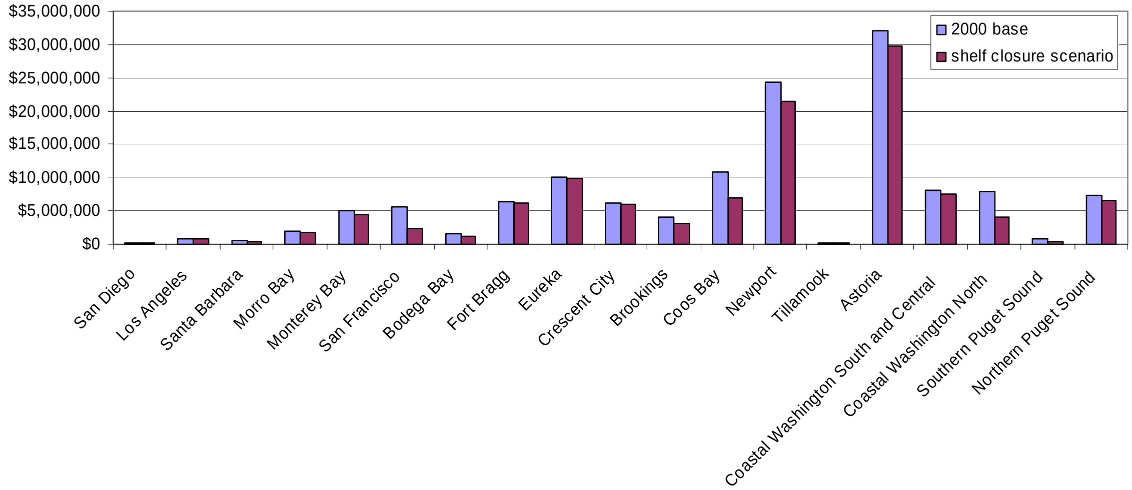
[14] Arguably this is an artifact of our baseline, and is an indication of the depleted state of the shelf. A baseline in the 1980s would in all likelihood paint a different picture, and the GFR analysis could easily be recalibrated for different base years. We thank Bob Francis this point.

contrast to the numerical scenarios, the effect may not so much be to redistribute landings and revenues from the exiting vessels to those remaining as to lower landings and revenues permanently. Figure 12 summarizes this effect along the coast, effectively depicting the income generated by vessels after the shelf closure, and absent any relocation of effort.

Figure 12 illustrates the degree to which the shelf closure affects different ports: in this scenario, after the shelf closure considerably less groundfish-related income is generated in places like Coos Bay and Coastal Washington than in, say, Eureka. In the case of Newport and Port Orford, while the absolute effects are greater in Newport, the relative change is bigger in Port Orford: the income lost due to the shelf closure is around $2.8 million in the Newport Area and $800,000 in the Brookings Area, or 11% and 20% of the 2000 base income, respectively. Clearly the effects on ports will depend on the extent to which fishermen can relocate to other areas. This and other questions about the effects on particular communities of spatial measures such as the 2002 in-season shelf closures remain a topic for further research. It is possible, using the GFR platform, to consider these relative impacts on a more detailed scale. Finer-scale fishery data would allow the consideration of seasonal effects, and a census of vessels in particular ports could be used to gauge the relocation possibilities. Together with the pending refinement and updating of the FEAM, it would then possible to assess the coast-wide impacts of spatial management measures and various alternative scenarios for how these are administered.

FIGURE 12: INCOME IMPACTS BEFORE AND AFTER THE SHELF CLOSURE



The coast-wide summary of results masks some considerable regional differences in how this scenario impacts communities. Consider our reference ports, Newport and Port Orford, which belong to the Newport Area and Brookings Area port group, respectively. In the Brookings Area, the shelf closure area accounts for 12% of landings and 16% of revenues. In the Newport Area, however, the reliance on these now closed areas is much less in terms of landings, and somewhat higher in revenues. This suggests that while only a small portion of total groundfish landings in Newport comes from the shelf closure areas (2%), they are relatively higher in market value, accounting for close to 20% of groundfish ex vessel revenues. Geographical differences like these suggest that spatial management measures may have downstream effects on the seafood value chain, e.g., if certain kinds of products are not available. Significantly, Port Orford accounts for 2/3 of the Brooking Area landings from inside the shelf closure area, and the impacts are consequently higher. Using the FEAM to translate landings into local income generated, and assuming that the multipliers—which capture the downstream "footprint" of each pound landed in terms of the dollars generated—are the same in the ports as for the whole port group,[15] there emerge considerable differences in how Newport and Port Orford fare under the shelf closure scenario.

Figure 13 shows the groundfish landings, ex vessel revenues and income for both ports in the 2000 base year and after the shelf closure scenario. Assuming there are no other factors adversely affecting the groundfish fleet, then

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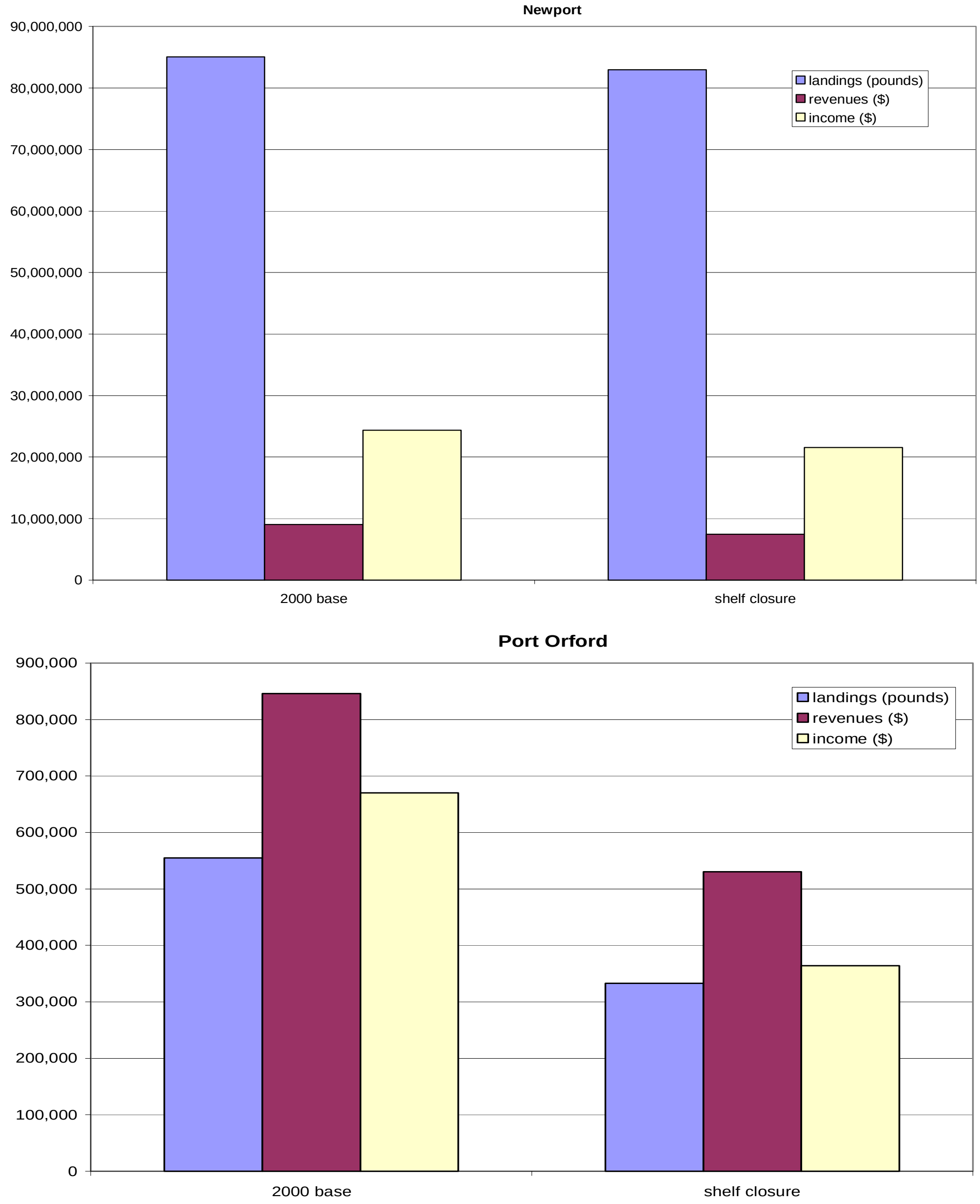
[15] This is a significant simplification, since the multiplier essentially captures the downstream value-added chain from landing to processed product and as such is dependent on the actual location of fish-buyers and processors. Simplification like this, however, are routinely made in regional economic impact modeling, given the lack of more detailed data.

Newport experiences only a slight decrease in landings and associated ex vessel revenues. Similarly, the amount of income generated from groundfish landed in Newport stays at around 90% of its base level. In contrast, Port Orford experiences much more severe effects. While its base year reliance on the shelf closure areas are much smaller in absolute terms, their relative importance for the port is borne out by the 40% reductions in landings and revenues, and the almost 50% reduction in income generated from groundfish landings.[16] On a per-pound basis, fish landed in Port Orford is more valuable than in Newport, which is likely the result of the species targeted, as well as the preferred product forms they are processed into.

FIGURE 13: THE SHELF CLOSURE IMPACTS ON PORT ORFORD AND NEWPORT



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[16] Notice that groundfish-related income is less than ex vessel revenues in Port Orford. This is a function of the assumptions about the cost-earnings structure of processors and harvesters made in the FEAM. Ex vessel revenues are paid at the docks, but depending on where repair costs and other expenses are paid, and where the value-added processing takes place, not all of those may remain in the local community.

4.2. Permit stacking in the Limited Entry (LE) trawl sector (scenario 5)

The PFMC is considering permit stacking in the LE trawl fleet, analogous to the permit stacking that has already taken place in the LE sablefish fishery. It is not clear yet what exactly the rules for such a trawl permit-stacking scheme would be. In the interest of investigating the sorts of geographic and distributional effects that might reasonably be expected, we designed a hypothetical permit-stacking scenario in consultation with our partners at PMCC.

In this scenario, we asked what would happen if half the trawl fleet is removed by permit stacking. Leaving the other fishery sectors unchanged from the base year, we sorted each vessel size group of the LE trawl sector according to ex vessel revenues in 2000. We then assumed that the higher revenue vessels would stay in the fishery, and the lower revenue ones would sell their permits and exit the fleet. We further assumed that willingness to buy or sell is proportionate to ex vessel revenues, and paired the highest revenue "buyer" with the highest revenue "exiter". The landings associated with each exiting vessels were then reassigned to each buying vessel. The match is exactly one-to-one, i.e. the remaining vessels all have two permits stacked.

There were a total of 243 LE trawlers in 2000, which were distributed as follows across the vessel size classes:[17]

- 2 in the 0 – 35 foot range;
- 92 in the 35 – 60 foot range;
- 116 in the 61 – 80 foot range;
- 32 in the 81 – 120 foot range; and
- 1 in the 120+ foot range.

After the permit stacking, there are half as many vessels in each size class, for a total of 122 LE trawlers. We assumed the sole vessel in the 120+ foot range would stay in the fleet for the purpose of our analysis.

To understand the impact of this scenario on the coast, consider that each trawler has potentially multiple landing ports. Assuming that trip limits stay the same and there are no reductions associated with stacked permits, the aggregate landings and revenues can be expected to stay the same as in the base year. Since vessels may be making ladings in multiple ports, we assigned the landings associated with the exiting vessels to those remaining in the fishery, and also assigned them proportionately to the various ports along the coast. This rests on the assumption that there is no change in the distribution of processors; this and other dynamic factors are outside the scope of our analysis.

The main effect of the permit stacking scenario is to make the vessels remaining in the fishery better off. We assumed that after stacking, the 2000 landings associated with the exiting vessel would accrue to the vessel remaining. Our analysis suggests that there are considerable differences in how much better off individual stackers can expect to become after stacking. There are a number of interesting patterns:

1) Among vessels in the 36 – 60 foot class (VS2), the average revenue increase after stacking is 20%. However, the biggest increases range from 25-37% of pre-stacking revenues, and are realized by vessels that made landed between $125,000 and $300,000 worth of groundfish in 2000;
2) There is no statistical correlation between pre-stacking revenues and the post-stacking increases in revenues; in fact, some vessels that are very close to the $125,000 mark have considerably smaller revenue gains—some as little as 7%;
3) Among vessels between 61 and 80 feet in length (VS3), the average revenue increase is almost double that of the VS2 group: almost 40%. Most revenue gains range from 40-50% and are realized by vessels that landed between $230,000 and $440,000 in groundfish revenues in 2000;
4) In the 81 to 120 foot class (VS4), the average gain is 33%, with the high end of these (between 35% and 45%) being realized by vessels that made between $335,000 and $570,000 worth of groundfish landings in 2000.

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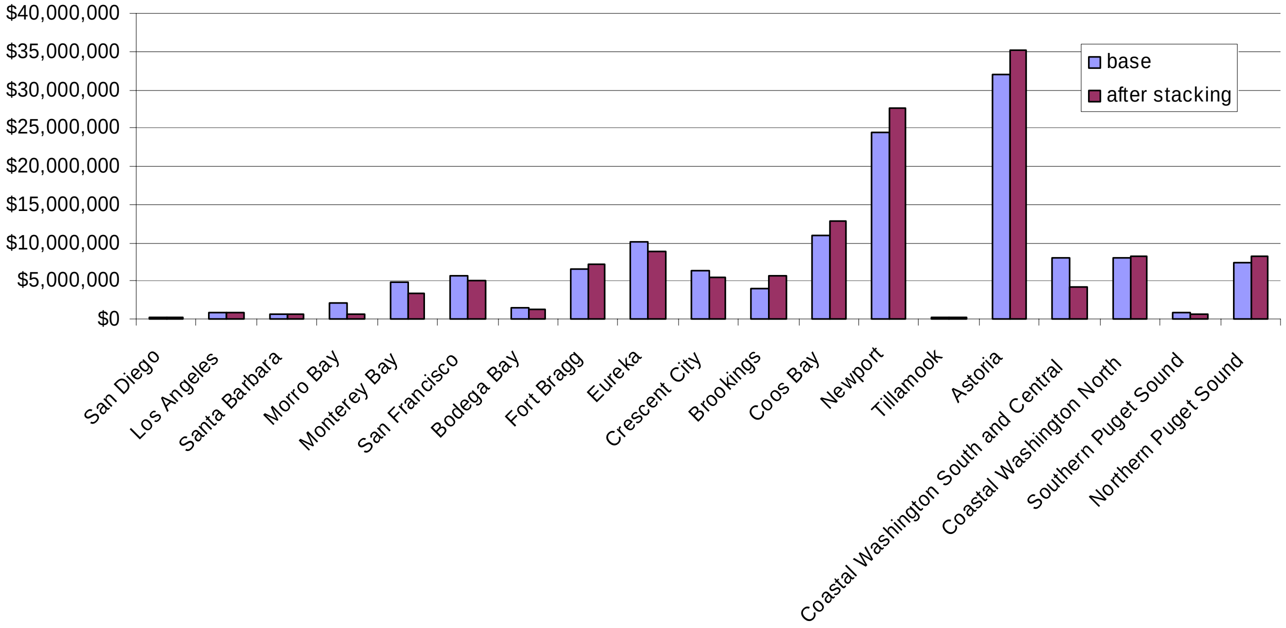
[17] In designating these size classes, we followed the expert judgment of fishermen on the PMCC board of directors and others; in principle, size groupings in other intervals are possible, such as those used in the Environmental Impact Statement for the 2003 groundfish management measures (PFMC 2003).

As should be apparent from these numbers, the permit stacking stands most to benefit vessels in the 61 to 80 foot range. These vessels would also land more than a third (38%) of groundfish landings (in 2000 terms), and almost 90% of the total jointly with the group of next larger vessels—those between 81 and 120 feet in lengths.

As for the spatial aspects of the LE trawl permit stacking, the effects vary along the coast. Not surprisingly, ports with larger trawl fleets are relatively more affected. We modeled the distributive effect on landing ports by assigning landings associated with the exiting vessels to those that bought their permits. The implicit assumption is that the remaining vessels would land their now stacked catch in the same ports as did the exiting vessels. Clearly, given market conditions and relationships with processors, this is not necessarily the case. Figure 14 below summarizes the results of the stacking scenario in reference to the base income impacts.

FIGURE 14: COASTWIDE INCOME IMPACTS AFTER STACKING IN THE LE TRAWL FLEET



Interestingly, applying the FEAM to the landings resulting in each port after the permits have been stacked, this scenario results in a net gain of income along the coast: around $3 million more than in the base year, or $142 million versus $139 million. This would suggest that permit stacking, even in a single sector can have positive income effects—at least in aggregate, at the scale of the whole coast.

Detailed results for all ports can be found on the project web site, www.ecotrust.org/gfr, where this scenario (No. 5) is summarized along with the earlier four numerical ones. Although all but two (Los Angeles and San Diego) of the port groups are affected in the permit stacking scenario, at the smaller spatial scale of the ports the results are more striking. Since some ports have no trawlers at all, significantly fewer ports are affected by this than by any other scenario we analyzed: only 1/3 of the 99 total. In terms of our reference ports, the trawl permit stacking scenarios has no impact on Port Orford. This is not surprising since no trawl vessels are home-ported there.[18] By contrast, Newport illustrates how the fleet might gain from stacking permits in the LE trawl sector. Again, assuming that processing and harvesting sector structures as embedded in the FEAM remain the same, Newport stands to experience a 17% increase in landings, a 19% increase in ex vessel revenues, and a 13% increase in groundfish-related income.

A number of caveats apply to this scenario, which—although more policy-oriented than the earlier numerical ones—is still somewhat removed from reality. For example, the groundfish-exclusive focus of our analysis may lead to the

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[18] The slight increase in income in Figure 11 are due to results for the other ports in the Brookings Area port group.

inadvertent elimination of more diversified vessels. Although less likely in the LE trawl sector, we cannot exclude the possibility that some vessels identified as "exiters" because of their relatively low groundfish landings are viable. Also, we excluded landings history and only used 2000 ex vessel revenues as a way of identifying who would buy and who would sell permits. The actual decisions are likely more complex, and any policy analysis would benefit from considering operating costs of various sizes of vessels, the financial health of individual vessels, or indications of buying/selling intention such as the survey on a buyback program conducted by the Fishermen's Marketing Association (Leipzig 2001).

Another limitation is that we limited the permit stacking to vessels within size classes. Especially on the outer margins of the revenue distribution, however, it is likely high performers in one class would consider buying permits from the next higher class, while it might be feasible for low performers to buy permits from the next lower size class. Depending on what fleet structure is desired after stacking, policy-makers may wish to consider imposing a priori constraints on the permit stacking, for example, by setting a size range within which permits can be traded. These and other considerations could be modeled in the GFR framework.

4.3. Other policy issues – applications to fleet buyback measures

The 2002 in-season shelf closure and the permit stacking scenario for the LE trawl sector are only two policy-relevant issues that can be examined using the GFR framework. The reduction scenarios considered in the GFR project are largely illustrative of the myriad effects associated with fleet restructurings, and that can be examined using this framework. There is, in principle, no limit to the type, number, and combinations of constraints that can be imposed on the databases to generate other scenarios. For example, another issue of considerable interest to West Coast fisheries is the proposal for a federally and/or industry funded vessel buyback before Congress (H.R. 1989). The Fishermen's Marketing Association (FMA) conducted a survey of vessel owners in the LE sector who were ready to leave the industry (Leipzig 2001). While our data set and the responses to the FMA survey are not linked, it would—in principle—be possible to use this and other information to analyze which communities would be affected by the buy-back.

There are two main ways in which the GFR project results and framework could be used to analyze a potential buyback. Firstly, the various numerical scenarios can be interpreted as potential outcomes of a buyback measure. On an aggregate level, the numerical results suggest how much money is needed to compensate vessels leaving the fleet under the various fleet reduction scenarios. Recall that the scenarios were silent on the mechanism by which a fleet reduction would be achieved, and only compared the before and after effects. A vessel buyback as proposed in H.R. 1989 is such a mechanism. Assuming that the estimates of the income redistributed to the remaining fleet are an indicator of how much vessels leaving would be willing to accept, then the coast-wide income impacts may serve as proxies for the size of the fleet reduction that can be achieved with a buyback between $37 and $75 million dollars (see Table 2). Similarly, the analysis provides a benchmark for estimating the number of vessels that might reasonably be expected to enter bids in a buyback. Given that the four GFR scenarios applied to <u>all</u> fleet sectors, whereas the buyback bill is targeted at reductions solely in the trawl sector, it is interesting to note that $50 million achieve—in our scenarios—the 50% target for the <u>entire</u> fleet. It is therefore reasonable to expect that that the buyback would succeed, and likely exceed, this target in the trawl sector.

Secondly, the GFR framework could also be used in the implementation of the trawl buyback program. By considering the actual vessels involved it would be possible for fisheries managers to use the information compiled in the GFR database and GIS to assess the geography of vessels submitting bids in the buyback program. This is also potentially useful for assessing any habitat impacts of the buyback. Furthermore, the removal of vessels from the fleet and therefore from the grounds is also likely to have competitive effects on vessels remaining in the fleet. In other words, the removal of trawl activity from the fishing grounds may lead to redistribution of fishing effort by other gear types, both from within and outside the groundfish fleet. Other considerations for structuring any buyback, such as past landings, permit diversity (and concomitant fishing opportunities) and economic viability could also be spatially integrated into the analysis.

5. Conclusion

The methods and analysis presented here complete the GFR project. Having compiled and spatially integrated a host of fishery-dependent and independent data, we conducted a static comparative analyses of a range of numerical and policy-driven reduction scenarios. Even at this level, considerable geographic differences emerge. Combining a spatial, relational database with regional economic analysis and a range of community considerations, we examined four numerical fleet reduction scenarios. These result in considerably different implications for fleet diversity, as well as for the economic health of coastal communities. Linking this sort of analysis with other considerations such as demographics, census and qualitative information, may provide a useful framework for decision-makers and communities in planning the transition of the West Coast groundfish fleet.

Over the course of the GFR project (spring 2001 to 2003), new management issues and concerns have emerged that can partially or wholly be addressed with the framework we developed for the GFR project, and whose potential uses extend beyond the narrow set of reduction scenarios considered here. In particular, the project makes use of what might be the first regional, spatially integrated, fisheries database such as the National Academy of Sciences suggested NMFS and its partner agencies develop (National Research Council 2002). To illustrate some of the applications of this spatial analytical framework, we also considered area-based management measures, using a hypothetical scenario derived from the 2002 shelf closure measures. The outcomes of the model scenario could be compared to the actual outcomes as recorded in fish tickets and other pertinent data.

Finally, we examined a hypothetical trawl permit stacking program, in anticipation of such a program under consideration at the PFMC. Using the full complement of fishery data, including a finer temporal resolution and information on the non-groundfish fisheries, agency staff and scientists could adapt the GFR framework to examine the spatial implications of any planned permit stacking or, for that matter, buyback program. In fact, since our numerical scenarios are independent of the mechanism by which fleet reductions are achieved, they can be interpreted as estimates of the relative efficacy that West Coast fisheries managers might expect of differently sized and structured reduction programs.

Throughout the project we identified, and discussed, ideas and possibilities for further research and analysis. Since our analysis to date is deliberately static, and since there are no readily available models that predict the behavior of the fishing fleet in response to management measures, one plausible extension of our analysis would be to invite expert testimonials as to how the fleet is likely to respond to any one reduction scenario. This is essentially what currently happens in the PFMC process, when managers and fishery participants deliberate on the likely effects of harvest rules on management measures.

The GFR analysis deals largely with the commercial fishery for groundfish. We integrated a number of data sets describing the recreational fishing effort into our database, but were unsuccessful in making the available data commensurate with those describing the commercial effort. Since recreational fishing suffers from an almost complete lack of spatially explicit data, we have only integrated a crude snapshot of recreational effort in our project deliverables to the public funding agency (PSMFC) where the GFR database and products will reside. We anticipate producing maps that show the degree of spatial overlap between recreational fishing effort and commercial effort, and between recreational fleet and particular habitats and species. Most of this remains an area for future analysis.

The regional economic impact analysis is limited to adapting and applying FEAM multipliers to the GFR reduction scenarios. This regional economic model, in turn, relies on 1996 inputs from a national model, and was last updated for the West Coast in 1998 (Davis 1998). In the past four years, however, the processing sector and other fishery-related businesses have undergone substantial changes. In particular, many communities and port groups that had value-added processing in the FEAM have lost this capacity, or new ones (often smaller) have sprung up. Staff at PFMC and PSMFC are working on revising and updating the FEAM, and together with the data on communities and port collected for the GFR project, this will provide more accurate estimates of economic impacts. As part of the documentation on the GFR database and model that we are preparing for the PSMFC, we also identify ways in which such updated information can be factored into the GFR framework.

Programmatically, Ecotrust will continue to expand its suite of spatial tools and integrated analytical platforms for community planning purposes on the West Coast. A logical extension of the GFR project would be to consider other fisheries on the West Coast and the trade-offs and other dynamics between them and the groundfish fishery, for example as fishermen activate dormant permits for salmon and other species. We are also exploring partnerships for modeling the linkages between ecosystems, fisheries and social systems, and may draw on some of the associations emerging in the GFR project as initial hypotheses for predictive relationships.

PART II – TECHNICAL DOCUMENTATION

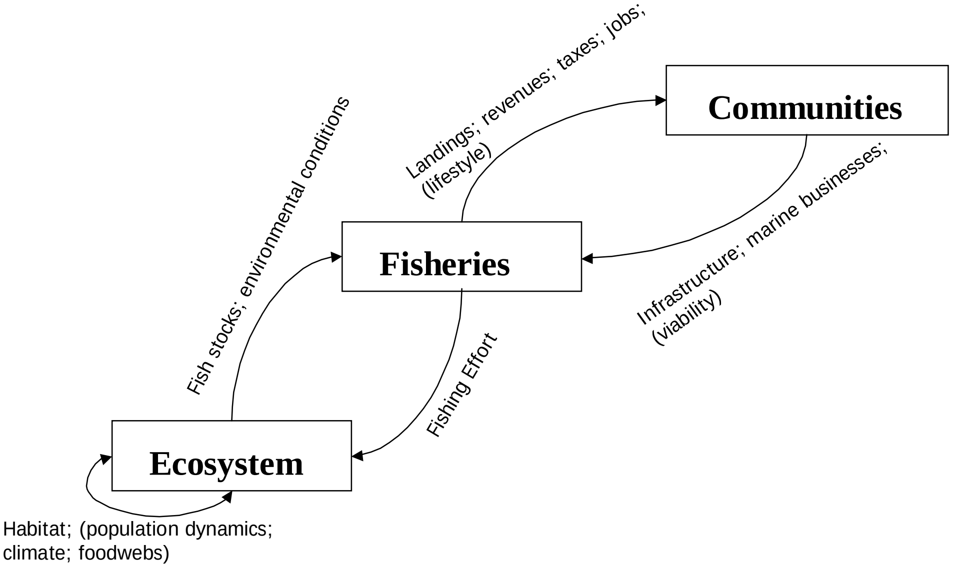
In this second part of the GFR project report we provide detailed technical documentation on the data sources, analytical protocols, and materials used. Since the project received considerable public funding, its database, results and the techniques for deriving them will reside in the public domain, under the auspices of the Pacific States Marine Fisheries Commission. Complementing the statistical capacity analysis outlined in Part I of this report, we discuss here the details of the GFR project database, the construction of the geographic information system, and the computational challenges encountered in building what may be the first regional, spatially integrated, fisheries database, as recommended by a panel of the National Academy of Sciences: "NMFS and its partner agencies should integrate existing data (…) to provide geographic databases for major fishing grounds" (National Research Council 2002, p.3). The need for such integrated approaches is a logical extension of the call for ecosystem-based management that underlies regulations requiring, for example, the assessment of ecological and socioeconomic impacts of proposed management measures (Ecosystems Principles Advisory Panel 1999). We submit the GFR framework as a step in that direction, and one made possible by a productive private-public partnership of funding agencies and researchers. In addition to the methods and techniques detailed below, Part II also contains reference materials and a series of technical appendices.

Methods and techniques

The GFR project centered on the question of capacity reductions and their impact on different fishery sectors and different parts of the coast. This was conceived as a first step towards understanding the restructuring of the fleet to make it more ecologically and economically sustainable. We wanted to know how removing particular kinds of vessels (by gear used, size, and species targeted) affects the fishing effort off the coast and the associated economic activity in ports. To the extent that particular classes of boats, gears or target species are associated with particular habitat types, changes in the fleet composition and activity also affect the fishing grounds.

Conceptually, we therefore had to chart multiple relationships between the marine ecosystem, the fishery it supports, and the communities supported in turn by fishing activities. This is captured in Figure 15, which is a sketch of the groundfish fishery (or fisheries, since there are many different commercial and recreational sectors) and how it relates to coastal communities and the ecosystem.

FIGURE 15: THE WEST COAST GROUNDFISH SYSTEM AND KEY RELATIONSHIPS



Many of the relationships between the various "layers" of this system are well described by existing data sources. The three states collect extensive data on fishing effort, landings, and the associated revenues. The National Marine

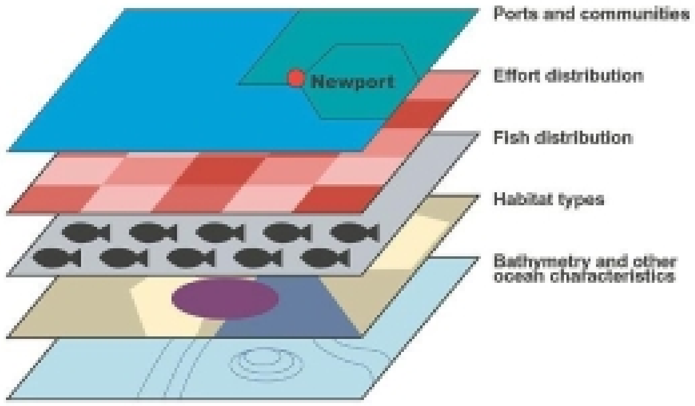
Fisheries Service (NMFS)[19] conducts periodic surveys that help establish the distribution, size and abundance of fish stocks. The United States Geological Survey (USGS), NOAA and other agencies collect geological, meteorological and oceanographic information. Natural scientists at universities are busy mapping habitats and other ecosystem information. The US Census Bureau collects detailed information on household income, demographics, education and other descriptors of the socioeconomic well-being of communities at the county level. And social scientists, anthropologists and historians conduct surveys and collect qualitative information on the coastal way of life. All this information can potentially be brought to bear on capacity reductions and other fishery management issues, yet the complexity and format of the information make it difficult to assimilate.

The GFR project is essentially an analysis of existing data (rather than collecting new data on the fishery), which we assembled and integrated in a spatial framework. Collectively, these data *describe* the linkages of the fishery system, and make it possible to examine the effects of fleet reductions in a broader context. It would be quite a different undertaking (and an anticipated future extension of the GFR project) to build a *prescriptive model* of these relationships. In other words, the analysis presented in Part I results from static comparisons of all the data describing the fleet under different sets of fleet reduction scenarios, and is couched in statements of the form “this happens in the fishery, and that happens in communities”. The scenarios describe, at best, correlations between different aspects of the fishery; more accurately, they report on the co-occurrence of phenomena in the fishery and on land. By contrast, a predictive model would generate statements of the form “this happens in the fishery, therefore that happens in communities”, i.e. describe causal relationships. Establishing these stronger relationships remains an area for further research.

There are various data describing the status of fish stocks, landings, revenues, jobs and other variables, but many relationships between these important aspects of fisheries are not developed to the point of building prescriptive models. The lifestyle aspect of fishing, for example, is clearly important to the social cohesion of coastal communities (The H. John Heinz III Center for Science Economics and the Environment 2000), but there are few, if any, sources of data that measure its role along the entire coast. There are some spatially explicit bioeconomic models that capture simple dynamics between fishing behavior and stocks (Wilen, Smith et al. 2000; Smith and Wilen forthcoming), but they have not yet been extended to multispecies fisheries such as the groundfish fishery. Nor are West Coast ecosystems well-described, though there are some important efforts in that direction (Pauly and Pitcher 2000; Field, Francis et al. 2001; Field and Francis 2002). An important exception to the general dearth of information on ecosystems are the habitat maps that are currently being compiled for the programmatic groundfish Essential Fish Habitat (EFH) Environmental Impact Statement (EIS) by a team of researchers under contract for NMFS; see the discussion in section 2.2. below.

The core work of the GFR project consists of making operational the linkages between different parts of the overall system depicted in Figure 15. To do so, we are integrating a number of existing databases and putting them into a shared spatial framework (see Figure 16), which can then be queried for analytical purposes.

FIGURE 16: GEOGRAPHIC INFORMATION LAYERS



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[19] NMFS has recently been renamed “NOAA Fisheries”; in this report, we use the two interchangeably.

It is important to note that once these various data are assembled in a relational database, they can be queried in a number of directions. In terms of the overall fishery system (Figure 15), for the GFR project we focused on the linkages between the fishery and communities. Other trajectories of inquiry, however, are possible. For example, as part of a contract with PSMFC we are producing spatial analyses of fishing effort for the EFH EIS that will be linked with habitat information (Sustainable Fisheries Division 2001). This constitutes one way of linking ecosystems and fisheries. In other words, while we built the GFR framework around fleet restructuring issues, its usefulness extends beyond those. Another potential application that has attracted interest from fishery managers and others is find out what happens when particular areas are closed to fishing—as occurred with the emergency in-season management measures adopted by the PFMC in June 2002 (see Part I, chapter 4.1) and subsequent harvest measures, or as would be the case for marine reserves.[20]

Underlying the GFR analytical framework is an iterative "query-and-map" process. Most data are available in numerical formats, and were compiled by project staff. A relational database (operating on SQL server) houses millions of records imported from a variety of data sources. This database is queried selectively, and the results are mapped in a geographic information system (GIS) using ArcInfo. Some information is available in already spatially coded formats, and can thus be imported directly into the GIS. For example, NOAA publishes extensive bathymetric information for the West Coast in standard formats. Similarly, GIS projects are by and large compatible across different software platforms. Data layers produced, for example, for the habitat mapping efforts in the NMFS EFH-EIS can be imported directly once they are available. These two components of the GFR project, database operations and spatial modeling, are further explained in the following two sections. By the same token, selective maps or coverages derived in the GFR project can be shared independently of the underlying data—thus protecting any proprietary or other sensitive data.

1. Database operations

The data for the GFR project are stored in a relational database that is managed in SQL Server 2000, totaling 2.47 GB in size. Source databases range considerably in size, with the over 1 million data rows of the annualized landing receipts comprising the one of the largest segments of the GFR database. Figure 17 illustrates how the data are linked through a system of overlapping fields. Through such links it is possible to stratify the entire database into subsets of interest. For example, we typically want to know what size vessels catch what quantity of different species of fish with what kind of gear. Or we might want to find information about a port where the catch is landed. Starting with the shared "PortID" we can locate landings made there, or an interview conducted there or a reference in the project library. It is important to note that there are no limits, in principle, to how large the database could grow. The relational structure makes it possible to add new information, as long as it shares at least one data field with any of the other data categories. From the database, information is exported to ArcInfo, providing the inputs to the spatial modeling for the GFR project. Summary information can also be displayed in a variety of other applications, notably statistical software packages. The baseline analysis section below shows some of the fishery trends calculated from the data using Excel.

Data sources include the Pacific Fisheries Information Network (PacFIN), personal interviews and observations, and literature. Many of the data are numeric and range from quantitative descriptions of fishing activity such as landings and revenues to the demographics of port communities. In light of the pervasive uncertainty and data shortage about the socioeconomic aspects of the fishery, however, we have, however, designed the project database to accommodate a variety of qualitative information as well, and are continuously adding new information to it. This qualitative information can be called up from the database through the same PortID and other cross-links, and added to any table or presentation of results. For example, the GFR database contains an extensive reference library that can be accessed through a port to call up all the literature containing information about that port.

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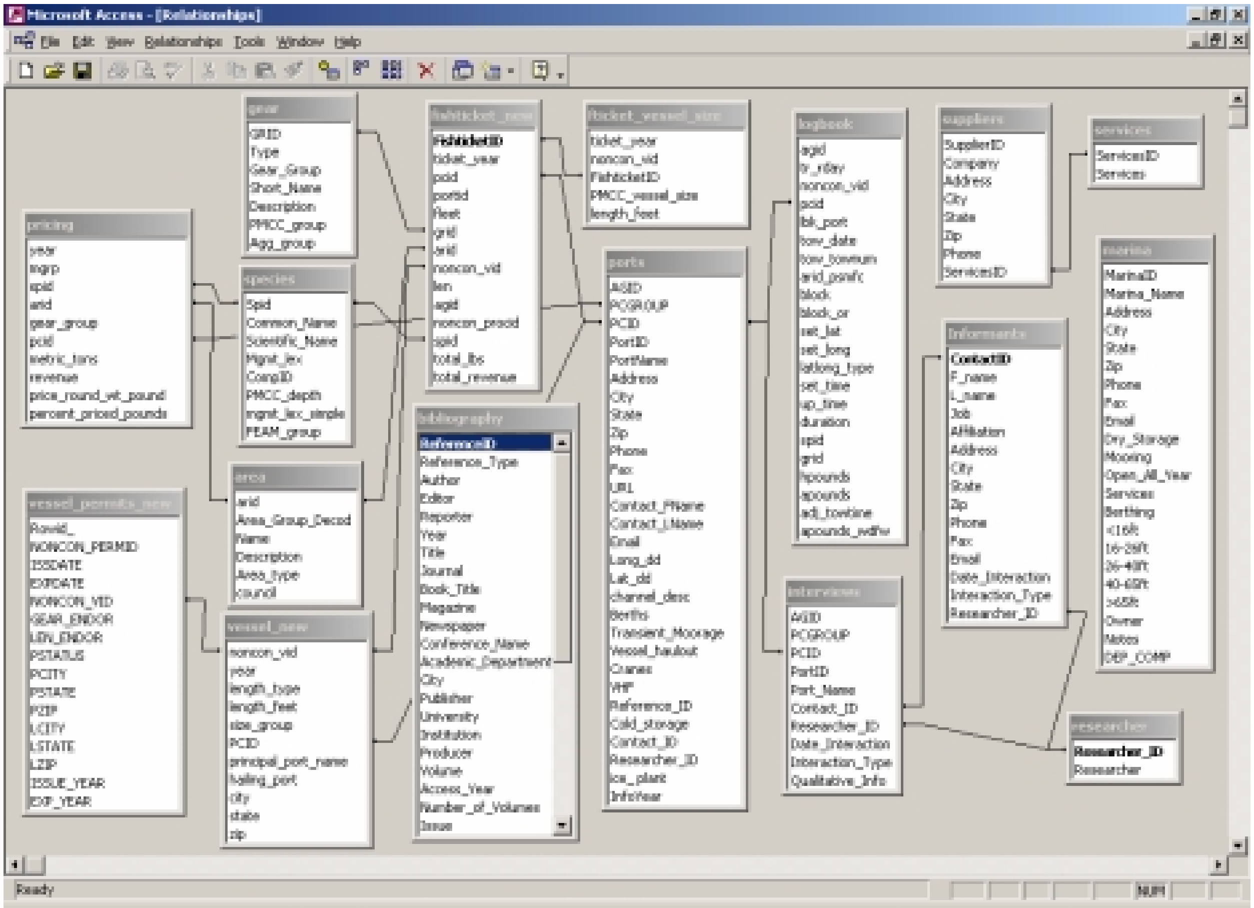
[20] Marine reserves are a form of marine protected areas (MPAs) that prohibit all extractive activities, including fishing. For definitions and a discussion of different types of MPAs see the recent study by the National Academy of Sciences, *Marine Protected Areas: Tools for sustaining ocean ecosystems* (2001).

FIGURE 17: GFR DATABASE LAY-OUT



1.1. Stratifying the fleet and species

A central function of the database is to enable the stratifying of the fleet by vessel size and gear types, and to sort species into larger groups by depth associations and species-groups. This diminishes the number of records that have to be handled for each query and thus reduces the computational complexity somewhat. Functionally, this stratification allows us to map the landings and revenues of vessels fishing for particular species with particular gears, or to identify the size and gear composition of the fleet in particular ports. In principle, the number of combinations and permutations one could query is only limited by the available data and processing time.

Fleet stratification. There are various ways of achieving a fleet reduction (attrition, buybacks, permit stacking, etc.), and they will tend to affect different sizes and types of vessels differently. Even within one fishery sector, the viability of vessels may differ according to their size, horsepower, crew and skipper expertise, and other factors that determine whether a vessels remains in the fleet or leaves. There is generally very little coast-wide information on these factors, which are important components of the capacity of the fleet (Smith and Hanna 1990). There tends to be no direct correlation between vessel lengths and fishing power or economic viability *per se* (Shannon Davis, per. comm. 9/24/02). Nonetheless, length is a convenient indicator of fleet diversity, which is furthermore recorded in landings and permit data. Since preserving the diversity of the fleet remaining after capacity reductions is a key element of the council plan,[21] we stratified the fleet into different length groups. There is no standard scheme for separating the fleet out by length, and a recent study for PSMFC uses four length categories for all West Coast

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[21] Preserving, or indeed increasing, the diversity of the fleet is important for maintaining a broad, fishery-based economic base in coastal communities. In the extreme, today's vastly reduced harvest allocations could be harvested by one or two large vessels, and centrally processed – this would do little to preserve the way of life supported by the vessels of all shapes and sizes that make up a diverse fleet.

fisheries (Radtke and Davis 2000). Since we were more specifically interested in the groundfish fleet, we used lengths identified by the fishermen on the PMCC board of directors to group the fleet into six length categories:

- 0 – 35 feet (VS 1);
- 36 – 60 feet (VS 2);
- 61 – 80 feet (VS 3);
- 81 – 120 feet (VS 4);
- 120+ feet (VS 5); and
- other (VS 6),

where "other" denotes vessels for which no length information was recorded. In principle, however, the data in the GFR database can be resorted and stratified in any number of ways, and groupings can in principle be changed for different kinds of inquiries.

The fleet is further stratified by the gears that vessels use to catch groundfish, whether as bycatch or to target groundfish species. We distinguish between a number of gear types that for most descriptive purposes in this report are aggregated into five major groups:

- trawl;
- hook and line;
- pot/trap;
- longline; and
- "other"

where the "other" category includes troll gears, net gears, and a variety of unidentified gear types. Appendix A contains the exact gear mappings from the gear codes contained in PacFIN to the habitat specific gear assignments that we developed in collaboration with NMFS, and to the above five aggregated groups.

Finally, we stratified vessels by the fleet sector they belong to, as identified by the permits associated with each vessel. Vessels participate either in the limited entry (LE) or open access (OA) fishery, which can be further divided into LE trawl; LE non-trawl, non-sablefish; LE non-trawl sablefish, and OA. There are, therefore, a total of 168 size-gear-permit combinations that vessels can be grouped into. Landing receipts indicate whether the vessel making the landing fishes in the LE or OA sector. We then matched the LE records to the limited entry permit database at PacFIN to further divide the limited entry fleet into gear and species endorsement sectors. Not all of the 168 combinations of these fleet stratification categories are filled (for example, there are no 120 foot gillnetters on the coast), nor will they necessarily all be considered in the analysis that follows.

A number of sources of uncertainty about fleet characteristics in our data are reflected in the "other" categories for gear-types and vessel sizes. Some of these uncertainties arise from a number of historical or poorly specified gear categories contained in PacFIN. For example, there is a category for foreign and joint venture boats that show up in the earlier segments of our data set. Since these are not relevant to our analysis of current capacity, and the effects of capacity reductions on the 2000 fleet, we have grouped these into the "other" category under the gear-types and exclude them from the analysis. Likewise, since we received annualized landing records for groundfish, some of these show up in landings made with gear-types used for targeting other fish species, i.e. as bycatch. Since our analysis is focused on capacity reductions in the targeted groundfish fleet, gears like troll or seine gear were also grouped into the "other" category and excluded from the analysis. Finally, there are a number of "catch-all" data categories in PacFIN, which do not have sufficient specificity to be useful for our analysis. Again, these ended up in our "other" category. For the complete assignments of gear-types, see Appendix A. Similarly, for vessel lengths, there are gaps in the landing receipts and permit data received from PacFIN. There is a considerable number of vessels for which there is no length information recorded. These are tracked in the "other", or VS6, category of vessel sizes in our analysis.

Species stratification. We categorized species by habitat associations, using depth range as an initial indicator. In other words, species are grouped by where they live both off the coast and in the water column. For the purposes of the GFR project, we follow the depth characterizations used in fishery science and management on the coast and distinguish between nearshore (less than 50 fathoms), shelf (30 to 275 fathoms), slope (100 to 700 fathoms) (Turk, Builder et al. 2001).[22] Notice that depth does not constitute a clear divider between habitats; rather, there is some overlap, and species of the shallow slope may be found on the deeper parts of the shelf and vice versa. The same is true for the nearshore and shelf. For analytical purposes, we used the species-depth associations mainly to narrow the depth ranges of particular fishing gears in the fish ticket analysis. Depth is but one characteristic of habitat types that different species prefer, and our characterizations stand to be improved by the forthcoming habitat associations produced for the EFH EIS.

TABLE 4: GFR SPECIES GROUPINGS

Depth associations	***Species groups***
Nearshore (0 – 50 fathoms)	Flatfish Roundfish(1) Rockfish
Shelf (30 – 275 fathoms)	Roundfish(2) Rockfish
Slope (100 – 700 fathoms)	Rockfish(3)
Dover sole, Thornyheads, Sablefish (DTS complex) (4)	
Whiting(5)	

Notes:

1) The only roundfish in the Nearshore group is cabezon; the rest are flatfish and rockfish.
2) The only roundfish in the Shelf group is lingcod; the rest are rockfish. There are no flatfish in this group.
3) There are only rockfish in this group; we grouped some miscellaneous “unspecified” or “deep” flatfish in the PacFIN data with the DTS complex.
4) DTS are flatfish, rockfish, and roundfish, respectively, and occur over the slope depth range, i.e., from 100 – 700 fathoms.
5) Whiting is a roundfish and in a class of its own.

We also stratify species in our database into two additional categories used in management: DTS refers to Dover sole, thornyheads, and sablefish, which are jointly targeted and managed and can be found all over the slope. So the “slope” category never contains any Dover, thornyheads or sablefish information throughout our analysis. Finally, Pacific whiting is in a separate category because of the unique characteristics of the fleet that targets it and its separate management. Throughout our analysis, we track it separately, e.g. when we display landings or revenues associated with the groundfish fishery. Also, we exclude whiting boats from the capacity calculation. Scenario results only contain whiting landings associated with vessels in the non-whiting fleet; in other words, we do not model any reductions in the whiting fleet. Table 4 provides a summary of depth/management groups we use to categorize the various groundfish species considered in the GFR analysis. The complete list of species in the GFR database and their assignments to depth and species groups can be found in Appendix B. While this project concerns the groundfish fishery, it is important to note that of the 379 species recorded in PacFIN for all fisheries on the West Coast, 299 are represented in the fish tickets showing groundfish landings. In other words, nearly 80% of <u>all</u> species recorded for the coast occur in landings recorded by the groundfish fishery.[23]

In the 2000 base year there were considerably different fisheries taking place in the various depths off the coast. For example, in the nearshore (generally less than 50 fathoms), both trawling for petrale sole and other flatfish, and hook and line fisheries for rockfish shared the same waters. We therefore further differentiated species into biologically defined groups of flatfish, roundfish, and rockfish, following the classification used in PacFIN.

Stratifying the fleet and species in this manner simplifies the computational task while allowing a high degree of connectivity between data categories. The relational architecture of the GFR database makes it possible to run queries across the various fleet and species strata. For example, we can identify all pot and trap vessels between 61 and 80 feet in length that show landings for slope rockfish, and then associate these landings with a port and a

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[22] These depth categories reflect management considerations, since some rockfish species managed as “nearshore” or “shelf” species can be found in deeper waters. Physiographically, the shelf break occurs at a depth of 50-100 fathoms, and anything deeper than that is continental slope. We thank Gary Greene for this observation. Functionally, the GFR analysis does not rely on these depth categories, and much better habitat indicators will be available in the future as part of the EFH EIS efforts by Greene and others.

[23] This is most likely a function of the fishing gear used for harvesting groundfish, and of the sheer geographic scope of the fishery. Some of the ancillary analysis facilitated by the GFR project, for example with regard to the habitats and species affected by groundfish effort, is surprisingly comprehensive in that a considerable proportion of all species tracked in PacFIN are captured in the groundfish harvest data.

particular area of the ocean. This combinatorial flexibility of the database forms the basis for the fleet restructuring analysis discussed in Part I.

1.2. Data sources

The GFR database contains 14 years worth of data on fishing vessels, landings, prices, and ports, as well as literature reviews, interviews with key individuals, and information on operational costs and practices of a variety of fishing vessels. Permit data on fishing vessels, together with their catches and revenues (landing receipts, or fish tickets), were obtained from the Pacific Fisheries Information Network (PacFIN), the coast-wide data storage and processing service run by the Pacific States Marine Fisheries Commission (PSMFC). Since landings are port specific, the catch and revenues data also serve as the basis for the community analysis, e.g., in considering the impacts of different fleet restructuring scenarios. Unless otherwise referenced, e.g. in terms of other studies of West Coast fisheries or the literature, all figures and numerical values discussed in the GFR report are the products of the project database and our operations on it.

Information on ports is supplemented by literature reviews, using publications such as the *United States Coast Pilot* (National Ocean Service (NOS) 2001) and the Urner Barry directory of the fishing industry (Urner Barry Publications Inc. 2001), as well as by site visits. Project staff spent more than six weeks traveling the coast from Puget Sound to San Diego, visiting ports and interviewing more than 100 fishermen, port officials, and others. Observations and qualitative information about ports are recorded, coded by information categories (i.e., number of traveling lifts, amount of cold storage etc.) and transferred into the main database. Unless otherwise referenced, e.g. by anonymously citing one of the many project informants,[24] descriptions of places are derived from project personnel's notes and observations.

In addition to interviews, we conducted a cost survey of the fleet to help us gauge the economic impacts of capacity reductions on different communities, as well as to make statements about the viability of the remaining fleet. The 2-page survey tool was adapted from the recent PSFMC cost-earnings study (Economics Data Program 2001), and handed out to willing fishermen using a "snowball" sampling technique. In other words, fishermen familiar with the project make introductions to other fishermen in a port, who in turn participate either directly in the GFR project or introduce the project staff to other fishermen. Using such local knowledge, it is possible to cover the major gear sectors represented in each port. Participants filled out the survey forms anonymously and sent them back to the California office of Ecotrust, where they were processed and coded. We have not focused much of our energy on collecting new data, but anticipate that such face-to-face sampling procedure—whether by us or others on the coast—will generate more useful information on costs, earnings, and other socioeconomic aspects of the fishery in the future.

Another qualitative and very important source of information were testimonials from about 20 expert witnesses, whom we recruited largely from the PMCC board of directors. This group collectively possesses more than 400 years of commercial and recreational fishing experience, and provided information on the likely home ranges of vessels fishing out of particular ports on the West Coast, as well as on other aspects of the project.

Additional data were available in already spatially coded formats and are discussed under the respective information layers detailed in section 2 below.

1.3. Data handling protocols

None of the PacFIN data allow us to identify actual vessels or their owners. Each member of the GFR project team signed a "Certificate of Non-Disclosure of Confidential Fisheries Data" in accordance with rules established by NMFS under the provisions of the Magnuson-Stevens Act. This confidentiality agreement insures that the economic activity of individuals and businesses is protected (Sampson and Crone 1997) and establishes a PacFIN review process prior to the publication of any data, even in aggregate form. Under this agreement, no identifying information about individual vessels or businesses can be published, and information about processors is aggregated to a level that makes it impossible for third parties to deduce financial details about any particular company. This protocol also means that, for ports with fewer than three processors, we did not receive individual processor ID's.

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[24] In social science research, "informant" does not carry any of the negative connotations typically associated with sinister motives and clandestine operations. Rather, it is the most generic way to refer to persons who contributed information to a research project, whether as interview subjects, participants in focus groups, surveys or other tools, or in unstructured conversations with the researcher.

PacFIN maintains effective control over the data provided to the GFR project—as to other research projects—by controlling the information flow at both the production and publication ends. In addition, PacFIN also fictionalized information such as vessel, processor and permit identifiers (ID numbers). Ecotrust personnel, therefore, had no way of identifying actual vessels or businesses. Methodologically, it is more important to track unique vessels in time and space than to know the actual vessels they represent. In other words, when we identify vessels, we do so on the basis of the fictional ID's provided by PacFIN, and do not in any way reference them to the actual vessel an ID represents, or to information about the vessel owner.

In line with these confidentiality provisions, we have taken further measures to protect people who have provided various kinds of information to the GFR project. Following standard protocols for empirical social science research (Denzin and Lincoln 2000), we have set up a system of tracking qualitative information that protects the anonymity of informants. We maintain an internal database of all the fishermen, managers, scientists, processors and others contacted for this project. Many have been interviewed or provided information about ports, communities, or the operating costs of their fishing vessels or processing business. In that capacity, they are identified only by an "Interview ID" rather than by name or initials. For the most part, we use these interviews to supplement sparse data on socioeconomics and to gain a deeper understanding of the West Coast fishery. In many places, an interview with a port officer or other long-time resident of a community is the only source of information available to corroborate project personnel's observations. Where indicated, e.g. to reference a particular piece of information, we cite the interviewee by his or her ID number (1-3 digits). The same format is maintained for external publication or presentation purposes.

Since we are compiling information from many different sources, we are taking extra caution in how we combine confidential and non-confidential information. For example, although processors are masked in the data we have received from PacFIN, presenting them side by side with information from published sources such as the Urner Barry directory (Urner Barry Publications Inc. 2001) might allow rather more inference about individual businesses than is desirable. We are effectively censoring ourselves, therefore, by limiting the number of cross-tabulations we perform or how we represent these in any published materials. We have instituted various quality control measures to make sure that these and other important details are tracked and attempt to present our analytical results in the least controversial way.

2. Spatial modeling

The centerpiece of the GFR project is the modeling and analysis of spatial data—both those that are already available in spatial formats and those that we interpreted spatially based on other formats. The challenge was to organize data from diverse sources, in diverse formats, and of varying quality, and integrate them into a single framework.

In order to understand fishing effort, for example, we were interested in all commercial and recreational sectors, since locally or regionally distinct fisheries are characterized, among other things, by the different gear-types employed. We distinguish between two commercial and two recreational sectors: a) commercial trawl, b) commercial non-trawl (further differentiated into hook and line, long line and pot/trap), c) commercial recreational (charter boat fishing vessels), and d) private recreational. For these fishing sectors, the availability and quality of data progressively declines. For example, fishing activity with trawl gear is recorded in 10 by 10 nm blocks and includes a measure of effort (tow duration). Data on the non-trawl sectors of the fishery are less spatial and typically contain no measure of fishing intensity or effort. The coarsest spatial units of PacFIN fish tickets are the statistical areas defined by the now defunct International North Pacific Fisheries Commission (INPFC). Only eight of these INPFC areas cover the entire West Coast from Cape Flattery in Washington to the Mexican border, and each covers thousands of square miles. The choice is therefore to either "dumb down" the trawl data, or increase the spatial resolution of the non-trawl data. Our approach to the latter is described in section 2.4.b) below. California records both commercial and CPFV fishing in the same 10x10 blocks used in the federal trawl fishery. The coverage, however, does not extend to the entire coast. Also, data on recreational fishing other than California CPFVs (e.g., private crafts) come from a variety of sources (mainly national telephone surveys and port sampling) that do not elicit precise spatial effort descriptions.

As depicted in Figure 13, the GFR framework contains a set of linked information layers that collectively create a "smart" map of the groundfish fishery supported by empirical data about fishing effort, species distributions, etc. In the following five sections, we discuss the steps involved in deriving each layer. A summary of data sources for spatial information can be found in Appendix D.

2.1. Bathymetry layer

We obtained and processed depth information available from NOAA Fisheries (NWFSC), NOAA National Oceans Service, and the California Department of Fish and Game (CDFG) to generate a continuous bathymetry map for our study area. It is also possible to pull other kinds of oceanographic information into the spatial database, notably sea temperatures and other indicators of environmental events.

2.2. Habitat layer

We compiled a habitat layer using data from a variety of sources, such as the USGS habitat GIS for the Monterey Bay National Marine Sanctuary (Wong and Eittreim 2001). Using known depth associations for various fish species, the habitat layer can be used to relate fishing effort to particular areas, and thus to habitats. It is therefore possible to make associations between gear types and the kinds of habitats they potentially impact. For example, if a particular fleet restructuring scenario singles out a particular gear-type and removes it from the fishing grounds, this can reasonably be expected to have disproportionate, positive effects on the habitat associated with the species that are caught using that gear.[25] The currently available habitat data, however, are fairly coarse and do not provide the kind of detail required to identify nursery areas, spawning grounds or other areas of biological and ecological significance. This stands to be remedied with new habitat information becoming available in the future, some of which may be published in the timeframe of the GFR project.

The Northwest Region of NMFS is currently conducting an Environmental Impact Statement (EIS) for groundfish Essential Fish Habitat (EFH), to support management measures that meet the habitat conservation provisions of the Sustainable Fisheries Act.[26] As part of this EIS, a team of researchers from Oregon State University and Moss Landing Marine Laboratories are compiling habitat maps for the entire continental shelf off Washington, Oregon and California, interpreting a number of data sets (side and multi-beam sonar, and various others) that describe the characteristics of the seafloor. Consolidating and standardizing dozens of Navy, private and public data sources, these habitat maps will likely provide the first comprehensive picture of habitat types along the West Coast. Since these maps are being prepared in a GIS, they can be imported seamlessly into the GFR framework, and vice versa.[27] In addition to providing descriptive context on the kinds of ecosystems supporting fishing activities and coastal communities, the habitat maps can support queries on the habitat associations of particular gear types or target species.

2.3. Fish distributions

We obtained all available years of shelf and slope surveys from the Alaska Fisheries Science Center (AFSC). These trawl surveys have been conducted in periodic intervals on the continental shelf and slope over the past 25 years. NOAA research vessels using otter trawl gear record the total number, size and age distribution and weight of fish sampled along fixed transects (Lauth 2000; Weinberg, M. E. Wilkins et al. 2002). This approach records all the fish encountered in different years along the same line, and should not be confused with targeted fishing behavior. Because of the consistency of the sampling protocol, however, the trawl surveys generate a comprehensive picture of species abundance—at least of those species encountered along the transects, using trawl methods. Unlike the stock assessment that the NMFS trawl surveys are routinely used for, in the GFR project we did not consider the size and age class of fish distributions.[28] Our analytical focus was not on rebuilding fish stocks. Rather, we were interested in mapping the distribution of species that fishing vessels are likely to encounter along various parts of the

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[25] Because of the ephemeral nature of some seafloor substrate, seasonality is an important consideration for understanding the relation between different gear types and locations. For example, in some places off California, rocks are exposed during the winter and covered with sand in the summer. We thank Gary Greene for this comment.

[26] For details and updates on the EFH-EIS, see the NWR's web site, http://www.nwr.noaa.gov/1sustfsh/groundfish/eis_efh/gf_seis.html

[27] As part of the PSMFC funding for the GFR project, we are providing a data layer that summarizes fishing effort to the NWR effort on the EFH EIS.

[28] Size and age class distributions of groundfish species are, however, being assembled as part of NOAA Fisheries Northwest Region's Essential Fish Habitat EIS, and are compatible with the GFR geographic information system.

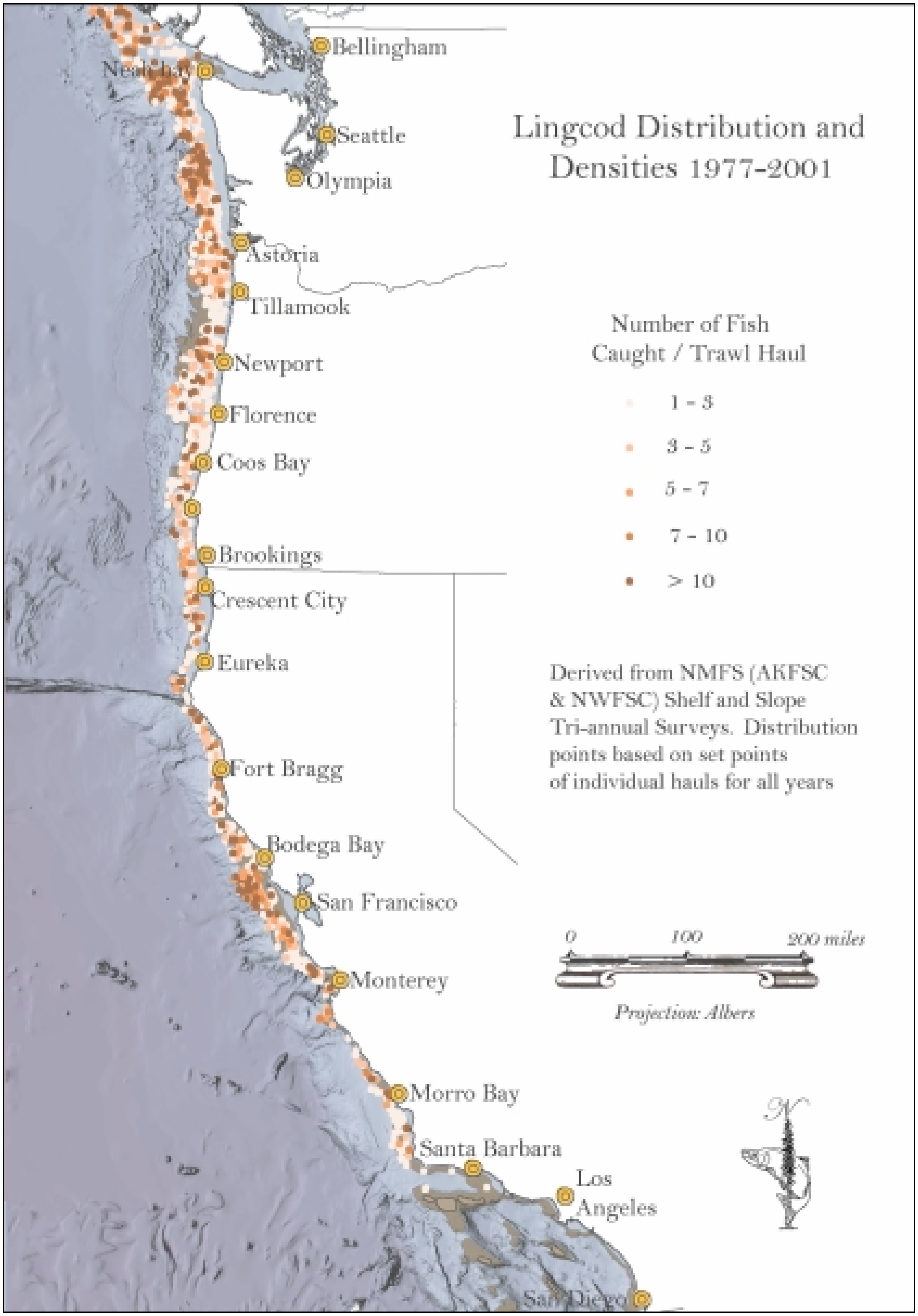
coast, and at different depths. We therefore only requested and imported into the database lists of species caught in the trawl surveys, together with their frequency and location.

We used start points of trawls as the spatial reference points for all trawls. Species and abundance (number of fish per species) were recorded for each trawl start point. Individual records of species targeted in the commercial fishery were extracted to generate species-specific density maps. We originally analyzed the data on a tri-annual basis, i.e. separately for those years that data were available. This, however, resulted in an insufficient correlation with target species from the fish ticket records that describe the non-trawl commercial fishing effort (see section 2.4.b below). In many cases data from the fish ticket records indicated abundant catches of species that did not show up at all, or only very infrequently, in the trawl survey for the corresponding year. This is most likely a function of the difference in fishing gear used, since many fishticket records report landings of non-trawl gear. We achieved a somewhat higher correlation by deriving single, cumulative species distribution maps for each target species using the same approach as NOAA’s Biogeography Group (NOAA's National Centers for Coastal Ocean Science and National Marine Sanctuaries Program 2002). We use these maps to help triangulate the spatial distribution of the non-trawl commercial fishing effort.

The discrepancy between the gear used in NMFS surveys and the gear use recorded in the landing receipts (especially those of the non-trawl sectors) is one of a number of limitations of our approach. Since the cumulative maps, however, contain many of the species targeted in non-trawl fisheries, albeit not necessarily depicting them in the exact places where fishermen would target them, we believe this is not a fatal flaw. Another limitation is the temporal mismatch between the NMFS surveys and the fishery dependent data. The trawl surveys typically take place in summer months, while the fishery operates year-round. The annualized nature of our fishticket data masks any effect the seasonal mismatch has on the spatial attribution, and it would be desirable to test this effect using more detailed (daily, weekly, or monthly) fishticket records. As it stands, there is a chance that our cumulative fish distributions are essentially summer time snapshots of the species distributions, with no way to compare how much of the annualized landings were caught during the same time of year.

Another confounder is the discrepancy in keying standards (i.e., how information are coded in the database) between the fish ticket system and the NMFS trawl survey data. We therefore re-assigned many species within the fish ticket data species codes to reflect the species designations used in the NMFS trawl surveys. We then grouped these into species complexes according to our depth associations for the 83 species targeted in the groundfish fishery, and mapped out their coast-wide distribution (see Figure 18). Many species (particularly rock fish species) were severely underrepresented or completely non-existent in the NMFS trawl survey data. This is due in part to the fact NMFS does not trawl in less than 50m (~ 100 fathoms) of water, and thus likely misses many species of rockfish that live in the part of the continental shelf classified as nearshore (i.e. less than 50 fathoms) for the purposes of the GFR project.

FIGURE 18: EXAMPLE OF SPECIES DISTRIBUTION MAPPING



2.4. Effort distributions

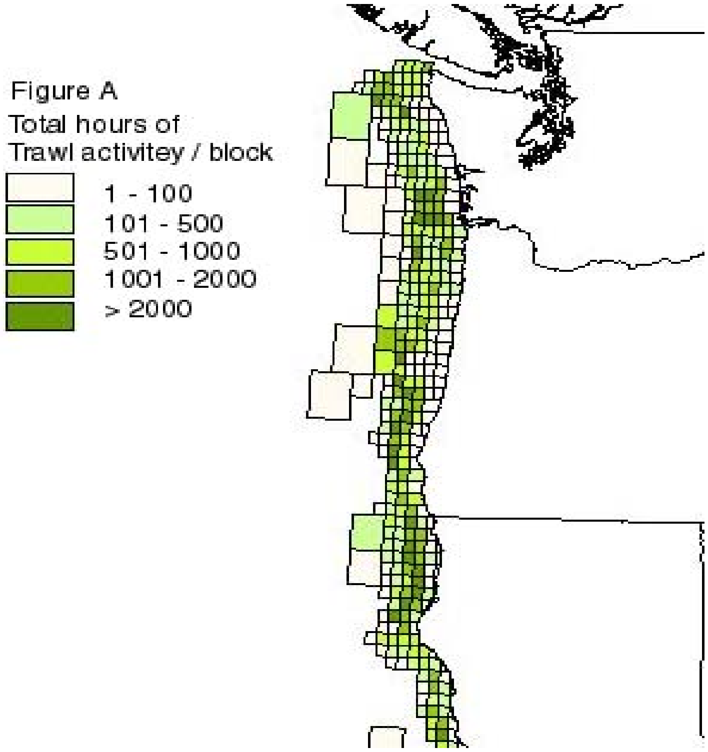
There are four kinds of fishing effort that we are modeling spatially in the GFR project: a) commercial trawl, b) commercial non-trawl (hook and line, longline, pot/trap), c) commercial recreational (CPFV), and d) private recreational fishing. Each comes with a unique set of challenges and procedures.

a) Commercial trawl effort – interpreting logbook data

In many ways, the data on the trawl sector are the most comprehensive, making the trawl effort layer the easiest to derive. There are two sources of data for describing trawl effort: logbooks and fish tickets. Vessels submit logbooks to the three state agencies, who process and forward them to PacFIN (Sampson and Crone 1997). Fish tickets are filled out by buyers in the landing ports for all gear types. We obtained logbook and fish ticket records for 14 years, 1987 to 2000. In this section we describe our method for spatially modeling the trawl effort using logbooks, since these are unique to this fishery sector. The next section contains our approach to spatially interpreting fish tickets.

The data fields contained in the logbooks include (in our case fictitious) vessel ID's; port ID's; the date, location (set points and block number), number of tows and duration of each tow; species caught; gear used; and the amount landed (both hailed and adjusted by fish tickets). From the latitude and longitude recorded for the set points it is relatively straightforward to map the distribution of trawl effort. We also use these set points to derive depth ranges at which trawl gear is used for the spatial interpretation of the fish tickets. Initially we referenced this by the 10x10 *nautical miles* fishing blocks recorded in the logbooks. Since this proved not sufficiently accurate for the spatial interpretation of the landing receipts for the non-trawl fisheries, we instead also summarized information at the level of smaller blocks measuring 9x9 *kilometers*, following the method used in a NOAA study on the biogeography of rockfishes (NOAA's National Centers for Coastal Ocean Science and National Marine Sanctuaries Program 2002).[29]

More accurately, what can be mapped from the trawl logbooks is the distribution of set points, since the haul points are not transcribed into PacFIN. This, and the fact that only the tow duration, but not the direction of each tow is recorded, introduces considerable uncertainty into the spatial interpretation of these records. Since trawl vessels are capable of covering considerable distances, with each tow potentially covering dozens of nautical miles, the effort maps likely misrepresents the actual distribution of catch. We used two methods for determining trawl activity.



In the first model, we determined the duration of each tow, using database procedures. Essentially we assigned the tow duration recorded in the logbooks to the block into which the recorded latitude and longitude of the set point fell. A new set of records is generated based on unique tow tracking information about duration of the tow (in hours), x, y location of set point, 10x10 minute block id, and gear used—as recorded in the logbook data. Species information is omitted as multiple species are recorded for each tow. This newly created record set is used to determine cumulative number of tows and cumulative tow duration for each block, generating a measure of trawl effort per area (see Figure A).

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[29] At the time of this writing, the NOAA Biogeography group was further refining its spatial resolution, aiming for 5x5 nm blocks (Mark Monaco, pers. comm. November 2002).

Secondly, we developed a constrained random direction model. This involves the following steps:

1) Based on the unique tows identified from the logbooks, we extract—from each record—the x and y-coordinates of each set point for each vessel, tow-date, and trip combination. We then derive a tow distance by multiplying the (recorded) tow duration by a constant.[30]
2) The tow distance is then added to the set point's y location to get a secondary y-coordinate. The start point and secondary y coordinate (associated with the x coordinate) are used to create a vertical line representing distance the vessel would have traveled (Figure B).
3) This line is then copied and rotated 360 degrees in 11.5 degree increments (for a total of 32 such increments, or possible directions) around the start point of the tow. Each rotated line is put into a comprehensive data layer. The resulting data layer represents 32 lines radiating from the tow start point each 11.5 degrees apart (Figure C). This data layer is then converted to a raster model.
4) As in the interpretation of fish tickets (see 2.4.b. below) we excluded areas that we identified as "untrawlable", adapting a method for interpreting the NMFS trawl survey data (Zimmermann 2002). Trawl and non-trawl fisheries are, by and large, mutually exclusive in that trawl gear is not used on high relief substrates and many of the non-trawl gear types target species that live in rocky habitats. Interviews with expert witnesses confirmed this; our technique effectively designates around 80-90% of the fishing grounds as trawlable.[31] The data derived in steps 1) – 3) are overlaid with untrawlable areas and bathymetry. If any given tow line intersects untrawlable areas, which—for the purposes of constraining direction—includes regulated areas and non-marine areas (islands, mainland), that line is removed from the analysis (Figure D). If all lines fall within untrawlable areas, the record is removed from the analysis. The total number of records removed from the analysis are tracked.
5) We further constrained these towpaths by factoring in the slope of the terrain, using bathymetry information. Considering the slope (rise over run) of each tow line remaining after step 4), any line with a slope greater than 1% is removed from the analysis (Figure E). If all lines have a slope greater than 1% then the line with the lowest slope is selected as the most likely tow line. Otherwise a random function is applied to determine the tow line. All other lines are removed from the data layer and the resulting line is copied into a master tow-lines data set (Figure F). This yields a reduced number of tow directions to each set point.
6) We picked one of those remaining tow directions at random for each set point and summarized the information from the logbook record by area. Once all tow lines have been delineated, these are overlaid with 9x9km blocks (used in previous analysis). Total distance towed is then summarized for each block (Figure G).

The technique outlined in steps 1) to 6) could be further improved with habitat information more detailed than the currently used trawlable/untrawlable distinction, as well as expert testimonials on the spatial behavior of trawlers.

Repeating the procedure in 1) through 6) for each year of data generates a time series of effort distribution maps—a kind of movie—that illustrates the changes in fishing effort over time in terms of pounds-landed associated with each fishing block. The trawl effort distribution also details the species caught per block, and pounds landed per port. Applying average prices for each species (another data set available from PacFIN), it is possible to derive the revenues generated per block. Figure 4 in Part I above illustrates the trawl effort logic for the years 1987, 1997 and 2000. The entire time series can be viewed as an animation at www.ecotrust.org/gfr. We normalized the catch per area by tow duration and number of tows, thus deriving a measure of catch per effort and area.

b) Commercial non-trawl effort – interpreting fish tickets

In order to map the fishing effort by commercial gear groups other than the trawl sector, and thus to compare and make visible the impacts of capacity reductions on different sectors of the fleet, we have developed a procedure for spatially interpreting landing receipts. Non-trawl, i.e. fixed gear, effort is captured in landing receipts filled out by fish-buyers in each port upon delivery. Information recorded in these fish tickets, and subsequently available from PacFIN, are the year and port where the catch was landed, the type of gear used, the (in our case fictitious) vessel ID, length, species landed, prices and ex vessel revenues, and INPFC area. The GFR analysis was conducted using

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[30] To determine the distance that each vessel traveled on that day and trip, we assumed an average speed of 3 knots. Since the we use meters as the spatial unit in the GIS, we multiply the duration in hours by 5556 meters, to convert from nautical miles (1852 meters in one nautical mile).

[31] For the non-trawl effort, we employ the reverse logic, focusing on non-trawlable areas.

annualized data on the total pounds of each species a particular vessel landed in a particular port, and for each unique INPFC area.

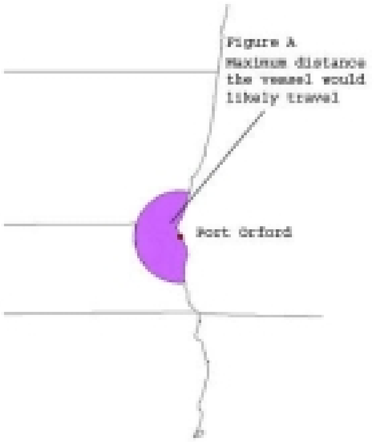
The effort mapping model is conducted exclusively in ArcInfo, a software application used for constructing and managing geographic information systems (GIS). An Arc Macro Language (AML) routine is used to control a "cursor" which steps through individual fish ticket records, extracts information, and performs a series of operations based on results of conditions set up in the AML routine. Each operation produces a spatial overlay, i.e., references the information to the shared map base. An error checking routine is run after each overlay to test the results of the analysis. If the operation results in a null value the previous overlay is passed to the next operation and the confidence level is reduced.

Using the smallest spatial resolution available for the entire study area (NOAA's National Centers for Coastal Ocean Science and National Marine Sanctuaries Program 2002), we developed a grid of 9km x 9km blocks that covers the entire Exclusive Economic Zone.[32] At the outset, a table is created to track how many tows or sets occur per block. This later serves as a reference to check for overcrowding, which occurs if the effort routine assigns too many vessels to the same block. Depending on a set of assumptions about the behavior of various fishing vessels—such as the number of vessels that realistically operate in the same place at the same time without adverse gear interactions—the threshold for overcrowding can be adjusted to reflect any density effects associated with numbers of vessels or gear types, or even the time period in which crowding is said to have occurred. For example, on the level of annualized fish tickets that we operate on, it is reasonable to assign more vessels to the same block than if the data were from the same day.

The model effectively steps each fish ticket record through a set of constraints, which in turn are derived from a number of external data sources. These include:

- Fish distribution information derived from NMFS trawl surveys (using a technique developed by NOAA's National Centers for Coastal Ocean Science and National Marine Sanctuaries Program 2002);
- A spatial analysis of untrawlable areas (Zimmermann 2002);
- Gear-depth associations (see Appendix A); and
- Expert testimonials on the likely maximum distance traveled by vessels of various lengths.

The first set of operations extracts information from the fish ticket data on the landing port, the length of the vessel, the target species (defined as the top 3 targeted species), gear-depth associations and the INPFC area-id. Each of these pieces of information is processed individually and factored into the overall model, as follows:



The length of the vessel is used to determine the maximum distance a boat is likely to have traveled. In the absence of comprehensive models of the behavior of the fishing fleet, we used interviews with expert witnesses (fishermen on the board of directors of our GFR project partners, the Pacific Marine Conservation Council) to derive a constant (2000), which we multiply with the boat length to derive maximum likely distance traveled in meters (figure A).

The resulting buffer is overlaid with the INPFC area ID (Figure B) reported on the fish ticket and checked for intersection. If there is no overlap then the area ID is omitted from the analysis and the port buffer is used instead. If there is an overlap, the resulting intersection is used in the remainder of the analysis (figure C).

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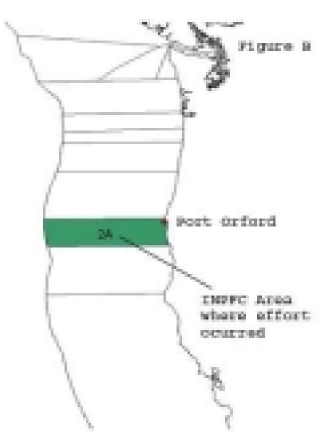
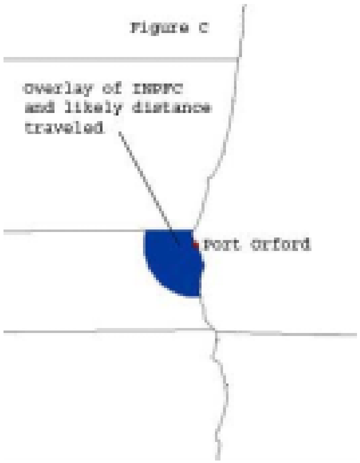
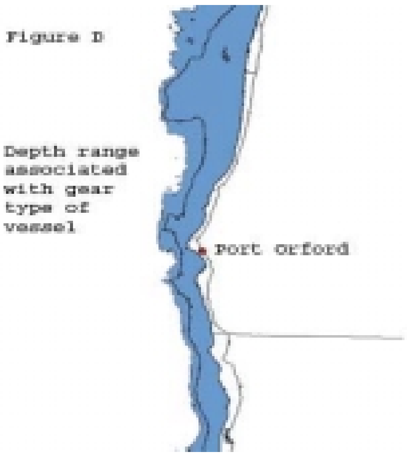
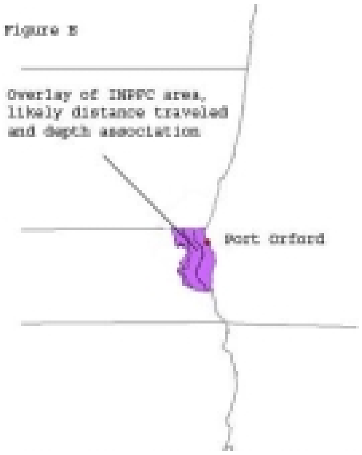
[32] These are comparable to, but should not be mistaken for the 10nm x10nm (nautical miles) blocks that are used for recording trawl logbook information. We found that the accuracy of the algorithm improved considerably using the smaller units.





Gear-depth association information is used to determine approximate depths at which a boat is likely to be concentrating effort (figure D). This is then overlaid with results of previous operation (or port buffer if no intersection was present) and area of overlap is identified (figure E). This area is used to “clip” the 9x9km blocks.





Those blocks with at least 50% of their original area intact are then used to summarize fish distribution information, which in turn was derived from NMFS trawl surveys. The blocks are weighted according to distribution and frequency of targeted species (figure F). The amount of untrawlable area is also summarized to the 9km x 9km block level (derived using a technique adapted from Zimmermann 2002), and the blocks are weighted by non-trawlable area (this assumed a positive relationship between untrawlable areas and fixed gear types)[33] (figure G).

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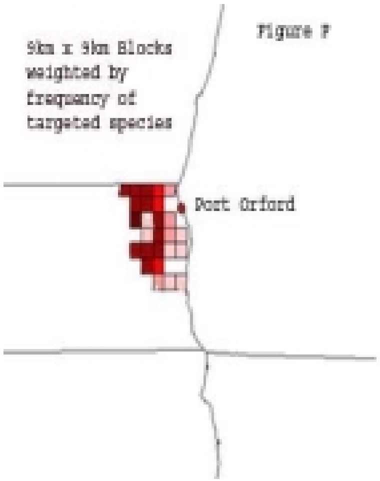
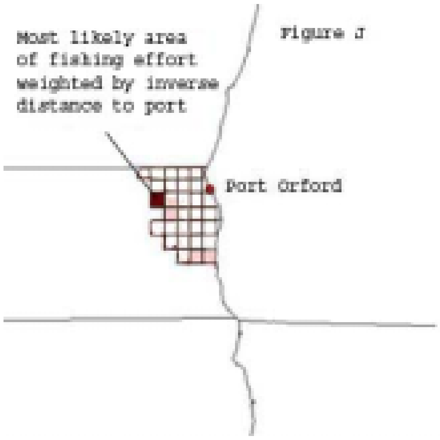
[33] In the case of the trawl fishery, the inverse relationship is assumed when processing fish ticket records.





Fish distribution, inverse distance from port (to center point of block) and amount of untrawlable area are then ranked for all blocks within the overlay using an equal interval classification. This results in three equal indices used to rank the overall likelihood a vessel would fish in any particular block.

The highest ranking block is then checked against the crowding table and if the threshold for the block has already been met, the block is removed from the analysis and the indices are re-created for the remaining blocks. The highest ranking block that has not been "overcrowded" is then assigned to the fish ticket record along with the confidence rating of the analysis and the cursor moves to the next record (Figure J). Appendix E contains a flowchart detailing this analytical sequence.

Caveats. There are a number of obvious limitations of this approach for spatially interpreting fish tickets. Firstly, there is a temporal mismatch between the annualized landing records we had available for the GFR project and the NMFS trawl surveys. The latter are central for deriving fish distributions, and are conducted only during summer months. It would therefore be desirable to use landing records at a finer temporal resolution and match them up with the trawl surveys. We are testing this for the appropriate time periods and one port, using line item landing records from the California Department and Fish and Game (CDFG). Processing constraints notwithstanding, the fish ticket algorithm is designed to work with any format of landing record. Using a subset of fish ticket records, we also use the CDFG data to validate the final block assignment by comparing them to the 10nm x 10 nm block used in California landing records.

Secondly, there is also a gear mismatch between the fish distributions derived from NMFS trawl surveys and the fixed gear effort distribution of interest here. There is a high degree of overlap between the species encountered in the NMFS surveys and those landed by commercial fishing vessels. It is, however, likely that the trawl gear used in the surveys does not encounter fish species at the same frequency and/or density as the fixed gear used by fishing vessels. Ideally, we would use fishery independent data from surveys conducted with fixed gear. The only such survey available appears to be the one conducted annually by the Halibut Commission, which only covers areas North of the study area.

Thirdly, the current habitat characterization of areas as either trawlable or untrawlable based on a spatial analysis may be further refined using additional sources of information. For example, sediment data from the forthcoming United States Geological Survey (USGS) seabed Interactive Mapping Server (IMS) cover a substantial part of the coast, from Cape Mendocino to Cape Flattery (see http://kai.er.usgs.gov/regional/contusa/gomex/index.html for more details). The USGS data set comprises cumulative “sediment grabs”, which yield information about the composition of the bottom substrate. We are incorporating an assumption that fixed gears would favor substrates that are comprised of more than 50% rock, while trawlers would avoid these areas. Of course, the EFH EIS effort is producing extensive new habitat information, but using these in the process for generating the spatial distribution of fishing effort may introduce some circularity into the process.

Fourthly, the information derived from expert witnesses could be further refined to reflect more or different areas of experience in the fishing industry, using—for example—more formal focus groups. In particular, given the absence of comprehensive studies of the economic behavior of the fleet, it might be desirable to use such expert knowledge to derive constants that approximate maximum distance traveled for each gear type, rather than the generic one we developed in relation to vessel length. Finally, more recent landing records could be used to extend the time series of our analysis. Furthermore, the data should reflect behavioral responses of the fleet in response to the in-season shelf closures. This could potentially be analyzed to derive, statistically, the spatial strategies of different gear types.

New sources of data, particularly observer data currently being collected in the non-trawl fishery, would provide a welcome opportunity to validate and fine-tune the approach detailed here. Our method for spatially interpreting fish tickets may thus provide a useful tool for analyzing historical trends of fishing activities and their associated habitat impacts. Analogously to Figure 4, it is then possible to generate the spatial distribution of fishing effort as recorded in fish tickets for the entire coast, and for all years.

c) Commercial recreational (CPFV) effort

One of the most challenging aspects of the GFR project was to find comparable data on recreational fishing effort on the coast. Although there are currently no proposals for fleet reductions in this segment of the fishery, we thought it would be interesting to at least compare levels of commercial and recreational fishing in the study area. The most comprehensive database available is a compilation of the commercial passenger fishing vessels (CPFV) logbooks that the California Department of Fish and Game requires from the substantial fleet in its waters. CPFVs operate along the entire West Coast, but are significantly concentrated in Southern California. These boats take passengers fishing for a fee, on trips ranging from a few hours to multiple days or even weeks. This historical analysis contains—in aggregated form—number and kind of fish caught per 10x10 nm fishing block from 1936 through 1997 (Sampson and Crone 1997; Hill and Schneider 1999).

d) Private recreational effort

There is very little information available that describes private recreational fishing off the West Coast. The Marine Recreational Fishery Statistics Surveys (MRFSS) administered by NMFS asks respondents where they go fishing, but since this is a phone survey, the spatial resolution and quality of data are rather poor. There are also a number of port-side and launch-ramp sampling programs administered by the three states, typically around salmon management issues. We collected and evaluated all data available, and are including them in our GIS deliverables to PSMFC. Other data sources, such as estimates of ramp usage in ports that receive funding from state and federal agencies, may provide additional information. These are just the bare beginnings of assessing the spatial extent and magnitude of private fishing effort. We compiled these estimates to the best of our abilities and generated coverages showing the amount of recreational fishing associated with various ports.

2.5. Ports and landings

Each port is quantitatively described in terms of the landings of groundfish made there, the associated revenues and the number and kinds of vessels that make their home there. In addition, there are census and other demographic data available, as well as maps of transportation routes, terrestrial biophysical features, and other characteristics that we are in the process of compiling. In addition, we have also collected a host of qualitative information on each port. This is harvested from published sources, interviews with community members and observations made by project staff during extensive field visits along the coast. We coded and collated this information for communities and counties on the West Coast. Community profiles such as those for Newport and Port Orford presented in Part I of this report can be requested from the Principal Investigator. In subsequent work of the Ecotrust Fisheries Program, it is our aim to produce an atlas, where a click on a port name calls up everything recorded about it in the GFR database in a pop-up window. We also anticipate analyzing this qualitative information on ports further, to devise one or more indices of, for example, how isolated a community is from major transportation routes. We plan to collaborate with researchers at the PSMFC, who have conducted similar qualitative research on ports, and have begun developing a “resiliency index” and measures for the degree of isolation of a community (personal communication, David Colpo, 11 July 2002, and Langdon-Pollock 2002).

3. Computational challenges

There are a lot of data about the fishery that—when integrated—could be very valuable for fishery management purposes. We have experienced, however, considerable computational challenges in processing tens of thousands of annual vessel summaries (in the case of the landing receipts data set) to the level of vessels lengths, species, and gear details desirable for the capacity restructuring analysis. The size of the data set increases by an order of magnitude when considering line item data, which would be desirable for capturing seasonal variations. Similarly, our database is limited to groundfish records, and an expansion to all fisheries would again increase the record set by 2-4 factors.

The problem is mainly one of processing a large set of historical records, in our case the 14 years from 1987 to 2000. For each year, there are around 50,000 fish ticket records, all of which have to be processed using the spatial fish ticket algorithm explained above. Using our in-house processing facilities, and not counting the numerous changes and refinements we have been making to the procedure, it takes about a week to process a year of annualized data—more for line item data. At the time of this writing, we are in conversations with national supercomputing facilities where these processes could likely be run in a much more time-efficient manner, once the procedure has been tested and validated. If this sort of regional, spatially integrated database were to become part of the routine data collection and analysis process for West Coast fishery management, the additional processing of subsequent years could likely be accomplished in one week or less. As part of our programmatic fisheries work, we will develop a protocol for processing geospatial datasets at these supercomputing facilities, and anticipate that this sort of one-off processing would be done on an annual schedule.

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Appendices

In the interest of keeping this document to a tolerable length, some of the appendices are omitted and can be found on the project website, www.ecotrust.org/gfr

Appendix A – List of gear-types contained in PacFIN data, and gear-types assigned for GFR project.

Appendix B – Flow chart of fish ticket algorithm

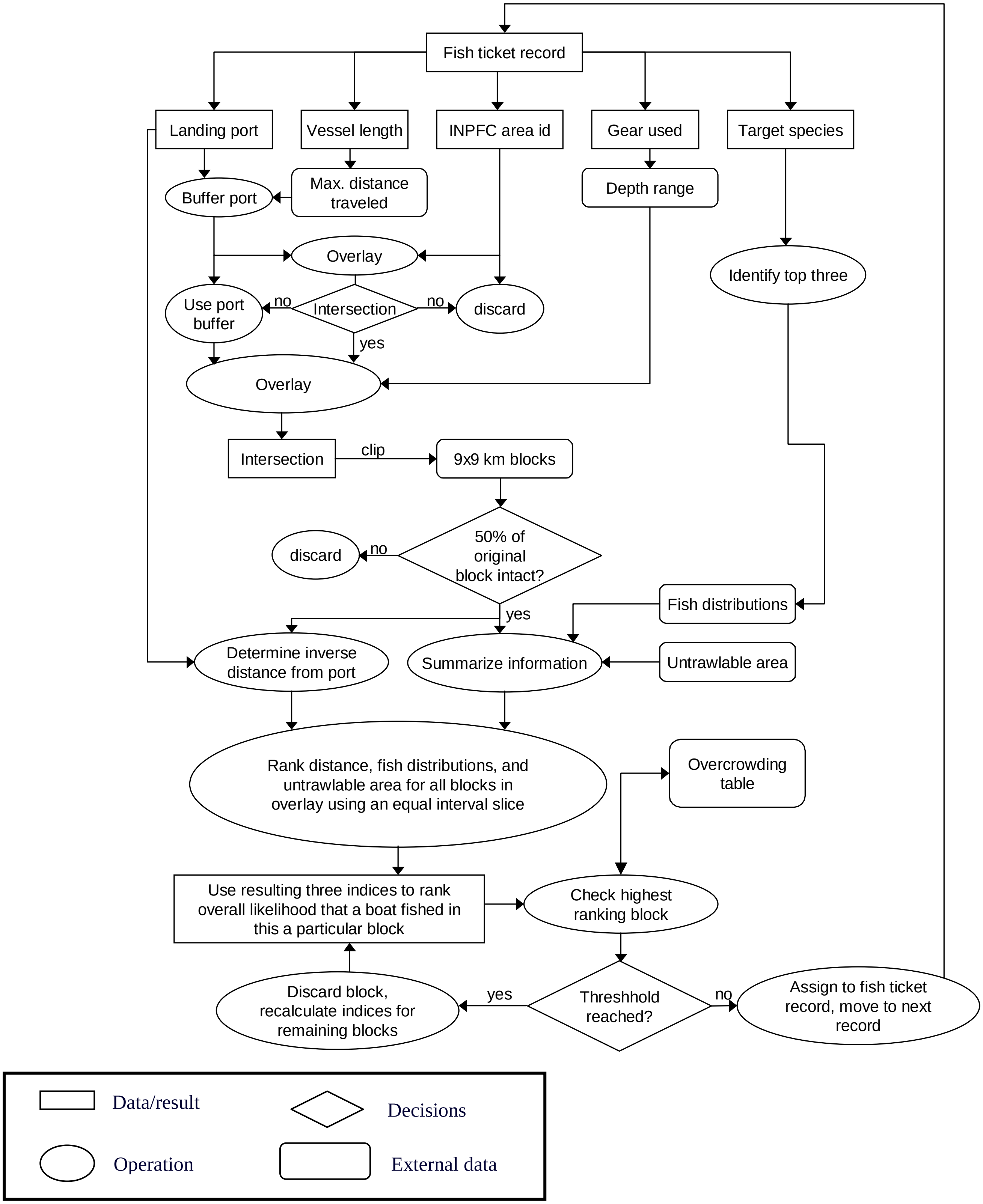
APPENDIX A – GEAR TABLE

PacFIN gear-id	short name	description	GFR project group	depth range
ODG	OTH-DREDGE	OTHER DREDGE GEAR	other	everywhere
SCD	SCL-DREDGE	SCALLOP DREDGE	dredge	0 - 50 fathoms
DRL	DROP LINE	DROP LINE	hook and line	0 - 275 fathoms
HDL	HAND LINE	HAND LINE	hook and line	0 - 275 fathoms
HLR	POLE(REC)	HOOK AND LINE (RECREATIONAL)	other	everywhere
JIG	JIG	JIG	jig	0 - 275 fathoms
LGL	LONGLINE	LONGLINE OR SETLINE	long line	30 - 275 fathoms
OHL	OTH HK&LN	OTHER HOOK AND LINE GEAR	other hook and line	everywhere
POL	POLE(COM)	POLE (COMMERCIAL)	hook and line	30 - 275 fathoms
STL	SETLINE	SETLINE	hook and line	30 - 275 fathoms
VHL	VRTCL HKL	VERTICAL HOOK AND LINE GEAR	hook and line	0 - 275 fathoms
DVG	DIVING GR	DIVING GEAR	other	0 - 50 fathoms
OTH	OTH-KNOWN	OTHER KNOWN GEAR	other	everywhere
RVT	RVR-TRAWL	RIVER TRAWL	other net	everywhere
USP	UNKN-GEAR	UNKNOWN OR UNSPECIFIED GEAR	other	everywhere
DGN	DRF GL NET	DRIFT GILL NET	gillnet	30 - 700 fathoms
DPN	DIP NET	DIP NET	other net	everywhere
GLN	GILL NET	GILL NET	gillnet	30 - 700 fathoms
ONT	OTHER NETS	OTHER NET GEAR	other net	everywhere
SEN	SEINE	SEINE	other net	everywhere
SGN	SUNKN GLNT	SUNKEN GILLNET	other net	everywhere
STN	SET NET	SET NET	other net	30 - 275 fathoms
TML	TRAMMEL	TRAMMEL	other net	everywhere
CLP	C&L POT	CRAB AND LOBSTER POT	crab pot	0 - 275 fathoms
CPT	CRAB POT	CRAB POT	crab pot	0 - 275 fathoms
FPT	FISH POT	FISH POT	pot/trap	everywhere
LPT	LBSTR POT	LOBSTER POT	crab pot	0 - 275 fathoms
OPT	OTHER POTS	OTHER POT GEAR	other pot	everywhere
PRW	PRWN TRAP	PRAWN TRAP	other pot	30 - 275 fathoms
SPT	SNAIL POT	SNAIL POT	other pot	everywhere
BTR	BTM-TROLL	BOTTOMFISH TROLL	hook and line	30 - 275 fathoms
HTR	HAND TROLL	HAND TROLL	troll	30 - 275 fathoms
PTR	P-G-TROLL	POWER GURDY TROLL	troll	30 - 275 fathoms
TRL	TROLL	TROLL	troll	30 - 275 fathoms
BMT	BEAM TRAWL	BEAM TRAWL	beam trawl	logbook set points
BTT	BTM-TRAWL	BOTTOM TRAWL	bottom trawl	logbook set points
CBF	CTCHER-FR	BOTTOM TRAWL, CATCHER BOAT, FOREIGN	other trawl	100-700 fathoms
CBJ	CTCHER-JV	BOTTOM TRAWL, CATCHER BOAT, JV	other	100-700 fathoms
DNT	DNSH SEINE	DANISH/SCOTTISH SEINE (TRAWL)	other trawl	0 - 275 fathoms
FFT	FLT-TRAWL	FLATFISH TRAWL	bottom trawl	30 - 275 fathoms

PacFIN gear-id	short name	description	GFR project group	depth range
GFL	GFTRAWL>8	GROUNDFISH TRAWL, FOOTROPE > 8 in.	large foot rope trawl	100-700 fathoms
GFS	GFTRAWL<8	GROUNDFISH TRAWL, FOOTROPE < 8 in	small foot rope trawl	30 - 700 fathoms
GFT	GFSH-TRAWL	GROUNDFISH TRAWL (OTTER)	bottom trawl	30 - 700 fathoms
LFZ	LARGE-FRZ	BOTTOM TRAWL, LARGE FREEZER TRAWLER	other trawl	100-700 fathoms
	SGL-SHRIMP	SHRIMP TRAWL, SINGLE RIGGED	shrimp trawl	30 - 275 fathoms
DRG	DREDGES	ALL DREDGE GEAR	other	everywhere
HKL	HOOK&LINE	ALL HOOK AND LINE GEAR EXCEPT TROLL	hook and line	everywhere
MSC	OTH GEARS	ALL OTHER MISCELLANEOUS GEAR	other	everywhere
NET	NETS	ALL NET GEAR EXCEPT TRAWL	other net	everywhere
POT	POT&TRAP	ALL POT AND TRAP GEAR	other pot and trap	everywhere
TLS	TROLLS	ALL TROLL GEAR	troll	everywhere
TWL	TRAWLS	ALL TRAWLS EXCEPT SHRIMP TRAWLS	other trawl	logbook set points
TWS	SH-TRAWLS	ALL SHRIMP TRAWLS	shrimp trawl	everywhere
ALL	GEARS	ALL GEARS	other	everywhere
XXX	NULL	UNKNOWN GEAR (BDS)	other	everywhere
MPT	CP-MTRAWL	MIDWATER TRAWL - CATCHER/PROCESSOR	midwater trawl	30 - 700 fathoms
MDT		MIDWATER TRAWL	midwater trawl	30 - 275 fathoms
OTW	OTH TRAWLS	OTHER TRAWL GEAR	other trawl	everywhere
PRT	PAIR TRAWL	PAIR TRAWL	other trawl	30 - 700 fathoms
RLT	RLR-TRAWL	ROLLER TRAWL	bottom trawl	logbook set points
SFZ	SMALL-FRZ	BOTTOM TRAWL, SMALL FREEZER TRAWLER	other trawl	30 - 700 fathoms
SRM	SURIMI	BOTTOM TRAWL, SURIMI TRAWLER	midwater trawl	30 - 700 fathoms
DST	DBL-SHRIMP	SHRIMP TRAWL, DOUBLE RIGGED	shrimp trawl	30 - 275 fathoms
PWT	PRWN-TRAWL	PRAWN TRAWL	prawn trawl	30 - 275 fathoms
SHT	SHMP-TRAWL	SHRIMP TRAWL, SINGLE OR DOUBLE RIG	shrimp trawl	30 - 275 fathoms
SST	SGL-SHRIMP	SHRIMP TRAWL-SINGLE RIGGED	shrimp trawl	30 - 275 fathoms

For the purposes of the GFR project, we follow the depth characterizations used in fishery science and management on the coast and distinguish between nearshore (less than 50 fathoms), shelf (30 to 275 fathoms), slope (100 to 700 fathoms) (Turk, Builder, West, Kamikawa, Wallace and Method 2001). These depth categories reflect management considerations, since some rockfish species managed as “nearshore” or “shelf” species can be found in deeper waters. Physiographically, the shelf break occurs at a depth of 50-100 fathoms, and anything deeper than that is continental slope. We thank Gary Greene for this observation. We applied the depth associations of target species to the gears used to catch them, thus arriving at the gear-depth associations we use for the fish ticket algorithm.

APPENDIX B – Flowchart for ArcINFO fish ticket procedure



Legend