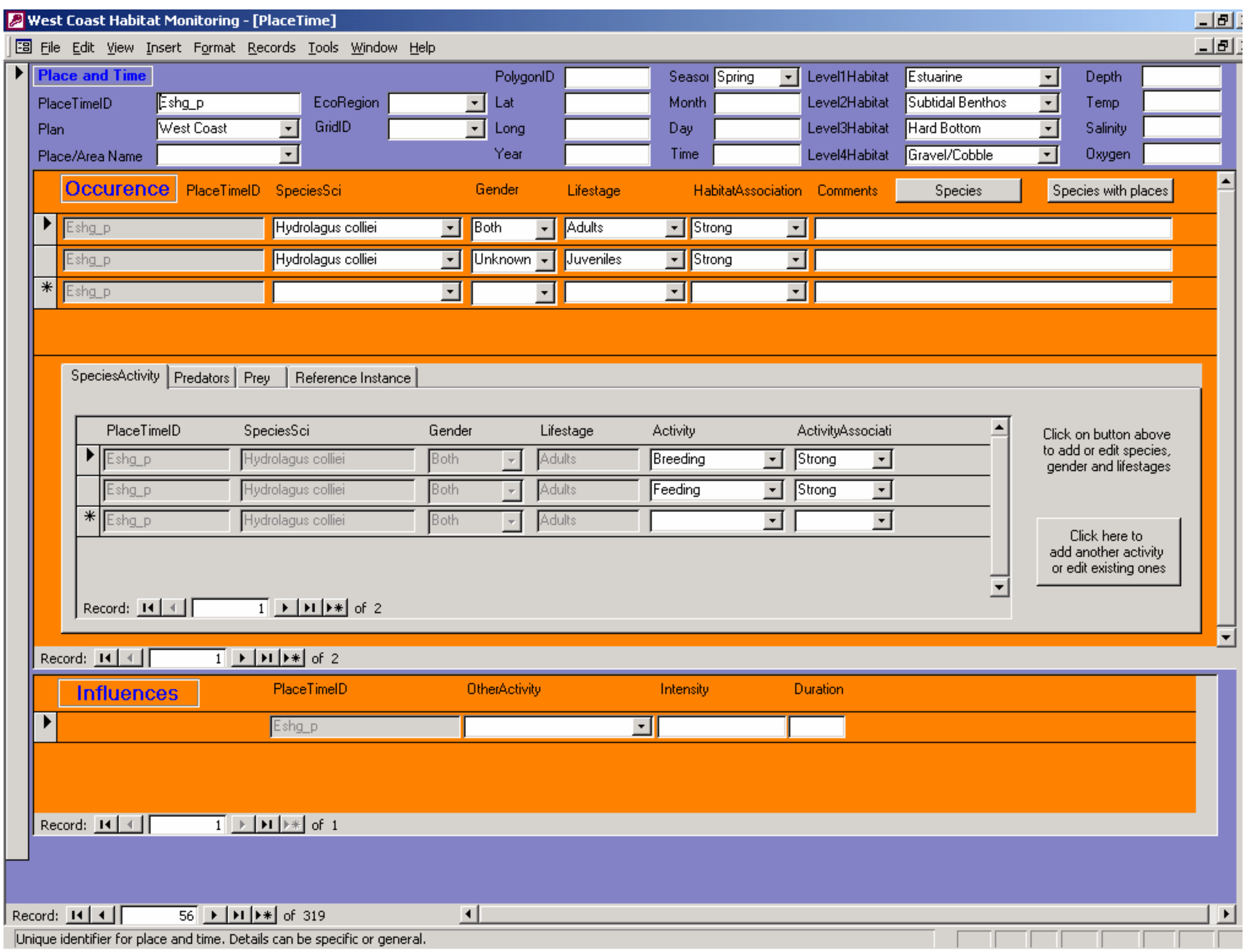
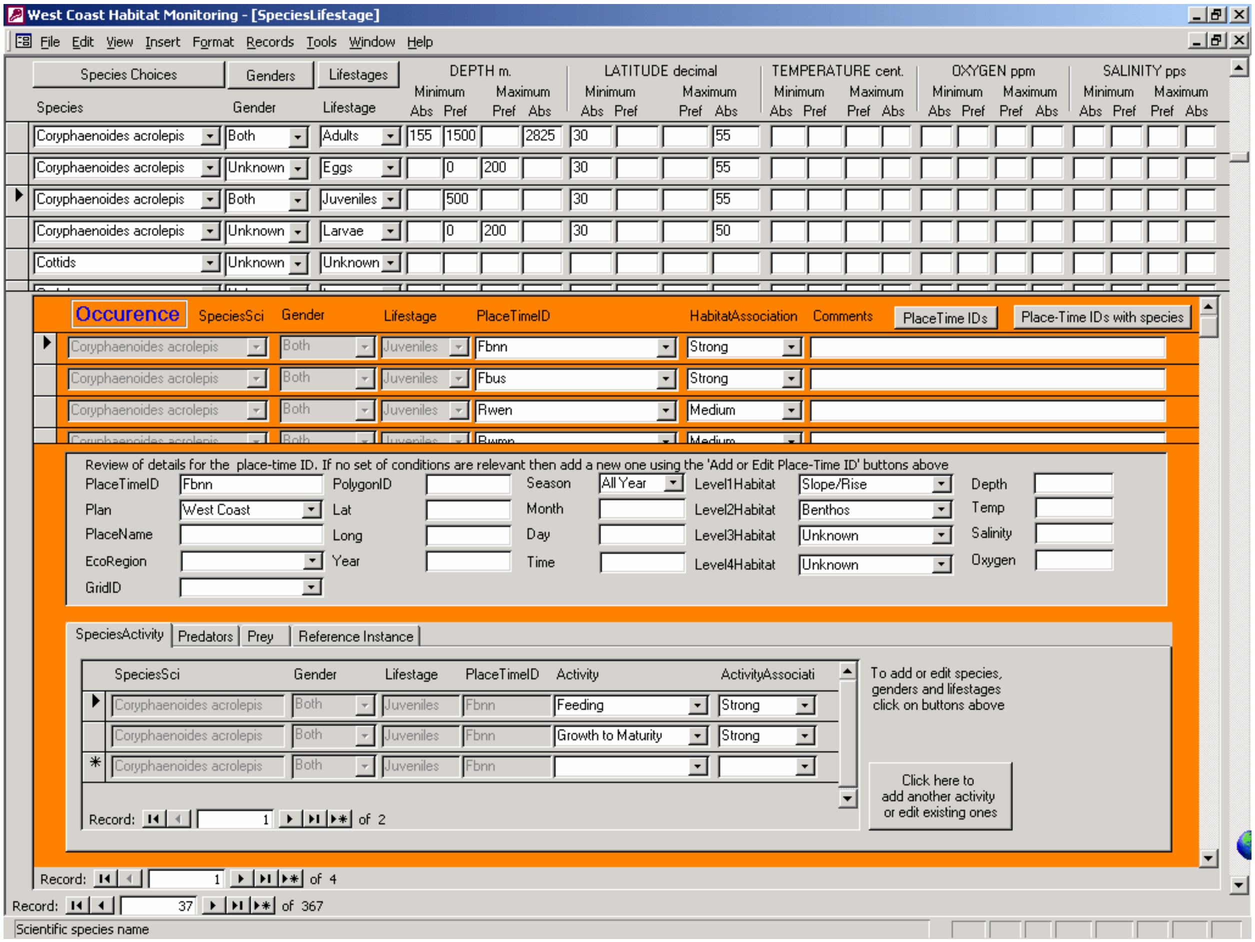
3.1 Data Entry

There are two main options for data entry: “place-time-centric” and “species-centric.” Essentially the first allows you to enter all the species-life stages for a given habitat whereas the latter allows you to do the converse and enter all the habitats for a given species-life stage. The ‘Place-Time’ scenario is more likely with data arising from a survey while the ‘Species-Centric’ approach is more likely with data arising from a literature survey. In both instances the associated, more detailed, place and time info can also be entered to the degree in which it is available. In both cases, data entry starts with a Main Data Entry Form (see below). This form is arranged in sequential sections, as emphasized by the different colors. It is important to use the correct set of record navigation buttons for each section. In the Place-Time version, the top level records for ‘Place and Time’ have a blue background with their record navigation buttons at the bottom of the form; note that there are four sets of navigation buttons in this form. The next two sections, Occurrences and Influences, are nested at the same (2nd) ‘level’ and have a copper colored background. Nested within Occurrence at the third level are four sub tables, each with an independent serving form, Species Activities, Predators, Prey and Instances of References.

The place-time-centric main data entry form appears as follows:



The species-centric main data entry form appears as follows:



The species version shows similar information, but it allows data entry by species and life stage, to simplify the process of entering data from the Updated Life History Descriptions document, which will be the primary data source in the first instance.

Whichever of the forms is used, the data always end up in the same underlying data tables in a unified and consistent data structure. The only difference is how this is shown in the user interface.

In both cases, all of the various sections of the form are synchronized. Thus when the user moves on to the next place-time or species record all of the associated data that have already been entered automatically appear in other parts of the form. Note that if new data are being entered then the correct matching PlaceTimeID and Species_Sci/Life Stage are automatically copied to the occurrences table. This principle also applies to all the other linked tables at the lower levels with their key fields.

Multiple ‘Occurrences’ and ‘Influences’ can be visible for any one PlaceTime record. These two logically occupy the same level in relation to the parent PlaceTime record and are given matching background colors in the Place-Time centric to visualize that fact.

Within the ‘Occurrences’ of a single species-life stage there can be multiple activities that the species-life stage is performing on the recorded habitat. There can also be multiple predators and prey in that location and multiple references relevant to that occurrence. All of these data elements are recorded on the tabbed sub forms. These have an ‘index-card’ like appearance to maximize the amount of data available on one screen.

Most of the data are presented in forms in a table-like format with multiple rows for records. This is considered to be the most useful and practical approach for the user who is entering and reviewing data. Often corrections (and also avoidance of typing errors) involve the comparison of adjoining records, especially when the data in question has been filtered and sorted. The table-like interface is far more useful for doing this since everything is visible at once.

Having all of the inter-linked data from related tables visible at once in adjoining sections also prevents confusion and errors during data entry and simplifies the making of corrections and/or modifications after the data have been entered. It is impossible to enter the wrong data in the key fields for related tables since the foreign key constraints automatically generate an error message when the user tries to do this. The form arrangement in any case does away with the need to re-type related key field data since it is automatically copied from the ‘parent table’ section to the ‘child table’ section of the form and cannot be edited there but only viewed.

Appendix 8E is a ‘tutorial’ explaining how the information for a given species is broken down and entered as records.

The database system has its own tool bar:

Under the West Coast heading the entire functionality of the main control form is reproduced so that users can call up any data entry form or analysis direct from the menu bar without having to re-locate the opening form. All of the important functions on the tool bar and many others are also provided by the main menu bar. It is therefore not essential to use this ‘WestCoastTools’ toolbar to operate the system and it can be turned off under the menu choices ‘Tools/Customise/Toolbars/WestCoastTools’ should the user prefer not to use it. The tool-bar can also be turned on and off by right clicking on the empty area to the right of the main menu bar at the top of the screen and then ticking ‘WestCoastTools’ on or off.

The user can unhide the main database window in order to access the underlying parts of the system directly. NB **Changes at this level should be made only by an experienced database designer or code developer who is responsible for the database.** This is especially important if there are multiple copies of the database being used which need to be synchronized. This could be where data are being entered at several different sites or data entry going on at one sight and query development at another. In such situations, requests for alterations and additions to the system should be first logged and then implemented on an organized basis so system development and the data management can proceed in a consistent and integrated fashion across sites.

3.2 Look-Up Tables

Look-Up data are those provided in tables such as Species, Genders, Lifestages, Eco-regions and Grids, Habitat Levels, and Activities. These data change less often than those in the other tables. New records are only occasionally added and existing ones are only rarely altered. When changes are made these immediately become available as data entry choices in the main data entry forms. When they are altered, all the records in the database that have the old values are updated automatically to reflect the change. Note that you can not delete one of these look-up values unless you have first deleted any records elsewhere in the database that refer back to it.

For convenience, some of the more likely look-up tables can also be called up from the main data entry forms (PlaceTime and SpeciesLifestage) via various buttons and also as sub-choices under the WestCoastTools tool-bar.

3.3 Sorting and filtering data

One important aspect is learning how to use the sorting and filtering buttons. A user can filter the data so that only records appear that have field values equal to that of the field the user is currently in. This is known as 'Filter by Selection' . Secondly a user can filter by form by first selecting this button and then choosing from the list of available values provided by the drop down boxes that become available for ALL fields. The user would then press the apply filter button to obtain the subset of data. The term '(filtered)' appears next to the record counters at the base of a form / table whenever a filter is in operation. Remember to check this and clear the filter afterwards by pressing the same button again. A user can also remove the filter completely with the 'clear-filter' button. In the filter design view a user can also clear the filter grid. Most of the data are already sorted according to its key fields. In some instances there are additional sort-order fields e.g. for life stages or seasons. This allows the order that the values appear in to the user to be assigned even when using normal descriptive terms. The user can resort the data according as desired as an aid to locating particular records during editing etc.

3.4 Analyses

3.4.1.1 Overview

These are currently under development. It has been requested to provide only a few working examples of the different types of query with documentation of how these are developed and can be adapted and extended. The client then intends to use these as the basis for developing their own queries.

Attention is drawn to the sections on Data Structure and Appendix 8C which detail the essential principles and knowledge required to make the best use of this system's capabilities in this respect.

Examples of a select query, a cross-tab query and a chart which plots the results of a cross-tab are provided. Other analyses that provide lists of species and life stages according to the various habitat categories, grid squares and eco-regions can be developed if the data are broken down to this extent in the future.

The queries in the examples are plotted via a generic method whereby axes labels are formed from the category values themselves and thus always reflect the data content. Thus there is no need to create a separate explicitly labeled chart each time the selection conditions or underlying data change.

Complex patterns of trophic interdependence are represented via the conjunction of the Occurrences, Predators and Prey tables. With some thought it may be possible to develop queries that can analyze these patterns.

Where analytical requirements demand the use of mathematical and statistical modeling software, queries can be developed to produce the correctly formatted data-sets for direct input into such applications. An example of this is provided with the **'HabitatAssociations1'** query.

Further queries could also be developed to interface the database with companion systems which could both receive and provide data in integrated analyses.

If data are provided there is the opportunity to analyze for the recorded 'Influences' (or 'impacts') where these may be natural or anthropogenic.

To concentrate on the scope of the data provided so far, a series of examples follows covering different classes of queries with explanations of how these were developed and how they can be extended. In addition to the detailed instructions given here it is recommended that anyone developing such queries should have a clear grasp of the principles of relational databases and query structuring and have good Access manuals or text books available. Beware that many of the text books place the 'cart before the horse' and embark on detailed 3rd generation code examples without first clearly explaining the essential underlying relational principles of such 4th generation database environments. Despite such systems being available for 20 years or more, by and large within biological resource management the penny has still not dropped! A very good reference work would be 'Access Database design and programming' by Steven Roman, published by O'Reilly, ISBN 1-56592-626-9.

A user should not alter any of these example queries, but should instead copy and rename them and then experiment on those new queries using them as a template to develop new lines of query. That way if it all goes horribly wrong the user can simply delete them go back to the unaltered source queries and copy them afresh. In addition, a strict and documented system of regular backups should be in place as well.

A user can copy and rename the queries by right clicking on them in the queries section of the main database window, selecting 'copy,' then right clicking in an empty space in the database window and selecting copy, entering a new query name, and then working with that new query. One important thing to bear in mind is that if a query uses other queries as its source and you rename those sources then obviously the name of the source also has to be altered in the query that uses it. E.g. the query called 'AllQuery1_Crosstab1' which uses 'AllQuery1' as a source. You can also 'import' individual queries from backups if you inadvertently damage one of these source queries.

Some charted output is provided as part of the system. This is mainly to demonstrate its capabilities in that any output can be charted where appropriate. It is beyond the scope of the resources available for this manual to explain in detail how to develop charts. Also, developing the kind of generic charts demonstrated here, that label their own axes etc according to dynamic inputs, assumes some expertise in the use of Access. Any additional charts required could be developed and provided in future.

3.4.1.2 Example 1: Species-based investigation

In this example we will develop a range of queries that will look at all the available data for a particular species. Obviously one of the conditions will be the species name. Thus the queries can simply be reapplied to any other species by altering the value of the species name under that condition. The main query will stratify according to all life stages. Genders will be ignored in this case as there is very little gender specific data that has been entered so fare. For each of the life stages we will look at each defined habitat in turn and list its definitive values. Within those 'strata' we will then analyze for species activity, predators, prey and even references in the literature. In summary the complete list of strata are:

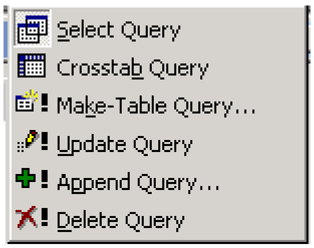
- Species
  - Life stage
    - Habitat
      - Species Activity
      - Predators
      - Prey
      - References

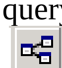
Note that the last four are all 'independent' attributes within habitat.

The example query is called 'AllQuery0.' The query is created from the 'Queries' section of the main database window and selecting 'Design View.' One can make good use of the 'Simple Query Wizard' and 'Crosstab Query Wizard' provided one has sufficient database experience. Care is required because it is possible to produce a working query that provides results that are nonsense if tables are linked and conditions combined in an illogical fashion.

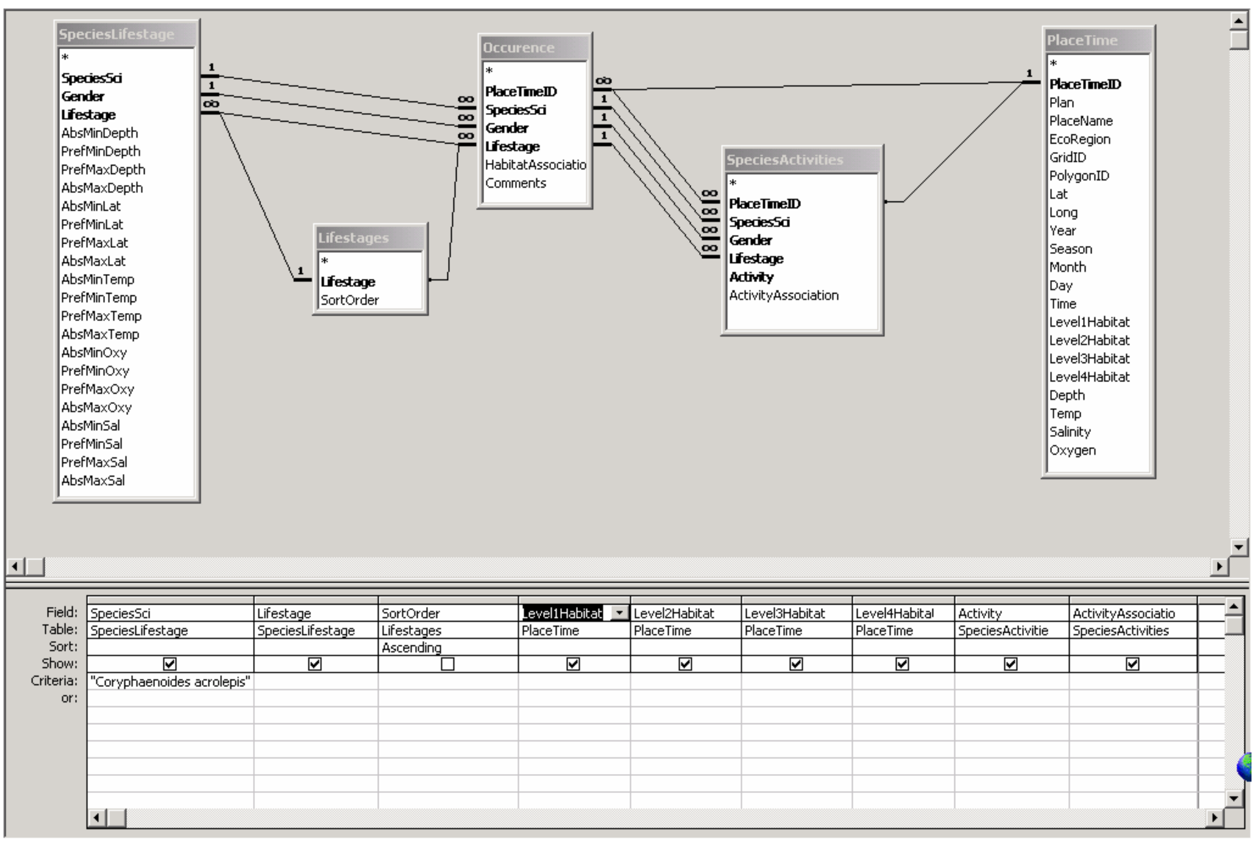
Tables are added to the design view by selecting them from the 'Show Table' list offered. Note that a user can also base a query upon another query as well.

Apart from the selection and cross-tab queries that produce a set of results a user can also alter the query type so that it adds, modifies or deletes data or even creates new tables. Make sure you know what you are doing before going down that road and have in place a religious back up procedure that is fully documented so that you can reverse out of any inadvertent disasters!



You should select the tables you require for your query by first looking at the 'map' of your database provided by the 'relationships' diagram.  This will serve to remind you of table and field names and how they relate to one another.

You should select the tables for the query from the 'Show Table' to produce a query as follows.

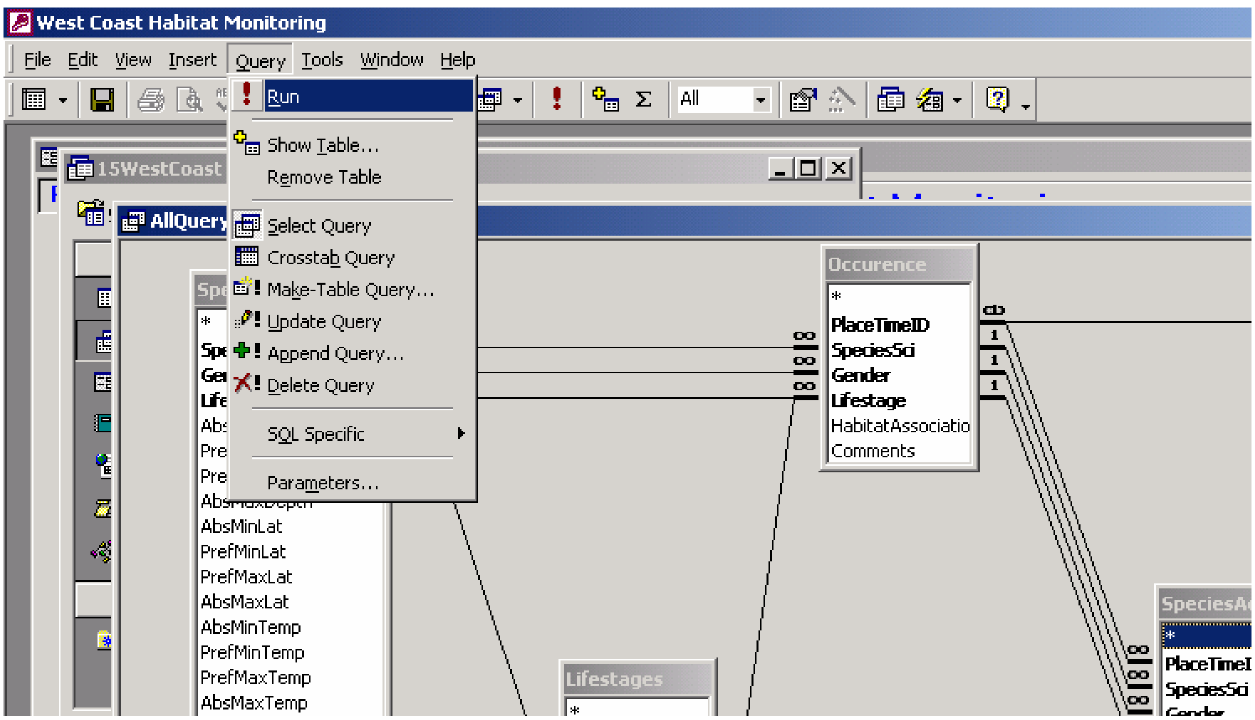


The 'foreign keys' are the lines representing the links between the tables. These are inherited from the relationships diagram. You can drag and size the tables to form the best layout.

You then double click or drag and drop the columns you require for your results. Note that a ‘criterion’ has been entered for the species name (‘Coryphaenoides acrolepis’) and that the SortOrder column of the Lifestages table has been utilized to make sure the results appear in life stage order,

You could copy this entire query to one of a new name and edit that to your preferences. You could add in or take out columns or conditions as you require. The simplest way to create your own new query is to open the AllQuery0 and use the ‘File’/Save As…’ option giving it the name of your choice.

You can run the query by a number of different methods the simplest being to press the red exclamation mark from the menu bar or toolbar.



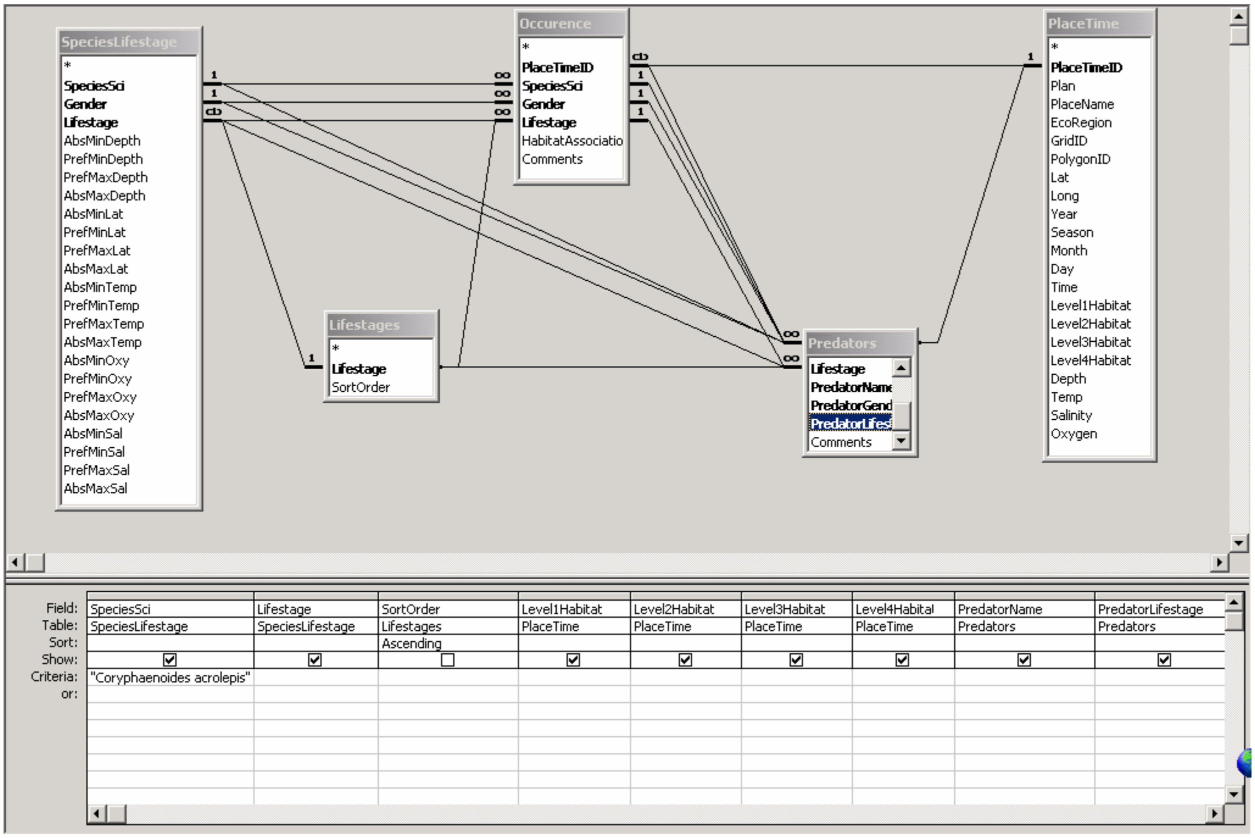
The results appear as follows:

AllQuery0 : Select Query

SpeciesSci	Lifestage	Level1Habitat	Level2Habitat	Level3Habitat	Level4Habitat	Activity	ActivityAssociation
Coryphaenoides acrolepis	Eggs	Shelf	Water Column	Epipelagic Zone	Unknown	Unknown	Unknown
Coryphaenoides acrolepis	Eggs	Slope/Rise/Plain	Water Column	Epipelagic Zone	Unknown	Unknown	Unknown
Coryphaenoides acrolepis	Larvae	Shelf	Water Column	Epipelagic Zone	Unknown	Feeding	Strong
Coryphaenoides acrolepis	Larvae	Slope/Rise/Plain	Water Column	Epipelagic Zone	Unknown	Feeding	Strong
Coryphaenoides acrolepis	Juveniles	Slope/Rise/Plain	Water Column	Mesopelagic Zone	Unknown	Feeding	Medium
Coryphaenoides acrolepis	Juveniles	Slope/Rise/Plain	Water Column	Epipelagic Zone	Unknown	Feeding	Medium
Coryphaenoides acrolepis	Juveniles	Slope/Rise	Benthos	Unknown	Unknown	Growth to M:	Strong
Coryphaenoides acrolepis	Juveniles	Slope/Rise	Benthos	Unknown	Unknown	Feeding	Strong
Coryphaenoides acrolepis	Adults	Slope/Rise	Benthos	Unconsolidated	Sand	All	Strong
Coryphaenoides acrolepis	Adults	Slope/Rise	Benthos	Unknown	Unknown	All	Strong
Coryphaenoides acrolepis	Adults	Slope/Rise	Basin	Unconsolidated	Sand	All	Strong

Record: 1 of 11

If instead you wished to investigate say predators then you would substitute the predators table for the activities table in the query design. See **'AllQuery1'**. That would appear as follows.



and the results would appear as follows:

AllQuery1 : Select Query

SpeciesSci	Lifestage	Level1Habitat	Level2Habitat	Level3Habitat	Level4Habitat	PredatorName	PredatorLifestage
Coryphaenoides acrolepis	Larvae	Shelf	Water Column	Epipelagic Zone	Unknown	Macrourids	Unknown
Coryphaenoides acrolepis	Larvae	Shelf	Water Column	Epipelagic Zone	Unknown	Coryphaenoides	Juveniles
Coryphaenoides acrolepis	Larvae	Shelf	Water Column	Epipelagic Zone	Unknown	Coryphaenoides	Adults
Coryphaenoides acrolepis	Juveniles	Slope/Rise	Benthos	Unknown	Unknown	Macrourids	Unknown
Coryphaenoides acrolepis	Juveniles	Slope/Rise	Benthos	Unknown	Unknown	Coryphaenoides	Adults
Coryphaenoides acrolepis	Adults	Slope/Rise	Benthos	Unknown	Unknown	Macrourids	Unknown
Coryphaenoides acrolepis	Adults	Slope/Rise	Benthos	Unknown	Unknown	Coryphaenoides	Adults

Record: 1 of 7

The same substitution can be done for prey species and references.

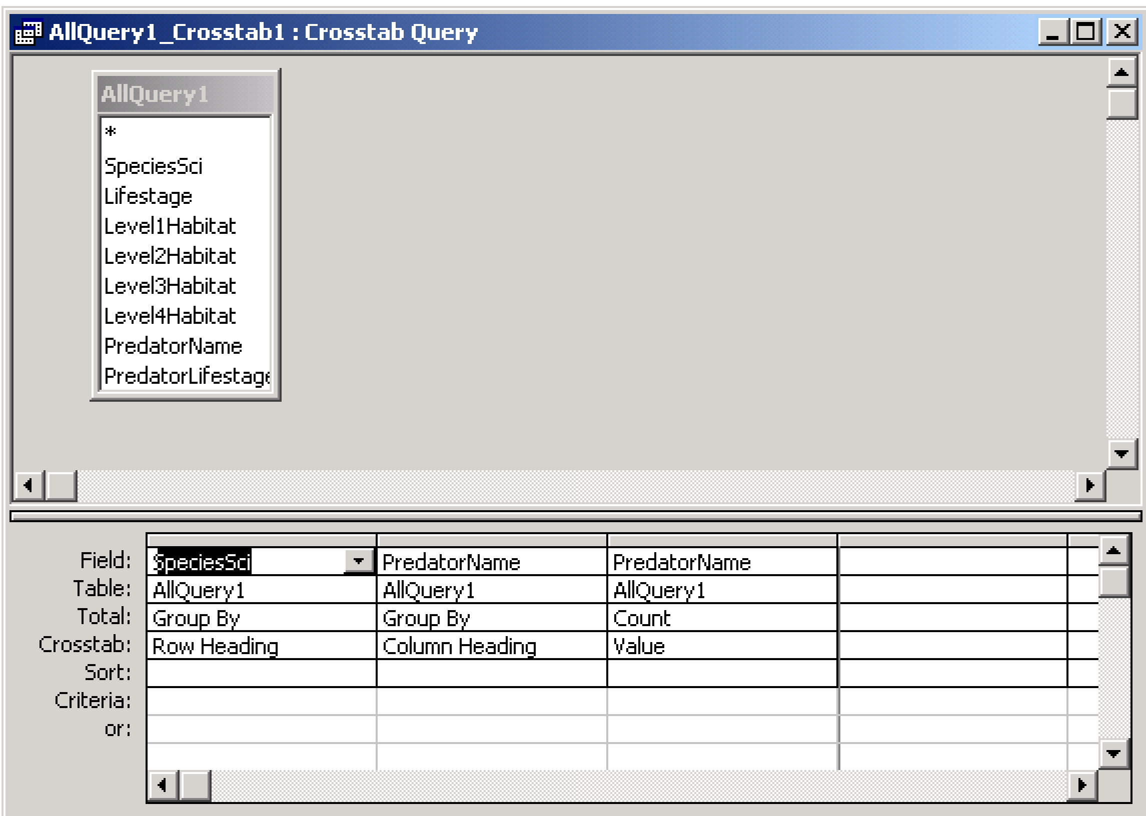
Such queries can form the source for other queries, charts that plot the results, or for exporting data to spreadsheets or other file formats for modeling etc.

One of the most common queries towards the end of a series of analyses is the cross-tab query which produces results more like a spreadsheet format. Indeed the results are often exported to spreadsheets for further manipulation.

For example, if we wished to find out which was the most common predator of a species regardless of the preys life stage or habitat setting we would form the following cross-tab query 'CrosstabAllQuery1' which takes the original query AllQuery1 as its input.

NB Remember that if you then alter such a source query you would then invalidate the cross-tab query based upon it. Care must be taken in this respect. It is often best to develop suites of parallel queries to avoid this pitfall and have some consistent naming conventions across and along the various streams to prevent the confusion that would otherwise develop.

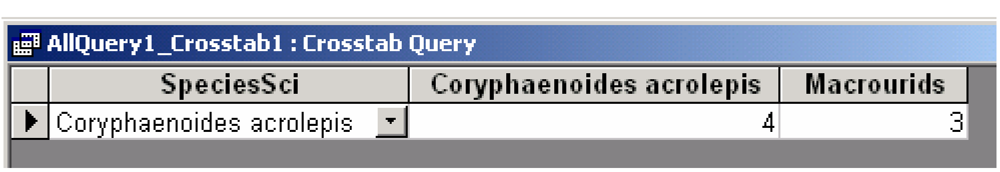
From the main database window select the queries-new- Design View.
Select the Queries tab from the Show Table box and select AllQuery1.



Select the columns SpeciesSci once and PredatorName twice, should look as above.

Set the values in the grid as illustrated above.
Save the query as 'AllQuery1_Crosstab1' or whatever you wish to call it.

Run the query and the results will appear as follows.



revealing a total of three situations where Macrourids are the predators and 4 of cannibalism.

Note that if you remove the single species criterion from the source query AllQuery1 then you get the following results revealing what has had predator data entered and what those predators are (Column Headings), and what they eat.

SpeciesSci	Albacore	Anoplopoma f	Artedius harri	Atheresthes st	chaetognaths	Clupeids	Coryphaenoides acrolepis	Crabs
Anoplopoma fimbria								
Coryphaenoides acrolepis							4	
Eopsetta jordani								
Gadus macrocephalus								
Galeorhinus zyopterus								
Hexagrammos decagrammu								
Hydrolagus colliei								
Lepidopsetta bilineata								
Merluccius productus	2	2				3		
Microstomus pacificus	3	4						
Ophiodon elongatus								
Platichthys stellatus								
Pleuronectes vetulus								
Psettichthys melanostictus								
Scorpaenichthys marmorat			1					
Sebastes alutus		2		2				
Sebastes atrovirens					1			
Sebastes auriculatus								
Sebastes chrysomelas					1			
Sebastes crameri	4							
Sebastes dalli					1			
Sebastes jordani								
Sebastes maliger					2			
Sebastes melanops					2			
Sebastes nebulosus					1			
Sebastes nigrocinctus					2			
Sebastes paucispinis	2							
Sebastes rastrelliger								
Sebastes serranoides					2			
Sebastes serriceps								
Sebastolobus alascanus								
Sebastolobus altivelis		1						

You could specify multiple criteria for both species and predator species to limit the results set depending on your line of investigation. The same kind of investigations could be made for Activities or prey data and all could be further refined by select only some levels of habitat classifications and only certain values within these. You could look at say only level2 habitats and only ‘benthos’ from within these.

You can further refine queries by editing the ‘SQL’ code version of them. This is particularly useful when creating more elaborate cross-tab queries and filters for charts etc.

You can select the SQL view from under View on the menu bar. The SQL for the AllQuery1 query would look like the following:

SELECT SpeciesLifestage.SpeciesSci, SpeciesLifestage.Lifestage, PlaceTime.Level1Habitat, PlaceTime.Level2Habitat, PlaceTime.Level3Habitat, PlaceTime.Level4Habitat, Predators.PredatorName, Predators.PredatorLifestage

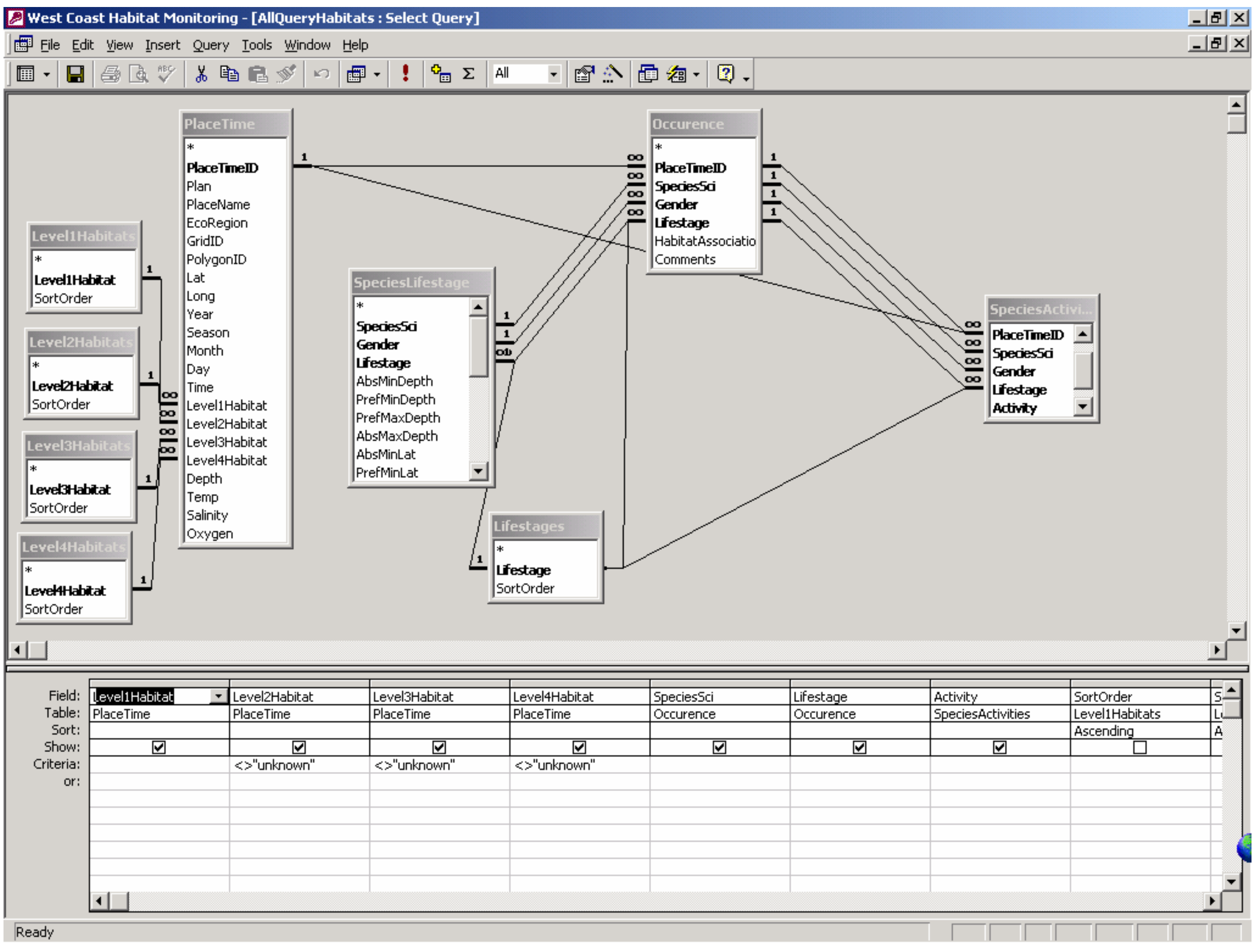
```
FROM ((Occurence INNER JOIN Lifestages ON Occurence.Lifestage = Lifestages.Lifestage)
INNER JOIN (PlaceTime INNER JOIN Predators ON PlaceTime.PlaceTimeID =
Predators.PlaceTimeID) ON (PlaceTime.PlaceTimeID = Occurence.PlaceTimeID) AND
(Occurence.Lifestage = Predators.Lifestage) AND (Occurence.Gender = Predators.Gender) AND
(Occurence.SpeciesSci = Predators.SpeciesSci) AND (Occurence.PlaceTimeID =
Predators.PlaceTimeID) AND (Lifestages.Lifestage = Predators.Lifestage)) INNER JOIN
SpeciesLifestage ON (SpeciesLifestage.Lifestage = Predators.Lifestage) AND
(SpeciesLifestage.Gender = Predators.Gender) AND (SpeciesLifestage.SpeciesSci =
Predators.SpeciesSci) AND (SpeciesLifestage.Lifestage = Occurence.Lifestage) AND
(SpeciesLifestage.Gender = Occurence.Gender) AND (SpeciesLifestage.SpeciesSci =
Occurence.SpeciesSci) AND (Lifestages.Lifestage = SpeciesLifestage.Lifestage)
WHERE (((SpeciesLifestage.SpeciesSci)="Coryphaenoides acrolepis"))
ORDER BY Lifestages.SortOrder;
```

3.4.1.3 Example 2: Habitat based investigation

This shorter example, 'AllQueryHabitats', demonstrates how to develop similar lines of queries except they are based on the perspective of habitats rather than species.

It is probably best to first look at the data from the 'Place-Time centric' data form (exactly the same data but arranged from a habitats perspective), which is chosen from the main opening form or from the drop down menu which is part of the West Coast Tools tool bar.

This query orders all habitats according to the values within the four habitat levels and assumes each level is nested within the previous. Then for each unique combination of habitats it lists the species life stages and their activities.



A portion of the results appear as follows:

Level1Habitat	Level2Habitat	Level3Habitat	Level4Habitat	SpeciesSci	Lifestage	Activity
Estuarine	Intertidal Benthos	Unconsolidated	Mud	Squalus acanthias	Juveniles	Growth to Maturity
Estuarine	Intertidal Benthos	Unconsolidated	Mud	Squalus acanthias	Adults	All
Estuarine	Intertidal Benthos	Unconsolidated	Mud	Raja inornata	Adults	All
Estuarine	Intertidal Benthos	Unconsolidated	Mud	Triakis semifasciata	Adults	All
Estuarine	Subtidal Benthos	Unconsolidated	Mixed mud/sand	Hippoglossoides elassodon	Juveniles	Feeding
Estuarine	Subtidal Benthos	Unconsolidated	Mixed mud/sand	Errex zachirus	Juveniles	Feeding
Estuarine	Subtidal Benthos	Unconsolidated	Mixed mud/sand	Eopsetta jordani	Juveniles	Feeding
Estuarine	Subtidal Benthos	Unconsolidated	Mixed mud/sand	Platichthys stellatus	Juveniles	Feeding
Estuarine	Subtidal Benthos	Unconsolidated	Mixed mud/sand	Psettichthys melanostictus	Juveniles	Growth to Maturity
Estuarine	Subtidal Benthos	Unconsolidated	Mixed mud/sand	Lepidopsetta bilineata	Juveniles	Growth to Maturity
Estuarine	Subtidal Benthos	Unconsolidated	Mixed mud/sand	Psettichthys melanostictus	Adults	All
Estuarine	Subtidal Benthos	Unconsolidated	Mixed mud/sand	Platichthys stellatus	Adults	All
Estuarine	Subtidal Benthos	Unconsolidated	Mixed mud/sand	Lepidopsetta bilineata	Adults	All
Estuarine	Subtidal Benthos	Unconsolidated	Mixed mud/sand	Gadus macrocephalus	Adults	Feeding
Estuarine	Subtidal Benthos	Unconsolidated	Mixed mud/sand	Errex zachirus	Adults	Feeding
Estuarine	Subtidal Benthos	Unconsolidated	Mixed mud/sand	Hippoglossoides elassodon	Adults	All
Estuarine	Subtidal Benthos	Unconsolidated	Sand	Lepidopsetta bilineata	Eggs	Unknown
Estuarine	Subtidal Benthos	Unconsolidated	Mud	Raja inornata	Eggs	Unknown
Estuarine	Subtidal Benthos	Unconsolidated	Sand	Microstomus pacificus	Juveniles	Growth to Maturity
Estuarine	Subtidal Benthos	Unconsolidated	Sand	Ophiodon elongatus	Juveniles	Feeding

Note that results have been filtered out where habitat values are ‘Unknown,’ which in fact is the majority of cases.

Again as with the first example, this query can be copied and renamed and then used as a template to extend and vary it, develop cross tabs and charts etc.

As with the first example from the species perspective, the SpeciesActivities table could be substituted with the Predators, Prey or references tables and the query modified to analyze the attributes in these tables instead.

3.4.1.4 Example 3: Using species level attributes

This example demonstrates an analysis of the general attributes recorded at the species level, i.e. absolute and preferred ranges of latitude, depth, temperature, salinity or oxygen.

You will have noted from the data entry screens that these attributes can be recorded at two levels of detail

a) the general ranges associated with a species, and

b) more precise values associated with a particular ‘TimePlaceID.’

How precise would depend on what level of detail is used with the PlaceTimeID. It could be a period for an area or a specific location at one exact time or for a given habitat definition. At present (October 2003) none of the facilities offered for the more detailed recording offered with b) are required or being utilized. Thus only the general species wide values are being used and it follows that these have to be applied to all locations and habitat types for all times. This affects the way the query is structured with those physiographic attributes being sourced from the SpeciesLifestage table.

In fact there is very little variation in the values of the extracted data for depth and latitude for each species; hence the results tend to be somewhat ‘uninteresting’ in terms of the variety in the query and chart output used to demonstrate the potential of these kinds of queries. Thus for the purposes of the best demonstration of the potential of these kinds of queries, the species, *Merluccius productus*, with most detailed variety has been chosen and the somewhat crude mid points of absolute ranges of latitude and depth used.

The final charted output appears as follows (Figure 13):

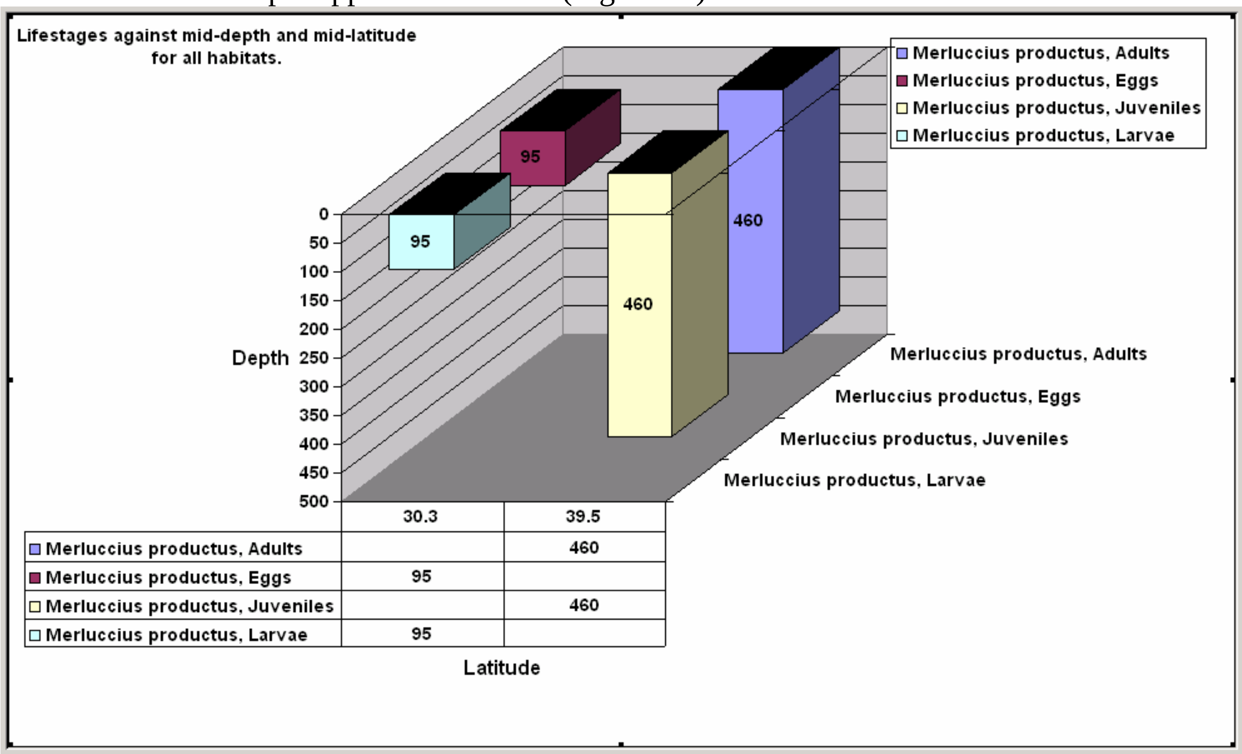


Figure 4 Life stages against mid depth and mid latitude from chart 'chtLifestageLatDepth'

This is one of the few species with where there is enough variety in the extracted depth/ latitude data to demonstrate the range of possible plotting. Most other species have the same depths and/or latitudes for each of the life stages.

This chart is also available from the main opening form under the Charts section via the button 'Lifestages by Lat-Depth'

The results of the underlying select query (which is named 'LifestageLatDepth') looks like this:

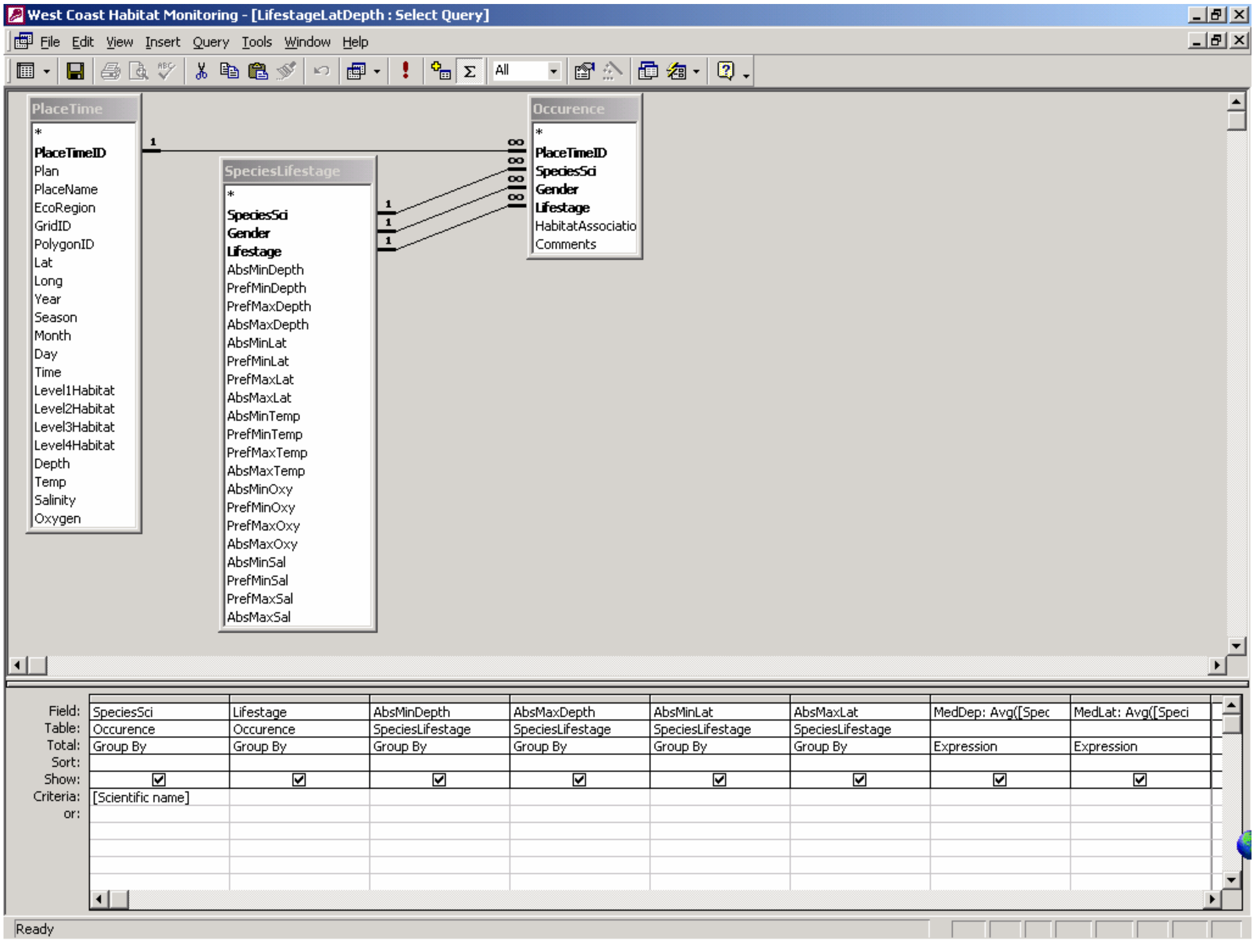
LifestageLatDepth : Select Query

SpeciesSci	Lifestage	AbsMinDepth	AbsMaxDepth	AbsMinLat	AbsMaxLat	MedDep	MedLat
Merluccius productus	Adults	0	920	24.5	54.5	460	39.5
Merluccius productus	Eggs	40	150	24.5	36	95	30.25
Merluccius productus	Juvenile	0	920	24.5	54.5	460	39.5
Merluccius productus	Larvae	40	150	24.5	36	95	30.25

Record: 1 of 4

This query is also available via the button ‘Lifestages by Lat-Depth’ under the Queries section on the main opening form ‘frmMain’.

The query is structures as follows:



This also demonstrates the use of ‘expressions’ in queries. The ‘MedDep’ and ‘MedLat’ in the query. This is where an output field is based on an underlying calculation rather than a simple value or simple aggregate function of those values (a straight average, count or sum etc)

Again you can copy and rename this query and use that new copy as a template to alter and develop your own queries.

3.4.1.5 Example 4: Counts of Habitats

There are a series of other queries and charts that provide examples of how aggregate functions can be used in Access. Again the form of the examples used is more to demonstrate what is possible within Access rather than for biological analytical rigor! User can use these examples as templates to develop their own queries that are appropriate to their line of biological investigation.

The query 'Habitats by Species Lifestage' simply counts the occurrence of sub-habitats within each of the level1 habitats, for each of the SpeciesLifestages.

Habitats by Species Lifestage : Select Query

SpeciesSci	Lifestage	Level1Habitat	CountOfLevel1Habitat
Anoplopoma fimbria	Adults	Shelf	2
Anoplopoma fimbria	Adults	Slope/Rise	1
Anoplopoma fimbria	Eggs	Slope/Rise	2
Anoplopoma fimbria	Juveniles	Shelf	1
Anoplopoma fimbria	Juveniles	Slope/Rise	3
Anoplopoma fimbria	Larvae	Shelf	1
Anoplopoma fimbria	Larvae	Slope/Rise	6
Antimora microlepis	Adults	Shelf	1
Antimora microlepis	Adults	Slope/Rise	1
Atheresthes stomias	Adults	Shelf	7

The query is also available from the main opening form under the queries section via the button 'Habitats by Species Lifestage'.

You can look at it in design view to see its simple structure.

This query is used as source data for the following query 'XtabBySpeciesByHabitat' which simply cross-tabs the output using the level1 habitat values as column headings instead of leaving them as row headings. That query is also available via the button 'Crosstab species by Habitat1' on the main opening form.

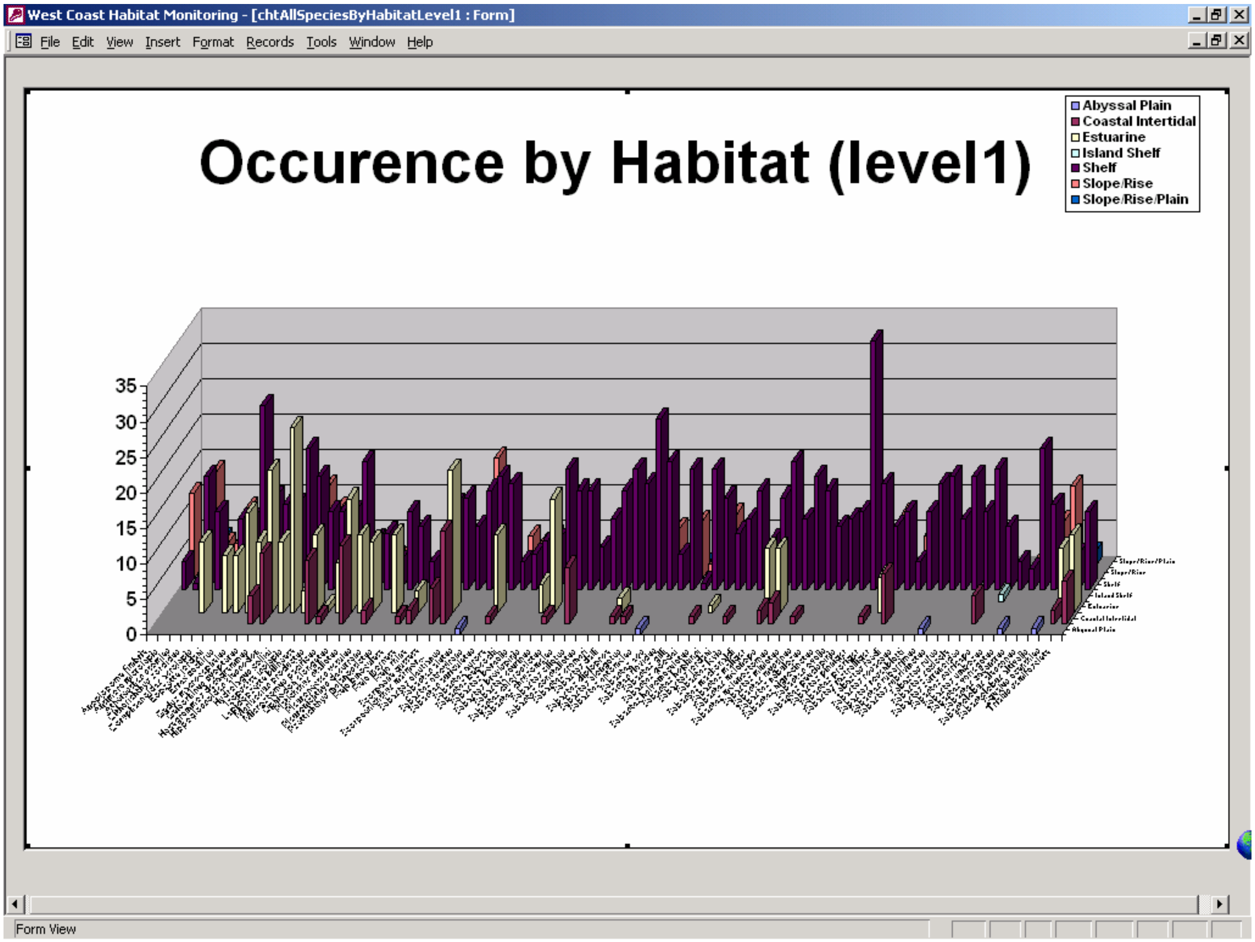
XtabSpeciesByHabitat : Crosstab Query

SpeciesSci	Abyssal Plain	Coastal Interti	Estuarine	Island Shelf	Shelf	Slope/Rise	Slope/Rise/Plain
Anoplopoma fimbria					4	12	
Antimora microlepis					1	1	
Atheresthes stomias					16	15	4
Citharichthys sordidu			10		11	5	2
Coryphaenoides acrc					2	5	4
Eopsetta jordani			8		10	10	1
Errex zachirus			8		10	8	2
Gadus macrocephalu			14		26	6	1
Galeorhinus zyopteru		4	10		13		
Hexagrammos decag		10	20		12		2
Hippoglossoides elas			10		12	8	
Hydrolagus colliei			26		20		
Isopsetta isolepis			3		16	13	

Record: 1 of 81

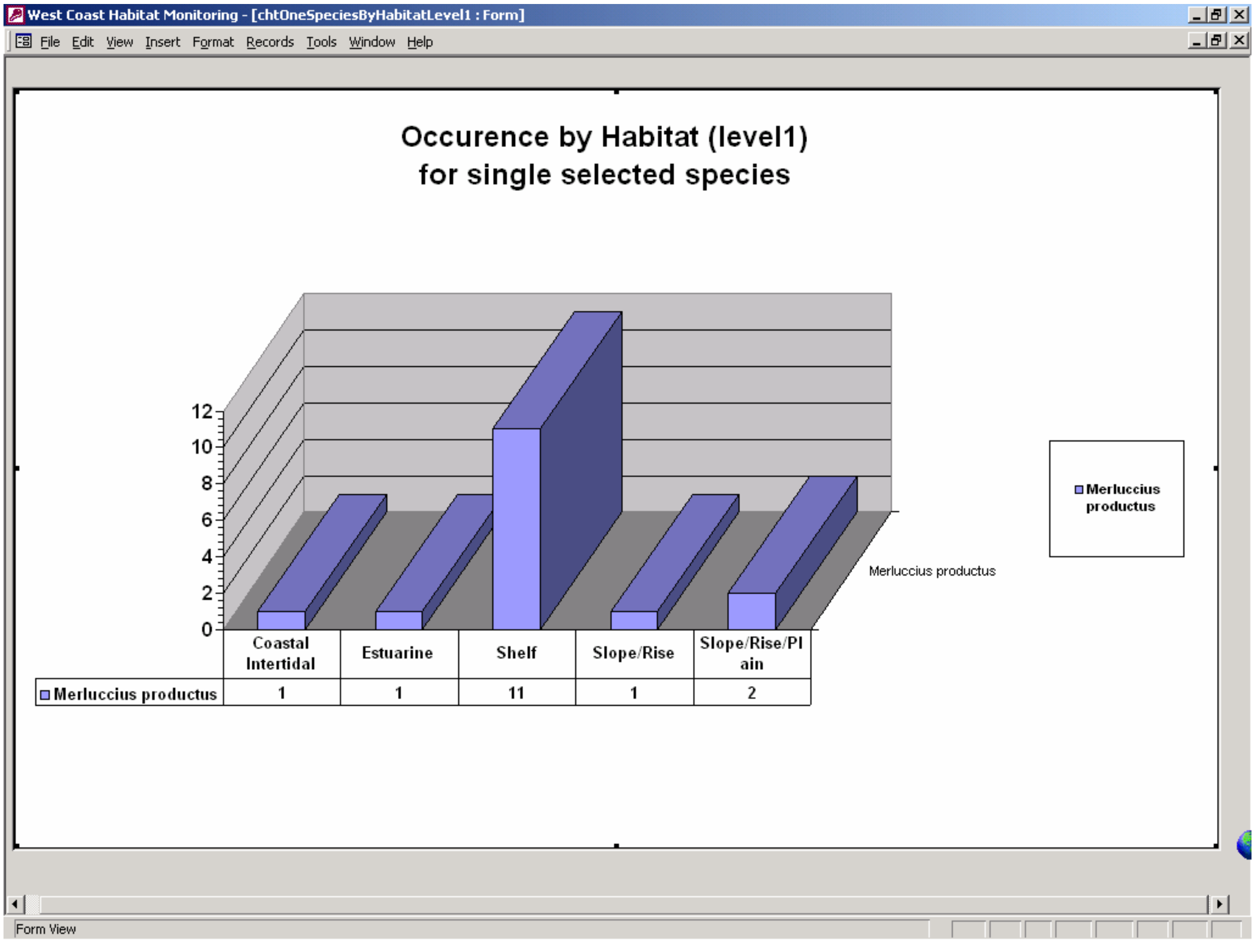
The same principle of cross-tabbing habitats by species life stage is used as the source for the two charts.

The chart ‘chtAllSpeciesByHabitatLevel1’ which counts and charts level 1 sub-habitat for all the species looks as follows:



This chart is also available from the main form via the button ‘AllSpeciesByHab.Level1’.

There is also a chart ‘chtOneSpeciesByHabitatLevel1’ which does the same but, for a single species for which the user supplies the name as a parameter.



This chart is also available from the main form via the button ‘OneSpeciesByHab.Level1’.

These charts are constructed within forms. Their cross-tabbed data sources are specified as SQL clauses under their ‘properties.’

3.4.1.6 Example 5: Data extraction

The query ‘HabitatAssociations1’ was used to extract an assemblage of data required for the Bayesian modeling software.

A portion of the output appears as follows:

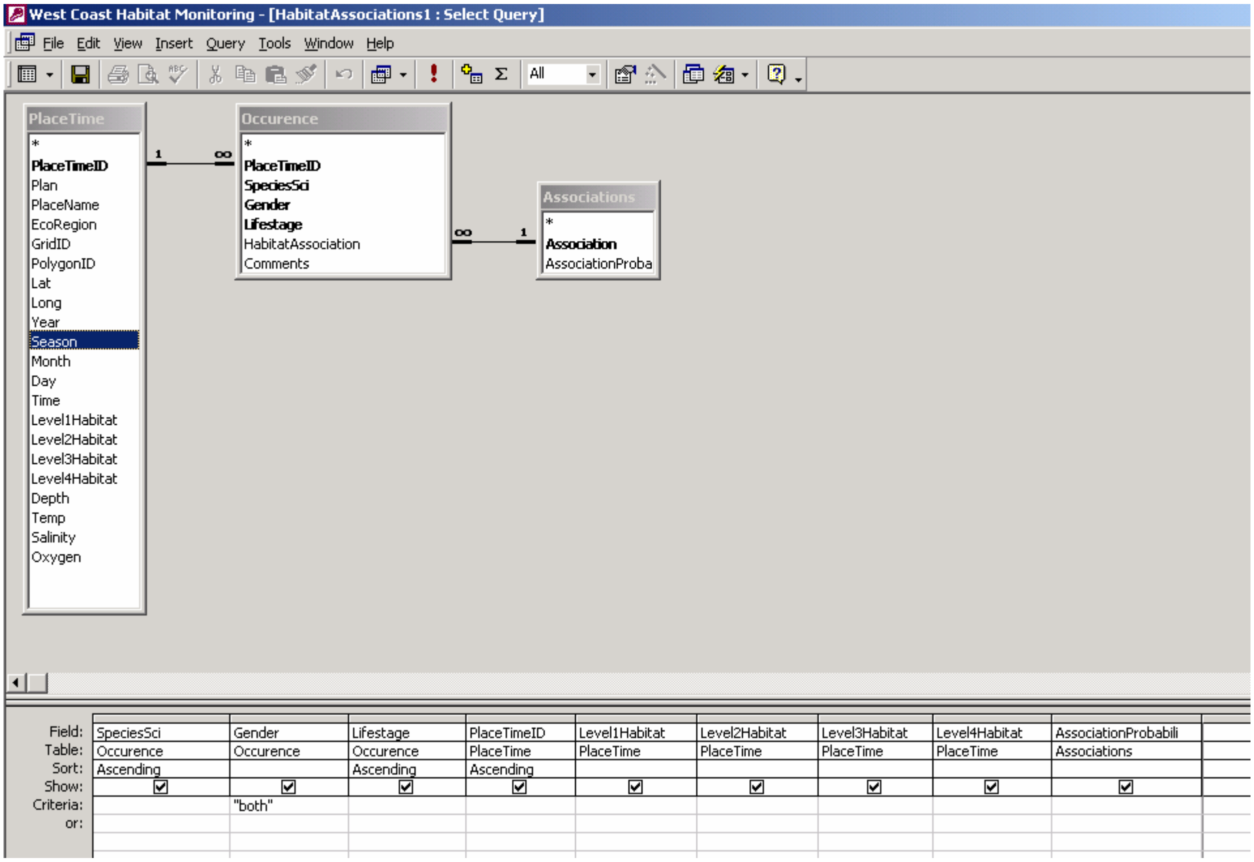
West Coast Habitat Monitoring - [HabitatAssociations1 : Select Query]

File Edit View Insert Format Records Tools Window Help

SpeciesSci	Gender	Lifestage	PlaceTimeID	Level1Habitat	Level2Habitat	Level3Habitat	Level4Habitat	AssociationProbability
Anoplopoma fimbria	Both	Adults	Fbun	Slope/Rise	Benthos	Unconsolidated	Unknown	1
Anoplopoma fimbria	Both	Adults	SbgU	Shelf	Benthos	Biogenic	Sea Urchins	0.66
Anoplopoma fimbria	Both	Adults	Ssum	Shelf	Submarine Cany	Unconsolidated	Mud	0.66
Anoplopoma fimbria	Both	Juveniles	Fbun	Slope/Rise	Benthos	Unconsolidated	Unknown	1
Anoplopoma fimbria	Both	Juveniles	Fwed	Slope/Rise	Water Column	Epipelagic Zone	Drift Algae	0.66
Anoplopoma fimbria	Both	Juveniles	Sbun	Shelf	Benthos	Unconsolidated	Unknown	1
Anoplopoma fimbria	Both	Larvae	Fbun	Slope/Rise	Benthos	Unconsolidated	Unknown	1
Anoplopoma fimbria	Both	Larvae	Fnnn	Slope/Rise	Unknown	Unknown	Unknown	0
Anoplopoma fimbria	Both	Larvae	Fwed	Slope/Rise	Water Column	Epipelagic Zone	Drift Algae	0.66
Anoplopoma fimbria	Both	Larvae	Fwen	Slope/Rise	Water Column	Epipelagic Zone	Unknown	1
Anoplopoma fimbria	Both	Larvae	Fwmn_p	Slope/Rise	Water Column	Mesopelagic Zone	Unknown	1
Anoplopoma fimbria	Both	Larvae	Fwmn_w	Slope/Rise	Water Column	Mesopelagic Zone	Unknown	1
Anoplopoma fimbria	Both	Larvae	Swen	Shelf	Water Column	Epipelagic Zone	Unknown	1
Antimora microlepis	Both	Adults	Fbnn	Slope/Rise	Benthos	Unknown	Unknown	1
Antimora microlepis	Both	Adults	Sbnn	Shelf	Benthos	Unknown	Unknown	1
Atheresthes stomias	Both	Adults	Fbcl	Slope/Rise	Benthos	Mixed Bottom	Sand/Cobble	1
Atheresthes stomias	Both	Adults	Fbcr	Slope/Rise	Benthos	Mixed Bottom	Soft Bottom/	0.33
Atheresthes stomias	Both	Adults	FbgP	Slope/Rise	Benthos	Biogenic	Sponges	0.33
Atheresthes stomias	Both	Adults	Fbub	Slope/Rise	Benthos	Unconsolidated	Mixed mud/s	1
Atheresthes stomias	Both	Adults	Fbus	Slope/Rise	Benthos	Unconsolidated	Sand	0.66
Atheresthes stomias	Both	Adults	Fbut	Slope/Rise	Benthos	Unconsolidated	Silt	0.66
Atheresthes stomias	Both	Adults	Sbcl	Shelf	Benthos	Mixed Bottom	Sand/Boulde	1
Atheresthes stomias	Both	Adults	Sbcr	Shelf	Benthos	Mixed Bottom	Soft Bottom/	0.33
Atheresthes stomias	Both	Adults	SbgP	Shelf	Benthos	Biogenic	Sponges	0.33
Atheresthes stomias	Both	Adults	Sbub	Shelf	Benthos	Unconsolidated	Mixed mud/s	1
Atheresthes stomias	Both	Adults	Sbus	Shelf	Benthos	Unconsolidated	Sand	0.66
Atheresthes stomias	Both	Adults	Sbut	Shelf	Benthos	Unconsolidated	Silt	0.66
Atheresthes stomias	Both	Juveniles	Fbcl	Slope/Rise	Benthos	Mixed Bottom	Sand/Cobble	1
Atheresthes stomias	Both	Juveniles	Fbcr	Slope/Rise	Benthos	Mixed Bottom	Soft Bottom/	0.33
Atheresthes stomias	Both	Juveniles	FbgP	Slope/Rise	Benthos	Biogenic	Sponges	0.33

It basically lists the numeric probability of habitat association for all habitats for each SpeciesLifestage and gender.

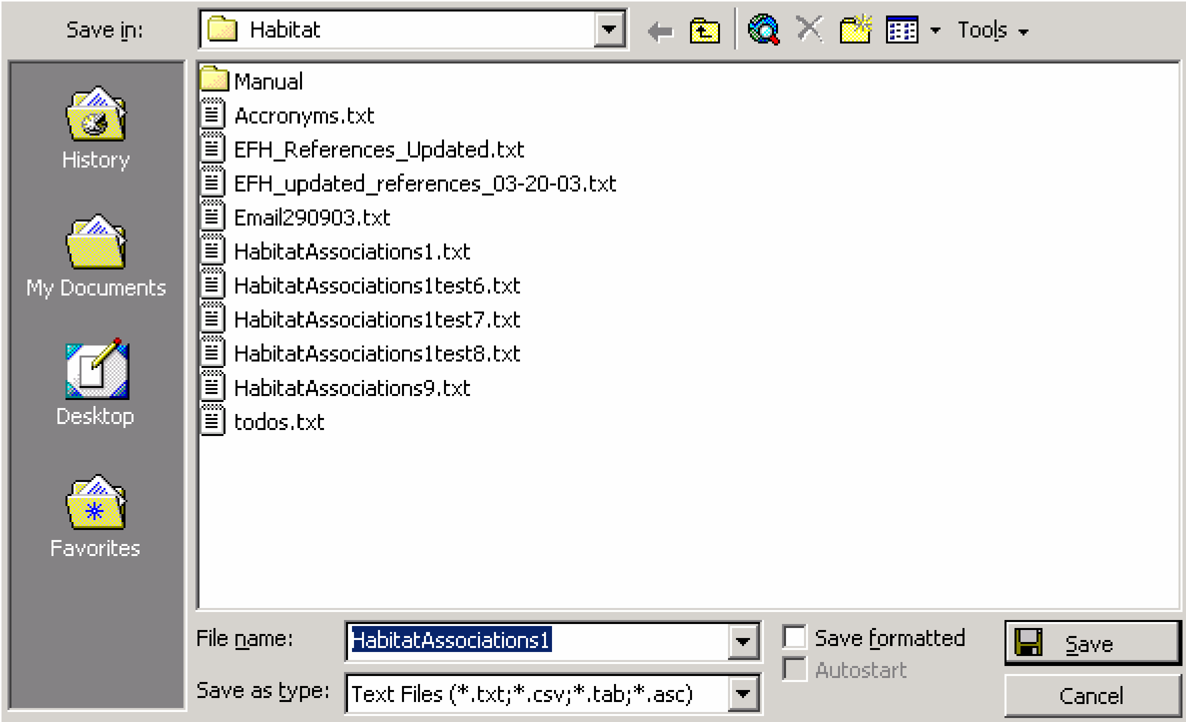
Its design view looks like this:



Once the query is written, it is used as a source for a menu-driven export routine that can export the data in a wide range of formats including that of spreadsheet files and standard comma delimited text files. The choice of format depends on the receiving software.

You can export a datasheet to a delimited or fixed-width text file; to do this, in the Database window, click the name of the table, query, view, or stored procedure you want to export, and then on the File menu, click Export.

The following screen comes up:



In the “Save as type” box, click Text Files (*.txt;*.csv;*.tab;*.asc).

Click the arrow to the right of the Save In box, and select the drive or folder to export to.

In the File Name box, enter the file name, and then click Save.

NB Make sure the ‘Save formatted’ box is NOT ticked.

Microsoft Access then starts the Export Text Wizard.

Follow the directions in the dialog boxes. Click Advanced to create or use an import/export specification.

You can call up this specification for re-use in future should you repeat the export procedure. You still have to go through the menu system but it at least remembers the settings you previously specified. It is also possible to save an export specification as a macro or visual basic code module. This can be done if required though for the assumed usage here we confine ourselves to the menu system which is powerful, flexible, and easy to use.

The resultant text appears as follows:

SpeciesSci,Gender,Lifestage,PlaceTimeID,Level1Habitat,Level2Habitat,Level3Habitat,Level4Habitat,AssociationProbability
Anoplopoma fimbria,Both,Adults,Fbun,Slope/Rise,Benthos,Unconsolidated,Unknown,100

Anoplopoma fimbria,Both,Adults,SbgU,Shelf,Benthos,Biogenic,Sea Urchins,66
Anoplopoma fimbria,Both,Adults,Ssum,Shelf,Submarine Canyon,Unconsolidated,Mud,66
Anoplopoma fimbria,Both,Juveniles,Fbun,Slope/Rise,Benthos,Unconsolidated,Unknown,100
Anoplopoma fimbria,Both,Juveniles,Fwed,Slope/Rise,Water Column,Epipelagic Zone,Drift Algae,66
Anoplopoma fimbria,Both,Juveniles,Sbun,Shelf,Benthos,Unconsolidated,Unknown,100
Anoplopoma fimbria,Both,Larvae,Fbun,Slope/Rise,Benthos,Unconsolidated,Unknown,100
Anoplopoma fimbria,Both,Larvae,Fnnn,Slope/Rise,Unknown,Unknown,Unknown,0
Anoplopoma fimbria,Both,Larvae,Fwed,Slope/Rise,Water Column,Epipelagic Zone,Drift Algae,66
Anoplopoma fimbria,Both,Larvae,Fwen,Slope/Rise,Water Column,Epipelagic Zone,Unknown,100
Anoplopoma fimbria,Both,Larvae,Fwmn_p,Slope/Rise,Water Column,Mesopelagic Zone,Unknown,100
Anoplopoma fimbria,Both,Larvae,Fwmn_w,Slope/Rise,Water Column,Mesopelagic Zone,Unknown,100
Anoplopoma fimbria,Both,Larvae,Swen,Shelf,Water Column,Epipelagic Zone,Unknown,100
Antimora microlepis,Both,Adults,Fbnn,Slope/Rise,Benthos,Unknown,Unknown,100
Antimora microlepis,Both,Adults,Sbnn,Shelf,Benthos,Unknown,Unknown,100
Atheresthes stomias,Both,Adults,Fbcl,Slope/Rise,Benthos,Mixed Bottom,Sand/Cobble,100
Atheresthes stomias,Both,Adults,Fbcr,Slope/Rise,Benthos,Mixed Bottom,Soft Bottom/rock,33

Etc etc …

APPENDIX 11A. EXAMPLE DATA EXTRACTION FROM UPDATED LIFE HISTORY DESCRIPTIONS

CANARY ROCKFISH (*Sebastes pinniger*)

Range

Canary rockfish are found between Cape Colnett, Baja California, and southeastern Alaska (lat. 56°N, long. 134°W) (Boehlert 1980, Boehlert and Kappenman 1980, Hart 1973, Love 1996, Miller and Lea 1972, Richardson and Laroche 1979).

Fishery

Canary rockfish are a major constituent of the commercial trawl fishery off Oregon and Washington (Boehlert 1980, Gunderson and Lenarz 1980, Love 1996). Off California, canary rockfish are caught mainly in the sport and commercial longline fisheries. They are moderately important in the party and private vessel sport fishery, from central California northward (Boehlert 1980, Love 1996).

Habitat

Canary rockfish are considered a middle shelf-mesobenthal species (Allen and Smith 1988). There is a major population concentration of canary rockfish between latitude 44° 30' and 45° 00' N off Oregon (Richardson and Laroche 1979).

Canary rockfish have a depth range from the surface (juveniles) to 274 m (Boehlert 1980, Hart 1973, Love 1996), but primarily inhabit waters 91-183 m deep (Boehlert and Kappenman 1980). Larvae and juveniles are pelagic (Boehlert and Kappenman 1980, Richardson and Laroche 1979). Larvae can be captured over a wide area, from 13-306 km offshore, and pelagic juveniles occur mostly beyond the continental shelf (Richardson and Laroche 1979).

Canary rockfish inhabit shallow water when they are young and deep water as adults (Mason 1995). Adults have two primary habitat preferences: some are semipelagic, forming loose schools above rocky areas; and some are nonschooling, solitary benthic individuals (Stein et al. 1992). Adult canary rockfish are associated with pinnacles and sharp drop-offs (Love 1996). They are also found near, but usually not on the bottom, often associating with yellowtail, widow, and silvergray rockfish (Love 1996). Canary rockfish are most abundant above hard bottoms (Boehlert and Kappenman 1980), and they have been observed among mixtures of mud and boulders (Love et al. 2002). In the southern part of its range, the canary rockfish appears to be a reef-associated species (Boehlert 1980). On Heceta Bank, near Oregon, they were commonly found in boulder and cobble fields in association with rosethorn, sharpchin, yelloweye and pygmy rockfish (Stein et al. 1992). In studies conducted off Southeast Alaska using an ROV, Johnson et al. (2003) reported finding canary rockfish primarily associated with complex bottoms composed of rocks and boulders, and a few individuals were seen near soft sediments.

Young-of-the-year rockfish can also be found in tide pools (Love 1996), and are associated with artificial reefs, and in interfaces between mud and rock (Cailliet et al. 2000). In central California, young-of-the-year (YOY) canary rockfish are first observed near the bottom at the seaward, sand-rock interface and farther seaward in deeper water (18-24 m) (Carr 1991). Their first appearance generally occurs shortly after the first upwellings of the spring (Carr 1991). They are often seen hovering above sand or small rock piles (VenTresca et al. 1996), and are seldom associated with kelp beds, although some YOY are associated with floating algae (Carr 1991).

Migrations and Movements

Canary rockfish are densely aggregating fish (Love 1996). Juveniles descend into deeper water as they mature (Love 1996). Canary rockfish move into deeper water with age and also are capable of major latitudinal movements (up to 380 nautical miles) (Lea et al. 1999). Juveniles have been reported to be associated with rocky sandy areas during the day and with sand flats during the night (Love et al. 2002).

Reproduction

Canary rockfish are ovoviviparous and have internal fertilization (Boehlert and Kappenman 1980, Richardson and Laroche 1979). Off California, canary rockfish spawn from November-March and from January-March off Oregon, Washington, and British Columbia (Hart 1973, Love 1996, Richardson and Laroche 1979). A wide range in larval sizes over a broad time span indicates that canary rockfish may have protracted and variable spawning (Richardson and Laroche 1979).

The age of 50% maturity of canary rockfish is 9 years; nearly all are mature by age 13 (Paul Reilly, personal communication). Maximum age has been estimated as 60 years (Adams 1992) to 75 years (ODFW, personal communication).

Growth and Development

The mean length of newly extruded canary rockfish larvae is 3.66 mm SL (Richardson and Laroche 1979). The transformation to pelagic juvenile occurs at sizes greater than 12.5 mm SL. Transformation to benthic juveniles occurs after 59.4 mm, during June-August (Richardson and Laroche 1979). Canary rockfish growth does not vary with latitude (Boehlert and Kappenman 1980). The maximum length canary rockfish grow to is 76 cm (Boehlert and Kappenman 1980, Hart 1973, Love 1996).

Off California, about 50% of the population is mature at 35.6 cm (5 or 6 years). A 48.3-cm long female carries approximately 260,000 young and fish 53.3- to 66-cm long carries about 1,900,000 young (Hart 1973). Canary rockfish can live to be 75 years old. A 10-year-old canary rockfish is approximately 50 cm SL (Love 1996). After age 11, females grow faster than males and mature at a larger size, but males live longer (Boehlert 1980, Boehlert and Yoklavich 1984, Love 1996).

Trophic Interactions

Canary rockfish primarily prey on planktonic creatures, such as krill, and occasionally on fish (Love 1996). Canary rockfish feeding increases during the spring-summer upwelling period when euphausiids are the dominant prey and the frequency of empty stomachs is lower (Boehlert et al. 1989).

APPENDIX 11B

List of tables:

Name
Activities
Associations
EcoRegions
Grids
Influences
Level1Habitats
Level2Habitats
Level3Habitats
Lifestages
Occurence
OtherActivities
phablist
PlaceTime
Plans
Predators
Prey
ReferenceInstance
References
Seasons
Species
SpeciesActivities
SpeciesLifestage

List of forms:

Name
frmActivities
frmAssociations
frmChart
frmEcoRegions
frmGrids
frmHabitats
frmInfluences
frmLifestages
frmMain
frmOccurence
frmOtherActivities
frmPlaceTime
frmPlans
frmPredators
frmPrey
frmReferenceInstance
frmReferences
frmSeasons
frmSpecies
frmSpeciesActivities
frmSpeciesLifestage
frmTestPlot
sfLevel1Habitats
sfLevel2Habitats
sfLevel3Habitats

APPENDIX 11C. THE DATABASE DESIGN PRINCIPLES

One of the primary aims of relational database design is to provide a system that is based around real physical entities and processes. If this principle is adhered to, it is much easier to develop a database system that is understandable to users and maintains data integrity. It also allows for much greater flexibility in analyses and future alterations and additions to the system. A critical aspect is that the complexity of the natural system being analyzed can be represented in terms of the data content rather than the data structures. Providing this is achieved then a deceptively simple system can be a powerful tool for both the environmental researcher and manager alike. It means that the resources used to both collect the data, and design the system to manage it, have been put to the best possible use. It also allows for the more effective integration with companion systems.

The integrity of the relational database is maintained through an extensive number of primary and foreign keys. The primary keys prevent the illogical addition of duplicate records. Though obviously sensible in itself, this becomes particularly important at the analysis stage since such duplicate values can cause multiplication of query results. Correctly normalized tables (to third normal form) and foreign keys that prevent many-to-many relationships between tables also guard against such errors in analysis.

Enforcing referential integrity via foreign keys also ensures the correct grouping of results during stratified analyses. These safeguards enforce certain requirements at the data entry stage. Basically these boil down to always first having a correct reference value in the reference tables before such a value can be used in the main data entry tables. For example, you cannot enter a species name in the SpeciesActivities section unless it first exists in the Species table. The same principle applies to life stages, habitat levels, grids and eco-regions, management plans and seasons and other activities. Even if one of these entities is not being used in a particular data element, at least one value such as ‘All’, ‘Unknown’ or ’Not-applicable’ must be entered in the relevant table. The system will not let you proceed with routine data entry until you have done this.

The values in these reference tables thus ensure the values entered during routine entry of the mass of data are consistent and correct. The reference values are also the source of choices offered in the drop down combo boxes which offer a choice of values to enter at both the table and form level. This saves on having to remember and type values correctly.

Having the data values presented in this way also means that full descriptive terms can be used instead of having to use meaningless codes and abbreviations. This both simplifies the database design and makes the system clearer to all users.

There are also simple rules enforced governing the allowable values for various attributes. Generally these allow either null values or ones that are within applicable physical ranges.

A system based around a sound fundamental data model is far simpler and thus comprehensible even to the non-database specialist. It also makes the definition of analyses far simpler; negating the need for hidden code modules. This gives the user far greater scope to use the system themselves as a research and management tool without constant recourse to a computing specialist.

If data are to be entered at different sites, then careful planning must be made as how to coordinate these sites to ensure the resultant data sets can be combined without compromising data integrity. The simplest option is to enter all the data into one database. It can be set up for multiple users to do this. The users can connect to it either via a local or wide area network or via the internet. For the latter option it would be necessary to develop the 'Active Server Pages' that would be required as an interface for internet data entry. The other possibility is for the database to be 'replicated' and later 'synchronized.' These strategic decisions need to be taken, communicated and enforced by those responsible for managing the database and adhered to by those using it!

APPENDIX 11D. EXAMPLE METHODOLOGY FOR GENERATING SPATIAL AND TEMPORAL DATA FROM SOURCE DOCUMENTS.

This example methodology is intended to demonstrate how spatial and temporal patterns could be extracted from the ‘Updated Life History Descriptions.doc’ document, if as and when this were required, and represented as hard data in the Habitat Use Database, that would then have the capability of being analyzed. For the time being these methods are not required because the database concentrates simply on mapping habitats that are capable of being matched to GIS substrates. It is, however, worth reading these sections since the principles explained are also applicable to most of the other attributes in the database, and how they all fit together in the overall framework.

The researcher should first decide on definite scales of spatial and temporal sub-division, e.g. four seasons and suitable grid squares. Then for each individual species using a chart of the West Coast region with these grids marked and isobaths marked proceed to mark on the stated ranges (maximum and preferred:- note: an additional range association field would be needed to reflect this). Also from the 'Habitat' sub heading in the document mark on the depth preferences within the range, what life stage they are, what season it is, and what they are doing at that time. Additional information on this score should also be gleaned from the sections on 'Movements and Migrations' and 'Reproduction' sections of the document.

Those plots should then be used as the basis for building up the bank of descriptive records. This should be done grid square by grid square and season by season within each grid square.

Thus wherever there is a grid square where the species occurs, we create the first record for the species. This record will list the grid square ID, the season (or value for whatever temporal attribute you have agreed upon). It need not list or assume particular values for the four habitat fields unless these are explicitly known, because this information will probably be sourced from the GIS info. However, where definite habitat data are available, they should be entered as they could later be used to refine the distribution within the grid square when matched against the substrate data from the GIS system. Where multiple habitat definitions exist within the same Grid square, then multiple PlaceTime records should be created to represent this.

All the other relevant data that are available for this grid square, at that time of year, should also be entered, i.e. any Place / Area name, EcoRegion, Lat-Long and possibly year. The depth temp salinity and oxygen values should again be gleaned of seasonal oceanographic charts where possible.

Anything can be used as a PlaceTimeID providing it is a unique value. Previous extensive discussion has agreed that this should be composed of a complex code combining the values from each of the attributes. Though such a code is never processed during analysis it is useful for comprehension during data entry and review.

e.g. for gridsquare, season, hab1, hab2, hab3, hab4, we could have a code such as G15_Sa_H1c_H2b_H3h_H4b or some such.

*(Data on 'Influences,' e.g. fishing activity, could be entered as well should you choose to use this feature. If so, duration would have to be summed according to the temporal scale that is being used, e.g. average days of fishing in the season per unit of fishing gears * 'average' numbers of fishing gears operating in that grid square during that season.)*

Then drop down into the 'Occurrence' sub form and enter the Species, Gender and Lifestage for that particular instance only.

Under 'SpeciesActivity' list the type of activity for that Species-Gender-Lifestage and likewise enter any details concerning predation and prey from the section on 'Trophic Interactions.

Enter additional records in this section for any other genders and lifestages that occur in that grid square in that season for THAT species.

Don't bother with the details for any other species at this stage as each species will be done in turn.

Then move on to the next 'PlaceTime' definition. This could be the same grid square and season but a different combination of habitat definitions within these or it might be a new season within the grid square or a new grid square altogether.

Repeat the whole process building up the description of the system Species by species, grid square by grid square, season by season, habitat by habitat, gender by gender, life stage by life stage, activity by activity.

Note that the easiest way to do this is by using the PlaceTime Centric form even though we are progressing species by species from the 'Updated Life Histories' document. Obviously as PlaceTime(habitat) definitions are built up these can be reused where applicable for other species and can be retrieved via the code and/or order of sorting provided in the drop down menu choices.

The following ‘scenarios’ will, hopefully, help explain how this method of data ‘extraction’ enables increasing complexity in the natural system to be encapsulated as an increase in data rather than an increase in data structures and database complexity. The principles are equally applicable when designing a survey to gather primary source data as they are here for use in ‘extracting’ data from secondary descriptive material.

Any given situation from the very simplest to the most complex is represented within identical data structures. The only difference is the <u>amount</u> of data required to describe the situation.

In the simplest case the entire environment could be described by a single record. There would be one life stage for one species occupying a uniform space for all time. If we introduced a

second life stage, that would double the number of records. If we then introduce a second species, also with two life stages, that would double the number of records again.
If we divide the area up into five eco-regions then that potentially increases the data by 5 times (not allowing for variable spatial distribution).
If we introduce two habitat types, that again would double the number of records (where both habitats occur).
If we introduce a 'year' then the data set is multiplied for each year recorded (not allowing for variable temporal distribution).
If we introduce a season then the number of records required is multiplied by the number of seasons (again not allowing for seasonal patterns) and so on for each new attribute that we introduce.
Each of these increases in complexity requires no alteration whatsoever to the structure of the database.

The same kind of principle applies to the linked subsidiary tables describing species activities, predators and prey.

It is useful to bear that 'scenario' in mind when breaking down the descriptive 'Updated Life Histories' document into data that is capable of analysis with this system.

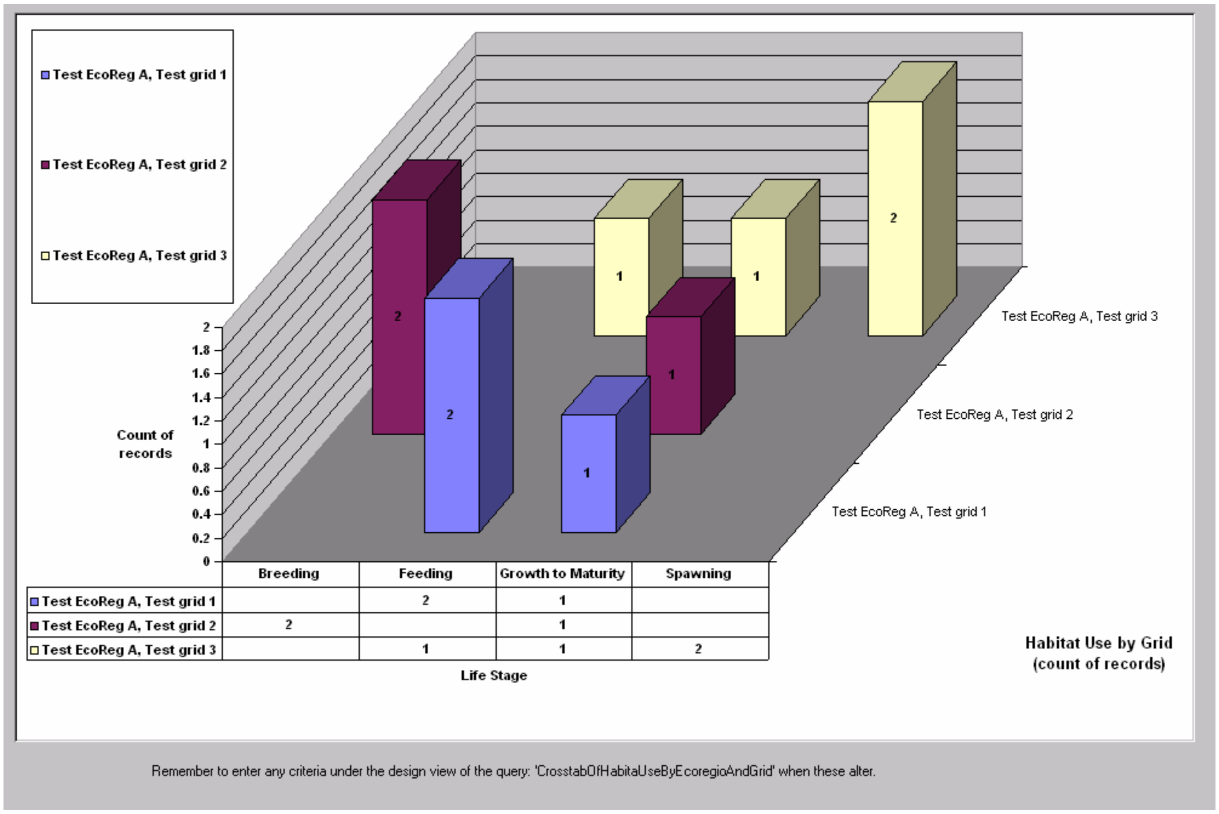
Thus, if it is intended to, say, break down analyses by EcoRegions, then these must be looked for in the information available. Even if a given Species-Lifestage genuinely occupies a given habitat throughout the entire West Coast, five records must be entered to describe it correctly; one per eco-region. That would mean in practice there being five occurrence records being entered for the SpeciesLifestage each with a different PlaceTimeID. Those related PlaceTime records would be identical apart from having

a) a different value under the EcoRegion field, and
b) a different PlaceTimeID code.

Of course in reality it is more likely that the SpeciesLifestage may for example only be recorded in three of the five EcoRegions. In this fashion real complex patterns of distribution can be correctly represented.

The principles outlined above for EcoRegions are equally applicable when dealing with Grids, Seasons, Years and the various combinations of habitats.

Here is an example of the charted output from a query analyzing test data for spatial distribution of species activity across a grid scheme within an Eco-Region for a particular species.



If only habitat variations are intended to be used for analyses then obviously that reduces the amount of data required, there not being the need to break things down into their EcoRegion and Seasonal components.

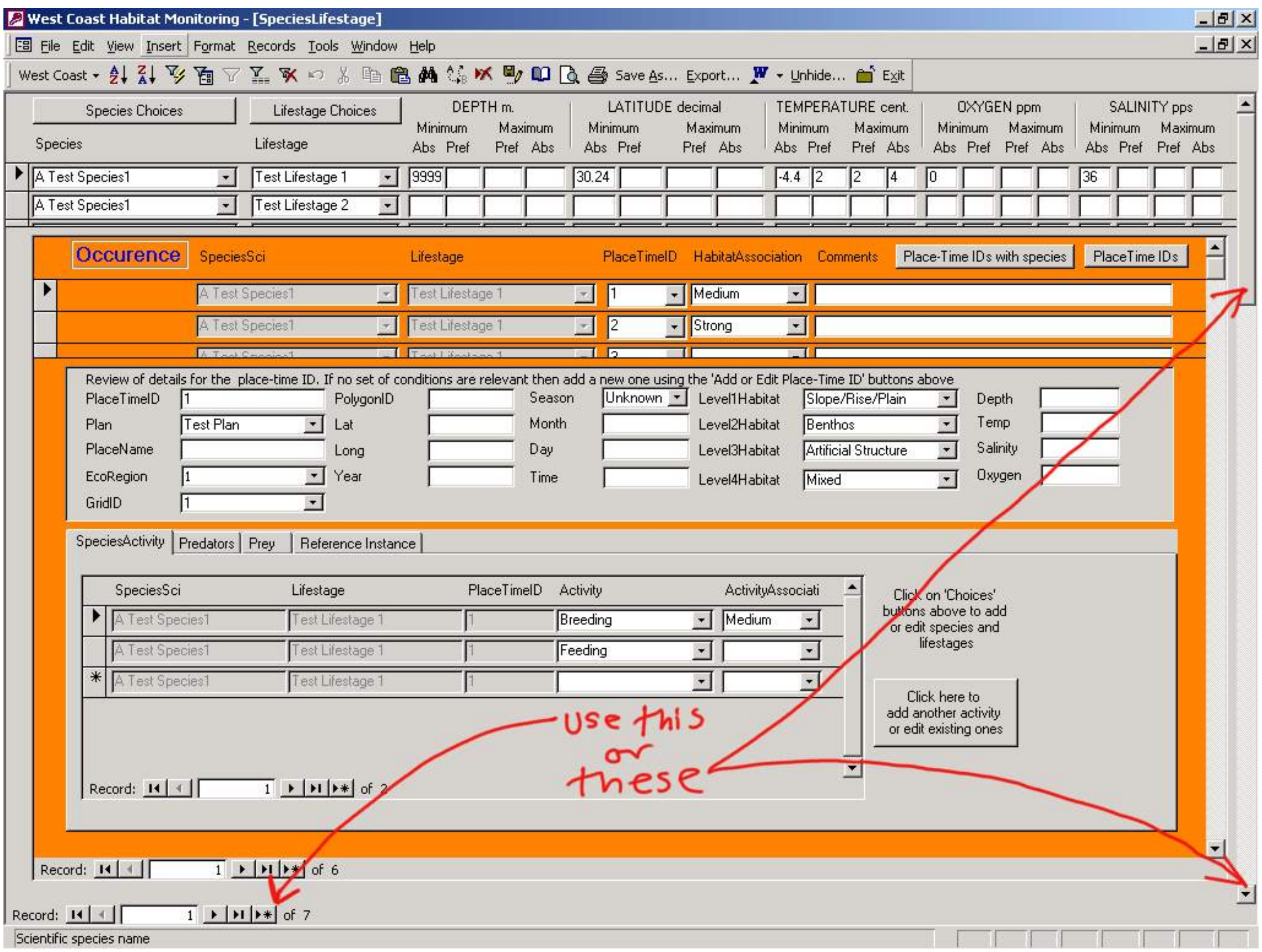
APPENDIX 11E. TUTORIAL FOR EXAMPLE DATA ENTRY

There follows a short tutorial of how data were extracted from the Updated Life Histories document for Petrale sole where it was confined to substrate classification, latitude, depth, salinity and temperature ranges. Temporal and spatial variation was ignored for the present.

The species names should all be in there to start with but you would in theory first go to species and check name. Use the Binocular 'find' symbol on the tool bar to search for the name you are looking for. Make sure the 'Look In' and 'Match' options are set correctly. The scientific names are also in alphabetical order in any case.

From the opening form 'frmMain' open the 'Data: Species centric' form by selecting that button.

Chose the new record button from the navigation buttons of the 'outer', 'parent' Species-Lifestage form as illustrated below:



Then click the drop down box for the 'Species Box' and pick out the species name for entry: Eopsetta jordani in this case.

Decide whether you are going to enter the Species Lifestage attributes to represent all life stages, a selection of life stages, or all the life stages for which information is available. According to your choice you will have one record or a number to enter (one per life stage chosen). Go through the document trawling out the values for the four range limits for depth, latitude, temperature, oxygen and salinity. This is probably best done by using the word search facility for the key word in each case for the species under consideration.

For Petrale Sole the initial depth information under the 'Fishery' and 'Habitat' sections indicates that adults have a preferred range of 300 to 460m but have an absolute range of 0 to 550m. The fields are filled in accordingly. A new record is created for the juvenile life stage. The details for each of the physical characteristics can be edited in for each of the life stages at the same time or each life stage can be completed separately for all of the characteristics needed for each field before moving onto the next life stage. Whichever is most convenient for the data enterer depending on the order the data is extracted from the descriptive document.

Remember entire records can be copied and pasted into the next row as a new record in order to save retyping. You obviously have to then edit the necessary key fields (e.g. here this would most likely be the 'Lifestage' field) so that the record is not a duplicate before that new record can be saved. It goes without saying that you would also amend any of the data in the fields for the physical characteristics where these were different from the previous record. The field above can also be copied where this is simpler by simply holding down the Ctrl and 'C' keys simultaneously in order to save retyping or selecting from a drop down list.

Appendix 7

Description of Habitat Suitability Index (HSI) modeling conducted by NOS

Habitat suitability modeling (HSM) is a tool for predicting the quality or suitability of habitat for a given species based on known affinities with habitat characteristics, such as depth and substrate type. This information is combined with maps of those same habitat characteristics to produce maps of expected distributions of species and life stages. One such technique is termed habitat suitability index (HSI) modeling. A suitability index provides a probability that the habitat is suitable for the species, and hence a probability that the species will occur where that habitat occurs. If the value of the index is high in a particular location, then the chances that the species occurs there are higher than if the value of the index is low. HSI models use regression techniques to analyze data on several environmental parameters and calculate an index of species occurrence. Since this methodology has potential for use in designating EFH and HAPC, we review it briefly here. It is described in more detail in various scientific publications (see for example Christensen *et al*. 1997, Clark *et al*. 1999, Coyne and Christensen 1997, Rubec *et al*. 1998, Rubec *et al*. 1999, Monaco and Christensen 1997 and Brown *et al*. 2000).

Suitability index (SI) values are generated for important habitat characteristics. For example, one can calculate the likelihood of a species being present given a certain depth and substrate type. In situations where trawl or other survey data are available, these can be used to generate SI values based on trends in species abundance with the habitat characteristic under consideration. Figure A3.1 shows data that indicate the change in the abundance of juvenile bocaccio with depth. The curved line is a mathematical model that has been used to represent the data points shown on the graph[1]. Table A3.1 shows how the model is used to calculate HSI values for different depths.

[1] We note that the model shown in Figure A3.1 is not a very good fit to the data, particularly at the margins of the depth distribution.

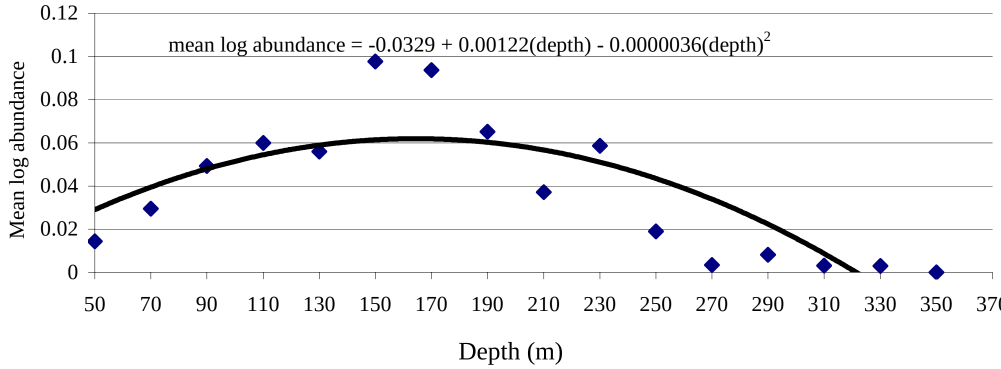


Figure A6.1 Polynomial regression curve fit with mean log abundance by categorical bathymetric class for juvenile bocaccio (graph provided by NOS).

Table A6.1 Example data matrix for calculating bathymetry SI values for juvenile bocaccio taken in NMFS trawl samples (Rubec *et al*., 1999).

Depth Class (m)	Effort (# of samples)	Mean log abundance	Predicted mean log abundance (x)	HSI (x/xmax)*10
50-69	219	.014	.019	3
70-89	361	.029	.035	5
90-109	447	.049	.048	7
110-129	489	.060	.058	8
130-149	398	.056	.065	9
150-169	252	.100	.069	10
170-189	200	.094	.070	10
190-209	213	.065	.069	10
210-229	182	.037	.064	9
230-249	98	.059	.057	8
250-269	92	.019	.047	7
270-289	89	.003	.034	5
290-309	74	.008	.018	3
310-329	98	.003	0	0
330-349	52	0	0	0

In data-poor situations, a literature review of the available information has been used to develop the HSI values. Each reference is used to provide a score indicating whether a species is present or absent within a given range for an environmental parameter. Presence/absence scores (1=present, 0=absent) are then summed for each range, and scaled by dividing by the maximum score. The resulting SI values range from 0 to 1, with 1 indicating highest suitability. For example, if authors of 5 out of 10 research studies said a certain fish was found between 50 and 100 meters, the SI score for that depth range would be 0.5

Table A6.2 illustrates how SI scores have been derived for depth as an example.

Table A6.2 Species occurrence table for presence of a species at different depths

	Depth category (m)				
Author	0-50	51-100	101-300	301-600	801-1000
Literature Reference 1	0	1	1	1	0
Literature Reference 2	0	1	1	0	0
Literature Reference 3	1	1	0	0	0
Literature Reference 4	1	1	0	0	0
Literature Reference 5	1	1	0	0	0
Literature Reference 6	0	1	1	0	0
Literature Reference 7	1	1	1	1	0
Total	4	7	4	2	0
SI Value	0.57	1.00	0.57	0.29	0.00

Species occurrence tables (also called matrices) are developed for each of the habitat characteristics in the model. Once SI values have been calculated for several habitat characteristics, by one or other of the methods described above, the values that relate to the conditions in each GIS map grid reference (i.e. based on maps of each of the habitat characteristics), are averaged (geometric mean) and these averages are values are mapped. The resulting maps show the expected distribution of each species and life stage included in the analysis (Figure A3.2).

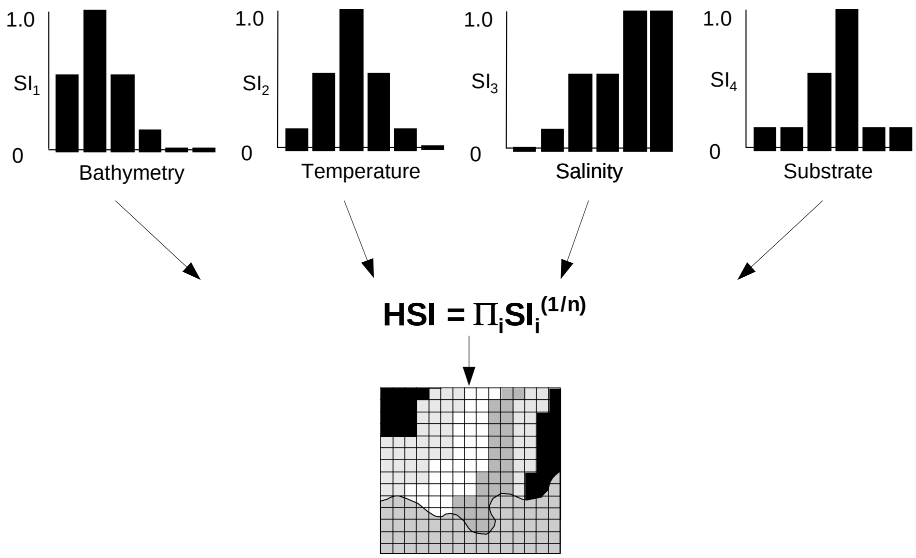


Figure A6.2 Mapping habitat suitability using SI scores (darker shades = higher suitability)

Currently, SI scores have been developed by NOS for 18 adult groundfish species from analyses of data from three central California marine sanctuaries. Depth and bottom substrate type were used as the habitat characteristics to examine habitat quality for benthic species. Mean sea surface temperature and depth were used to model pelagic species distribution. The substrate type consisted of two categories- hard and soft, although there are plans to further classify these to include, sand, mud, cobble, gravel, rock and boulders.

Extrapolation of SI scores spatially ideally requires that the following conditions are met:

(1) independence between the factors that are used to construct the SI scores;
(2) there is sufficient variability in the studies so as to reflect conditions prevailing across the entire fisheries management area.

In addition, if literature studies are used, the studies should be carefully screened to ensure that differences in results between studies are genuinely related to habitat suitability, and are not confounded by differing methodologies, historical changes in habitat suitability (e.g. through pollution), changes in population size or density (e.g. through fishing pressure), or geographical location. Also, the references should contain no repetitions, for example through literature reviews or other citations of previous research findings

It seems unlikely that all these conditions have been fully met in the HSI approach. For example, there is strong evidence to suggest that there is important interaction between the habitat factors used to construct the HSI scores. In addition, the use of the geometric mean to calculate the overall HSI may give unintended, or inaccurate results when one of the component indices is very low. However, some model validation has been conducted, with favorable results. For example, comparing predicted suitability scores with independent trawl survey data or recreational catch data indicates a satisfactory model fit in most cases.

Appendix 8

Description of Fishing Gears Used on the U.S. West Coast
DRAFT 12/3/03

Fran Recht, Pacific States Marine Fisheries Commission

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Description of Fishing Gears Used on the U.S. West Coast DRAFT 12/3/03

Fran Recht, Pacific States Marine Fisheries Commission

I. Background

The Essential Fish Habitat (EFH) regulations of the Magnuson-Stevens Fishery Conservation and Management Act[1] require fishery management plans to evaluate the potential adverse effects of fishing on the essential fish habitat of the fish managed by the Pacific Fishery Management Council (Council), and minimize those effects to the extent practicable.

This document describes the gear used on the west coast of the United States (excluding Alaska) and what components of the gear might effect structural habitat features. This gear description is one part of a 'fishing gear impact analysis' that requires an understanding of the gears used, how gear affects habitat, the amount and distribution of fishing effort, and the sensitivity and resiliency of various habitat types.

It describes the types of fishing gear used on the west coast in potential groundfish essential fish habitat[2] and the parts of the gear that may impact structural habitat features. It includes gear used by fishermen fishing for groundfish as well as gear used to fish for other species. The list of gear types used on the west coast is found in Table X on page X and was taken from ANotice of the Continuing Effect of the List of Fisheries published in the Federal Register[3].
This document does not cover the following issues:

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[1] 50 CFR 600.815(a)(2)(i)

[2] Groundfish is a general term referring to the fish that as adults, with a few exceptions, live on or near the bottom of the ocean. Groundfish essential fish habitat means those waters and substrate necessary for the spawning, breeding, feeding, or growth to maturity of these species. The Pacific Coast Groundfish fishery management plan includes 82 groundfish species which, depending on species, can be found from estuaries seaward to the 200 mile limit of U.S fishery management jurisdiction (EEZ). These species include 55 rockfish species, 12 flatfish species 6 roundfish species, 6 species of sharks and skates, and 3 other species. A list of these fish are found in Appendix X. The description of EFH for these species is found in Appendix X.

[3] Vol 67, No. 12, Thursday January 17, 2002; http://www.nmfs.noaa.gov/prot_res/PR2/Fisheries_Interactions/list_of_fisheries.html. This list of commercial fisheries includes salmon net pen aquaculture and Washington and California kelp harvest. These activities are not included in this fishery gear description, but are described under the non-fishing effects section of the EFH environmental impact statement. The list does not include ghost shrimp pumping nor the poke pole fishery which are briefly described in this document.

1. *Effects of fishing on habitat*. These effects are discussed in the NOAA literature review (Johnson, 2002) in Appendix X.
2. *Fishing effort or distribution*. These are covered in Section X and in Appendix X (risk assessment map)[4].
3. *Gear impact analysis*. The gear impact analysis is a part of the larger risk assessment for groundfish EFH, which deals with both fishing and non fishing effects on habitat as well as natural disturbances. The risk assessment is presented in Appendix X.
4. *Legal requirements for fishing gear*. Legal requirements for gear for Council managed fisheries is found in the Code of the Federal Register 50 CFR 660. There are also gear requirements for state managed fisheries that are found in the regulations of each state.

It is important to note that fishing gear constantly changes in response to factors such as increases in vessel power and design, efforts to increase efficiency, targeting of new species, efforts to reduce the catch of non-targeted species and avoid certain types of habitat, and responses to regulations. While general attributes of gear can be described, innovative fishermen have made many variations in terms of how gear is rigged and handled, which can change gear performance and how gear effects habitat. For example, alterations in towing speed and scope ratios (which determines the angle at which the gear is towed behind the boat) can cause similar gears to have different effects (Rose et al. 2002).

Gear Used in the Groundfish Fishery

Many different types of fishing gear are used to capture groundfish in commercial, tribal, and recreational fisheries. Groundfish are caught with trawl nets, gillnets, longline, troll, jig, rod and reel, vertical hook and line, pots (also called traps) and other gear (e.g. spears, throw nets).

The groundfish commercial fishery is made up of “limited entry” and “open access” fisheries, with most of the commercial groundfish catch being taken under the limited entry program. There is also a tribal groundfish fishery and a recreational groundfish fishery. Table 2 (below) summarizes the gear used by each of these sectors

Limited entry program

The ‘limited entry’ program, established in 1994 reserves a portion of the total groundfish catch (quota) to vessels that have specific limited entry permits. This system was designed to control the capacity of the groundfish fishing fleet by limiting the number of fishing vessels, limiting the number of vessels using each of the three major gear types (trawl, pot, longline), and controlling increases in harvest capacity by limiting vessel length (PFMC, October 2002).

The total number of limited entry permits in April 2002 were 499; with 269 of them being for vessels that are allowed to use only trawl gear; 194 that are allowed to use only longline gear; 27 allowed to use only pot gear, and 9 that have endorsements to use a combination of these

[4]Information on the number of vessels by fishery, location, and vessel size has also been complied. See the Pacific Fishery Management Council’s draft environmental impact statement for the 2003 Pacific Coast Groundfish Fishery (PFMC, 2002): http://www.pcouncil.org/groundfish/gfother/eis0103.html

gears. Included in these permits are 164 'fixed gear' (pots and longline) permits that are 'sablefish endorsed', allowing vessels with these permits to fish for sablefish (black cod). Up to three sablefish permits can be used by one vessel. (NOAA 2002). The trawl fishery harvests the most commercial groundfish under the limited entry program. Table 1 summarizes the limited entry permit count for 2002[5] by gear type, while Table 2 summarizes the gears used by fishery sector.

5 For a more detailed table with Tier 1,2, and 3 sablefish endorsement counts see http://www.nwr.noaa.gov/1sustfsh/permits/prmcount.htm

Table 1 2002 West Coast Groundfish Limited Entry Permit Count

Gear Endorsement	Non-Sablefish Endorsed	Sablefish Endorsed	Total Permits
Longline Gear Only (non sablefish endorsed)	63		63
Longline Gear Only (sablefish endorsed)		131	131
Pot Gear Only (sablefish endorsed)		27	27
Trawl Gear Only (non-sablefish endorsed)	269		269
Pot and Longline Gear (dual gear endorsement)		4	4
Trawl and Pot Gear (dual gear endorsement)		1	
Trawl and Longline Gear (dual gear endorsement)	3	1	4
Total Permits	335	164	499

Open Access Program (groundfish)
In contrast to the limited entry program, the open access program means that any fishermen can participate in the federally managed fishery without having to hold a permit (though states may add their own participation requirements). A portion of the total allowed groundfish catch is dedicated to the open access component of the fishery.

The open access groundfish fishery includes two sectors: vessels that target groundfish (the '**directed open access fishery**') and vessels that catch groundfish incidentally when fishing for other fish (the '**incidental open access fishery**'). Between 1995 -1998 there were 2723 unique fishing vessels in the **directed open access fishery** and 2024 unique vessels in the **incidental open access fishery**. Some of these vessels (1231) participated in both the directed and incidental open access fisheries. Between November 2000 and October 2001, 1341 vessels landed some groundfish in both directed and incidental open access fisheries (PFMC, October 2002).

The **directed open access fishery** includes both 'dead' fish fisheries and 'live' fish fisheries, which refer to the state of the fish when they are landed. Gear used in the open access fishery to target dead groundfish include vertical hook and line, rod/reel, pot, longline, troll/dinglebar, jig, sculpin trawl, setnet, and drifted (fly gear). The live fishery uses pot gear, rod/reel hook and line gear, and stick gear (Goen and Hastie, 2002).

The **incidental open access fishery** includes vessels where groundfish represent less than half of total revenue for a vessel landing some amount of groundfish. For example, the open access sector includes trawl vessels with gear that does not target on groundfish, called 'exempted trawl gear'. These vessels target pink shrimp, ridgeback and spot prawns, California Halibut, and sea cucumbers and are allowed a take a limited amount of groundfish as bycatch. Other fisheries under this open access category include the Dungeness crab fishery, the California setnet and driftnet fisheries, the pot fishery for pink shrimp, the Pacific halibut fishery, the salmon troll fishery, and fisheries for coastal pelagic species and highly migratory species. Those fisheries employ pot, hook and line (rod/reel), longline, round haul (seine), setnet, driftnet, troll, and harpoon gear (Goen and Hastie, 2002). Table 2 below summarizes gear types used in the open access fishery and other groundfish fisheries.

Tribal fishery

Groundfish are also harvested by tribal fishers in Washington under regulations that are established annually by the tribes in consultation with the Pacific Fishery Management Council. Portions of the catch quota for whiting, sablefish and black rockfish are set aside for the tribal fishery. Participants in tribal commercial fisheries use similar gear and fishing strategies to those of non-tribal fishers in Washington (PFMC, October 2002).

Recreational Fishery

Groundfish are also harvested by marine sport anglers fishing from docks and piers, beaches, and from private or charter boats. Some groundfish are also harvested by recreational divers. Commercial passenger fishing vessels (charter boats) and private boats take the majority of the recreational harvest, consisting mainly of nearshore rockfish species and lingcod. Hook and line and spears are the only legal gear allowed for recreational fisheries outside of three miles. Inside three miles groundfish are also caught with dip nets, throw nets, or baited traps or pots. In 2001 there were a total of 404,000 angler trips on charter vessels and 448,000 trips on private vessels that either targeted groundfish or caught groundfish incidentally (PFMC, October 2002).

TABLE 2

Table 2 Gear Types Used in the West Coast Groundfish Fisheries [6]			
	Trawl and Other Net	Longline, Pot, Hook and Line	Other
Limited Entry Fishery (commercial)	Bottom Trawl Mid-water trawl Whiting trawl Scottish Seine	Pot Longline	
Open Access Fishery **Directed** Fishery (commercial)	Set Gillnet Sculpin Trawl	Pot Longline Vertical hook/line Rod/Reel Troll/dinglebar Jig Drifted (fly gear) Stick	
Open Access Fishery **Incidental** Fishery (commercial)	Exempted trawl (pink shrimp, spot and ridgeback prawn, CA halibut, sea cucumber) setnet driftnet purse seine (round haul net)	Pot (Dungeness crab, CA sheephead, spot prawn) longline rod/reel troll	dive (spear) dive (with hook and line) poke pole
Tribal	as above	as above	as above
Recreational	dip net, throw net (within 3 miles)	Hook and Line methods Pots (within 3 miles) (from shore, private boat, commercial passenger vessel	dive (spear)

Gear Used In Non-Groundfish Fisheries

Most fishing gear used to target non-groundfish species (such as salmon, shrimp, prawns, scallops, crabs,,sea urchins, sea cucumbers, California and Pacific Halibut, herring, market squid, tunas, and other coastal pelagic and highly migratory species) is similar to those used to target groundfish. These gears include trawls, trolls, traps or pots, longlines, hook and

[6] Adapted from Goen and Hastie, 2002

line, jig, set net, trammel nets. Other gear that may be used includes seine nets, brush weirs, and mechanical collecting methods used to harvest kelp and sea urchins. This gear is described in section D, below.

II. Description of Gear Used in Commercial Fishing Operations

This section describes basic characteristics of commercial gear used in state and federal marine and estuarine waters off Washington, Oregon, and California[7]. The fishing gear descriptions below are organized under the broad categories of net gear, dredge gear, pot gear, gear that uses hooks and lines, and other gear.

A. Gear That Uses Nets

1. Trawl Gear

General Characteristics of Trawl Gear

Trawling involves the towing of a funnel shaped net or nets behind a fishing vessel [1]. This section of the document describes gear that use "doors" (see below) to spread the mouth of the net. Gear that doesn't use doors to open the net, for example beam trawls and Scottish seine gear, may also considered trawl gear, but is sufficiently different to be described separately in this document.

The trawl gear varies depending on the species sought and the size and horsepower of the boats used. Trawl gear may be fished on the bottom, near the bottom, or up in the water column to catch a large variety of species. These include deep water slope fish (the deep water complex of sablefish, dover sole, shortspine thornyheads and longspine thornyheads); shelf and slope rockfish, midwater rockfish (widow, yellowtail, chilipepper), shelf and slope flatfish, lingcod, skates, Pacific cod, Pacific whiting, spiny dogfish, pink shrimp, spot and ridgeback prawns, California halibut, sea cucumbers, sculpins and seaurchins.

The rigging, adjusting, and fishing of trawl gear is complex. Fishermen work to configure their gear to require the minimum horsepower while maintaining configuration of the net.

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[7]The books *Fisheries of the North Pacific* (Browning, 1980) and *Commercial Fishing Methods* (Sainsbury, 1996) provided much of the original information in these sections, though comments from fishermen, state and federal agency and PFMC staff, have helped refine and improve the descriptions. Additional information in this document came from *Marine Fisheries Ecology (*Jennings, 2001), *A Guide to Oregon's Commercial Fishing Vessels* (Austin, 1984), *California Marine Living Resources: A Status Report* (CDFG, 2001), National Marine Fisheries Service (Goen and Hastie, 2002), Pacific Fishery Management Council (October, 2002), the websites of the http://www.dfg.ca.govWashington Department of Fish and Wildlife and the California Seafood Council. Information was also drawn from a basic trawl training class given by Sara Skamser of Foulweather Trawl of Newport, Oregon; from gear descriptions developed by the North Pacific Fishery Management Council; and from state and federal regulations regarding gear design.

1Pair trawling, which involves towing a net held open between two boats, was common in the 1930s and 1940s, but is not currently practiced. Pair trawling could occur on the bottom or in the water column.

Drag, lift, thrust and gravity are all considerations. Inefficiently rigged gear increases drag and fuel burn. A properly tuned set of door, sweeps and net should have very light contact with the bottom, should have low drag and therefore require less horsepower and fuel burn to fish (Larkin, 2003).

The mouth of trawl nets is spread horizontally in the water column by the use of two doors located one on each side of the net, forward and outward of the net.· The doors, generally made of metal, are pushed apart and down by hydrodynamic forces and by their own weight, and some increase their spread by bottom friction. Fishermen choose trawl doors based on the horse power of their vessel, the type of fishery they are pursuing, bottom type and other factors. Doors are made by many different companies and may be rectangular, oval and flat or slightly V shaped. They can also be cambered (curved) and/or vented.

Fishermen, through trial and error, will tune the doors depending on conditions, bottom, and species sought, to get the proper angle of the gear. Fishermen will adjust the doors to control the angle of the forward end of the door, the amount of spread, and other factors. Doors can be adjusted on both the inside where the main towing wire attaches and the backside where the net system attaches.

Trawl nets can vary in size from small to very large, controlled by the horsepower of the vessel. The trawl net is wide at the mouth tapering to an intermediate piece attached to the codend, the bag that collects the fish. The mesh sizes for the net and cod-end are regulated to allow undersized species to escape during fishing.

Trawl nets are generally made of polyethylene (P.E.) or high-tensile polyethylene (H.T.P.E). Some older nets are made of nylon fibers. Most nets are constructed of 4mm or 5 mm twine and web. Some of the heavier nets may be made of 6mm twine and some small nets may be constructed of 3mm twine. A tougher netting is used around bottom contact areas (where wear occurs) and also around the headrope to protect the web from damage from the floats. Lighter netting is used on the top and the main body (belly) of the net. (Heavy web has traditionally been a double twine version of the body netting. For example, double 6 mm orange P.E. netting has been used for the guard mesh and single 5 mm orange P.E. netting for the body of the trawl.) Some newer P.E. fibers (using new manufacturing processes) allow a smaller diameter twine to be used, resulting in nets that are easier to pull (increasing fuel efficiency).

Different net configurations and designs are used. To catch bottom-dwelling species, such as flat fish, the width of the mouth of the net is generally more important than the height, while for fish that swim higher in the water column, the height of the net opening is more important (Sainsbury, 1996).

The top of the mouth of the net is called the headrope (headline or floatline). The headrope usually overhangs the footrope to ensure that fish disturbed by the groundrope do not escape upwards, but are shepherded down into the cod-end at the back of the net. (midwater square net, no overhang, shrimp trawl roughly same) New headrope and trawl designs are now

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2Historically, this trawl gear was known as otter trawl gear , named after the otter doors (also called otter boards . These terms is no longer commonly used, but appears in the literature.

being tested by NMFS, state agencies, and the fishing community in order to minimize bycatch of rockfish in flatfish trawls.

The footrope or groundrope is directly attached to the lower leading edge of the mouth of the net. The purpose of the headrope and footropes are to provide a framework for the net, which the web is hung on (McMullen, 2003). It also has two conflicting functions of separating the target species from the seabed while raising the netting far enough above the seabed to prevent damage (Rose et. al, 2002). The footrope may be weighted with chain or may be rope-wrapped cable when used on a soft bottom. If the net is to be towed over rough bottoms (as for rockfish or spot prawns) or over soft sea beds that may contain boulders rubber disks or rubber rollers (also called bobbins) are attached to the footrope under the center and wing sections of the net, to allow the net to ride over obstacles. This protects the netting more effectively, but may inhibit fish from passing back into the net and allows more opportunities for escape under the net (Rose et. al. 2002).

Two or more riblines are used on bottom trawl nets and midwater trawl nets. The riblines go fore and aft in the net to provide strength to the net, help prevent security in event of a tear in the net, and prevent tears from going all the way around the net (McMullen, 2003). Shrimp nets don't commonly use riblines.

Midwater and bottom fish trawl nets are attached by sets of bridles (upper and lower bridles) to the doors, or may be attached to mud gear which in turn is attached to the doors. (NOTE: shrimp bridles are often just a synthetic rope extension of the headrope and footrope). Bridles are made of wire rope (also called cable). They function to hold the net open as it is towed and help herd fish into the path of the trawl net. The fishermen selects the length of these bridles Y and their angle of attack is based on the herding characteristics of the target species. Flatfish trawls for example are fished with long bridles, while shrimp trawls usually have short bridles (Rose et. al 2002). Bridle length is also dependent on seabed type (Rose et. al 2002). On rough ground where there is a high risk of snagging on obstructions only short bridle lengths are possible.

A properly tuned set of door, sweeps and net should have very light contact with the bottom, should have low drag and therefore require less horsepower and fuel burn to fish (Larkin, 2003).

Most trawl vessels targeting fish on the west coast are stern trawlers, using one net that is set and retrieved off the stern of the vessel, though a few retrieve their nets over the side. Many stern trawl vessels on the west coast also have a sloping stern ramp to allow for ease of handling large catches of fish. Shrimp trawlers often use two nets towed from each side of the boat, these are called double riggers, with net retrieval being accomplished either over the side of the vessel or from the stern.

Weight of Fishing Gear Components in Water Versus Weight in Air

It should be noted when reviewing information about gear, that fishing gear (e.g. trawl doors, bobbins) weighs less in the water than it does in air. The effective weight of objects in water depends on the specific gravity of the materials. For example the weight of steel in air is decreased by about 14% by immersion. The weight of gear made of rubber components may be decreased by 87% and some netting materials, being lighter than water, will actually be buoyant (Rose et al., 2002).

Bottom Trawl Gear

A bottom trawl is a trawl in which the doors or the footrope of the net are in contact with the seabed. Additionally, any trawl that doesn't meet the requirements for a mid-water trawl (including an unprotected footrope, no bobbins or rollers on the net) is also considered a bottom trawl. Botton trawl nets may be used to target groundfish, flatfish or shrimp. The type and construction of net varies by the species.

Fish are herded into the path of the net by the noise and disturbance of the sea bed (mud clouds, etc.) and by the turbulence created by the doors, bridles, and mudgear (Sainsbury 1996). These cause fish to aggregate directly in front of the mouth of the net (Jennings et. al 2001). The footrope may be strung with rollers, disks, or bobbins to help it move over the seabed.

A bottom (fish) trawl is generally towed at one and a half to two and half knots on or above the ocean floor. The speed is dependent on the depth and the type of bottom being fished. For example, when fishing dover sole in sand and mud the speed may be 1.8 knots, in deeper mud it may be 2.5 knots (Thompson, 2003).

Bottom Trawl Nets (for fish)

Flatfish and bottomfish nets

Flatfish and bottomfish bottom trawl nets are composed of a tapered top and bottom body of netting with the top panel extending forward of the bottom panel. This top panel is called the hood or overhang. The side wings are often cut back to minimize damage to the wings of the trawl and reduce drag. Large meshes are able to be used in the top of the trawl as the fish tend to follow the twine back into the net rather than pass through the mesh. The minimum mesh size is set by regulations, and must measure 4.5" between knots throughout the net and codend. However a larger mesh is often used in the forward upper part of the net.

Shrimp nets are technically a bottom trawl because of the contact of the doors with the bottom. However these nets are sufficiently different to be described separately below. Bottom trawl nets are not intended to drag along the bottom. Groundfish bottom trawl regulations restrict the amount, size, and attachment of the chafing gear (protective netting) that can be used on the cod-end. To help keep the cod-end off the bottom, nets are buoyed with plastic floats (sometimes aluminum floats) that are attached to the headrope of the net and codend to help the net stay buoyant. Keeping the net off the bottom helps avoid getting sand and mud in the catch (especially in flatfish trawls) to improve product quality and allows the net to rise over rocks. However, floats cause drag and decrease fuel efficiency, so there are many things to be considered (Larkin, 2003, Thompson 2003). Typically nets are designed to balance the floatation with the drag and decrease in fuel efficiency cause by the float.
Common net designs for shelf fisheries may have a total headrope length of about 85-95 feet (center and wings) (26-29 m) and footrope lengths of 50-110 feet (15-34 m).

The four seam Aberdeen trawl with a cut back wing, is commonly used for the deepwater commercial groundfish fleet throughout the west coast. The net opens to a height of about 15 feet (4.6 meters) and is used for for black cod and thornyheads as well as petrale or dover sole. The footrope is composed of either 8 inch discs or 14 inch rockhopper gear, hung to chain. (Skamser 2002)

The two seam eastern trawl is used primarily for flat fish fishing in shallow waters and by lower horse powered vessels. It is a low rise net with a wide bottom and a full wing (Skamser 2002). The traditional bottom net design for flatfish, creates net mouth openings of 8 feet (2.4 m) in height or less (Sainsbury 1996). The footrope is now often a disc footrope hung to a cable. Older footropes are sometimes a cable wrapped with rope to which the web is directly attached.

New flatfish net designs are being tried in efforts to reduce bycatch of rockfish. In collaborative research projects fishermen, agency scientists, and gear manufacturers are designing and testing various net configurations including low rise trawl nets and nets with cut-back hoods.

Rockfish nets rigged with *bobbin*s have been used *to fish dover sole in the deep water, round fish in shallow*er water. Prior to the small footrope regulation, nets used for fishing rockfish generally used r*oller gear* with 14 inch rollers. However, when fishing over very rough bottoms,20 inch tire gear was also used (see below)..

Oregon, Washington, and California's groundfish fleet no longer uses the traditional, higher rising rockfish net (also called Atlantic Western ? or snapper trawl). A few boats in Alaska still use this net and NMFS uses this net for surveys. (Skamser, 2003). This net, fished in areas of hard bottom, is used to catch higher swimming fish by creating a larger mouth opening, using a three bridle system and a four seam net. One design uses a net with a W cut shape into the end of the wings, with a third bridle from the doors attached to the inside of this W. This allows the pull of the tow to be directed to the bottom and center legs of the wings, while allowing the top leg of the bridle which is attached to the top of the wing to be lengthened allowing the W to open up and the headrope to rise. This net usually has large roller gear or tire gear on the footrope. (Sainsbury 1996, Skamser 2002). Tire gear are sections of tires greater than 14inches that are fastened together in the center of the net with large bobbins on the outside of these tires. They are attached to the net with chains. This gear allows the net to get over very rough irregular bottom. The tire gear helps the net move over the bottom without snagging as do bobbins, but these are bigger and allow for fishing over tougher bottoms. This gear is no longer used for rockfish fishing.

The cod-end of the bottom trawl nets have two or four riblines made of synthetic rope that run down the length of the cod-end. Additionally the cod-end has expansion straps around the circumference of the cod-end to restrict the expansion of the netting and allow it to be hauled up the stern ramp. Protective pieces of synthetic rope called chafing gear (usually of P.E. fiber) is attached to the cod-end to protect it from abrasion.

Doors

Bottom trawl doors are generally made of steel and slide along the seabed. Removable steel shoes are often also used on steel bottom doors and can be replaced as they wear.

The doors are designed so that the friction of the doors along the bottom as well as hydrodynamic force cause the doors to spread apart (Sainsbury, 1996). The distance between the doors (the door spread) in shelf fisheries is generally 110 - 165 feet (34-50 m); the door spread in deep water fisheries is generally from 165- 650 feet (50-200 m);

The mud cloud generated by trawl doors is not due to the “plowing” of the sediment. The mud is generated from the turbulence created on the back side of the door, which sucks sediment in behind the door into eddies that are formed (Brown, 2003). Increasingly (see below), cambered doors are being used which reduces this mud cloud.

The all-steel “V” door is commonly used. This groundfish trawl door is a rectangular steel plate that has a shallow curve or bend along the middle of the length of the door (axis is horizontal for the bend). The V is shallow with a rise from the centerline to the outside of the door of about 8 inches (20 cm). When the vessel is towing the net, the apex of the V faces toward the boat. The main wire (the cable from the vessel that tows the doors) is attached to a heavy steel bracket (bail) on the doors at various angles chosen to get the desired towing angle (some doors do not use fixed or hinged bails, but use chains). This bracket is often hinged, allowing the main plate to swivel when an obstruction such as a large boulder is encountered. U bolts are welded onto steel plates which are set on the outside of the door close to the trailing edge of the door. Bridles or tail chains are secured between these U bolts on one end and attach to the mudgear on the other, which in turn are attached to the net.

V-doors are widely used on the west coast and are manufactured by different companies. For boats 400-600 horsepower, V doors such as those made by NorEastern Trawl Systems (NETS), are about 6 feet x 9 feet (1.8-2.7m) in size and weigh about 1300 pounds (590 kg) on deck (but less under water, see below). Boats under 400 HP will use doors about 5 x 7 feet in size (1.5-2.1 m) . This door weighs about 950 pounds (431 kg) on deck. Vented V doors and high aspect doors used for both bottom and mid-water trawling (where the doors are long and narrow, with the bend in the middle of the long side) are also in useIn California and Washington, the trawl doors made by U.S.A. Jet Door are also popular. These doors are like the V door though overall surface area to height differs slightly. A door that measures about 5.8 x 9.1 feet (1.8m x 2.8 m) weighs about 2100 pounds on deck (953 kg). Also in use on the west coast is the Type 2 trawl door made by Thyboron, a vented V-door with a chain bail and removable magnesium shoes(Skamser, 2002).

Cambered doors, rather than the flatter V doors, are increasingly being used by fishermen on the west coast, as they are more fuel efficient (Brown, 2003). These are doors with a constant curve along the vertical axis of the door, similar to that of an airplane wing, which increases hydrodynamic efficiency. The cambered door not only reduces the drag per spreading force ratio (increasing vessel efficiency), but also reduces the mud cloud generated by the door (Brown, 2003). Slotted doors also create very little turbulence behind the door and very little mud cloud.

Footrope

The footrope or groundrope is directly attached to the lower leading edge of the mouth of the net. The footrope may be weighted with chain or may be rope-wrapped cable when used on a soft bottom. If the net is to be towed over rough bottoms (as for rockfish or spot prawns) rubber disks or rubber rollers (bobbins) are attached to the footrope under the center and wing sections of the net, to allow the net to ride over obstacles. “Bunt” bobbins are heavily structured, hard rubber half spheres with a 2.5 inch (6.4 cm) hole running through it horizontally (to allow them to be strung onto 5/8 inch or 3/4 inch steel cable (1.6 -1.9 cm) or to 3/8 to 4/8 inch chain (0.95-1.3 cm). This cable or chain (carrying the bobbins) is then shackled onto the fishing line at each wing tip of the net and at intervals along the footrope length it is hung to the fishing line with chain toggles that are generally 18 inches (46 cm) in length. They do not roll as do the bobbins strung on the center of the net, but are dragged along the bottom. A common is 14 inch diamater, (36 cm) in diameter. These weigh about 25 pounds on deck (Skamser, 2003).

The bobbins on the center part of the net are designed to roll over the bottom and vary in size from 9 to 24 inches (23-61 cm), with 14 inch (36 cm) rollers being most commonly used. On deck a 14 inch roller weighs about 17 pounds. Bobbins on the center part of the net are spaced about two feet (.6 m) apart, those on the wings, about three feet (.9 m) apart. Spacers which are either cylindrical or round are made of various materials, commonly rubber. The rubber spacers in common use weigh about 3 pounds on deck and are elongated in shape. On cable footropes cable clamps are often used on each side of the bobbin. These clamps lock tightly onto the footrope and prevent the roller from slipping to the right or left (Browning 1980). Rockhopper gear (see rockfish gear) (also called “tire gear” or “western glider gear”) has a 14 inch (36 cm) rubber disk every two feet (61 cm) with seven inch (18 cm) filler discs. The 14 inch disc has a hole near the top with another line (either chain or cable) running through it. This line is attached to the fishing line at two foot intervals (Skamser, 2003). In contrast to the bobbin footrope which is designed to roll, rockhopper gear is designed to pivot, swinging up and back under the net to lift the net over obstructions.

In November 1999, in order to keep trawlers from capturing canary rockfish and lingcod which associate with high relief rocky habitat on the continental shelf, the Pacific Fishery Management Council adopted a proposal, suggested by the fishing industry, that limits trawl footrope size (that is the size of the components on the footrope) to eight inches (20 cm). This rule prohibits vessels from delivering nearshore and shelf rockfish species and many flatfish species if they have footropes with rollers eight inches or larger. Though only preliminary research has been done, it is widely believed that this gear restriction has been very effective in keeping boats from being able to fish in this high relief habitat.

Bridles and Mud Gear

Trawl nets are attached by upper and lower bridles to the doors, or the bridles may be attached to mud gear which in turn is attached to the doors. Bridles are made of wire cable. They function to hold the net open as it is towed and help herd fish into the path of the trawl net. The bridles may be 20 fathoms (37m) or more in length (McMullen, 2003). On bottom trawl gear, parts of the bottom bridle are strung with a contiguous series of rubber disks (cookies, donuts) that are 1.5 inches to5 inches in diameter (3.8-12.7 cm) (generally about 4 inchesin size). These disks protect the cables and increase their herding effectiveness. Additionally mud gear (also called sweeps) help with herding. The cables of mudgear are also covered with disks, generally smaller than that on the bridles. The mudgear typically is 40 to 75 fathoms in length (73 to 137 m) (McMullen, 2003).

Flatfish trawls may be fished with long bridles, while trawls on rough ground, where there is a high risk of snagging on boulders or other obstructions, use short bridles.

Other Gear- Chains *(note: check again with Sarah if this is flatfish gear)*

Chain toggles may be attached directly to the footrope between the wing tips of flatfish trawls at intervals of about 20 inches (50.8 cm) and drops from it in loops up to about 18 inches deep (0.46 cm) to help stir up the fish and have them rise into the net.

Midwater Trawl Gear

Midwater trawls, also called pelagic or off-bottom trawls, are trawls where the doors may be in contact with the seabed (although they usually are not), while the footrope generally remains suspended above the seafloor, but may contact the bottom on occasion. Midwater trawls are generally towed above the ocean floor, although they may be used near the bottom. They are also generally towed faster than bottom trawls to stay with the schooling fish they target. Towing time varies from a few minutes to several hours. Depths trawled can range from 60- 4200 ft (20 to700 fathoms) at distances from the surf line to about 40 miles off shore. *(Note: check towing speeds , depths towed).*

Nets

Mid-water trawl nets require a large vertical as well as horizontal mouth opening to encompass schools of fish and give the net stability during operation. A midwater trawl net has very large meshes or parallel lines (ropes) in lieu of meshes in the front to allow it to open to its full width, decreasing in mesh size in the intermediate parts of the net and down into the codend of the net For example the mesh sizes in the front of a mid-water trawl may be 120' long. The wings of the net are very long and tall and additionally, to achieve the large opening, deep side panels in addition to the top and bottom belly panels commonly found in bottom nets are used (Skamser, 2003). A mid-water trawl net may be 900 feet or more in length (274 meters) and have footropes 300 feet -600 feet (91-183 m) in length along the center and wings (Skamser, 2003).

Net are usually rigged so that the towing forces are more evident in the headline and the net literally hangs from it (Sainsbury 1996). For mid-water trawl nets weights suspended from the lower bridle legs and footrope promote maximum vertical mouth opening. When fishing in the deep, an extension piece may be added to the lower part of the net to maintain a vertical square opening (Skamser, 2003). When fishing close to the bottom, an extension may be fitted to the top of the net, bringing the headrope forward of the footrope, as with bottom trawls to prevent the fish from swimming upward and over the top of the net (Sainsbury 1996).

The cod-end of the mid-water net generally has four riblines made of synthetic rope (or sometimes, in some codends for Pacific whiting, chain) that run down its length, and expansion straps around the circumference of the cod-end to restrict the expansion of the netting and allow it to be hauled up the stern ramp. Chafing gear (usually of P.E. fiber) is sometimes attached to the cod-end to protect it from abrasion on the stern ramp (or if the net touches the bottom).

Semi-pelagic or hybrid nets

These types of nets have not been commonly used in the Washington, Oregon, or California groundfish fleet, though some expermental nets of this type are being used for Pacific cod in Alaska (Skamser, 2003). Semi-pelagic or hybrid nets are able to be used for either midwater or bottom trawling applications (Sainsbury 1996). These nets fish on or near the sea bed for fish schooling anywhere up to 66 feet (20 m) above the bottom and have a large mouth opening which can open to that 66 foot height. A little confusing This net can also be fished off-bottom for fish much higher in the water column These nets are relatively small so they are easily maneuvered. Some designs (such as the net made by NorEastern Trawl Systems) connects the doors only to the upper wings of the nets (which utilize rope or large meshes), with the footrope being kept down with weights. This type of net was designed to fish on the bottom and can operate well in shallower water. Other designs, such as those used by factory trawlers, use four *(or even six or eight? check this)* bridles attached to the headrope, side panels, and footrope, allowing a very large mouth opening, for example one that is 102 x 54 feet in size (31 x 16.5 m). This net also employs floats attached to the top edge of the side panels and a long roller gear footrope. It can be fished either on or just off the bottom.

Doors

Mid-water doors are usually made of steel, though some mid-water doors use aluminum alloy. When used in mid-water trawling, doors do not often come in contact with the ocean floor, but build up enough hydrodynamic force to spread the net by being pulled through the water at an angle. Mid-water doors are often taller than they are wide (with a height often twice the length) and are curved to increase spreading efficiency.

The door spread (distance between doors) in mid-water fisheries, the door spread may be 330- 650 feet (100-200 m).

Footropes

The mid-water trawling regulations prohibit footrope protection at the trawl mouth, and nets must not have rollers, bobbins, tires, wheels, rubber discs or any similar devices. Sweeplines, including the bottom leg of the bridle must be bare. Additionally, for at least 20 feet (6.15 m) immediately behind the footrope or headrope, bare ropes or mesh of 16 inch (40.6 cm) minimum mesh size must completely encircle net.

Groundweights

Auxiliary weights are sometimes added to mid-water trawl gear to increase downward force at various points. Weight chains or small diameter weights are often attached to the footrope and are also used on the bottom bridles of the nets to help the net achieve its maximum opening size. Depending on the size and rigging arrangements these may range from 400 lbs (180 kg) for a 500 horsepower vessel up to 1100 lbs (500 kg) for a 1100 horsepower vessel. Other manufacturers, e.g. Gloria Trawl company make the bottom web with lead line for the same purpose, using 3/8th-7/16th braided rope (Skamser, 2003).

Shrimp and Prawn Trawl Gear

Shrimp trawls are a type of bottom trawl but have different configurations from other bottom trawl gear and so are described separately here. Most shrimp vessels on the west coast fish are double-rigged, using one net suspended from large outriggers on each side of the vessel, and two pairs of doors, one door on each side of the net. The nets are set and retrieved over the side of the vessel or up the stern. Hydraulic drums, winches, and booms are used to retrieve the gear.

Shrimp trawls are generally towed at one and a half to two and half knots just above the ocean floor, usually about 12 inches off the seabed (Thompson, 2003, McMullen, 2003).

Nets

Pink shrimp nets

The pink shrimp trawl fishery commonly uses a four seam net in a box trawl design. The net does not have a hood (that is there is no overhanging piece of the net in front of the headrope). It is a high-rise trawl, with the net opening being between 12 feet to 8 feet high (3.6-5.5 m). The footrope and headropes are of equal length (commonly 80 to 90 feet long (24-27 m)) with about a 50-55 % rise ratio, that is the mouth of a net with these size components is about 45-50 feet wide when fishing).

Unlike other cod-ends, the cod-end of shrimp net is generally not constructed with riblines that run the length of the cod-end.

Spot prawn nets

The spot prawn trawl uses a short low design with a very strong footrope (that is, with large roller or tire gear). A description of this footrope is found above in the bottom trawl section.

Bycatch Reduction Devices *(check wording and requirements)* Some shrimp and spot trawls (pink sprimp trawls, spot prawns in California and Washington) are required to use a bycatch reduction device (BRD). Finfish excluders have been required in pink shrimp trawls in California since September 2001 and since July 1, 2002 in Oregon and Washington.

California rules allow fish eyes, soft panels, and Nordmore grates to be used. Fish eyes are football sized and shaped frames made of aluminum or steel that is inserted into a slit made in the top of the net about 80 inches up from the terminal end in front of the codend. Soft panels are panels of net with meshes larger than the mesh of the net (e.g. commonly with meshes about 4.5 inches in size) that are sewn into the top of the net. A Nordmore grate is a rectangular or round rigid grate with aluminum or plastic tubes secured at spacings no larger than two inches. This grate has to fully cover the inside of the codend in cross-section and is usually placed in the later part of the codend.

In Oregon and Washington, rules requiring BRDs have been implemented seasonally since July 2002 to allowed fishermen and agency scientists to refine the devices and test effectiveness (Hannah, 2002). In April, 2003 new rules defined what devices are legal. Nordmore grates are allows as well as soft panel devices, as long as the panels are made out of a single continuous piece of netting (that is, no “zippers” are allowed). Fish eye devices may no longer be used.

Testing in Oregon has shown that a modified Nordmore grate, is more effective and has less shrimp loss than either fish eyes or soft panel BRDs. The grate design is a circular or elliptical- shaped panel, rather than the typical rectangular one with narrower bar spacings of 1 1/4 inches (3.2 cm). It is typically made out of plastic. This system excludes rockfish, whiting and some smelt and slender sole, thereby simplifying the task of sorting the shrimp. Additionally, fishermen are experimenting with using a “down panel” of net, a tapered panel of small meshed net attached inside the trawl net and hanging down from the top of the net about half-way into the net body to force shrimp to the bottom of the codend, further decreasing shrimp loss in the BRD (Hannah 2002). West coast fishermen have also experimented with a very effective grate, sometimes called the “Logan Grate”, named after inventor Stan Logan, used in Canada’s west coast pink shrimp fisheries. This grate is circular, shaped like a bar-be-que grill, is made of aluminum tubing, and has the bar spacings as noted above (Skamser, 2003).

Other innovations, such as the one designed by Brad Pettinger in Oregon, include a hinged grate (in the middle of the longitudinal direction) to allow the device to be wrapped around the net reel without damage to the grate.

Doors

A single rigged shrimp vessel may use the same doors that are used by groundfish trawl vessels, while a double rigged shrimp vessel uses doors that are typically much larger than those used by groundfish trawlers. Shrimpers seek stable doors that can get down to the bottom fast. They are generally made of wood with a wide flat steel shoe (heavy plate) on the bottom. The weight of the door is spread over this wide shoe, reducing its pressure per square inch and allowing it to slide across the bottom (McMullen, 2003). The doors are rigged with short bridles to the net.

A typical shrimp door measures 9 foot by 9 foot (2.7 by 2.7 meters) in size (Brown, 2003), but can vary from 6 foot by 6 foot doors to those that are up to 10 foot long and 9 high (McMullen, 2003). A 7 foot by 7 foot door weighs about 950 pounds in air (McMullen, 2003)

In choosing doors, fishermen have to consider the trade-offs inherent in different gear. For example, while higher doors may catch more shrimp, there is a trade-off, as higher doors also requires a larger horizontal width to make them stable, which reduces the efficiency of the spreading force (Brown, 2003).

Footrope for the Pink Shrimp fishery

The footropes used in pink shrimp trawling are not protected with any rollers or bobbins or other gear and are generally rigged to run about 12-18 inches off the bottom (31-46 cm). That is, the footrope of shrimp nets is not designed to contact the bottom. A groundline with disks or bobbins that are two to five inches (5 cm-13 cm) in size may be suspended below the footrope by ladder chains that drags along the bottom and/or the net might have a tickler chain that runs slightly in front of the footrope (McMullen, 2003). The purpose of the disks or bobbins is to prevent the gear from digging into the soft bottom sediment (Brown, 2003). There are many considerations necessary when chosing gear. While smaller diameter disks or bobbins on the gear may fish better than larger diameter gear, larger diameter gear is better at keeping the gear from digging into the bottom. Smaller diameter disks may tend to dig in and could even stop the boat in soft sediment (Brown, 2003).)

Footrope for the Spot prawn fishery

The spot prawn trawl fishery uses large tire gear and rollers on the footrope. Use of this gear is being phased out (see below). In Oregon the footrope assembly consists of chain and roller gear up to 24 inches in diameter is connected to the net by dropper chains. In Washington, the rollers, bobbins, or discs on the footrope on spot prawn trawl nets must be between 8" and 28" in size, and must roll independently and freely. Additionally no tickler chains or any other gear that drags across the bottom in front of the mouth of the net may be used

The spot prawn trawl fishery in the states of Washington, Oregon, and California is in transition due to concerns about high groundfish bycatch levels, percentage of male prawns caught, and habitat impacts. In Washington spot prawn trawling was phased out in 2002 and closed in 2003, with fishermen allowed to transition to pot gear. Five trawlers held permits in

2002. In Oregon, six boats currently hold trawl permits. Phasing out the trawl gear and allowing these fisherman to transition to pot gear is currently being considered. In California the spot prawn trawl fishery was closed by the California Fish and Game Commission under an emergency closure rule in September 13th, 2002 for the duration of that season (through October 31, 2002). In 2003 the Commission will consider a variety of options for long term regulation changes.

Bridles
The bridles that link the doors to the net are short, usually about 15-22 feet in length in a double rigged shrimp trawl(McMullen, 2003). A single rigged shrimp bridle may be up to 100 ft. in length (MuMullen, 2003). Mud gear is not used.

Other Gear- Chains
Tickler chains or more commonly now, ladder chains with a 2.5 inch disc-covered belly section, are sometimes used in the shrimp trawl to drag along the muddy bottom to stir up the shrimp so they rise and enter the net.

Trawl Gear Components That Contact or Effect the Seabed

(The following information is excerpted with permission from Rose et al. 2002, except as noted in brackets)

Trawl gear has several components that contact or effect the seabed. Variations in the composition and design of these components influence their effects on benthic ecosystems.

Of the major components, trawl doors affect the smallest area of seabed, though trawl door marks are the most recognizable and frequently observed effect of trawls on the seabed. The doors travel across the seabed oriented at an angle to the direction of travel. The resulting track marks consist of the area of direct contact as well as a berm of sediment displaced toward the trawl centerline. These two swaths total a few meters in width. The design of the door significantly influences the degree of contact. The downward force exerted by the door on the seabed is influenced by the weight of door and the downward hydrodynamic forces generated by the door counteracted in part by the upward force from the cables attached to the towing vessel. The width of the door contact area with the seafloor is also a factor.

The traditional V door is designed and rigged to have only light contact with the seabed, especially on muddy grounds. The hinge on the door to which the main wire is attached is designed to swivel when an obstruction such a large boulder is encountered. The door's inefficient hydrodynamic shape creates vortices which suspend seabed materials. *(? Check original paper to check re vortices).* In some fisheries this sediment cloud helps herd the fish and is an important part of the capture system. Advances have been made in trawl door design to increase their hydrodynamic efficiency. Changes include doors with higher aspect ratios and doors with slotting and cambering. These doors tend to rely very little on seabed contact for their spreading force, have a smaller contact footprint and suspend less sediment.

The bridles [and mudgear] are cables that connect the trawl doors to the trawl net. The bottom bridle [and mudgear] may be in contact with the seabed for a part of their distance. The length of these components and their angle of attack is based on the herding characteristics of the target species. For example flatfish trawls may be fished with bridles [and mudgear] longer than 109 *(Check if copied correctly)* fathoms (200 m) while shrimp trawls usually have short bridles. Additionally, the length of bridle wire is also dependent on seabed type, with short bridles being used on rough ground where there is a high risk of snagging on boulders or other obstructions. Sometimes bridles are covered with hose or strung with a contiguous series of rubber disks (cookies) up to 15 cm diameter, to protect the cables and increase their herding effectiveness. When using long bridles [and mudgear], these components contact more seabed than any other trawl component. The force of contact of these sections with the seabed results from the weight of these bridles [and mudgear] (in water) per length. Unless chain is used or supplementary weights are added, the bridles [and mudgear] skim the surface of the seabed. Small-scale vertical features on soft substrates can be flattened by this action. Emergent structures and organisms can be vulnerable to penetration or undercutting by bridles, especially where the bridles have a small diameter. [However, it should be noted that on the west coast, few, if any fishermen fish bottom bridles with small diameters, most all are covered by three or four inch disks *(check to see if larger disks are used)*, while mud gear disks are about two and a half to four inches McMullen, 2003]. The ease with which wires traveling across the seabed can be displaced upwards by these structures will be reduced as the tension in the wire increases.

[Note: mudgear 40-75 fathoms long and bridles of 17 fathoms are more typical on the west coast (Skamser,2003, McMullen, 2003.) The typical contact distance may be 55 fathoms or less (100 m). Additionally, hose is no longer commonly used to protect the bridles (Larkin, 2003).]

Footropes, the components of the trawl attached directly to the lower, leading edge of the net, may also contact the seabed. [Though, for example, the footrope of shrimp nets does not, McMullen, 2003}. Footropes are constructed similarly to bridles, composed of cable or chain that may be covered with protective material (rubber disks, bobbins, etc.). The diameter of the protective gear is commonly larger than bridles (up to 1 m) and often varies along the length of the footrope, so only part of the footrope may be in direct contact with the seabed.

Footrope effects are related in part to its contact force and the area over which this force is distributed. The force exerted downward on the seabed from the footrope is dependent on the weight per unit length (which may vary along the length of the footrope)[3] and by the up-pull from the netting to which it is attached. Allowing footrope components to roll may reduce effects, but these rollers are generally only located in the center section of the footrope. In fact some footrope components are designed specifically so that the components do not roll. These components, e.g. rockhopper gear, are designed so that when they hit an obstacle they turn back under the belly of the net and lift the net over the obstruction. Large diameter footrope components can also produce vortexes in their wake, contributing to sediment suspension. This large diameter also makes a component less likely to undercut smaller emergent structures or organisms or to penetrate the substrate, but are more likely to run over these structures. When footrope components are eight inches or greater (20 cm), these larger diameter components are separated by lengths of smaller diameter components, creating spaces where some seafloor features are not directly contacted as the trawl passes. This may reduce effects on emergent structures and organisms.

On most trawls, the netting itself is not designed to directly contact the seabed and anything that protrudes far enough above the seabed to contact the netting has already been contacted by the footrope . The netting may retain objects and organisms that are undercut or suspended off the seabed by the passage of the footrope. If rocks enter a cod-end or the cod-end becomes loaded with dense fish (e.g. flatfish), the cod-end may be weighed down enough to drag on the seabed. [It should be noted that use of roller gear makes it uncommon for rocks to enter the cod-end. McMullen, 2003].

Auxiliary weights added to the lower corners of pelagic trawls may contact the seabed when these are fished near or on the seabed. The pressure that these weights exert on the seabed is the resultant of their weight in water and the upward forces exerted on them by other gear components.

2. Beam Trawls

The beam trawl is the oldest of all trawling types. The gear derives its name from the rigid beam (once made of wood, now of aluminum or steel) that is supported at each end by a vertical 'sled' structure called the trawl head. This beam is used to keep the mouth of the net open horizontally.

Beam trawl gear is no longer common due to the unwieldy nature of the long beam and their lower efficiency, but it is well suited for small boats fishing inshore areas and for inshore areas with steep slopes. For harvesting some bottom-dwelling species, beam trawls have some advantages over door trawls. The opening of the net remains constant in size during turns, effectiveness is less affected by soft muddy bottoms, there is less drag, and vessels having restricted warp capacity (the amount of net towing line) can fish deeper waters since only about half the warp (length) is needed as compared to gear where doors are used. The warp length/depth ratio is 3:1 (Rose et al. 2002).

Beam trawl gear was the only trawl gear allowed in California from 1952 to 1963 to harvest pink shrimp (Pandalus jordani), when trawls using doors were allowed to begin fishing. Currently in California, beam trawls are only used in San Francisco Bay, mainly for California bay shrimp (Crangon franciscorum) which is used as live bait for sturgeon and striped bass sport fishing and provides a small market for human consumption. There are currently 11 permits. Staghorn sculpin, yellowfin goby, and long jaw mudsucker may also be caught with a commercial bay shrimp permit.

Beam trawl gear is the only trawl gear currently being used for shrimp in Puget Sound. Tribal fishers may use trawl gear (with doors) to fish for shrimp, though this fishery has not been purused in the last couple of years (Cain, 2003). There are currently eight active permits (approximately five permits are used to fish pink shrimp in the Straits of Juan de Fuca and three for coonstripe shrimp in the San Juan Islands). These shrimp are used for human consumption, the pink shrimp being peeled for cocktail use, the coonstripe sold whole. Beam trawl gear is not used in Oregon.

Beam trawls use simple funnel shaped nets without wings that are made of polypropylene fibers. Net mesh sizes are set by regulation. On the west coast, one trawl is generally used at a time. Some vessels retrieve the net over the side, while others use a stern ramp. The horizontal opening of the net is set by the length of the beam. In Puget Sound, beam lengths up to 60 feet (18 m) are used for pink shrimp and up to 25 feet (7.6 m) for coonstripe shrimp, but this beam length will vary depending on vessel size. In San Francisco Bay the beam used is 20-25 feet wide (6-7.6 m).

The bottom of the net is attached to the beam which is supported on a fixed sled or skid called a trawl head (also called beam head). The sled, generally oval or triangular in shape, is made of heavy steel, the bottom of which is protected from wear by replaceable steel ‘shoes’ that are welded in place. To reduce wear of the plate, a ‘heel’ is welded to the aft end of the shoe. The skid lifts the net about four to six inches off the bottom (10-15 cm). The top of the net is buoyed with floats, so that the net mouth opening is about five feet wide (1.5 m).

When fishing on soft bottom, the beam trawl may be rigged (between the shoes) with tickler chains (also called mud ropes) to stir up the shellfish lying on or buried in the sand and mud. The number of chains varies depending on the target species and the bottom type. Small inshore vessels use shrimp beam trawls that are relatively light and rarely have more than one chain fitted between the shoes. This is sufficient in sandy bottoms to cause shrimp to flee into the water column and be caught in the net (Jennings et. al 2001). The addition of extra tickler chains has been shown to increase the bycatch of non-target organisms and flatfish that are buried more deeply by increasing bottom contact and penetration of the sediment.

The trawling wire (warp) from the vessel is attached to the towing bridle by a shackle. The towing bridle is formed of three or more chains, depending on the beam length, one from each shoe and the other from the beam, brought together at the shackle.

Towing speeds depend on the species being targeted. For pink shrimp, towing speeds are about two knots. For coonstripe shrimp towing speeds is about one knot. For California bay shrimp towing speeds are about one to two knots. Tows are generally short in duration for both the coonstripe and bay shrimp fishery and shellfish and fish are generally alive when caught.

Beam Trawl Gear Components That Contact or Effect the Seabed

(excerpted from Rose et al. 2002)

During beam trawl fishing, the sole plates on the trawl head and the tickler chains are in direct contact with the seabed. The sole plates generally contact the seabed at a slight angle. The pressure exerted by the trawl head on the seabed is strongly related to the towing speed. As the speed increased the lift on the gear increases and the resultant pressure force decreases. A less firm bottom contact, e.g. on softer grounds, can also be obtained by shortening the warp length. A shrimp beam trawl weighs (in air) several hundred kilograms.

Tickler chains also contact the bottom. Generally only one tickler chain is used when fishing shrimp. The pressure exerted by the tickler chain is substantially lower than that exerted by the trawl heads, though the area covered is greater. When the tickler chain is towed over the seabed, sediments are transported. Smaller particles will go into suspension and may be transported away by currents or resettle in the track of the trawl. Local variations in morphology such as ripples may be flatted out. The amount of penetration into the seabed depends on sediment type, with the greatest amount of penetration occuring on very fine to fine muddy sand. If more than one chain is used on the beam trawl, the added weight increases contact with the seabed and increases fluidization of the sediment as each chain passes, allowing following chains to penetrate deeper (Jennings et. al 2001).

3. Demersal Seines

Scottish seines, also know as a Scottish fly dragging seines, are considered demersal seines as they are nets that fish on the bottom and moves across the bottom when closing. On the west coast it is used in the nearshore and shelf areas to fish flatfish such as sand dabs. Petrale sole, English sole and chili pepper rockfish are also caught with this method. There is currently one fisherman in California who uses this method.

This fishing technique uses a single boat that surrounds an area of water with a very long seine ropes (warps) with a net in the center. In some ways this gear is similar to trawl gear in that it harvests bottom fish by herding the fish with gear (the seine ropes) that is in contact with the seabed. However, this gear does not use doors to spread the net; the net is spread by the two warps. Additionally, the net is similar to a trawl net except it of lighter construction and has a small, light footrope.

The seine ropes, used both for herding the fish and then for hauling the net from the seabed to the boat, are made of polypropylene rope with a lead core, enough to attain a negative buoyancy. It is about 2 miles (3.2 kilometers) in length with a shipping weight of about 1000 pounds (each 125 fathom (229 m) coil weighs about 180 lbs (82 kg) on deck, (16-20 coils are used per set). The net is a low rise net with the opening at the mouth is approximately 150 feet wide and 6 feet high. This low rise configuration better targets slow swimming flatfish that live on the bottom. The net’s footrope (the leading lower edge of the net that comes in contact with the seabed) is approximately 150 feet (46 meters) in length and made of three-quarter inch synthetic fiber (polydacron). A grass (hemp) rope with approximately 80 to 100 pounds of seine leads is attached to the footrope to “tickle” the bottom front end of the net. Because of the small sized components on the footrope, for fishery management purposes it is considered a “small footrope trawl” and qualifies for a limited entry trawl permit (DeVore, 2002).

Because the long seine ropes are vulnerable to snagging, this gear is generally used only on relatively smooth seabed (Sainsbury, 1996). Where snags are encountered, the location is marked and avoided in subsequent tows. In California this gear is used on smooth ‘green mud’ bottom in areas with good upwelling, with the fishermen returning to the same grounds year after year. At the slow speeds of the tow, water pressure helps the rope to skim over the bottom, just touching the sediment and raising a small mud cloud (Fitz, 2002).

The gear is set with or against the wind and tide off either side of the boat. The gear is set out in a diamond shape, with the net bag affixed to the middle of the base of the diamond. To set the gear a flag with a radar reflector, a marker buoy (dhan buoy) and floatation buoys is fastened to the end of the first coil of the seine rope. The seine rope is set out from the coil or reel around a vertical roller set above the rail. After half to two thirds of the seine rope from one side of vessel is set out (between 8 to 10 coils of 125 fathoms each) a turn of about 60 degrees is made and the rest of the first half of the remaining warp is set out. The vessel then slows down to set the net. The net bag and codend is thrown clear of the mouth of the net as it is put off the vessel. The engine is put on full speed again and the vessel begins to set the second eight to ten coils of seine rope off the other side of the vessel turning back to the marker buoy.

The marker buoy is lifted aboard and the free ends of both warps placed through the rollers of the towing block. That is, both ends of the rope are hauled simultaneously as the boat moves forward at idle speed (approximately 550-600 rpm) (Fitz, 2002). The towing begins with the winch pulling in the warps at a very slow rate about 50ft/min (15m/min), gradually increasing to about 75 ft/min (Fits, 2002). As the gear is hauled, the seine rope which is moving slowly along the ocean floor creates a mud cloud which the fish avoid by moving to the center of the closing gear. The fish enter the net at the end of the set when the ropes close (which also closes the mouth of the net). At that point the gear is retrieved as rapidly as possible, with the hauling rate increasing to about 200-300 ft/min (60-90m/min)(Sainsbury 1996). When the net is along side the vessel it is brought aboard by a net reel or power block. A “set” takes approximately two hours from the time the gear is set out to the time it is completely back on board. Fish spend only ten minutes or less in the net during retrieval from the ocean floor to the boat and are alive when they reach the deck. (Fitz, 2002).

Demersal Seine Gear Components That Contact or Effect the Seabed

The lead-core seine ropes of the Scottish seine gear are in contact with the seabed over a length of several hundred meters (as compared to the 100 m or less for bottom trawls). When the gear is hauled the ropes connected to each end of the net are gradually closed. The rate of closure is relatively slow, possibly allowing more time for mobile animals to avoid the rope rather than being overrun. The lighter construction of the net and the lower speed of hauling generate lower tensions in these ropes than in trawl sweeps and bridles. This lower rigidity makes these ropes more able to conform to substrate features instead of cutting through them. Where the rope contacts the substrate, its forward movement displaces sediment as it moves. The amount of tension on the rope determines the amount of displacement and the force exerted on objects that the rope passes over (excerpted from Rose et al. 2002).

The impact of Scottish seine gear on the seabed is minimal because of the slow, gentle movement of the ropes from the initial setting of the gear to the final closing stages of the net. The net itself actually only moves across the seabed a relatively short distance and because the net is very light when compareed to a trawl, there is very little disturbance to the seabed (Amos, 1985).

4. Round Haul (Seine) Gear

Purse seine, lampara, and drum seines (bait nets) are called round-haul gear. This gear captures fish by surrounding them in a wall of netting that is then closed off and hauled aboard. These round-haul nets, primarily purse seines, are used to catch market squid, sardines, herring, anchovy, mackerel, bonito, tuna, and salmon. Squid are fished in the Half Moon Bay to Monterey area and in southern California. Bonito and light-meat tunas such as yellowfin and skipjack are primarily caught in southern California. Other tunas caught in purse seine nets in California include northern bluefin and big eye. Round-haul fishermen also fish Pacific herring with purse seine nets in San Francisco Bay, California, Yaquina Bay, Newport and in Puget Sound, Washington. Purse seines are also used in the anchovy bait fishery in Washington coastal estuaries. An experimental purse seine fishery for sardines, regulated by the states of Oregon and Washington, is also being conducted off Oregon and Washington. A purse seine fishery for salmon is conducted in the Puget Sound. Purse seine gear is otherwise not legal gear in Washington.

In **purse seine fisheries** a net, usually made of nylon, is hung vertically, like a curtain, between a cork line at the top of the net and a heavy lead line at the bottom of the net. The vessel sets the net around a school of fish by traveling in a large circle around the fish, while a skiff holds the other end of the net while the vessel completes the circle. The lead line is about 10% shorter than the corkline, to allow for the easier pursing of the net. This design also prevents the corkline from sinking when the net is hauled (Browning, 1980). The net has a landing bag at the bottom (which has smaller meshes than the rest of the net). Rings (purse rings) are attached with bridles 1 fathom (1.8 meters) long to the lead line. A cable “purse line” is run through the rings of the net as the net is set off the vessel. When it is time to haul the net, the vessel crew closes or purses the bottom of the seine by pulling on the purse line with a hydraulic deck winch. This closes the net below the fish preventing escape, like closing a drawstring purse. The seine is retrieved by the vessel through a hydraulic power block attached to the vessel’s boom or rigging. The bag is then boomed aboard or the fish are dip brailed or pumped from the seine into the vessel’s hold.

In the California fishery for market squid, two vessels are utilized in the fishing operations. A light vessel is used to locate and concentrate a school of squid using strong lights to attract squid to the surface, while the second vessel catches the fish using a round haul net.

The seine used for salmon (the only salmon seine fishery occurs in Puget Sound) is a long, deep seine, that cannot exceed 1800 feet (549 meters) in length along the cork line, and with purse seine and lead combined not exceeding 2200 feet (671 meters). Mesh sizes cannot be smaller than four inches (10.2 cm) except in the bag (bunt) of the net, which can have mesh of three and a half inches (8.9 cm). During the fall purse seine fishery for chum in some areas, the top 100 meshes below the cork line must have a five inch mesh to allow the escapement of immature king salmon. The depth of the seine depends on bottom conditions and water depth, but adding to or subtracting to the net is a time consuming task, and depth is not frequently changed. To offset the problem of the net snagging on the bottom, many salmon seines are built with a taper in one or both ends. This tapering narrows that part of the net and allows it to be fished in shallow water close to the beach with a minimum of fouling (Browning 1980).

The California seine fishery for mackerel and anchovy uses seines similar in size to the herring seines of Washington (Browning 1980) with mesh sizes appropriate to the species being fished.

The **lampara net**, also called a bait net, was the forerunner of the purse seine net. It is a shorter and shallower net than the purse seine and can be set and hauled in less time and with less power and was used for species such as sardines, anchovies, and mackerels (Browning 1980). It was the prime net used for the sardines in Monterey Bay and San Pedro in the early 1900s. It has a cork line and a lead line but does not use purse line, purse ring bridles or purse rings It has a large central bag of webbing (bunt) and short wings of larger mesh, hung so the leadline at the bottom of the net is pulled in advance of the corkline at the top. The net is set with one tow line secured to a buoy or to a skiff, the other to the fishing vessel itself. The set is made rapidly around a school of fish, with the haul quickly begun to keep the catch in the net. With both wings pulled simultaneously, the leadline closes, forming a floor through which the fish cannot escape and drawing the net into a scoop. The lampara is not commonly used anymore in California except for in the bait fishery for smelt and other species and to take white croaker, perch, and queenfish. (CDFG 2001). In Washington lampara gear is used to fish herring and is also sometimes used in the coastal anchovy bait fishery.

The **drum seine vessel** uses a 6ft. -8 ft. (1.8-2.4 m) hydraulic drum to set and retrieve a shorter, shallower, narrow purse seine net with cork and lead lines of equal or almost equal length, rather than the shorter leadline of the standard seine. The nets are generally 250-300 fathoms in length (457-549 m) and are about 18 fathoms (33 m) deep (Sainsbury 1996). It is used in California for bait fish fishing. (CHECK is it also used in the WA sockeye fishery?)

Beach seines or drag seines (Washington). These seine nets are used to catch salmon in Puget Sound and are also used to harvest smelt and perch. The long rectangular drag seine net, with its float line on the top and a lead line on the bottom to assure good contact with the bottom, are set by boat off the beach, river bank, or sandbars. Tow lines are fitted to both ends of the net as working lines.

One end of the net is fastened to a stake, anchored to the beach, or held onshore by people. The other end of the net is taken away from the shore by a boat ahead of migrating fish. The net is set in an arc around the fish, trapping the fish as that end of the net is then brought back again to shore and also fastened to the beach. The weighted part of the net sinks to the bottom while the top remains buoyant. The net is then hauled back in by manpower, power winches, tractors or four wheel drive vehicles from the end that was anchored to the beach last. As the net is hauled the weighted end of the net drags along the bottom trapping fish in its path. Nets can also be set with two boats each carrying half the net out off the beach and then simultaneously dropping the nets as the boat arcs each end back to shore. Nets can have a bunt or bag in the middle of the two wings, or be a straight wall of webbing.

Round-Haul Gear Components That Contact or Effect the Seabed

The leadlines of beach seine nets are designed to be in contact with the bottom and move across the bottom when being hauled. The leadlines of other round haul nets may be in contact with the bottom when fished in shallow water or close to shore (e.g. for salmon).

5. Gillnets and Trammel nets

Gillnets are flat, rectangular nets that hang vertically in the water from a buoyed cork line that is weighted with a lead line. The cork and lead lines and the nylon nets are much lighter than those used in seine netting, while the anchors used on set gillnets are often heavier or larger than those used with longlines (Rose et al. 2002). The nets are made of a lightweight multifilament nylon or monofilament strands with certain specific mesh sizes to select the catch The size is selected so the heads of the desired fish go through the mesh, but their bodies do not. When the fish tries to escape they tend to become entangled in the net. The mesh size is set by regulation with the goal that undersized fish of the desired species can pass through the net without being caught. Therefore, mesh sizes vary considerably depending on species. For example the California swordfish fishery uses a minimum mesh size of 14 inches (36 cm) (more commonly 18 to 22 inches), while salmon fisheries may use a mesh size of five to seven inches (13-18 cm) depending on the salmon species.

The gillnet's webbing hangs fairly vertically in the water column, but it tends to bulge under current effects. Much slack is built into the net because the fish swimming into a taut section of webbing tend to bounce away from the net rather than become entangled in it. (Browning 1980) The percentage of slack built into the net depends on the shape and configuration of the fish. For example, salmon nets may have 40% slack, while swordfish nets need 45% slack, while California halibut need about 75% slack (West, 2003).

A **trammel net** is a gillnet made with two or more walls joined to a common float line. On the Columbia River for example trammel nets use three walls of webbing. The inner net hangs deeper than the outer webbing. When a fish hits the net it passes through the outer webbing, strikes the inner webbing with its smaller mesh and carries through to the larger webbing on the opposite side, trapping itself in the pocket formed by the intertwined webbing. Trammel nets were once in use for California Halibut but it is no longer used, having been replaced by monofilament nets that are not as easily fouled by kelp, sticks, and plastic trash.

Gillnets can either be fished as a set or anchor net **(setnet)** (where ends are anchored in place) or as a drift net **(driftnet)**, where the net drifts freely in the water, unattached to the ocean floor, though one end may also be tied off to a vessel which also drifts. Trammel nets are only fished as **setnets**.

The **setnet** is banned in Washington and Oregon except for small numbers of treaty set net fishermen on the Columbia River above Bonneville Dam and on certain smaller rivers of western Washington. This treaty fishery takes salmon, dogfish and true cod; lingcod and rockfish is caught as bycatch.

In California, setnets are only allowed outside of three miles. Setnets can be fished at all water depths depending on the behavior of the fish being pursued. For example white seabass can be pursued by setnets both when they reside near the bottom (during some parts of their life cycle) as well as when they are in the upper parts of the water column. There is a setnet fishery for bonito, flying fish, and white croaker (mesh sizes of 2.75- 3 inches, 7.0 cm-7.6 cm), fishery for white seabass (using minimum mesh sizes of six inches, 15.2 cm), and a fishery for barracuda with a 3.5" (8.9 cm) mesh size. In California setnets are also used for angel shark, California halibut, lingcod, mullet, and perch. While trammel nets are also allowed to be used in these fisheries, these nets are not currently known to be in use (West, 2003).

In nearshore California waters, outside of three miles, setnets for rockfish are also regulated by depth restrictions; however, they are currently not being used because of the strict limits for certain rockfish such as bocaccio (West, 2003). Additional regulations require the California halibut setnets to have breakaway panels strung between each section (gang) of net to assure mammals will be able to break through nets they encounter.

Setnets are held in place by anchors. The bottom of the net is held down by the use of leadlines that utilize about 100 pounds of weight per 100 fathoms of line.

Driftnets are banned in Washington ocean waters. Driftnets are prohibited in California coastal waters (inside three miles). Driftnets are used to catch salmon (and sturgeon) in Puget Sound**,** Grays Harbor, Willapa Bay, and on the lower Columbia River. They are also used in the Columbia River for shad and smelt. Driftnets are also used in Washington estuaries and inland waters for roe herring, sturgeon and smelt. Driftnets are used for common thresher shark and swordfish in California and Oregon in waters 50 to 100 miles offshore (80-161 kilometers). This fishery also takes shortfin mako shark and pelagic and bigeye thresher shark. Blue shark and striped marlin are occasionally caught but not sold. Driftnets also are used for white seabass, barracuda, yellowtail fishing in California in waters from three to ten miles offshore (4.8-16 kilometers).

Regulations also control the length of the gillnet. For examples, swordfish driftnets can be no longer than one nautical mile (1000 fathoms or 1.8 km) in length in California. In Washington salmon gillnets can be a maximum length of 300 fathoms (.55 km) in length. In Oregon the maximum length for Columbia River salmon gillnets is 250 fathoms (.46 km).

The driftnet can be fished at the surface or in midwater. The depth of the net in the water column is determined by the length of the tether lines (also called support lines) that are hung from each buoy (buoy ball). The net has a slight negative buoyancy and these tether lines allows the net to drop down through the water column to a desired depth. Additional negative buoyancy for the net is achieved by a small weighted lead line (typically 40 pounds of weight over a 100 fathom leadline, West, 2003). The swordfish fishery is required to be conducted with nets 36 feet below the surface (11m) to minimize marine mammal and seabird interactions. "Pingers" (plastic pieces that emanate a sound frequency that marine mammal sonar systems can pick up) are added to the tether and leadlines of swordfish gillnets at intervals of 25 fathoms (48 m) to further minimize marine mammal interactions.

Driftnets are deployed in various ways; from a stern-mounted reel and roller, from a box roller with no reel (with nets being folded on deck or into boxes), or from a bow mounted reel and roller. They are allowed to fish for a number of hours before retrieval, with the fish being removed from the net as the net is hauled back aboard the vessel. The gillnets fished for salmon are generally set close to the beach, setting the net in a similar procedure to that used by fishermen using a drum seine net. That is, the fishermen drops the float (with a light) close to the beach and motors offshore in a straight line, letting out the line for the float and then playing out the net off the vessel's power reel. As the end of the cork line comes into sight on the reel, the fisherman brakes the reel and brings his vessel to a stop. In order to avoid fouling at least four to five fathoms (7 -9 meters) of tow line is then played out between the net and the boat. The net and vessel then drifts with the currents and are influenced by the tides. Drifts can last through one tidal cycle or less depending on current conditions and the amount of fish. Driftnets must be fished in "substantially a straight line"; encircling of fish is prohibited. To haul the net the procedure is reverse, hauling the towline and net in with the reel, while "picking" the fish from the net as it comes aboard.

Gillnet and Trammel Net Gear Components That Contact or Effect the Seabed (Excerpted from Rose et al. 2002)

The benthic effects of a set gillnet fishing operation occurs during the retrieval of the gear. At this point the nets and leadlines are more likely to snag bottom structures or the exposed sedentary benthos. The anchoring system can also affect bottom organisms and structure if they are dragged along the bottom before ascent. Lost nets can tear organisms from the seabed or overturn cobble and small boulders to which organisms may be attached if the are moved along the seabed by currents. Gillnets may be lost during bad weather or through interaction with mobile gears. Retrieval of gear lost to inclement weather is now high due to the increased use of GPS (global positioning systems), while gillnets lost to interactions with other gear is less likely to be retrieved. Once lost, gear may continue to fish. The extent of this 'ghost fishing' will be related to factors such as water depth, light levels, and water movements as well as vertical profile. A lost gillnet can provide a new surface for epibenthic organisms such as bryozoans to settle on and niches for fish and crabs. Although these organisms will help make the net visible to finfish, it can also provide a food source as certain organisms settle on the net or are caught in the net. This will commonly attract fish or other scavengers to eat those caught and the scavenger species can also get entangled. Overtime, especially in areas of high water flow, nets become bundled up, reducing their ability to entangle fish. In deep water, where fouling is very limited and currents slower, derelict nets may fish for longer periods.

Because nets are expensive and can easily become torn if they are snagged on hard or rough bottoms, the goal of setnetters is to avoid these areas, while setting their nets just off to the side and parallel to these areas, on mud or sandy bottoms. Similarly for fear of snagging, efforts are also made to avoid dragging the anchor on retrieval (West, 2003). A 1000 fathom long swordfish net, cut loose during a storm to avoid the sinking of a vessel, when retrieved 6 days later had already bunched up into a dense mass the size of a small house and was not catching fish (West, 2003).

6. Dip Net Fisheries

Dipnets have small nets attached to the end of a long shaft. They are used for harvesting salmon and lamprey eels? in tribal fisheries in the Columbia River. They are also used for harvesting herring and smelt. Herring is harvested using dip nets in bays and the ocean. Dip nets are used to harvest smelt in rivers.

7. Salmon Reef Net

Native Americans of the Puget Sound were using reef nets before white man arrived on the west coast and they continue to be used effectively today in a highly selective fishery by both Native American and other Puget Sound residents. The net is fished among the reefs, set out horizontally in the narrow passages the salmon must traverse to get into fresh water. Fish are guided by two 200 foot leads over the webbing into the bunt (bag) part of the net that collects the fish. Nets are 300 meshes long. Fishermen stationed on a low watch tower built atop a boat or raft watch the fish go into the net and determine the right time to pull the net up. The lead line of the net is raised and the fish are trapped in the bunt and can be brailed (removed with a large sized dip net) from it or the net can be lifted and the fish spilled into holding pens. As the fish do not gill or surround the salmon with a net the fish are kept in excellent shape and non-target salmon species can be released. Pictures of reef nets are available on the Washington Department of Fish and Wildlife website: www.wa.gov/wdfw/fish/regs/commregs/reefnet.htm

B. Dredge Gear

1. New Bedford Style Dredge

The only dredges used on the west coast are used for the Weathervane Scallop fishery. This fishery uses large dredge gear known as the New Bedford style dredge, which scrapes up complete scallops in their shells from the seabed as the dredge is towed behind the vessel with a steel cable. Scallops are fished in waters up to 60 fathoms deep (109 m), usually in areas of firm sand or rocky bottom where scallops will not be bothered by silting (Browning 1980).

The dredge is composed of a low, rectangular heavy steel frame attached to a bag made of four inch (10 cm) heavy steel rings on the bottom and on the top of the rear end of the bag where the shells gather. Further forward on the top of the bag, the bag is generally polypropylene mesh (generally six inch (15 cm) stretched mesh). The bag is a constant width throughout its length, being held out at the rear by a steel bar called the clubstick.

The dredge frame is between seven and fifteen feet wide (2.1 - 4.6 m) and is attached by a triangular shaped frame to a single towing wire. An 11 foot (3.3m) dredge weighs approximately 1400 lb (636 kg) when empty (air weight) and up to 4000 lb (1818 kg) when full (Sainsbury, 1996). A 15 foot dredge weighs 2400 lbs (1089 kg) dry weight (bag and frame), with the frame alone weighing about 1900 lb (862 kg) (NPFMC, 2002).

Unlike other types of dredges, the New Bedford scallop dredge does not use a pressure plate to hold the bottom bar of the frame on the bottom nor does the lower bar have 'teeth' used to penetrate the substrate. The lower bar of the frame is suspended above the sediment by runners or 'shoes' on each side. These shoes are about four inches by nine inches in size (10 cm-23 cm). Tickler chains are strung along the frame and disturb the bottom (and the scallops) ahead of the chain footrope, encouraging the scallops to rise and enter the net. Over rocky bottoms, a chain matrix may be used. Some dredges are designed to produce a vortex behind a baffle to assist in raising the scallops off the seabed.

Both shoes and chain links wear from the abrasion of bottom contact and must be frequently replaced. Shoes are changed every four to five days because they bear most of the weight (NPFMC, 2002).

Vessels used for scallop harvesting are often converted double-rigged shrimpers that deploy the dredges one from each outrigger off the sides of the vessel. As scallops can swim quickly for short distances by expelling water fore and aft from its shell, towing speeds are generally faster than those used to harvest flatfish or bottom fish, about 4.3-4.8 knots. Tows last about an hour.

The dredge fishery for scallops developed in 1981 in Oregon, landing millions of pounds of scallops initially, but the resource was quickly depleted. Landings have averaged about 50,000 lbs annually in recent years (McCrae, 2002). Scallops are shucked either on board or at the processing plant. In Oregon, shells cannot be discarded into bays (Hettman, 2002)

Dredge Gear Components That Contact or Effect the Seabed

(Excerpted from Rose et al. 2002)

The effect of dredge gear on the seabed is dependent on the power and capability of the fishing vessel, the towing speed, the weight of the dredge and its size and design. The principal contact with the seabed is made by the shoes, tickler chains and footrope, with the lower edge of the frame only encountering higher sand waves and emergent structures. The chain bag also is pulled across the seabed. Hydraulic baffles may increase the suspension of sediment, while reducing the need for elements in direct contact with the bottom.

C. Gear that uses pots

1. Pot Gear

The words “pot” and “trap” are used interchangeably to mean baited boxes set on the ocean floor to catch various fish and shellfish. They can be circular, rectangular or conical in shape. The pots may be set out individually or fished in stings. On the west coast, live sablefish, Dungeness crab, spot prawns, rock, box, and hermit crabs, spider crabs, spiny lobster and finfish (California sheephead, cabezon, kelp and rock greenling, California scorpionfish, moray eels, and many species of rockfish) are caught in pots.

All pots contain entry ports and escape ports that allow undersized species to escape. Additionally, all pots used must have biodegradable escape panels or fasteners that prevent the pot from holding fish or crab if the pot is lost. All pots are marked at the surface. The markings are set by regulation. Pots fished in a line need to be marked at each terminal end, with a pole and flag, and sometimes, additionally, a light or radar reflector. Dungeness pots must be fished individually and each is marked by a buoy.

Dungeness crab

The pots used for the Dungeness crab fishery are circular, from three to four feet in diameter (.9-1.2 m), 1 foot high (.3 m) and weigh from 75 to 160 pounds (34-73 kg) (most 85-115 lbs) (Austin, 1984, Eder, 2003). The frames of most all west coast pots are made from three-quarter inch welded steel, wrapped with strips of used inner tube to protect the steel from corrosion. (A few fishermen use vinyl coated steel, fewer still use pots with stainless steel frames). Stainless steel wire is used to weave a three to four inch diameter mesh over the steel frame. A bait holder is secured to the inside of the pot. Bait is generally squid, mackerel, sardines and sometimes razor clams or herring. Sometimes additionally a mesh bag or stainless pin with bait is secured (hanging bait) so that the crab can access the bait. Each pot contains at least two escape rings in the upper part of the sides of the pot 4.25 inch (10.8 cm) ring and two rectangular or oval tunnels generally 8" x 4" (20.3 by 10.2 cm) (sometimes larger) on opposite sides of the pot to allow crabs to crawl in after the bait. Triggers close the tunnels so it is difficult for large crabs to escape. A ring on the upper half of the sides gives undersized crabs an escape route. Once the fresh bait is gone the traps hold very little or no attraction to crabs or most animals. An escape panel, mostly of 120 thread cotton, sometimes of iron or other biodegradable tie, will decay over time, keeping the pots from holding crabs if pots are lost.

Pots are baited and set out (pushed overboard by the crew) one at a time as the vessel follows a particular depth contour (depths fished generally range from 3 to 80 fathoms (5.5- 146.3 meters). (Occasionally outside of 100 fathoms or shallower than 3 fathoms). Because crabs prefer soft bottom habitat, they are mostly fished on open flats of mud or sand, sometimes habitat with some gravel, and sometimes are set close to rocky outcrops or other edges (Eder, 2003). A single line (generally 3/8th inch polypropylene) and bullet shaped buoy or buoys attached to each pot marks its position on the bottom. Typically 30-100 pots (but sometimes many more) are fished in a “string”(a series of individual pots consecutive along a fathom curve), and with several strings being deployed. These strings are usually set parallel to each other and approximately parallel to the beach. A common spacing is about 15 pots per mile (varying from 10-25 pots/mile).

Crab pots are left to fish from one to seven days, depending on fishing conditions. Pots are retrieved individually by snagging the buoy line with a hooked pole as the boat moves forward at about two knots, into the prevailing current, placing the line in the hydraulic power block (crab block) and lifting the pot onto the vessel. The pot is emptied, with the crabs sorted, the legal crabs put into seawater (either into a ‘live tank’ inserted into the hull, or into the flooded hull itself. The pot is re-baited and reset. The retrieval and re-setting of the pots is a rapid, coordinated art, with pots being retrieved at a rapid rate of about one to two minutes per pot, as the boat moves forward, with the re-baited pot being put back into the water just before the pick-up of the next pot is reached. The pot is generally reset in the same area, but if that area is not productive, the fishermen may pick up their pots and search around to set in another spot. (The new location may be chosen based on a history of knowledge of the area, information from other fishermen, information from the productivity of the fisherman’s gear in other locations).

Crabs are alive when sold and are kept alive in the fishermen’s hold by pumping seawater through the circulating seawater tanks, at about a 15 minute exchange rate. (In a very few ports, e.g. Port Orford and Trinidad, California, where crabs are sold daily, live crabs may be kept in dry containers (e.g. totes), instead of seawater tanks.)

Blackcod Fishery

The pots used for the blackcod pot fishery are highly selective for blackcod and are fished off a long-line in series (a set of pots) at various depths. They are generally fished in waters up to o 600 fathoms, though sometimes as deep as 760-800 fathoms. Up to 50 pots are attached to each groundline line. The groundline is usually ¾ inch polypropylene (ranging from 5/8" to 1 1/8"). Pots are spaced every 15 to 40 fathoms along the line, with 20 fathoms being average. An anchor weighs each end of the line. About 60 pounds (27 kg) of weight is used (varying from 50 to 80 pounds) and are often round weights wrapped in mesh bags. Surface buoys and flagpoles mark the location of the lines. Pots are set and retrieved using line haulers and hydraulic blocks and overhead hoists. The pots are large and either rectangular, trapezoidal, basket-shaped, or cylindrical in shape. They usually weigh less than 50 pounds, Pots are set and retrieved using line haulers and/or a drums.

The pots are either rectangular, trapezoidal or conical in shape. The most common, trapezoidal pots are approximately 6' x 2.5' in size and weigh about 55 pounds. The conical pots are usually about four to five foot bottom diameter and three foot high and weigh roughly the same as a trapezoidal pot. The bigger rectangular pots may be over 100 pounds in weight. The trapezoidal and conical pots have collapsible bottoms so more pots can be stacked on deck. Pots are usually baited with pacific whiting or sometimes whiting and squid. A single or, more commonly, a double tunnel system allows the fish to enter, but not easily escape. Pots are steel frame covered with mostly 3.5" nylon web (Eder, 2003), tunnels are of knotless nylon web. A panel of cotton webbing usually about nine inches square, but no less than eight inches (20.3 cm), is built into the pots to eliminate the retention of fish if they get lost. A 21 thread cotton webbing rots away in less than five months (Browning, 1980). Many sablefish pot fishermen are now using escape rings to allow the escape of smaller fish while the pot is fishing. This reduces the number of fish the fishermen have to handle and reduces fish mortality due to handling in the release of small fish (Hettman, 2002 personal communication).

Prawn fishery

Pots used for the prawn fishery (e.g. spot prawns, coonstripe) have a smaller mesh than other types of pots.

The coonstripe shrimp trap uses various trap configurations (CDFG, 2001), the most common being a rectangular trap covered in 1 3/8 inch mesh shrimp trawl webbing, with two circular openings. The traps are set in depths ranging from 15-30 fathoms in strings composed of between 20 and 30 traps per string. Fishermen will use 300 to 400 traps during the fishing season. The traps are baited with a variety of baits including herring, sardine, and mackerel. Each pot string is marked with a surface buoy on each end.

The mesh of spot prawn traps in California must be at least one inch by one inch (2.5 cm) in size and the number of traps per vessel is limited to 500 in the Southern California Bight and to 300 pots per vessel within northern California state waters during peak egg-bearing season. In Washington, there is also a maximum number of 500 pots per permit and pot size is limited to a maximum 153 inch (3.9 m) bottom perimeter and a maximum 24 inch (.6m) height. At least 50 percent of the net webbing or mesh on the pots must easily allow passage of a 7/8" diameter dowel. Each end of a pot string must be marked with a surface buoy on each end.

Other pot fisheries

Pots used for any **groundfish fishery** must have escape panels constructed with 21 thread or smaller untreated cotton twine that will result in at least an 8 inch diameter (20.3 cm) opening when the twine deteriorates. Pots are often rectangular or conical in shape and are generally constructed of twine meshes on a steel framework (Hettman, 2002). Finfish traps are used in nearshore waters off southern California are used to take California sheephead, cabezon, kelp and rock greenling, California scorpionfish, several species of rockfish and moral eel. They are also used in central and northern California for cabezon, greenling, and nearshore rockfish. At least one fisherman in Astoria, Oregon is using pots for cabezon, greenling, nearshore rockfish and wolf eel.

Hagfish pots are tubular traps with an inward tapering tunnel. One or more pots may be attached to a single line.

Spiny lobster traps (in southern California) and the central and southern California **red rock crab** traps use coated wire traps that are generally lighter than a Dungeness crab pot and are weighted with brick weights.

Pot Gear Components That Contact or Effect the Seabed

The effect of a pot on the seabed is related to its weight and structure as well as to how far and fast it moves along the seabed before ascending. The weight of the trap is increasingly countered by the lift from the hauling line as the pot comes off of the seabed (Rose et. al 2002).

For pots on a groundline with weights at each end, if the vessel isn't above the part of the gear being retrieved the gear groundline and weights or anchors can effect bottom organisms and structure if they are dragged along the bottom before ascent (Rose et. al, 2002). Fishermen however make a conscious effort to get right over the gear as they pull each pot, so as to lift the fewest number of pots off the bottom off the bottom at a time (Eder, 2003). This results in much less strain on the line, which can part, if pots are dragged Because black cod pots aren't always fished on the contour, they are sometimes placed on sloping ground. In these cases, pots will be pulled from the downhill, deeper end so that the pots don't drag along the hillside. This allows the pots to be picked up easier, minimizing strain on the gear and equipment, while taking better care of the bottom (Eder, 2003).

Lost pots can continue to fish after they are lost, though fouling reduces the fishing effectiveness of lost pots (Rose et. al. 2002). Additionally, biodegradable panels are required in all pots to provide escape routes to the fish if a pot is lost.

Dungeness pots are hauled in rapidly by the crab block, generally resulting in little disturbance. If there is a long scope (e.g. if have 30 fathoms of line in 10 fathoms of water), the gear will tend to drag more then if there is shorter scope. Because the boat is moving towards the pot as it picks up the gear, drag is minimized. If the crab pots are tacky (partially buried in sediment), it is especially important to get right over the pot to pick it up (Eder, 2003).

D. Hook and Line Gear

There is a variety of commercial fishing gear that uses hooks and lines in various configurations to catch finfish. These include longline, vertical hook and line, jigs, handlines, rod and reels, vertical and horizontal setlines, troll lines, cable gear and stick gear.

1. Longline Gear

This fishery involves the setting out of a horizontal line to which other lines (gangions) with baited hooks are attached. This horizontal line is secured between anchored lines and identified by floating surface buoys, bamboo poles and flags. The longline may be laid along or just above the ocean floor (a bottom longline) or may be fished in the water column (floating or pelagic longline).

Blackcod, Pacific halibut, groundfish, dogfish, and sturgeon (on the lower Columbia River) are targetted on the bottom longline. The longline also takes lingcod and rock fish.

Pelagic longline is used to target swordfish, shark and tunas. California and Washington do not allow the use of pelagic longline gear in waters off their coast (out to 200 miles). However these species caught with longline gear can be landed in their ports. California requires vessels to file an offshore fishing declaration to land longline-caught fish in their ports (Goen and Hastie 2002). Oregon allows fishing with pelagic longline gear under a Developmental Fisheries Program Permit (for swordfish and blue shark) outside of 25 miles, but currently there is no participation in this program.

To deploy the longline gear, the vessels sets the first anchor and then steams ahead, following a selected pathway (e.g., a depth contour, so that the other lines can be set parallel to the first) with the ground line poles and baited hooks being set off the stern of the boat usually down a chute. (Hooks are baited either by hand or by automatic baiting machines. Common baits are squid, herring, octopus, and cod.) Hooks of various sizes are attached to gangions of various lengths that are tied on or snapped onto the line at the desired interval. Hook size and spacing (ranging from 3-12 feet apart), depth, and soak time (fishing time) vary.

The number of groundlines set and the spacing of the ‘strings’ on each line is highly variable (Hettman, 2002, personal communication). Gear is hauled with a gurdy and roller complex, with fish being taken off the hooks as the groundline comes aboard, and skates being separated from each other and gangions removed for rebaiting.

Bottom Longlines

Bottom longline gear fits into two categories: gear that targets fish living directly on the bottom (halibut, cabezon, lingcod etc.) and gear that targets fish living very near the bottom (sablefish, rockfish etc.). Marking buoys, buoy lines and anchors are the same for both types of bottom longline. Additionally hook spacing and size, gangion size and length can also be the same. The difference in longlines for fish living directly on the bottom as opposed to fish living near the bottom comes between gangions and the groundline and in the composition of the groundline itself.

Common features of bottom longline gear

Buoys and Anchors

The longline is marked on both ends with a cane flagpole with a radar reflector and a flotation buoy.

Below the buoys the buoy line (30-50 fathoms longer than the water depth) travels from the surface down to the anchor on the bottom.

The anchor is usually 25-50 lbs. And has two or more legs extending from a main shank. A length of chain extends from the base of the anchor's legs along the main shank to a few inches past the attaching eye. This chain serves to dislodge the anchor from being hung up on rocky bottom. The chain is fixed securely to the legs end of the main shank of the anchor and is tied with a relatively weak 'string' to the eye end of the anchor. The lower end of the buoy line has an anchor gangion spliced into it. The anchor gangion is tied into the loose end of the anchor chain, a few links past the eye. If the anchor becomes stuck in rocky ocean bottom, the string 'weak link' breaks, and the pull from the buoy line is then transferred from the eye end of the anchor to the legs end of the anchor and the anchor is pulled out backwards (Pettis, 2002)..

Gangions

Gangions for halibut are usually #72 thread braided nylon. Lighter material is used for smaller fish. The length of the halibut gangion varies from 30 inches and longer, based on the height of the vessel's railing, as the railman will want to have the gangion in hand before the fish is pulled from the water. Gangions can be either tied on "stuck" or snap-on. Gangion spacing with snap gear depends on the expected density of halibut in the area to be fished. A "hot spot" may have the gangions snapped on just far enough apart that the fish will not tangle each other, wheras a scouting set may be spaced 60 feet or more apart, though 9-15 feet would be standard. Gangion spacing on stuck gear is a blend of expected fish density, groundline lay (stiffness) and gear storage methods. For instance if the gear is to be coiled into wash tubs and the line is somewhat stiff, the hook spacing will be a multiple of the length of the line it takes to make a comfortable fit coil in the tub. With very soft lay line (i.e. line with 'no memory') the spacing would be based on expected fish density (Pettis, 2002).

Hooks

Nearly all modern longline operations use 'circle' hooks. These hooks are shaped somewhat like the clenched talon of a bird of pery in that the point of the hook circles back toward the shank and ends up pointing well below the eye of the hook. Hooks range from #16 halibut hooks, that are about three inches tall (7.6 cm) to #7 hooks about that are about one and a quarter inches tall (3.2 cm) for black cod and other smaller fish (Pettis, 2002).

Gear for fish living directly on the bottom

Groundline

The ground line used to fish for fish living on the bottom is usually about 5/16th inch diameter and is made of nylon or another non-buoyant material. Also ground line made of polypropylene with some lead fibers mixed in is used.

Ground line is stored either wound on a hydraulic powered reel, for snap on gangion gear sets or is coiled up in round ‘wash tubs’ for tied-on or ‘stuck’ gangion gear (Pettis, 2002)..

Weights

Weights of one to five pounds are sometimes attached to the groudline either to speed sinking rate through upper waters that might house non-desired species, or when fishing uneven bottom contours to ensure the groundline does not ‘clothesline’ from high point to high point missing the lower ground completely (Pettis, 2002).

Gear for fishing living near the bottom

When fishing for fish that live directly on the ocean bottom, the fisherman must put his gear where the fish live, directly on the bottom. One problem with doing this is that many other ‘hungry’ sea creatures live there as well. In an attempt to save his bait for the desired species, and keep it above the rest (starfish, crabs, etc.), the fishermen seeking fish species that live just off the bottom will use a modified groundline and a series of weights and small floats (Pettis, 2002).

Groundline

Groundline used slightly off the bottom is made of materials that have positive buoyance (e.g. polypropylene). This helps the floats hold the hooks and bait above the bottom.

Floats and Weights

A series of weights are used along the groundline to sink the groundline to the bottom. The floats have enough buoyancy to lift the groundline, hooks and gangions, but not enough to hold up the weights. The floats keep most of the hooks above the bottom. The height off the bottom can be regulated with the amount of line used between the groundline and the weights. Another way to control ‘fishing height’ is the number of hooks between weights and floats. (Pettis, 2002).

Advantages of each type of bottom longline

The direct on the bottom longline gets the gear down and fishing faster. This is beneficial during short duration fisheries such as West Coast halibut with only ten hour seasons. This gear sinks faster and is less effected by surface currents, so fishing very close to other fisheres on ‘hot spots’ creates fewer tangles. Sinking faster also reduces marine bird bycatch. (Pettis, 2002).

The just above the bottom longline keeps the bait ‘fishing’ much longer. It also allows the hooked fish to swim around a little abouve the bottom. This helps keeps predators from damaging desired fish and allows unwanted fish)those without swim bladders) to be released alive when hauling. Fewer opportunities to snag the bottom exist when only the anchors and small groundline weights contact the bottom. This reduces the impact of the gear on the ocean floor environment. (Pettis, 2002).

Examples of gear configurations for some groundfish longline fisheries

A Pacific halibut ground line is generally composed of ten skates of 300 fathoms (548.6 meters), covering 18,000 feet (5.6 km or 3 nautical miles). It is generally composed of #72 nylon twine with a test of 1800 pounds. Each skate weighs 32 pounds (on deck). Each gangion, also composed of #72 thread braided nylon, averages about 58 inches (1.5 meters) long, is attached to the groundline with snap gear, with a hook at the other end.   Each groundline might contain up to 800 hooks and take three hours to retrieve.   (Hook spacings of 26 feet (7.9 meters) are common, but spacings between 18 feet (5.5 meters) and 36 feet (11 meters) also have been used.) Halibut longlines are generally set at depths ranging from 30-150 fathoms (but some may be fished down to 600 fathoms) and are left to fish for six to twelve hours before hauling. (Browning, 1980?)

A blackcod ground line might cover one and a half nautical miles (2.8 km) and contain 3,000 hooks.. Hook spacings of about three feet (.9 meters) is about standard. The groundline and gangions are similar to that used for the halibut fishery (generally #72 nylon twine). Blackcod gear is generally hauled after four to six hours due to the propensity of black cod to escape or to be taken by predators. Blackcod is fished year round from inside 100 fathoms to 500 fathoms, with most of the fishery historically taking place in 350-400 fathoms (Browning, 1980)

A groundfish ground line typically covers one nautical mile (1.9 km) and is composed of ten skates of groundline, each 100-150 fathoms long. Gangions are snapped onto the groundline at three to four foot intervals.   Herring and squid are used for bait on the hooks. Intermediate weights are used on the groundline to minimize the movement of the groundline across the bottom. The gear is left to fish for two to twelve hours before hauling. (NPFMC, 2002)

A sturgeon longline fishery takes place on the lower Columbia River. Gillnet boats are used, and groundlines are wound on the net reel. The seasons are variable but may run for two months in early spring and a month or more in the summer.

Gear Components of Bottom Longlines That Contact or Effect the Seabed

The principal components of the longline that can produce effects on the seabed are the anchors or weights, the hooks and the mainline. The key determinant of the effects of longlines is how far they travel over the seabed during setting or retrieval. Significant travel distance is more likely during retrieval. If the hauling vessel is not above the part of the line that is being lifted, the line, hooks and anchors can be pulled across the seabed before ascending. If the hooks and line snare exposed organisms they can be injured or detached. Lines may undercut emergent structures or roll over them. The relatively low breaking strength of the line may limit damage to more durable seafloor features. (Rose et. al. 2002)

The mainline can also be moved numerous feet along the bottom and up into the water column by fish, particularly halibut during escape runs. Objects in the path of the groundline can be disturbed (Johnson 2002).

Pelagic Longlines

As noted above, pelagic longline gear is currently not in use in the U.S. waters off Washington, Oregon, or California. It is prohibited gear in Washington and California and while allowed under a developmental fishery permit in Oregon, no permits are currently in effect.

Though the gear is not in use currently, it is described here for informational purposes. Pelagic longline gear can be fished either near the surface or at a certain depth. Several lines may be fished at the same time, kept separated with the help of outriggers. Pelagic longlines can be fixed (anchored to the seafloor) or can be drifted. The nets can be kept near the surface or at a specified depth in the water column by a series of floats and weights. Drift longlines may remain attached to a vessel, but the vessel drifts with the gear as it is being fished (Goen and Hastie 2002).

2. Handline and Jig Gear

Handline and jig fisheries use vertical, weighted monofilament lines on which baited hooks are attached at intervals using wire spreaders or individual leaders attached with swivels. In a typical jig arrangement, a line is 400 pound (181 kg) test monofilament and the jig weighs eight pounds. The hooks are attached to the mainline and are dressed up with colorful segments of rubber surgical tubing, hoochies, or bait (herring or other fish). By hand, or with mechanical gear, the jig is dropped to the bottom to determine the depth. The line is then usually lifted a short distance off the bottom and then jigged vertically up and down to produce movements of the hoochies or bait and induce the fish into biting. This type of gear is used to harvest lingcod and rockfish.

With mechanical jigs, the gear is automated and lets out and reels in line as programmed. It can also be programmed to sense when the gear hits the sea bed and automatically pull in enough line so that the hooks stay a few feet above the bottom without snagging (Sainsbury 1996) . When a pre-set weight of fish has been hooked, the jigger can automatically reel in the monofilament line. Mechanical jiggers will generally utilize between six and sixteen hooks on gangions and many lines can be actively jigged. Squid jigging vessels may utilize up to 30 jigs and attract the squid with bright lights.

Handlines can also be fished without active jigging.

Handline/Jig Gear Components That Contact or Effect the Seabed

The jig (weight) is dropped periodically to the seabed to determine depth.

3. Stick (Pipe) Gear

Stick gear uses a plastic (PVC) or aluminum pipe which is suspended from a mainline and weighted with about a three pound weight (1.5 kg). Wire spreaders are attached at a selected distance up and down the pipe. Leaders are attached with a swivel clip to these wire spreaders. This gear can move along the bottom and is often set near the edge of kelp beds (Riley, 2002)

Stick Gear Components That Contact or Effect the Seabed

The weight contacts the seabed and can bounce along the bottom.

4. Rod and Reel Gear

Fishing poles rigged with monofilament line of various strengths and hooks of various sizes and designs are used to fish salmon and groundfish in commercial, recreational and charter boat (also called party boat or commercial passenger vessel) fisheries. Flashers, hoochies, and bait are used to attract fish to the hooks. Lines may be cast or trolled. Lines are weighted with sinkers that generally range from half an ounce to six ounces (.23-2.7grams). These may be round or pyramid or crescent shaped. Weighted lines and hooks are cast overboard and allowed to descend to the desired depth. When a fish is on the line, fish are reeled back in. The number of hooks and lines fished may be regulated. When multiple hooks are fished, each hook may be fished from an eight to twelve inch "dropper" line attached with a three way swivel to the leader from the main fishing line. Multiple leaders may be attached to each other. Leaders are generally 24" long with one dropper line attached to each end.

Rod and Real Gear Components That Contact or Effect the Seabed

When fishing near the bottom or near reefs, the sinkers may come in contact with the substrate.

5. Vertical Hook and Line (also called vertical longline, buoy or Portuguese long line)

Vertical longline gear is used in Southern California and Oregon to target rockfish. This hook-and-line gear involves a single line anchored at the bottom and buoyed at the surface so as to fish vertically. Baited circle hooks are spaced about 12 inches apart (30.5 cm) and are tied, with monofilament leader, to the mainline. Wind and waves jiggle the buoy, which wiggles the line and the hooks.

Vertical Hook and Line Gear Components That Contact or Effect the Seabed

The anchor contacts the seabed.

6. Troll Gear

Trolling involves towing multiple lines with multiple hooks behind a vessel moving at speeds suited to the fish desired (e.g. a speed of one to four knots for salmon, four to eight knots for albacore). Fishing lines are rigged to a pair (or more, depending on regulations) of three inch to six inch diameter outriggers (trolling poles) which are lowered to approximately 45 degree angles from the boat. Tag lines which are attached to the trolling pole hold the fishing lines away from the boat. A wedge-shaped stabilizer made of steel or wood and lead is often also hung on steel wire or chain from each outrigger to help stabilize the boat. These stabilizers ride from 10-20 feet (1.5-3.0 meters) below the surface.

Fishing lines are set and retrieved using gurdies (powered spools or reels) mounted on the vessel in sets of two, three or four. Each gurdy spool, usually powered by hydraulics, contains and works one main line.

Salmon Troll Fishery:

Salmon troll vessels ranges in size from 18 to 60 feet. Steel lines (main lines), attached to the poles by a tag line, are weighted with 20-65 pound (9-29 kg) lead weights called cannonballs. The main lines and cannonballs are used to control fishing depth and to keep the lines apart. Up to four main lines are used on each outrigger, though two or three mainlines are most common. Each line may have four to ten spreads per line depending on the species of salmon targetted. A spread consists of monofilament leaders with attractants and hooks attached. Spreads are placed every two to five fathoms up from the cannonball, generally by being snapped onto the main line between stops set onto the main line. Troll fishermen have used longer and fewer spreads to better target chinook while avoiding coho salmon (Heikkila, 2002). Fish are attracted to the hooks with a flasher and terminal gear usually consists of plugs, spoons, plastic squid hoochies or hooks baited with herring or anchovy. Hooks must be single point, single shank, and barbless.

Fishing lines are set and retrieved using gurdies (powered spools or reels) mounted on the vessel in sets of two, three, or four. Each gurdy spool contains and works one main line.

Salmon are fished pelagically as well as close to the bottom in water depths up to about 80 fathoms (146 meters) and up to 50 miles (85 kilometers) offshore, from central California to the U.S./Canadian over bottom habitat of any type. The fishery occurs intermittently between March and October, subject to area restrictions.

While many salmon fishermen will stay at sea for many days before delivering their iced product, the addition of freezer capacity has allowed other vessels to stay at sea much longer and go much further away from port.

Salmon Troll Gear Components That Contact or Effect the Seabed

Most salmon troll gear never comes in contact with the seabed. However, in shallow areas (less than 10 fathoms (18 m) with flat sandy bottoms near the surf zone, the cannonballs and hooks may be fished in contact with the bottom (Tracy, 2002). However, most fishermen will avoid contact with the bottom because of loss of gear, safety concern, and encounters with lost crab pot gear (Heikkila, 2002). In order to avoid loss of line and outriggers if hang-ups occur, the cannonball weights may be attached to the lines by leather straps or other lighter line which is designed to break should the weight hang up on the seabed or gear.

Albacore Troll Fishery

Vessels targeting albacore tuna range in size from 40 to 70 feet and tow up to 13 lines of varying lengths from the outrigger poles and the stern. A lure called a jig is attached to the end of each generally unweighted line (unless ocean conditions require weights to keep lures from bouncing free of the water). One or two lines on each pole may also be weighted with chain heavy enough to sink line and lure so that outside lines may be hauled over them without snagging. Jigs have metal heads, plastic skirts or feathers, and large, barbless double hooks. Fish are pulled aboard by hand or by line haulers (pulleys) located on the stern.

Albacore jigs are fished on the surface of the water. While the season is open year round, albacore are usually fished from July through October, when the water is warmer not too far offshore (e.g. 20-60 miles (32-96 km). . (Albacore prefer water from 58 - 64 degrees Fahrenheit (14-18 degrees C). However, some fishermen will venture out much further, as far as 1500 miles (2413 km) offshore (Goblirsh, 2002). The development of vessels with large fuel capacity and on-board freezing systems has allowed this far-ranging fishery. Some of these fishermen deliver back to the west coast, others go to Midway, Hawaii and the South Pacific, delivering to at-sea tenders or to ports in these places.

Albacore Troll Gear Components That Contact or Effect the Seabed

Albacore gear does not come in contact with or effect the seabed.

Groundfish Troll Fishery

Troll gear is also used to harvest groundfish. One type of gear is often called ‘dingle bar’ gear, so named because when the five to seven foot iron bar (1.5-1.75" in diameter) touches bottom there is a distinct ‘ding’ transmitted up the steel trolling wire. The gear is designed to be fished three to six feet above rocky bottom and the iron weight is allowed to touch the bottom only occasionally to adjust for varying depths. This gear is used primarily to target lingcod (sometimes halibut) and is very selective. It has been used to target lingcod for over 50 years. (Heikkila, 2002).

The gear is attached to trolling wire with double troll snaps usually two to three feet above where the iron bar is attached. The mainline is normally 400 pound/test monofilament line (181 kg) with small brass spreaders with three swivels spread six feet apart. Two four to five inch (10-13 cm) hard plastic floats are placed in the middle and end of the gear. The fishing lures, six to eight ounce (170-227 gram) lead-head jigs, are hung on five foot, 200 lb/test monofilament gangions attached to the center swivel of the spreaders. The jigs are baited with large plastic worms called ‘scampies’ and are sometimes tipped with bait. Normally four to eight jigs are used. (Heikkila, 2002).

Other groundfish trolling gear is similar to the above described ‘dingle bar’ gear, except it uses a bent steel bar about four feet in length (1.2 m) that weighs about 40 pounds (18 kg) rigged at the end of the steel main line (trolling wire). The bend in the bar assists the bar slide over the seabed or rocks. It is attached to the main line by a breaking strap which will break if a hang-up occurs. The gear consists of a snap link attached to a swivel, followed by

1 fathom (1.8 m) of monofilament line, then about 2 ft of thicker spreader bar. This combination is repeated a number of times to form a string. Gangions of monofilament and heavy stainless wire with weighted hooks are connected to each swivel of the string. At the end of the string, a rigid plastic float is rigged to provide drag and flotation to keep the string and hooks horizontal and suspend the hooks just above the bottom. Ten to fifteen of these strings may be attached to main line above the bent weight bar at various depths to target rockfish congregating at different depths around rock pinnacles (Sainsbury 1996, CDFG, 2001).

To fish a number of depths near the surface, floats are rigged on the main lines, followed by a number of leaders and a heavy weight (CDFG, 2001). By adjusting the weights, length of main line and location of leaders, the hooks can be rigged to fish a range of depths within the desired band. (Sainsbury 1996)

Groundfish Troll Gear Components That Contact or Effect the Seabed

The iron and steel "dingle" bars can contact the seafloor. The hooks and line can snag on rocks, corals, kelps and other objects during retrieval. This may upend smaller rocks and break hard corals, while leaving soft corals unaffected. Invertebrates and other light weight objects can also be dislodged.

7. Mooching

Mooching is a fishing technique used for catching salmon. It involves fishing multiple fishing poles with baited hooks behind a vessel while the vessel either drifts or stays stationary in the current. This is not legal commercial gear in Oregon and Washington where the gurdies or poles have to be fixed to the vessel, but it is used for recreational fishing. Salmon mooching is both a commercial and recreational fishery in California, primarily south of Point Arena and particularly in Monterey Bay and San Francisco Bay. This fishery is usually pursued by small outboard boats owned by recreational fishermen who also hold a commercial permit. This fishing gear is described in the recreational fishing section below. Mooching gear does not generally come in contact with or effect the seabed.

E. Other Fishing Gear

1. Dive, Hand/Mechanical Collection Fisheries

In Washington and Oregon sea urchins, clam, octopus, oyster, sea cucumber, scallop, and ghost shrimp are harvested by hand, dive, or mechanical collection methods. Finfish are also taken by divers using a spear or speargun and live fish are taken in California by divers using a short fishing line deployed underwater near the target fish. In California, abalone and seaurchin are taken in dive fisheries as are crab, scallops, and lobster. Swordfish is taken with harpoons, and other fish (e.g. skates, rays, certain sharks are taken with spears, spearguns, harpoons, and bow and arrows). Bow and arrow gear may also be used to take certain finfish.

Dive fisheries (using either a self contained air tank, or breathing off a hose "hooka" from a low pressure air compressor vessel) are used to pursue various fish and shellfish such as urchins, lobsters, and sea cucumbers which are hand collected, sometimes using rakes or other hand carried implements. Regulations may control the number of divers in the water by permit. Scuba gear is also used to pursue finfish with a spear or speargun. The swordfish fishery uses harpoons. Clam rakes are used to harvest clams in estuarine and shoreline waters.

Harpoons, spears and sticks are shafts with sharp, pointed, or barbed tips. These may be propelled by hand or by mechanical means. Harpoons are not legal gear in Washington. The harpoon is attached by line to an inflatable buoy and to the fishing vessel by a recovery line (tag line) that spools out of line on board the vessel. The movement of the fish, once struck is shown by the buoy, so that the vessel may follow its movements. Swordfish harpoon vessels in California work in conjunction with an airplane to spot swordfish basking at the surface. Harpoons are hand propelled. Modern harpoons may employ electrical shocks to kill or stun the fish so it can be brought on-board without excessive fighting activity.

Urchin harvest occurs at depths of five to 100 feet (1.5- 30.5 m), with most dives taking place in 20-60 feet (in Oregon and Washington, dives must be in water depths greater than 10 feet (3.5 m) from the mean-lower low water). Red, purple, and green urchins are harvested commercially. Red and green are primarily harvested in Washington, red in Oregon, and red and purple in California). Urchins are harvested from the ocean bottom with a hand-held rake or hook and put into a hoop net bag or wire basket. The basket is winched onto the boat and emptied into a larger net bag. Limited entry permits and lower size limits areused in Washington, Oregon and California to control the harvest for red sea urchins (additionally upper size limits and seasonal and area restrictions are used in Washington, and seasonal requirements and log book requirements are in place for regulating this fishery in California).

Clams are taken in shallow estuarine waters or along the nearshore by hand-held hoes and rakes, and in some cases (e.g. geoduck clams) by using hand held water hoses with a one inch (2.5 cm) nozzle at the end that is attached to a 11 hp motor. This water hose liquifies the sediment around the clam and allows it to be captured. Abalone are taken in dive fisheries by hand sometimes employing hand held hooks.

There is currently interest in Oregon to harvest bay clams using a water hose similar to that used in the geoduck fishery, but with a smaller pump (5hp) that pushes air through a nozzle that is a half inch in diameter. Lack of capability to monitor effects has put a hold on these experimental fishery permits. Gapers are generally found in a sandy/muddy/shell habitat from the intertidal zone to depths of 17 fathoms (30m). If allowed in Oregon, mechanical gear would be limited to depths greater than ten feet (3 m) to protect the intertidal zone.

Gear Components of Dive and Hand/Mechanical Collection Gear That Contact or Effect the Seabed

The urchin collection bags may sit on the bottom during harvesting. Clam rakes and hoes and water from hoses disturbs the bottom to dislodge the shellfish. Hooks used to dislodge abalone from their substrate can contact the substrate.

2. Herring spawn on kelp

A fishery for herring eggs (roe) that have been laid on naturally growing kelp is conducted in Puget Sound, Washington and in California. The kelp fronds with their clinging eggs are cut by hand from small skiffs. The weight of the catch (including the plants) is limited to twenty-five pounds in California. Oregon also had a fishery for eggs on kelp, with Macrosystis (giant kelp) shipped in from California and hung on rocks for the herring to spawn on (Hettman, 2002, personal communication).

3. Herring brush weir

In Puget Sound, Washington, fishermen also construct structures that are placed in bays where herring spawn. The weir is removed from the water and the eggs collected.

4. Ghost shrimp pumps

Commercial fishermen use gas operated pumps or hand propelled pumps in the nearshore to harvest mud and ghost shrimp from tidal mudflats. The mouth of these pumps mechanically evacuates smallish diameter holes in portions of the sediment.

5. Poke Pole

Poke poles are long bamboo poles with baited hooks attached to the end that are used in intertidal areas by recreational fishermen along the northern California coast to capture cabezon, greenling, and an occasional shallow water rockfish or prickleback.

5.Bait Pens

List of continuing fisheries notes WA, OR, and CA bait pens with about 13 participants. Information needed.

6.Live Groundfish

Only legal commercial fishing gear of certain types is allowed to be used to harvest live finfish and shellfish. The gears have already been described, but further information is provided here to define the gears used in the live fish fishery.

Live groundfish are caught in the open access groundfish hook and line fishery, with limited entry longline gear and with limited entry pot gear, and a variety of other hook gears (e.g. stick gear). Additionally, California halibut and rockfish taken in gill and trammel nets have increasingly appeared in the live/premium fish fishery (CDFG, Dec 2001). A new development is California urchin divers fishing with hooka gear underwater during the off-season for urchins. They fish a short line (18" line) underwater to target the same fish that are targetted by the other hook and line gear. Landings of 80-100 pounds (36-45 kg) of fish have been made at times by the three or four fishermen who currently are using this gear in California (Calvis, 2002).

In California hook and line gear for the live-fish fishery within one mile of the mainline shore has been limited, since 1995, to a maximum of 150 hooks per vessel and 15 hooks per line. (CDFG, 2001). Traps are limited to 50 per fisherman.

In Washington, it is illegal to possess live bottom fish taken under a commercial fishing license.

In Oregon, nearshore rockfish and species such as cabezon and greenling are the target of the live fish fishery. Only sablefish and rockfish have certain limits on their catch (the catch is credited against the federally set limited-entry allocations). This fishery occurs in waters of ten fathoms or less (18 m). In early 2002, an Oregon Development Fisheries Permit was required for fishermen landing live fish species (e.g. cabezon, greenling (except kelp greenling), brown, gopher, copper, black and yellow, kelp, vermilion, and grass rockfish (among others), buffalo sculpin, Irish lords, and many surfperch species). Additionally commercial fishing for food fish is prohibited in Oregon bays and estuaries and within 600 feet (183 m) seaward of any jetty. Only legal gears must be used to catch nearshore live fish.

Live Finfish (non-groundfish), Live Shellfish Fisheries

Baited traps, no larger than three feet in its largest dimension, are used for shiner perch, Pacific staghorn sculpin and longjaw mudsuckers in California.

Dip nets and baited hoop nets not greater than three feet (. 9 m) in diameter may be used to take herring, Pacific staghorn sculpin, shiner surfperch, surf smelt, topsmelt, anchovies, shrimp, and squid in California.. Hawaiian type throw nets are also used to take these species north of Point Conception.

Beach nets not over 20 feet (6 m) in length with meshes at least 7/8ths of an inch in length are allowed to be used to take surf smelt north of Point Conception, California.

Prawns (spot and ridgeback primarily) are taken with a trap fishery as are Dungeness crab.

II. Gear Used in Tribal Fisheries

The Gear Used in Tribal Fisheries is the same as the gear used in the commercial and recreational fisheries described above and below.

III. Gear Used In Recreational Fisheries

Recreational fishing is fishing with authorized gear for personal use only and not for sale or barter.

The only gear legal to use for groundfish in the area between 3 and 200 miles from shore (4.8-322 km) are hook and lines and spears (see description above).

Rockfish and cabezon are generally fished off lines with multiple hooks suspended. Baits include sand and ghost shrimp, pile worms, herring and squid. Alternatively a quarter of an ounce to a one ounce "leadhead jig" with a rubber worm is used. Lingcod is fished using dead bait or sometimes live greenling.

In California recreational groundfish fishermen are restricted to one line and three hooks. Rod and reel gear and handlines are used.

In Washington only one line with two hooks is allowed to be used for all species taken in marine waters. In some Puget Sound areas (Marine Areas 5-13) anglers are required to use only barbless hooks for all species. The exception to this rule is that anglers may use another line equipped with a forage fish jig with up to nine barbed hooks in certain areas (Marine areas 5-13) (WDFW, 2002). Dip nets are allowed to be used to land legally hooked fish.

Flatfish are fished in areas with sandy or muddy bottom with rod and reel gear using a small jig or a hook baited with shrimp, marine worm, or mussels.

Pacific Halibut is taken with rod and reel gear using large herring, jigs, spoons or shrimp flies deployed on wire or very heavy monofilament leaders.

The only recreational gear allowed to be used for salmon is hook and line gear that is cast, trolled or mooched. Shore and boat anglers use spinners or bait; offshore anglers troll or mooch. Ocean coho are fished in the upper layers of the water while chinook are deeper and caught with larger plugs (greater than six inches) herring, spoons, spinners or metal jigs.

Trolling involves towing lines from fishing poles behind a vessel. Salmon mooching uses different terminal gear (gear at the end of the line than trolling) though lines are also drifted behind the vessel from fishing poles. In Washington, primarily Puget Sound, and in Oregon, a technique called motor mooching is used. The vessel uses a trolling motor to keep the boat relatively stationary in respect to the current. The gear is rigged to create a spinning bait (herring, sardine or anchovy). The pole is secured in a pole holder on board, or the line may be cast and reeled. In California, drift mooching is practiced. The boat motor is turned off and the boat drifts with the current. The hook is turned around backwards in the bait, usually anchovy (that is the hook is embedded in the biggest part of the fish) and the intent of the technique is to gut hook the fish.

Large tuna poles are generally used and once the fish hits the bait, more fishing line is fed to allow the hook to go deeper, then the rod is jerked. Circle hooks have been required (instead of J hooks for a number of years to reduce hooking mortality when prohibited fish are released, but hooking mortality remains very high (46%) in comparison to sport trolling hooking mortality rates of about 14% (Grover, 2002).

Green and white sturgeon are fished by both boat and shore anglers using shrimp, smelt or herring.

Striped bass (an introduced species) is fished in San Pablo and San Francisco Bays and the ocean area offshore these bays. Gear is generally caught by bait fishing or trolling, though sometimes fly fishing or casting plugs or jigs is used. Trolling or bait fishing gear is generally used although some fishers may cast jigs or plugs or flyfish.. Dead baits include threadfin shad, anchovies, sardines, staghorn sculpins, gobies, shrimp, blood worms and pile worms. Drift fishing with live anchovies or shiner perch occurs in San Francisco Bay and the ocean, while live golden shiner minnows or threadfin shad are sometimes used in the delta. Trolling methods are specialized for striped bass and many types of plugs, jigs, spoons are used, frequently in combination.

There are no federal regulations for recreational take of coastal pelagic species (e.g. sardines, anchovy, herring, smelt, squid or mackerel); state regulations apply. Surf smelt are taken from beaches with dip and A frame nets. Pacific herring, northern anchovy, sardine and smelt are caught in bays with multiple-hook herring jigs or nets. Bait includes sand and kelp worms, sand shrimp, clam necks and mussels. Dip nets are allowed to be used to harvest these forage fish in Washington for recreational purposes.

Recreational fisheries for highly migratory species (billfish, sharks, tunas, dorado) use hook and line gear fished from private or charter vessels.

For albacore tuna, anglers use live bait or metal-headed plastic or feather jigs trolled at five knots or faster. Handlines are often used instead of a rod and reel.

There are numerous surfperch species targeted by sport fishermen. Redtail and silver surfperch are found mostly in the surf. Striped seaperch, pile perch, white seaperch, shiner surfperch all live near rocks, docks or pilings in bays. Baits include sand and kelp worms, sand shrimp, clam necks and mussels. Surfperch are fished with rod and reel gear using gear that has multiple hooks.

In CA beach nets may be used to take surf smelt north of Point Conception.

Spears harpoons, bow and arrow fishing tackle may be used to take rays, skates, and sharks (except the white shark).

Clams, mussels, limpets, and other invertebrates are collected from tidal and nearshore waters by hand or using rakes, shovels or other implements allowed by law. In Washington, oysters taken in all areas must be shucked with the shells left on the beach where they were harvested. Herring rakes and smelt rakes are prohibited gear in Washington.

Crabs are allowed to be taken by rings (baited hoop nets) or with baited traps or with dipnets, tangle lines, or snares. The pots are lightweight.

There is a recreational pot fishery for coonstripe shrimp in California and for both coonstripe and spot shrimp in Puget Sound. The pots are lightweight.

Recreational fishermen in San Francisco Bay are allowed to use a hand powered shrimp trawl no greater than 18" by 24" at the mouth and a daily bag limit of five pounds.

Components of Recreational Gear That Contact or Effect the Seabed

The principal components of the hook and line gear that could produce benthic habitat effects are the weights, hooks and line. Potential impacts could be related to the line snagging on rocks, corals, kelps and other objects during retrieval. This may upend smaller rocks and break hard corals, while leaving soft corals unaffected. Invertebrates and other light weight objects can also be dislodged. If during escape runs large bottom fish, e.g. halibut, remain on or near the bottom, objects in their path can also be disturbed (Johnson, 2002).

Pots gear used by recreational fishermen contacts the seabed.

Rakes and shovels used for harvest of shellfish and shrimp pumps is intended to disturb the seabed to dislodge the shellfish.

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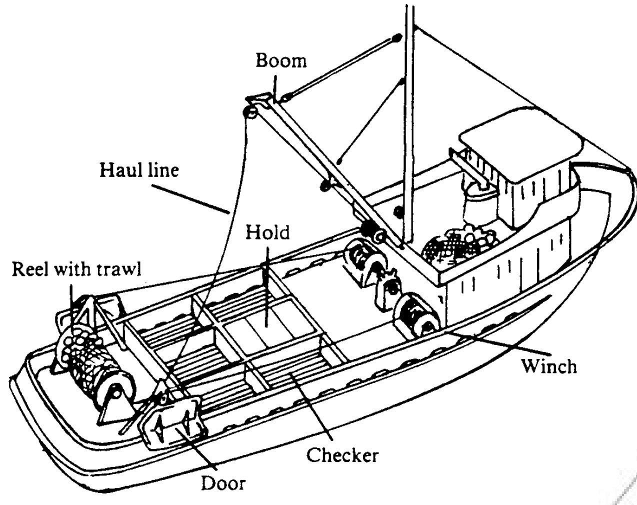
V. Diagrams of Fishing Gears

(The following images were assembled by Fran Recht, Pacific States Marine Fisheries Commission and Jennifer Gilden, Pacific Fishery Management Council). With the exception of the copyrighted diagrams, these images may be used if the source of the image is retained.

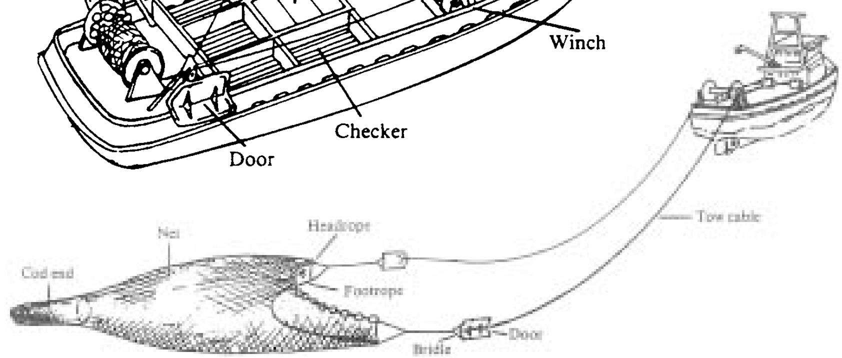
Trawling

Bottom trawling

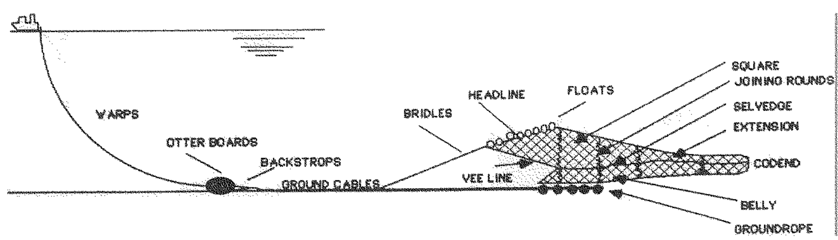
Bottom trawler
(Goblirsch)



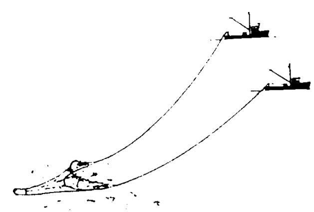
Bottom trawling
(Goblirsch)



Bottom otter trawl
components (NMFS)

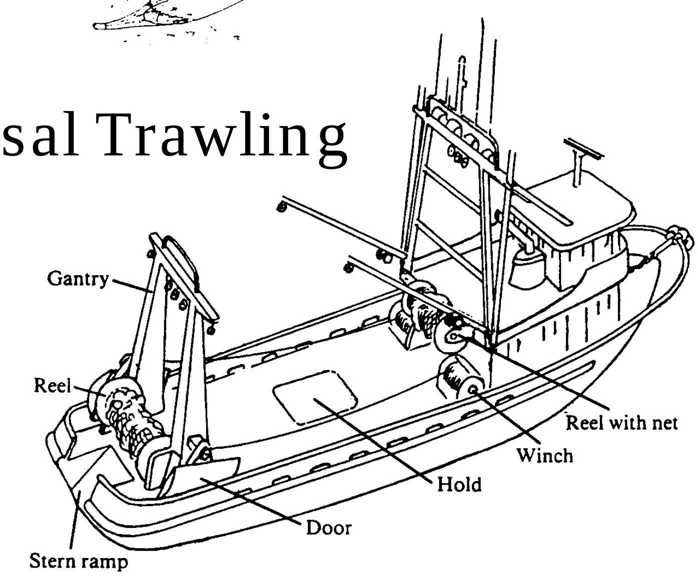


Bottom pair trawling
(© Sainsbury)



Midwater/Demersal Trawling

Midwater trawler
(Goblirsch)



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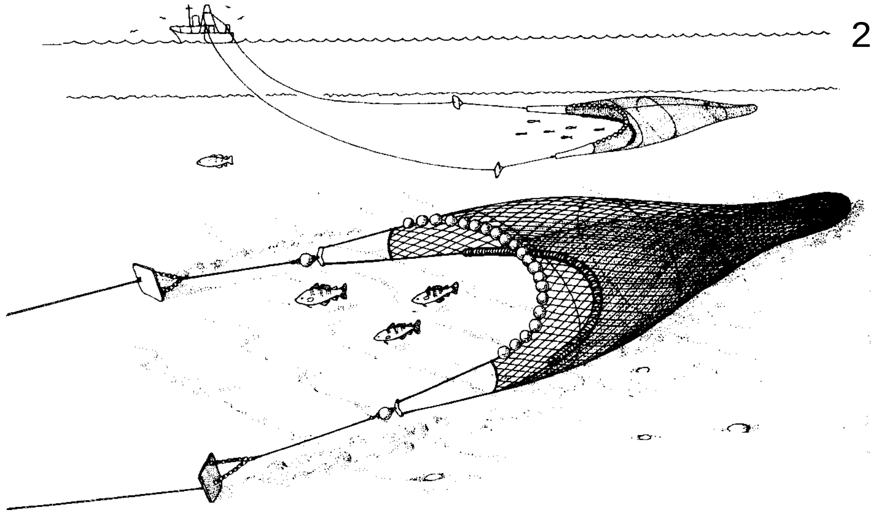
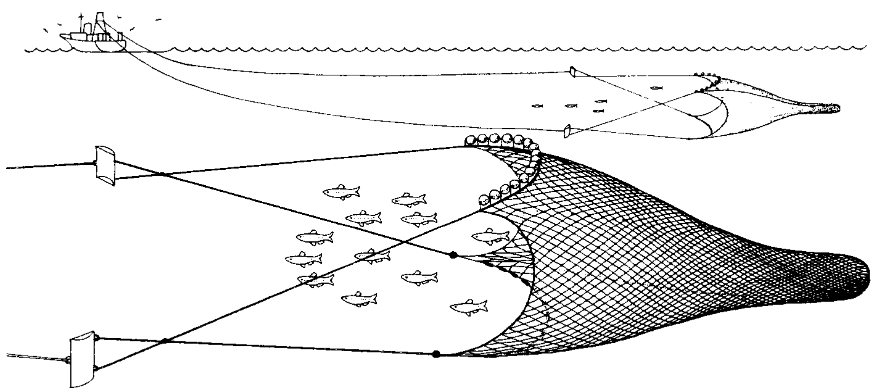
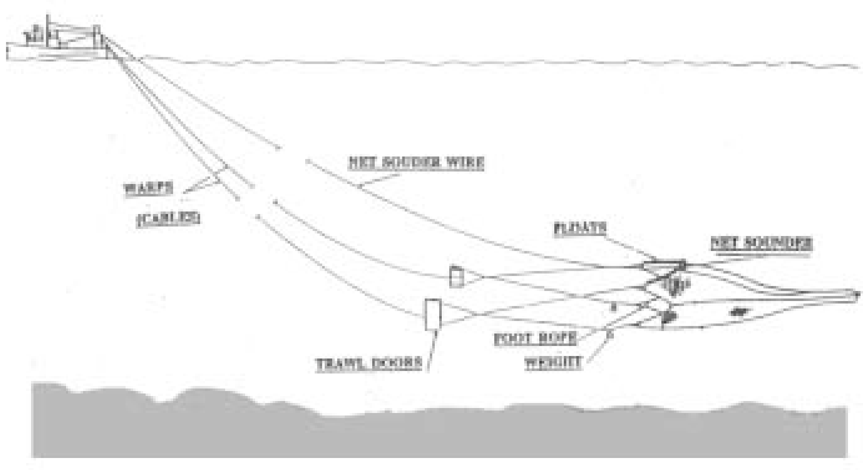


Demersal trawl gear (© Jennings)



Midwater trawling (© Jennings)



Midwater trawl components

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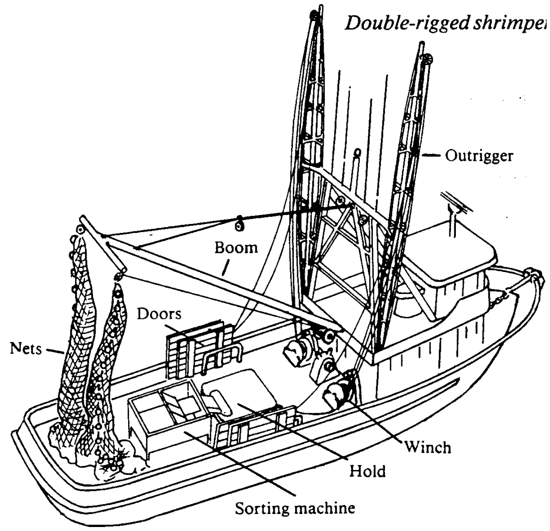
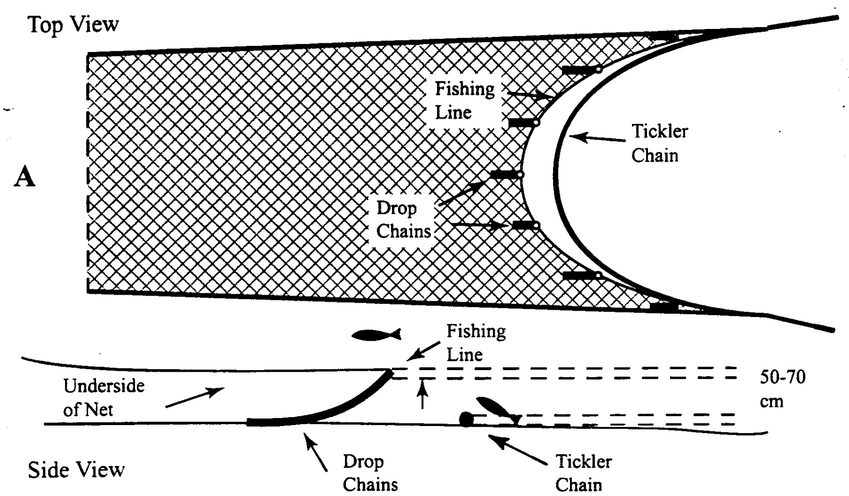
Shrimp trawling

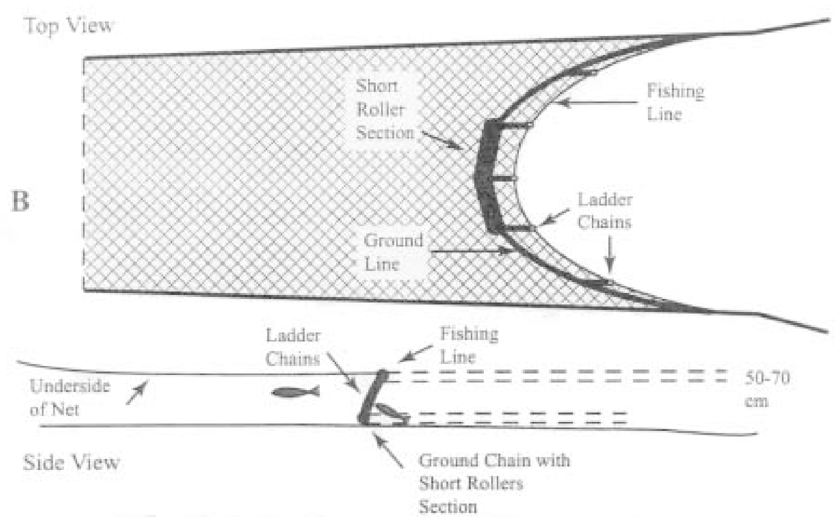
Shrimp trawler (Goblirsch)



Shrimp trawl with tickler and dropper chains (Hanna and Jones)

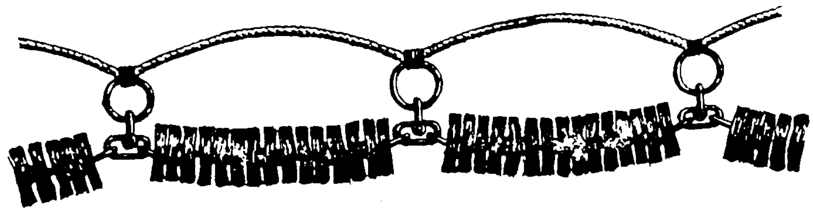


Shrimp trawl with ladder-roller con-figuration (Hannah and Jones)

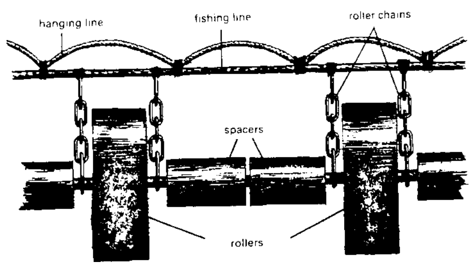


Trawl Equipment (Footrope design)

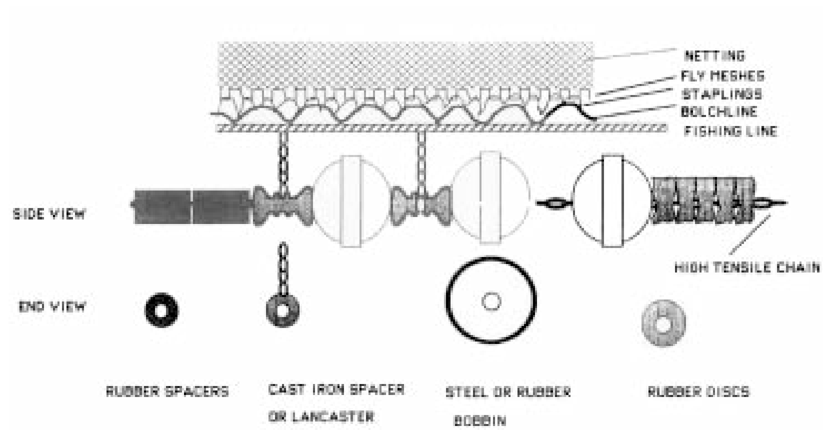
Rubber cookies threaded onto chain (© Sainsbury)



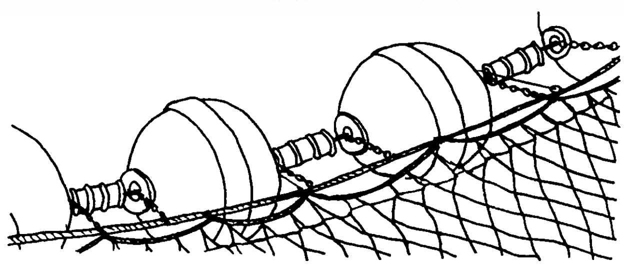
Heavy rubber roller and smaller spacers (© Sainsbury)



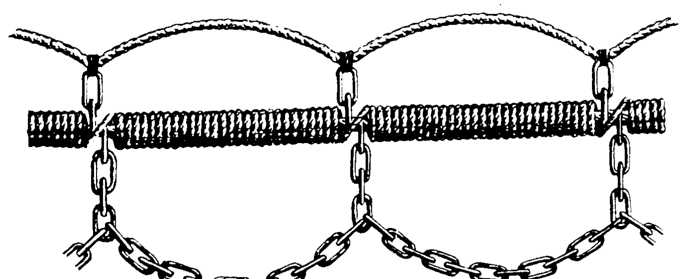
Trawl groundrope components



Steel bobbins and spacers (© Sainsbury)



Wrapped wire and looped chain (© Sainsbury)



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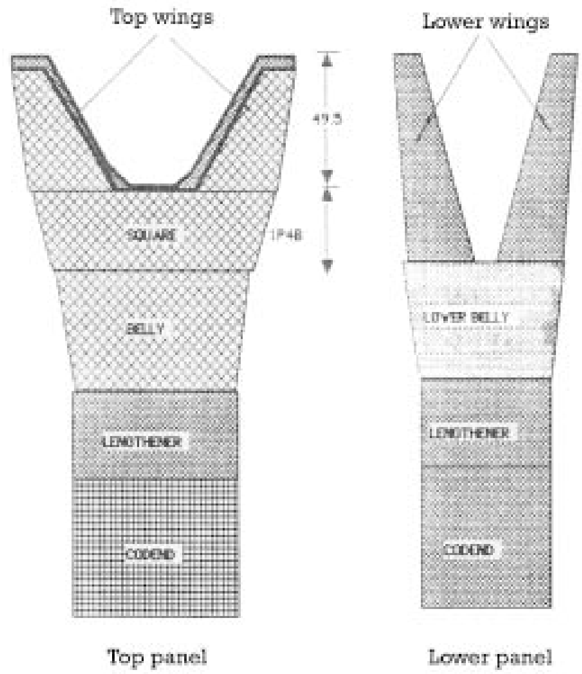
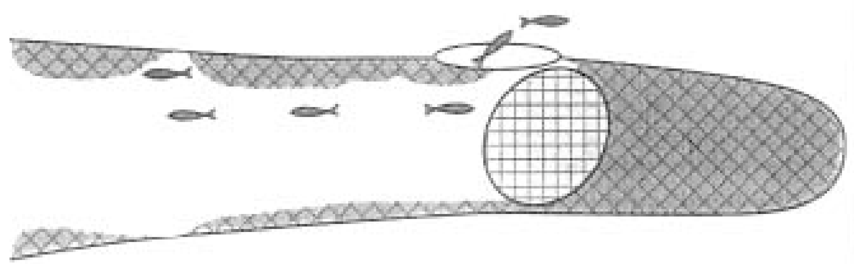
Trawl design

Netting panels in trawls

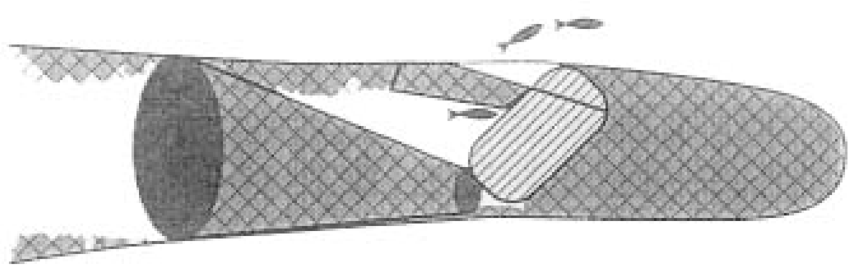


Bycatch reduction devices

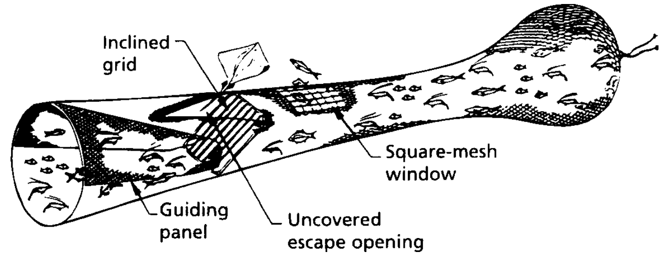
Large mesh panel bycatch reduction device (Hannah and Jones)



Nordmore grate bycatch reduction device (Hannah and Jones)



Trawl efficiency device/TED (© Sainsbury)



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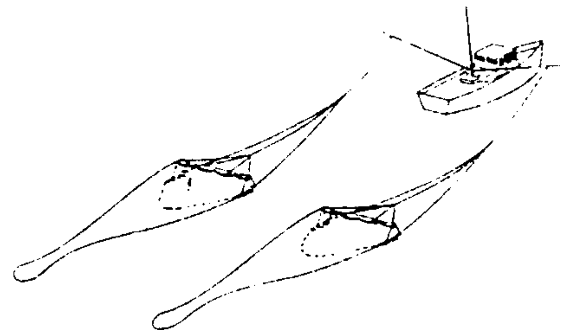
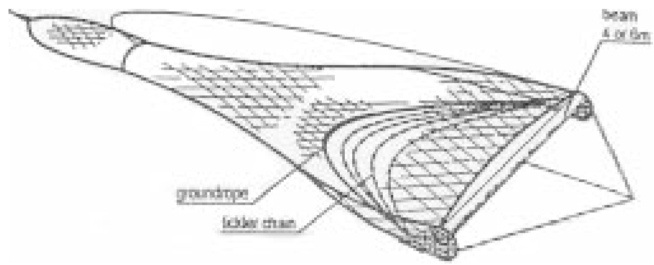
Beam trawling

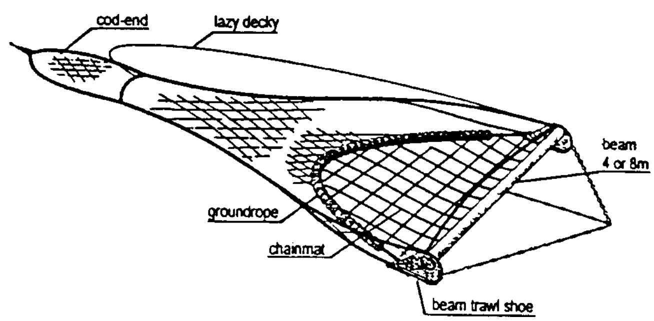
Beam trawls
(© Sainsbury)



Beam trawl design 1
(Watling and Morse)

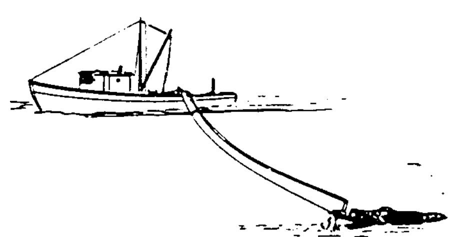


Beam trawl design 2
(Watling and Morse)



Dredging

Dredging (© Sainsbury)



Scallop dredge
(Goblirsch)

To be added

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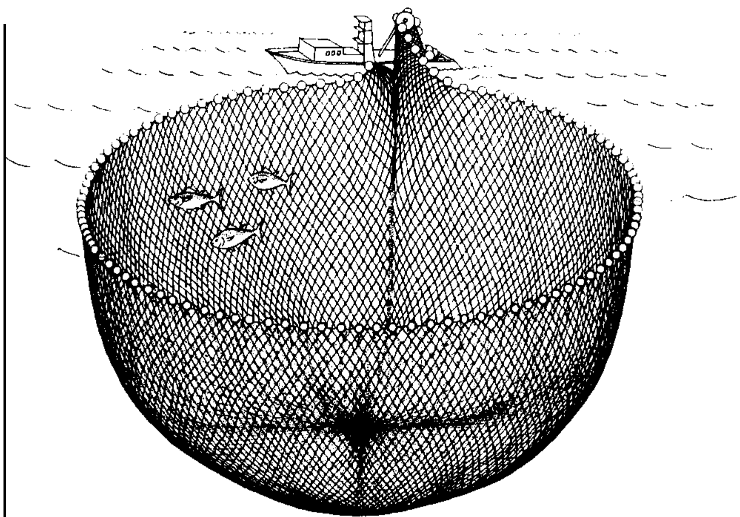
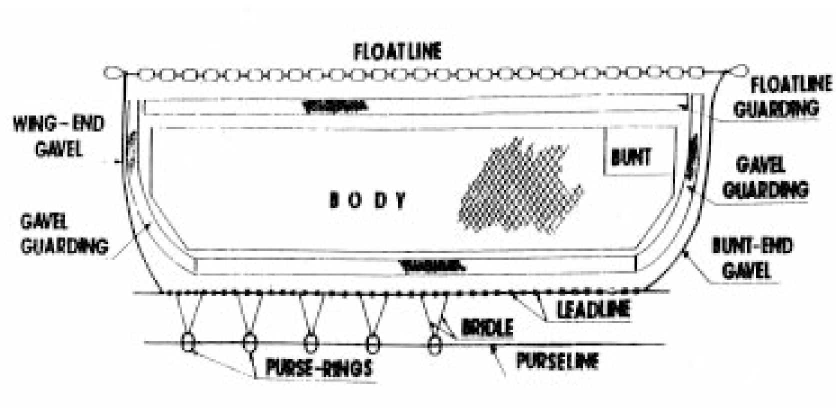
Seining

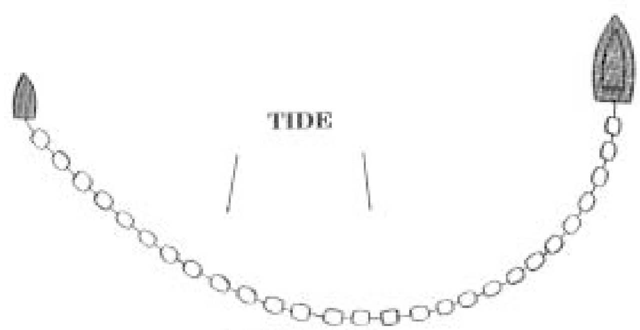
Purse seine gear (© Jennings)



Purse seine cross section (WDFW)



Purse seine boat positions



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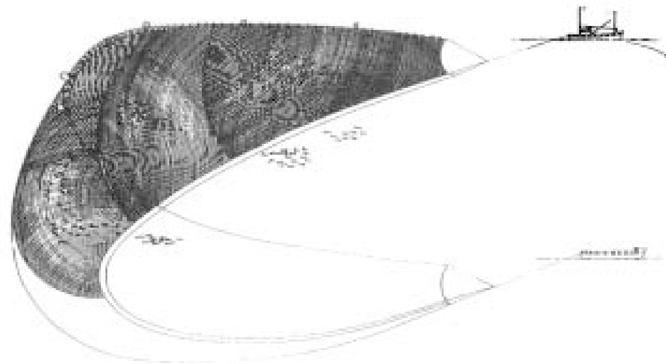
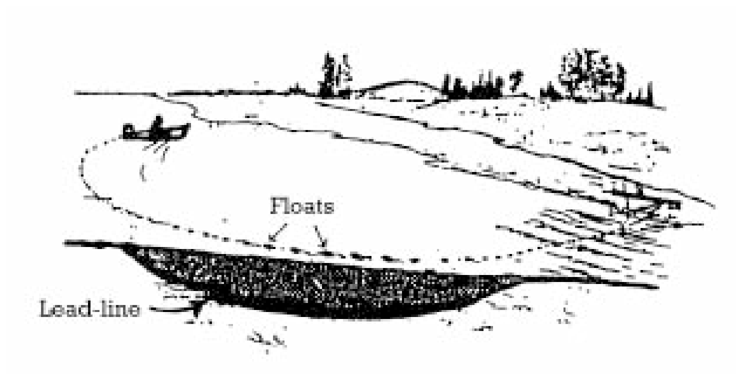
Purse seiner towing net

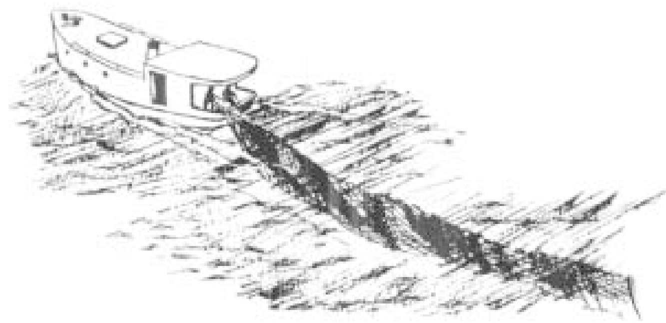


Beach seine (WDFW)

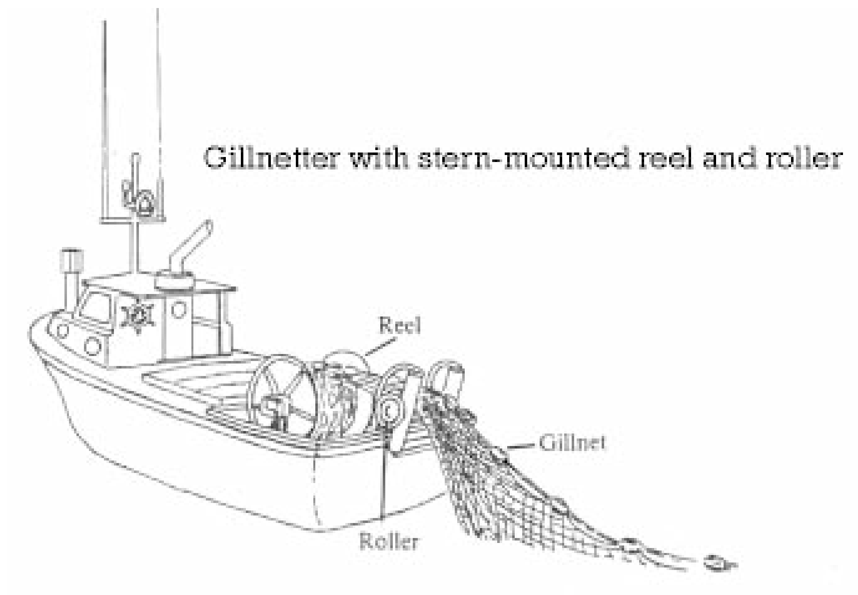


Gillnetting

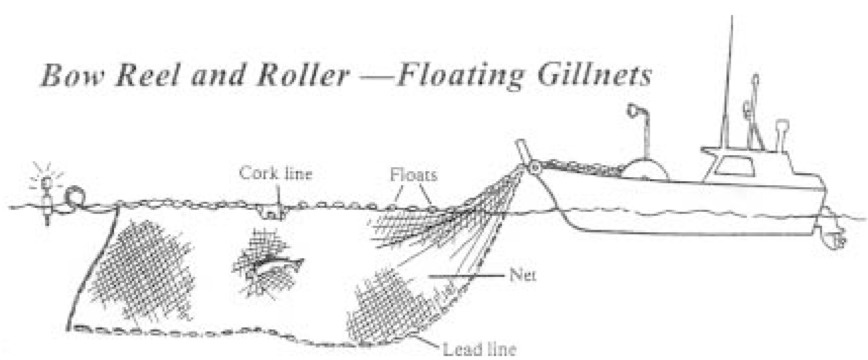
Gillnetting

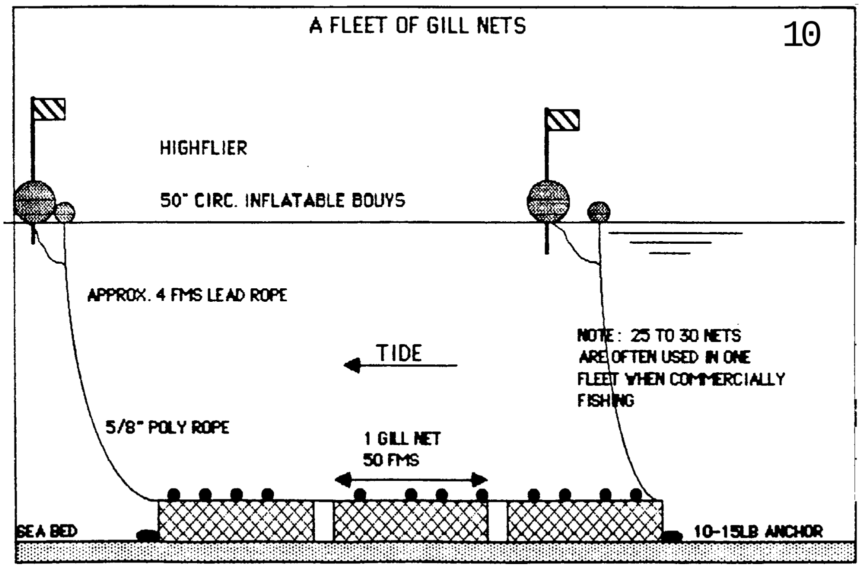


Gillnetter (Goblirsch)

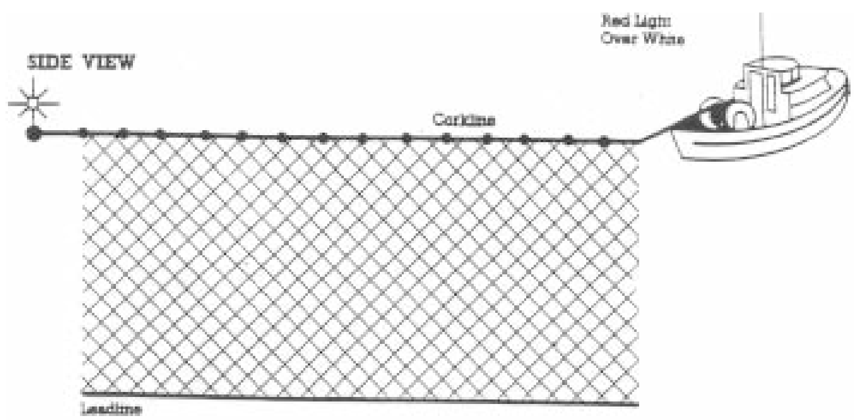


Floating gillnets (Goblirsch)

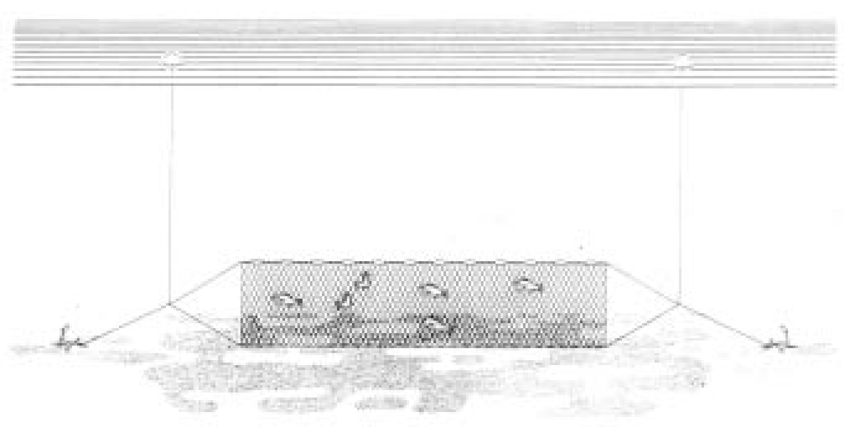




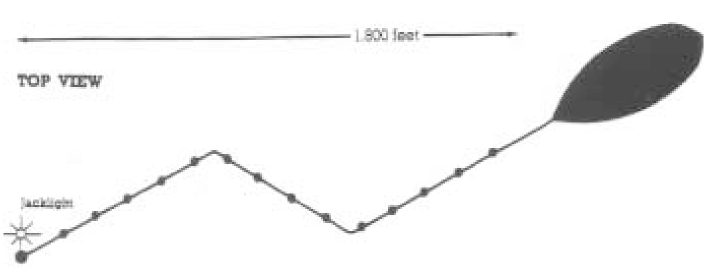
A fleet of gillnets (WDFW)



Gillnetter - side view

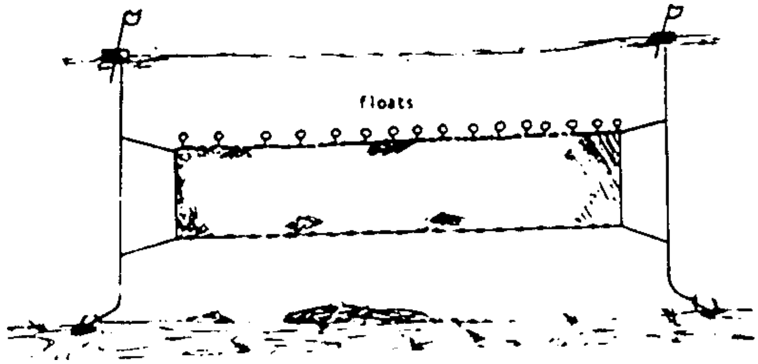


Gillnet (NMFS)

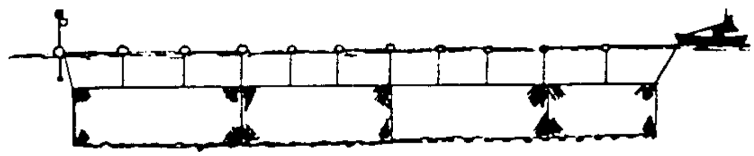


Gillnet net position

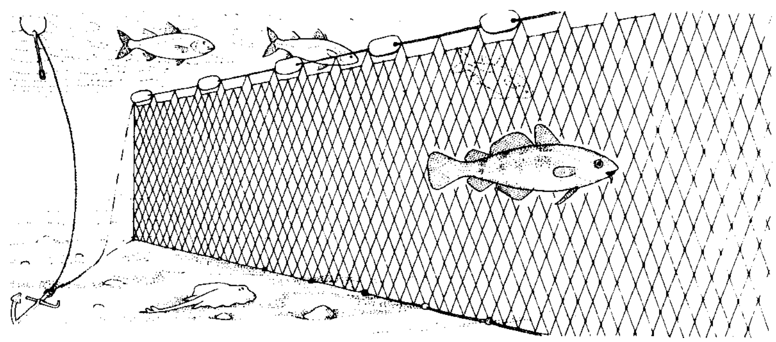
On/off bottom gillnet (setnet) (© Sainsbury)



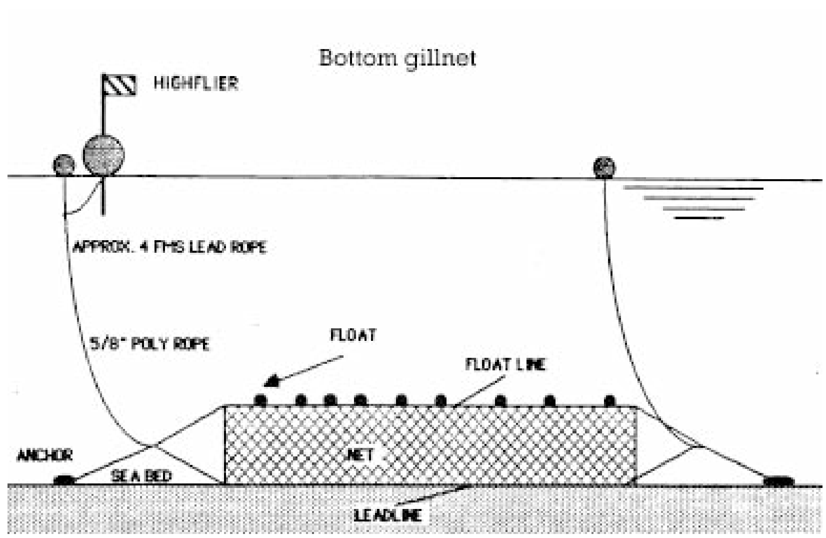
Gillnet (© Sainsbury)



Gillnet (© Jennings)



Bottom gillnet (setnet) (WDFW)



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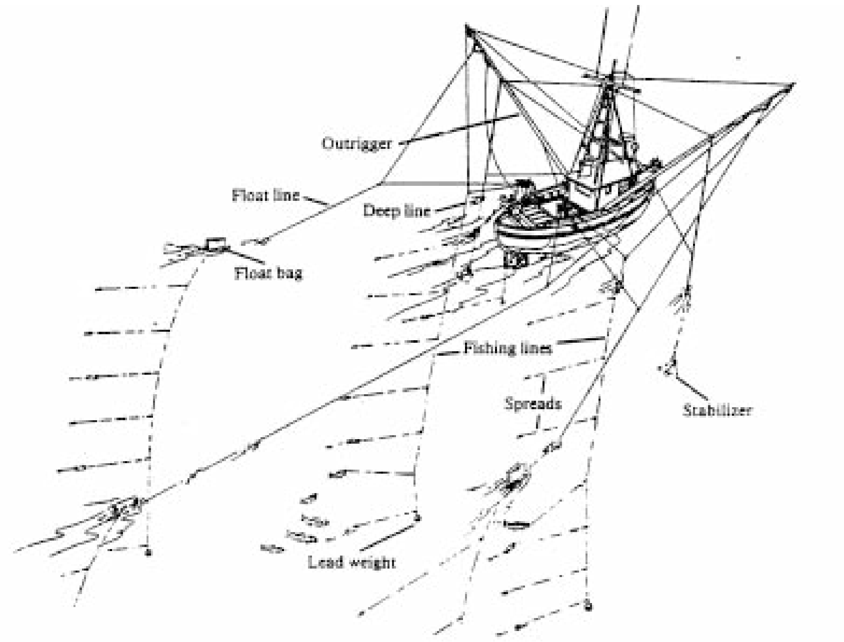
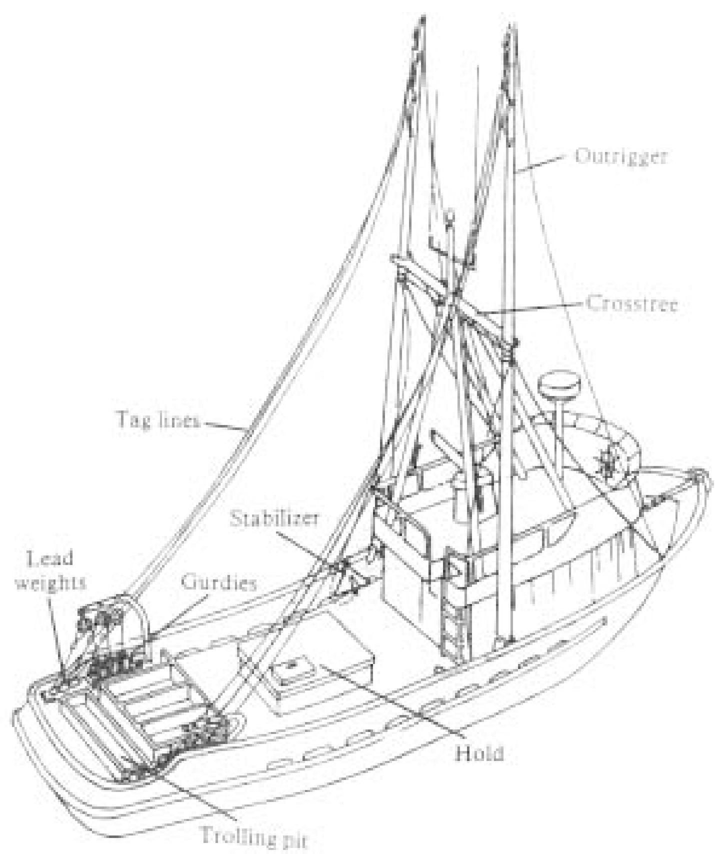
Trolling

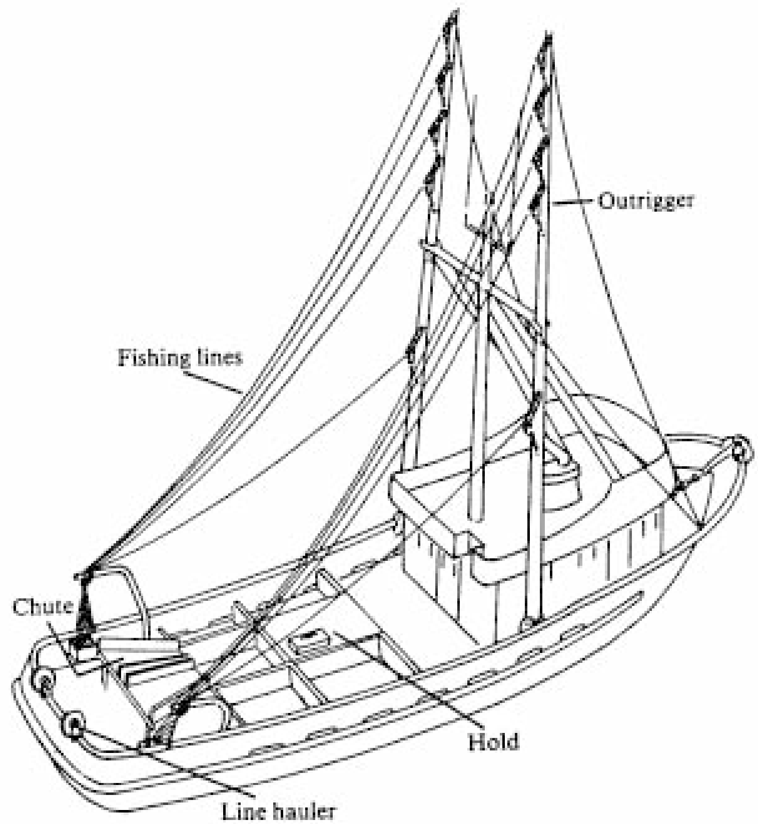
Trolling (Goblirsch)



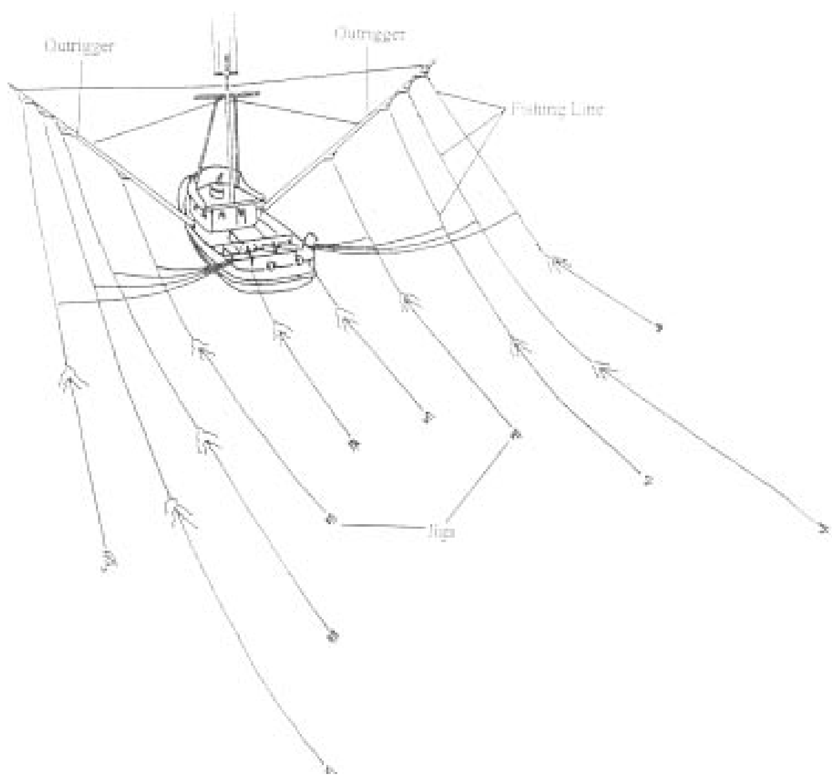
Salmon troller (Goblirsch)



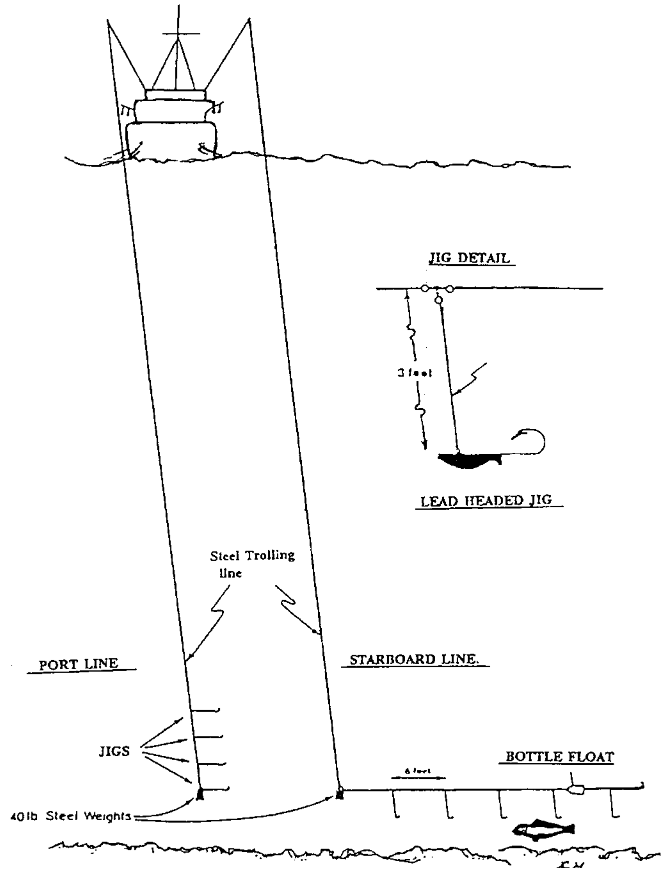
Albacore troller
(Gobrlirsch)



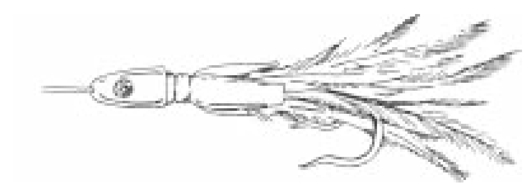
Albacore troll gear
(Goblirsch)



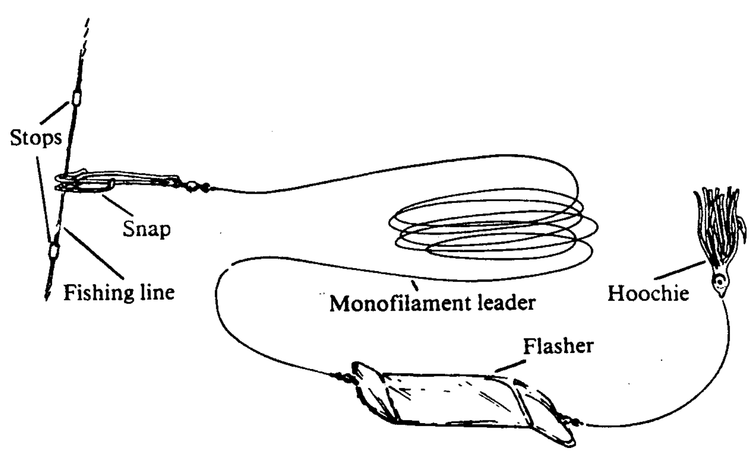
Bottomfish troll gear



Tuna jig

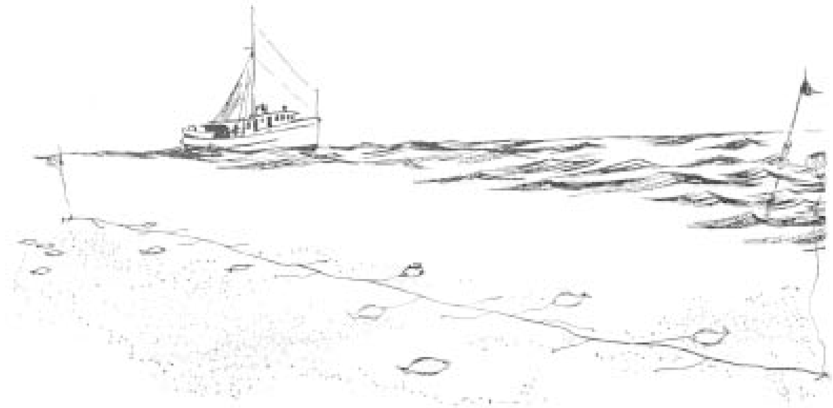


Salmon spread

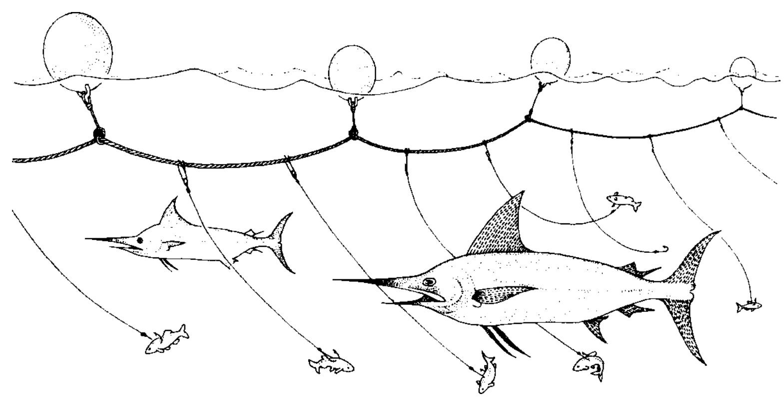


Longlining

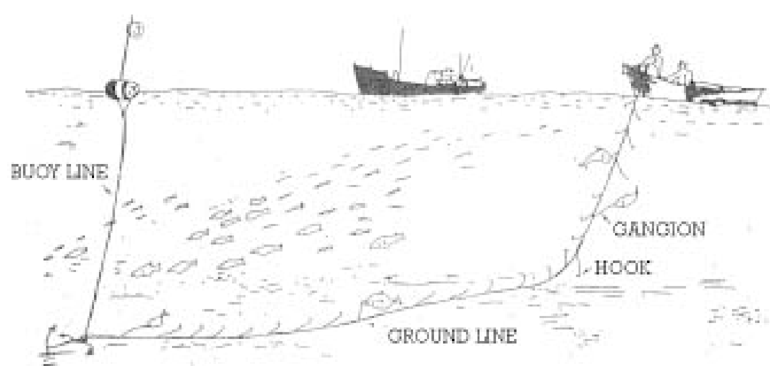
Bottomfish longline



Longline (© Jennings)



Set longline gear



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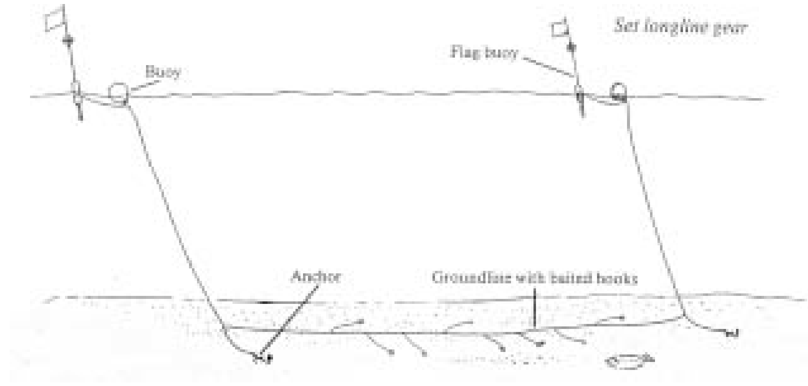
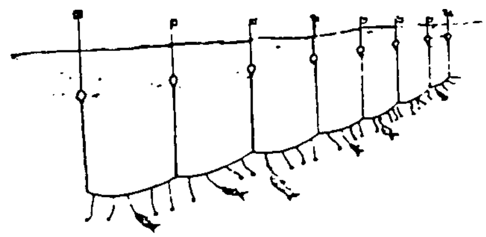
Set longline gear

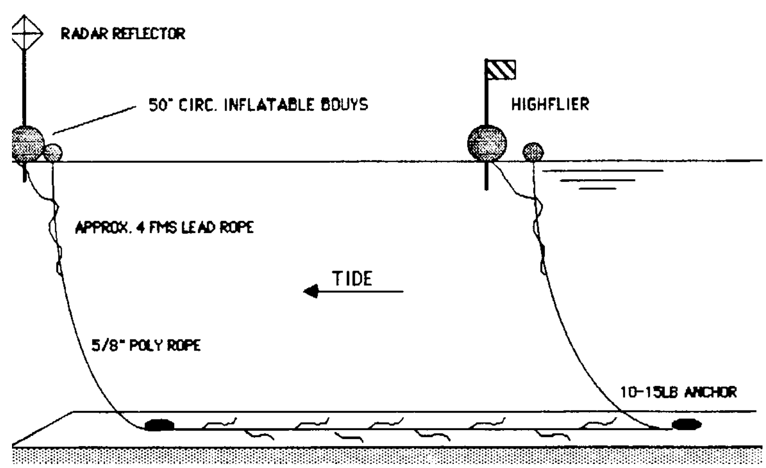


Surface longline
(© Sainsbury)



Vertical longline
(© Sainsbury)

A fleet of longlines



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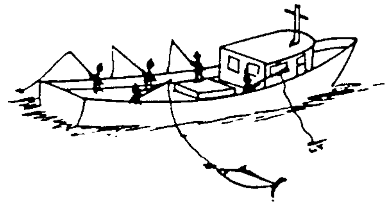
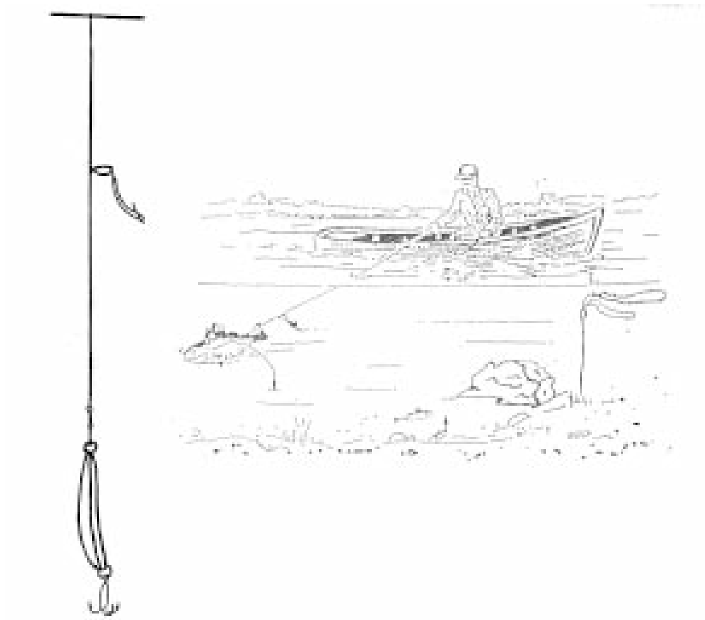
Other hook-and-line gear

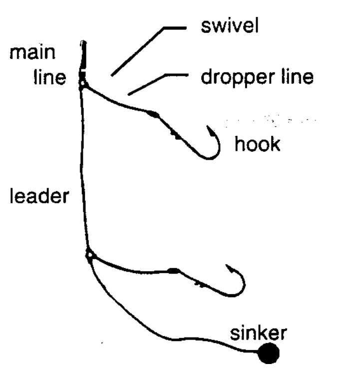
Pole and line
(© Sainsbury)



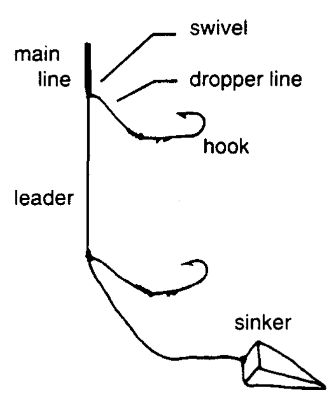
Handline jig gear



Bottomfish fish-finder rig



Redtail surfperch surf-fishing rig



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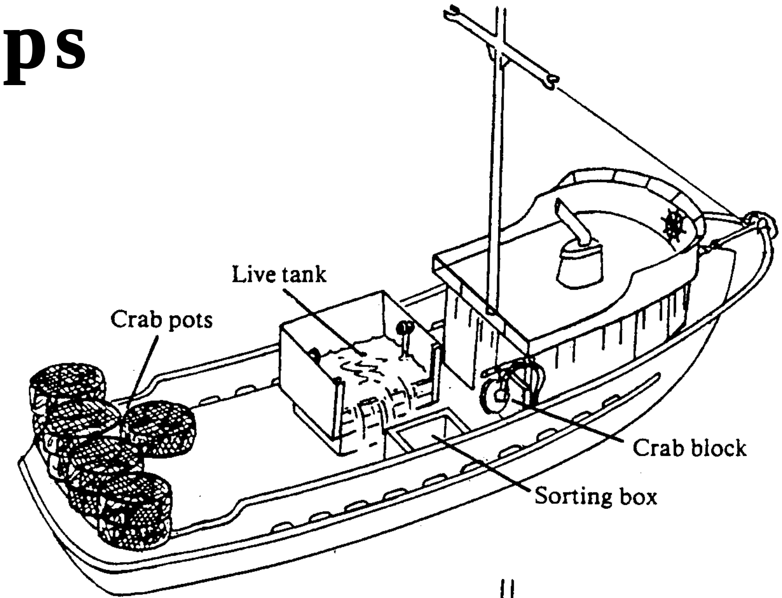
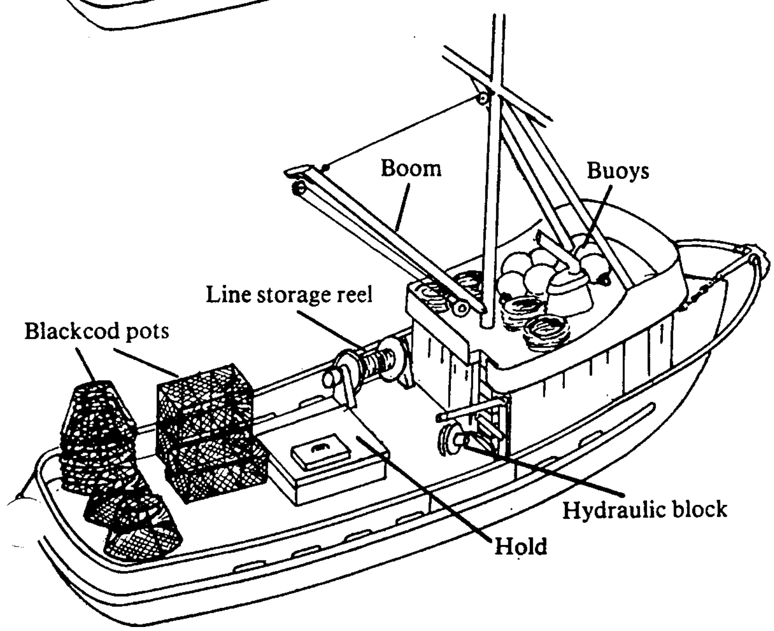
Pots and traps

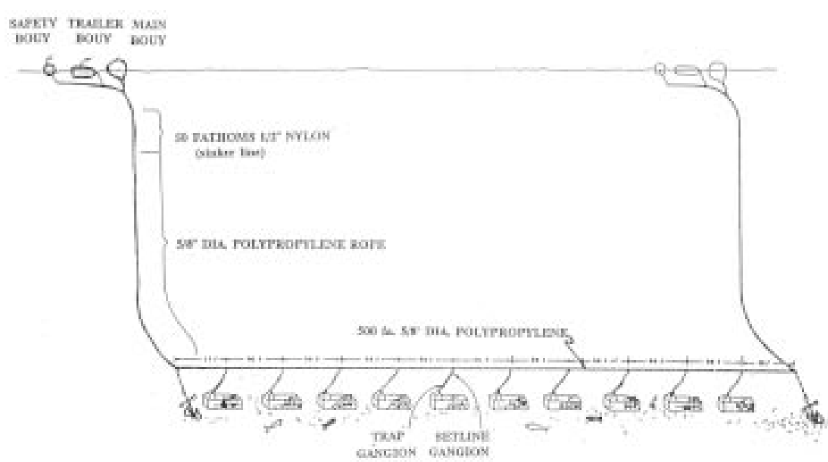
Crabber (Goblirsch)



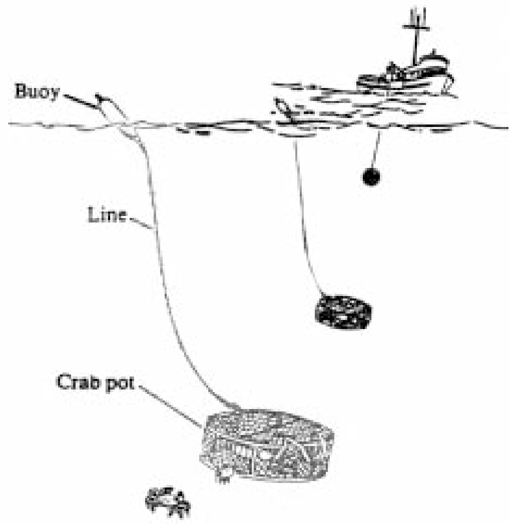
Longliner using pots (Goblirsch)



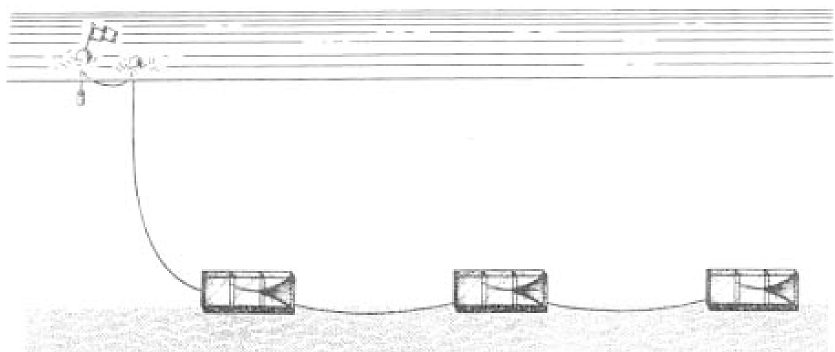
Bottomfish trap (pot) gear (WDFW)



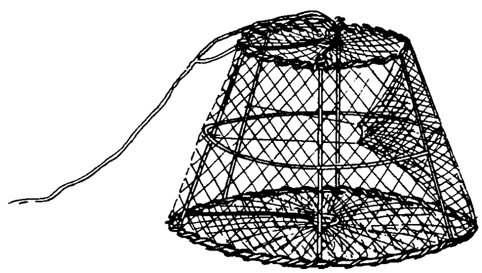
Set crab pots
(Goblirsch)



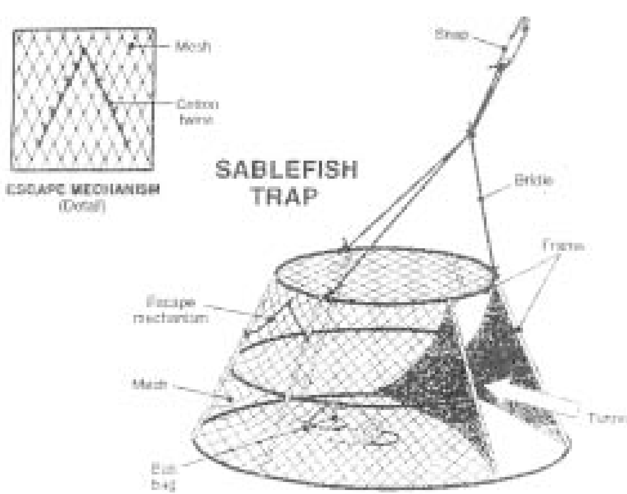
Traps on sea floor
(NMFS)



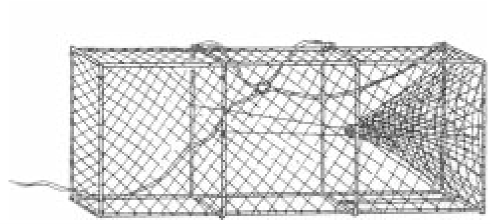
Basket-shaped sablefish (blackcod) pot



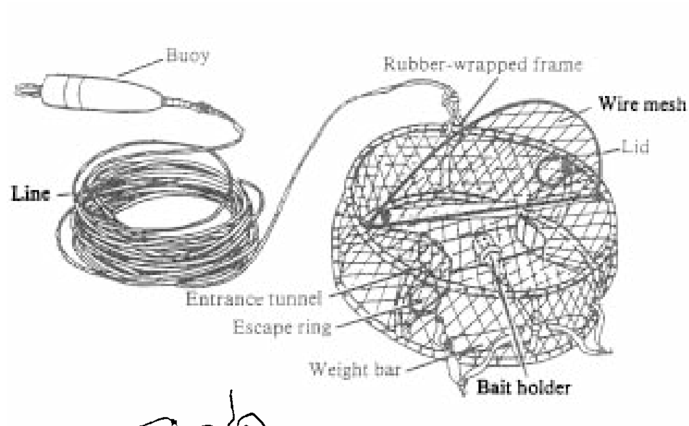
Sablefish trap
(Canada Dept. of Fisheries and Oceans)



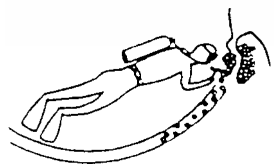
Rectangular sablefish (blackcod) pot



Crab pot (Goblirsch)

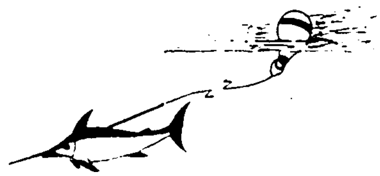


Diving (© Sainsbury)

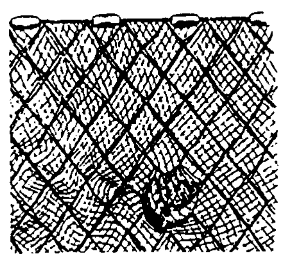


Other gears

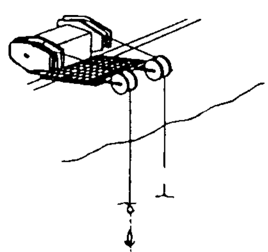
Harpooning (© Sainsbury)



Trammel net (© Sainsbury)



Mechanized lines (© Sainsbury)



Appendix 9

Gear Types in the PacFIN Database

The following table provides a list of the gear types contained in PACFIN database

Type	GRID	Gear Group	Short Name	Description	Date Entered
1	ODG	DRG	OTH-DREDGE	OTHER DREDGE GEAR	
1	SCD	DRG	SCL-DREDGE	SCALLOP DREDGE	
1	DRL	HKL	DROP LINE	DROP LINE	
1	HDL	HKL	HAND LINE	HAND LINE	
1	HLR	HKL	POLE(REC)	HOOK AND LINE (RECREATIONAL)	
1	JIG	HKL	JIG	JIG	
1	LGL	HKL	LONGLINE	LONGLINE OR SETLINE	
1	OHL	HKL	OTH HK&LN	OTHER HOOK AND LINE GEAR	
1	POL	HKL	POLE(COM)	POLE (COMMERCIAL)	
1	STL	HKL	SETLINE	SETLINE	
1	VHL	HKL	VRTCL HKL	VERTICAL HOOK AND LINE GEAR	10-DEC-98
1	DVG	MSC	DIVING GR	DIVING GEAR	22-DEC-98
1	OTH	MSC	OTH-KNOWN	OTHER KNOWN GEAR	
1	RVT	MSC	RVR-TRAWL	RIVER TRAWL	
1	USP	MSC	UNKN-GEAR	UNKNOWN OR UNSPECIFIED GEAR	
1	DGN	NET	DRF GL NET	DRIFT GILL NET	22-DEC-98
1	DPN	NET	DIP NET	DIP NET	
1	GLN	NET	GILL NET	GILL NET	
1	ONT	NET	OTHER NETS	OTHER NET GEAR	
1	SEN	NET	SEINE	SEINE	
1	SGN	NET	SUNKN GLNT	SUNKEN GILLNET	
1	STN	NET	SET NET	SET NET	
1	TML	NET	TRAMMEL	TRAMMEL	
1	CLP	POT	C&L POT	CRAB AND LOBSTER POT	
1	CPT	POT	CRAB POT	CRAB POT	
1	FPT	POT	FISH POT	FISH POT	
1	LPT	POT	LBSTR POT	LOBSTER POT	
1	OPT	POT	OTHER POTS	OTHER POT GEAR	
1	PRW	POT	PRWN TRAP	PRAWN TRAP	
1	SPT	POT	SNAIL POT	SNAIL POT	
1	BTR	TLS	BTM-TROLL	BOTTOMFISH TROLL	
1	HTR	TLS	HAND TROLL	HAND TROLL	
1	PTR	TLS	P-G-TROLL	POWER GURDY TROLL	
1	TRL	TLS	TROLL	TROLL	
1	BMT	TWL	BEAM TRAWL	BEAM TRAWL	
1	BTT	TWL	BTM-TRAWL	BOTTOM TRAWL	
1	CBF	TWL	CTCHER-FR	BOTTOM TRAWL, CATCHER BOAT, FOREIGN	
1	CBJ	TWL	CTCHER-JV	BOTTOM TRAWL, CATCHER BOAT, JV	
1	DNT	TWL	DNSH SEINE	DANISH/SCOTTISH SEINE (TRAWL)	07-JUN-00
1	FFT	TWL	FLT-TRAWL	FLATFISH TRAWL	
1	GFL	TWL	GFTRAWL>8	GROUNDFISH TRAWL, FOOTROPE > 8 in.	07-JUN-00
1	GFS	TWL	GFTRAWL<8	GROUNDFISH TRAWL, FOOTROPE < 8 in.	07-JUN-00
1	GFT	TWL	GFSH-TRAWL	GROUNDFISH TRAWL (OTTER)	

1	LFZ	TWL	LARGE-FRZ	BOTTOM TRAWL, LARGE FREEZER TRAWLER
1	MDT	TWL	MID-TRAWL	MIDWATER TRAWL
1	MPT	TWL	CP-MTRAWL	MIDWATER TRAWL - CATCHER/PROCESSOR
1	OTW	TWL	OTH TRAWLS	OTHER TRAWL GEAR
1	PRT	TWL	PAIR TRAWL	PAIR TRAWL
1	RLT	TWL	RLR-TRAWL	ROLLER TRAWL
1	SFZ	TWL	SMALL-FRZ	BOTTOM TRAWL, SMALL FREEZER TRAWLER
1	SRM	TWL	SURIMI	BOTTOM TRAWL, SURIMI TRAWLER
1	DST	TWS	DBL-SHRIMP	SHRIMP TRAWL, DOUBLE RIGGED
1	PWT	TWS	PRWN-TRAWL	PRAWN TRAWL
1	SHT	TWS	SHMP-TRAWL	SHRIMP TRAWL, SINGLE OR DOUBLE RIG
1	SST	TWS	SGL-SHRIMP	SHRIMP TRAWL, SINGLE RIGGED
2	DRG	ALL	DREDGES	ALL DREDGE GEAR
2	HKL	ALL	HOOK&LINE	ALL HOOK AND LINE GEAR EXCEPT TROLL
2	MSC	ALL	OTH GEARS	ALL OTHER MISCELLANEOUS GEAR
2	NET	ALL	NETS	ALL NET GEAR EXCEPT TRAWL
2	POT	ALL	POT&TRAP	ALL POT AND TRAP GEAR
2	TLS	ALL	TROLLS	ALL TROLL GEAR
2	TWL	ALL	TRAWLS	ALL TRAWLS EXCEPT SHRIMP TRAWLS
2	TWS	ALL	SH-TRAWLS	ALL SHRIMP TRAWLS

Appendix 10

Pacific Coast Groundfish EFH

The Effects of Fishing Gears on Habitat: West Coast Perspective

DRAFT 6

Prepared for

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1 INTRODUCTION

The U.S. District Court for the District of Columbia has found that the EAs prepared by NOAA Fisheries' for the Councils' amendments on the subject of EFH were inadequate and in violation of NEPA. The suit that gave rise to this finding specifically contested the adequacy of the evaluations of fishing gear impacts on EFH in the fishery management plan amendments, and the analyses of environmental impacts in the EAs. In response, NOAA Fisheries has initiated a project to complete new NEPA analyses for Amendment 11 to the Pacific Coast Groundfish FMP.

Pre-planning for this NEPA process requires an understanding of the status of groundfish habitat and associated risks and a conceptual framework for predicting the costs and benefits of conservation strategies. The pre-planning effort is being overseen by the Pacific Fishery Management Council's (Council) *ad hoc* Groundfish Habitat Technical Review Committee (Committee). On February 19-20, 2003, the Committee reviewed the proposed risk assessment framework and recommended that Pacific States Marine Fisheries Commission contract for development of an index of fishing gear impacts by gear type that will serve as an input into the model. The Committee suggested that, while several literature review and indices exist that may be utilized for this project, there is no clear direction on how that information should be applied to the west coast. As justification for the recommendation, the committee cited the general lack of west coast specific studies and the need to determine specifically how to make inferences from studies that occurred in other parts of the world.

This document describes the process followed in the development of a draft index of adverse effects for fishing gears that are utilized on the west coast of the US. The draft index consists of two matrices (spreadsheets), one describing the sensitivity levels of bottom habitats to gear impacts and another describing recovery times from gear impacts. The values in the matrices will be used as input variables for a Bayesian risk assessment model being developed to form the basis for developing fishing impacts alternatives for the overall EIS. The form of each matrix is based on gear types used on the west coast, bottom habitat type designations used in the GIS mapping of habitat (See Analytical Framework Document), and the available literature on gear impacts. Development of the final two matrices required several preliminary steps. The overall process is described in the following sections.

2 METHODS

The overall analysis consisted of three phases, each building upon the preceding phase, with the final Phase 3 being development of the draft index of gear impacts. Three major sources of information were drawn from in the process: TerraLogic's GIS-based classification scheme of habitat types; Recht's (2003) review of gear types used on the west coast; and recent major reviews (particularly Johnson 2002) of the impacts of fishing gear on bottom habitats. The overall "information flow" is shown schematically below (Fig. 1).

Information Flow for Development of Impact Matrices for Pacific Gear Effects

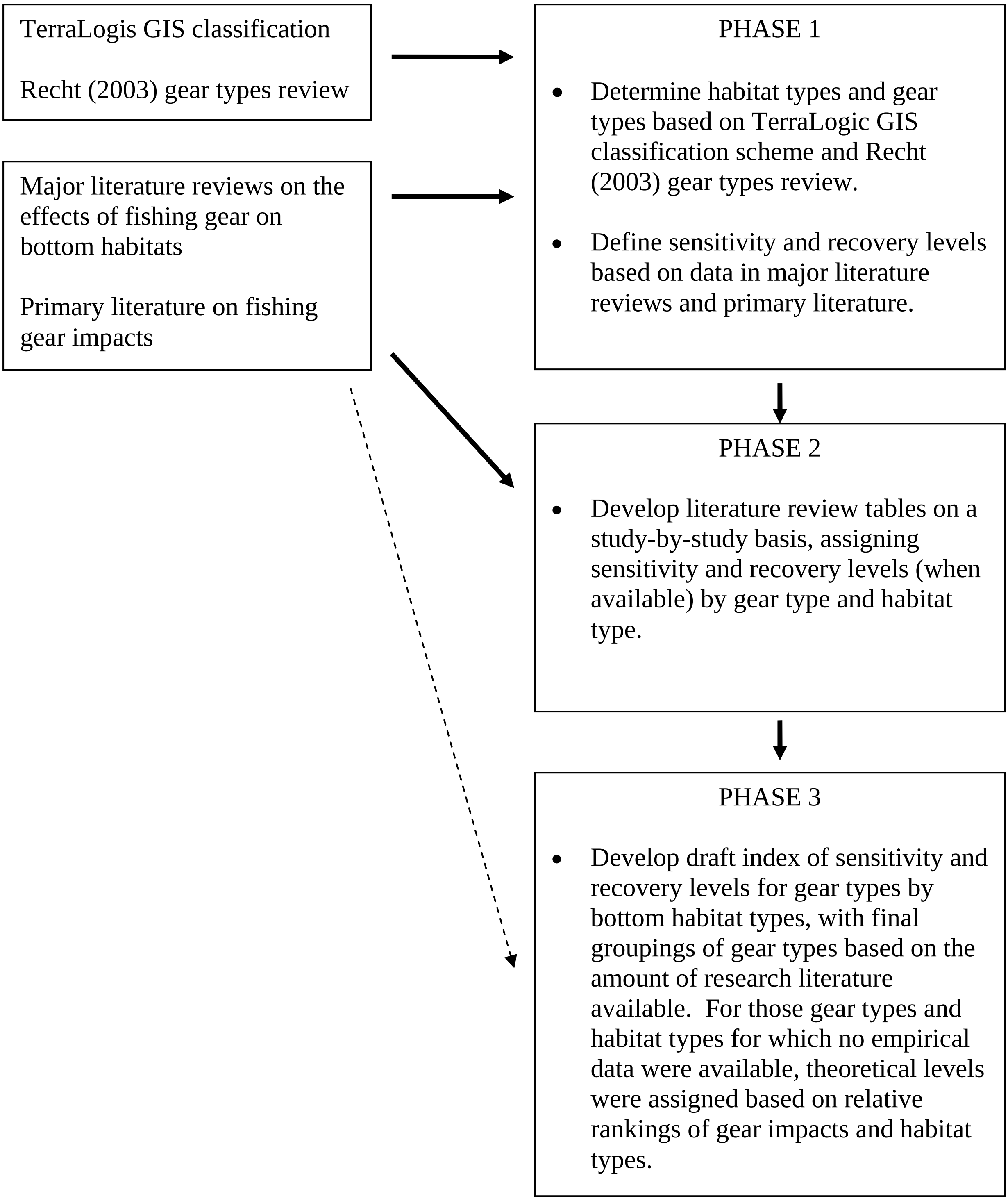

Fig. 1. Information flow diagram showing how information from other components of the overall project were used in relation to the literature that provided the "raw data" for the present analysis (see text for details).

Phase 1: Descriptors for gear types, habitat types, and impact levels

The first phase of the analysis was designed to set the limits on the universe of west coast gear types and habitat types examined. The approach to quantifying the relative levels of sensitivity of the habitats to contact from the various gear types, and the scaling of the time taken for the habitats to recover from different types of impacts, was also determined during Phase 1.

2.1.1 Gear types

Recht (2003) describes gear types used on the west coast of the US. This paper provided the primary basis for the gear classification scheme used in this analysis. Seven major categories – trawls, nets, dredges, traps and pots, hook and line, trolling, and miscellaneous – were expanded into a total of approximately thirty (30) types of gear:

Trawls (TWL)
- Otter Trawl
- Shrimp Trawl
- Beam Trawl
- Midwater Trawl

Nets (NET)
- Demersal Seine
- Round Hall Seine
- Gillnet
- Trammel Net
- Dip Net
- Salmon Reef Net

Dredges (DRG)
- New Bedford Dredge
- Hydraulic Clam Dredge
- Oyster Dredge

Traps & Pots (POT)
- Pots

Hook & Line (HKL)
- Hook & Line
- Bottom Longline
- Pelagic Longline
- Handline, Jig
- Stick (Pipe)
- Rod & Reel
- Vertical Hook & Line
- Mooching

Trolling (TLS)
- Trolling

Miscellaneous (MSC)
- Diving, Hand/ Mech.
- Herring Spawn Kelp
- Herring Brush Weir
- Ghost Shrimp Pump
- Poke Pole
- Bait Pen
- Live Fish, Shellfish

2.1.2 Habitat types

The Analytical Framework document (MRAG 2003) describes the classification of benthic habitat based on physical features in several levels of a hierarchical system. The levels, in order, are: megahabitat, seafloor induration, meso/macrohabitat, and modifier(s). For the west coast, the following types have been delineated:

Level 1: Megahabitat:

Continental Rise/Apron;
Basin Floor;
Continental Slope;
Ridge;
Continental Shelf.

Level 2: Seafloor Induration:

Hard substrate;
Soft substrate.

Level 3: Meso/macrohabitat:

Canyon wall;
Canyon floor;
Exposure, bedrock;
Gully;
Gully floor;
Ice-formed feature;
Landslide.

Level 4: Modifier:

Bimodal pavement;
Outwash;
Unconsolidated sediment.

Each unique combination of these four characteristics defines a unique benthic habitat type. For the west coast EFH project, 35 unique benthic habitat types have been delineated (see Analytical Framework document for details). A total of forty-three (43) megahabitat/substrate/macrohabitat types are described in the present analysis. It should be noted that the extra habitat types are a result of adding the "Estuarine" megahabitat (with three substrate types) and the "Biogenic" substrate type to all other megahabitat types. These forty-three and, if available, their assigned Pencil Codes were used in the present analysis.

2.1.3 Sensitivity and Recovery scales

The final step in Phase 1 was the development of scales for habitat sensitivity levels to gear impacts and recovery times for habitat impacted by fishing gears. The sensitivity scale consists of four levels (0, 1, 2, and 3) representing relative sensitivity to gear impacts. The descriptors for the sensitivities at each level are based on the actual impacts reported in the references listed in the tables in Annex 1. The recovery scale is in units of time (years) with the values taken directly from each report cited.

2.2 Phase 2: Literature summaries

The second phase of the analysis was the construction of summaries of the literature on gear impacts on a study-by-study basis. These summaries were tabulated in spreadsheet format and grouped by habitat and gear types. This arrangement allows appropriate mean values (and variability around the means) to be calculated for direct entry into the final two spreadsheets (Phase 3). For example, referring to Table A1.1, the mean value ‘0.5’ is the mean of the six sensitivity levels for the impact of otter trawls on Soft Sediment substrates in Estuarine megahabitats. There are six references listed in the rows above that row, and the actual sensitivity levels (as described in Table 2) reported in those references ranged from 0 to 1. Mean values with standard errors were calculated in this way for various combinations of gear and habitat categories so that they could be directly entered into the final impact matrices (Tables 3 - 5). At present, variability around each mean is presented as standard error of the mean.

Johnson (2002) provides a major review of the national and international literature on fishing impacts on bottom habitats and was relied upon heavily for constructing these tables. Other reviews that provided additional literature and/or interpretations of the literature were Watling and Norse (1998), Auster and Langton (1999), Dayton et al. (2002), National Research Council (2002), and Morgan and Chuenpagdee (2003).

Several points should be noted regarding the literature summary tables (Tables A1.1 – A1.6):

- References were used only if they provided quantitative information on sensitivity and/or recovery of habitat. Hence, the reviews cited above contain references that are not listed in the results tables. In some cases, however, these references may have contributed to the theoretical analysis used to derive sensitivity and recovery values for gear/habitat combinations for which no empirical data were available (see below).

- More than thirty fishing gear types are used on the west coast (Recht 2003). There have been no studies on the impacts of most of these on bottom habitats. Hence, most gear types are not listed in the summary tables. Those for which useful studies were found included eight gear types: otter trawls, beam trawls, shrimp trawls, New Bedford/scallop dredges, hydraulic dredges, oyster dredges, pots, and hand/mechanical harvesting. Nearly all (69 of 73) of the studies listed, however, have been done on two major gear categories "trawls" and "dredges" (see references listed in Tables A1.1 - A1.6 in Annex 1).

- Only two studies directly on west coast gears were found to be useful. Hence, research from areas other than the Pacific coast provided most of the information on which this analysis is based.

2.3 Phase 3: Draft indices of sensitivity and recovery for the effects of fishing gear on bottom habitats

The existing literature dealing with fishing gear impacts on the seabed is substantial, consisting of well over 100 studies globally (Johnson 2002). Much of this research, however, does not provide data useful for quantitative modeling. Moreover, the vast majority of the research has been done only on trawls and dredges, and there has been very little work done in water exceeding 200 meters in depth. Therefore, development of a comprehensive (in terms of gear and habitat types) index required using a combination of empirical data with theoretical information. It also required making decisions with respect to how many gear and habitat types should be included.

Indices of sensitivity and recovery for the effects of fishing gear on bottom habitats were prepared by converting the mean values in the literature summary tables into a form useful for modeling. For example, referring to Table 3, the value ‘0.7’ for the sensitivity of "Estuarine, Soft Sediment" habitats to "Bottom Trawls" is the mean of the first seven studies listed in Table A1.1 in Annex 1; these seven included six studies on otter trawls and one on beam trawls, both being combined into the category "Bottom Trawls" in Table 4. All the mean values in Tables 4 and 5 were derived in this fashion by combining the appropriate categories in the tables in Annex 1.

3 RESULTS

3.1 Phase 1: Descriptors for gear types, habitat types, and impact levels

Table 1. Habitat descriptors based on water depth, substrate, megahabitat, and macrohabitat. Megahabitat/substrate/macrohabitat taxonomy and Pencil Codes (as provided by TerraLogic GIS). Tables 1a, b and c are provided to show how the final habitat categories in Table 1d are related to environmental features (e.g. water depth) commonly used as habitat descriptors. NOTE: Only the Megahabitat/Substrate/Macrohabitat designations shown in Table 1d are used further in the report (and therefore listed in Tables 4 - 5, and Table A1.1) because these are the "habitat types" used in the GIS analysis.

Table 1a. Habitat descriptors

WATER DEPTH	**SUBSTRATE**	**MEGAHABITAT**
0 to 10+ m	Rocky	Estuarine
10 to 200 m	Boulder	Shelf
200 to 4000 m	Cobble	Slope
	Gravel	Basin
	Halimeda	Ridge
	Pebble	
	Sedimentary	
	Mud	
	Sand	
	Mixed (Rocky+Sedimentary)	
	Biogenic	
	Algae	
	Seagrass	
	Invertebrates	

Table 1b. Habitat descriptors based on water depth and substrate

0 to 10+ m water depth (Estuarine)			
Rocky Estuarine	**Sedimentary Estuarine**	**Mixed (Rocky+ Sedimentary)**	**Biogenic Estuarine**
Boulder	Mud		Algae
Cobble	Sand		Seagrass
Gravel			Invertebrates
Halimeda			
Pebble			
10 to 200 m water depth (Shelf)			
Rocky Shelf	**Sedimentary Shelf**	**Mixed (Rocky+ Sedimentary)**	**Biogenic Shelf**

Boulder	Mud		Algae
Cobble	Sand		Seagrass
Gravel			Invertebrates
Halimeda			
Pebble			
200 to 4000 m (Slope/Basin/Ridge)			
Rocky Slope/ Basin/ Ridge	**Sedimentary Slope/ Basin/ Ridge**	**Mixed (Rocky+ Sedimentary)**	**Biogenic Slope/ Basin/ Ridge**
Boulder	Mud		Algae
Cobble	Sand		Seagrass
Gravel			Invertebrates
Halimeda			
Pebble			

Table 1c. Habitat descriptors based on megahabitat and substrate

Estuarine (0 to 10+ m water depth)			
Rocky Estuarine	**Sedimentary Estuarine**	**Mixed (Rocky+ Sedimentary)**	**Biogenic Estuarine**
Boulder	Mud		Algae
Cobble	Sand		Seagrass
Gravel			Invertebrates
Halimeda			
Pebble			
Shelf (10 to 200 m water depth)			
Rocky Shelf	**Sedimentary Shelf**	**Mixed (Rocky+ Sedimentary)**	**Biogenic Shelf**
Boulder	Mud		Algae
Cobble	Sand		Seagrass
Gravel			Invertebrates
Halimeda			
Pebble			
Slope (200 to 3000 m)			
Rocky Slope	**Sedimentary Slope**	**Mixed (Rocky+ Sedimentary)**	**Biogenic Slope**
Boulder	Mud		Invertebrates
Cobble	Sand		
Gravel			
Halimeda			
Pebble			
Basin (1000 to 2500 m)			
Rocky Basin	**Sedimentary Basin**	**Mixed (Rocky+ Sedimentary)**	**Biogenic Basin**
Boulder	Mud		Invertebrates
Cobble	Sand		
Gravel			

Halimeda			
Pebble			
Ridge (200 to 2500 m)			
Rocky Ridge	**Sedimentary Ridge**	**Mixed (Rocky+ Sedimentary)**	**Biogenic Ridge**
Boulder	Mud		Invertebrates
Cobble	Sand		
Gravel			
Halimeda			
Pebble			

Table 1d. Habitat descriptors based on megahabitat, substrate, and macrohabitat

MEGAH X SUBSTRATE X MACROH		**Habitat Code**
Estuarine (0 to 10+ m water depth)		
	Estuarine, Hard	
	Estuarine, Soft Sediment	
	Estuarine, Biogenic	
Shelf (10 to 200 m water depth)		
	Shelf, Hard, Exposure	She
	Shelf, Soft Sediment	Ss_u
	Shelf, Hard, Canyon Wall	Shc
	Shelf, Soft Sediment, Canyon Wall	Ssc_u
	Shelf, Hard, Canyon Floor	
	Shelf, Soft, Canyon Floor	Ssc/f_u
	Shelf, Hard, Gully	
	Shelf, Soft, Gully	Ssg
	Shelf, Hard, Glacial Pavement	Shi_b/p
	Shelf, Soft, Glacial Outwash	Ssi_o
	Shelf, Biogenic	
Slope (200 to 3000 m)		
	Slope, Hard, Exposure	Fhe
	Slope, Soft Sediment	Fs_u
	Slope, Hard, Canyon Wall	Fhc
	Slope, Soft Sediment, Canyon Wall	Fsc_u
	Slope, Hard, Canyon Floor	Fhc/f
	Slope, Soft, Canyon Floor	Fsc/f_u
	Slope, Hard, Gully	Fhg
	Slope, Soft, Gully	Fsg
	Slope, Hard, Landslide	Fhl
	Slope, Soft, Landslide	Fsl
	Slope, Hard, Glacial Pavement	
	Slope, Soft, Glacial Outwash	
	Slope, Biogenic	

MEGAH X SUBSTRATE X MACROH		Habitat Code
Basin (200 to 4000 m)		
	Basin, Hard, Exposure	Bhe
	Basin, Soft Sediment	Bs_u
	Basin, Hard, Canyon Wall	
	Basin, Soft Sediment, Canyon Wall	Bsc_u
	Basin, Hard, Canyon Floor	
	Basin, Soft, Canyon Floor	Bsc/f_u
	Basin, Hard, Gully	
	Basin, Soft, Gully	Bsg
	Basin, Hard, Landslide	
	Basin, Soft, Landslide	
	Basin, Hard, Glacial Pavement	
	Basin, Soft, Glacial Outwash	
	Shelf, Biogenic	
Ridge (200 to 2500 m)		
	Ridge, Hard, Exposure	Rhe
	Ridge, Soft Sediment	Rs_u
	Ridge, Biogenic	
Cont. Rise (3000 to 5000 m)		
	Rise, Hard, Exposure	Ahe
	Rise, Soft Sediment	As_u
	Rise, Hard, Canyon Wall	Ahc
	Rise, Soft Sediment, Canyon Wall	Asc_u
	Rise, Hard, Canyon Floor	
	Rise, Soft Sediment, Canyon Floor	Asc/f
	Rise, Hard, Gully	
	Rise, Soft, Gully	Asg

Table 2. Descriptions of sensitivity levels and recovery time (years) for gear impact assessments.

Sensitivity Level	Sensitivity Description
0	No detectable adverse impacts on seabed; i.e. no significant differences between impact and control areas in any metrics.
1	Minor impacts such as shallow furrows on bottom; small differences between impact and control sites, <25% in most measured metrics.
2	Substantial changes such as deep furrows on bottom; differences between impact and control sites 25 to 50% in most metrics measured.
3	Major changes in bottom structure such as re-arranged boulders; large losses of many organisms with differences between impact and control sites >50% in most measured metrics.
Recovery Time	**Recovery Description**
0	No recovery time required because no detectable adverse impacts on seabed.
n	n = time (years) required for return to pre-impact condition; i.e. no significant differences between impact and control areas in any metrics

As indicated in Table 2, the sensitivity levels 0 to 3 were intended to provide a relative scale for defining the actual sensitivity descriptions which were based on literature values. The range of sensitivity impacts found in the existing literature (see references listed in the tables in Annex 1) is from no detectable impacts (level 0) to major changes in various seabed characteristics (level 3). This range of levels corresponds to a range of actual measured changes ranging from "no significant differences" in any metrics measured to 100% (or nearly so) losses of some organisms. Sensitivity range intervals as indicated in Table 2 (no significant differences, <25% difference, etc) were chosen and assigned to the four sensitivity levels. The values for recovery times were the actual times (converted to years) reported in the literature for the metrics measured. This procedure was developed because there was a wide range of metrics measured and reported in the literature, and it was necessary to assess each study on a quantitative scale that could be applied to all studies.

3.2 Phase 2: Literature summaries

Six tables summarizing the available literature are provided in Annex 1. Table A1.1 is a summary of references on impacts of all gear types on estuarine habitats. Table A1.2 is a summary of references on impacts of trawls on shelf habitats. Table A1.3 is a summary of references on impacts of dredges on shelf habitats. Table A1.4 is a summary of references on impacts of multiple mobile gears on shelf habitats. Table A1.5 is a summary of references on impacts of pots and traps on shelf habitats. Table A1.6 is a summary of references on impacts of trawls on slope habitats.

These tables represent the "raw data" of subsequent analyses. As an illustration of how the values in the tables were derived, consider the study by Brylinsky et al. (1994) on the effects of otter trawls on estuarine soft sediment bottoms (Table A1.1). A sensitivity level of "1" was assigned based on the reported impacts of relatively shallow trawl marks (5 cm deep) and decreases in some invertebrate populations but no differences in others. A recovery time of "0.6 yr" was assigned because the recovery times reported ranged from 2 to 7 months for the trawl marks to 4 to 6 weeks for some invertebrate taxa. The derivation of the actual sensitivity and recovery time levels assigned for each study can be checked by examining the information provided in the corresponding "Sensitivity Comments" and "Recovery Comments" cells.

Phase 3: Draft index of effects of fishing gear on bottom habitats

In order to develop as many mean values as possible with reasonable error terms, it was necessary to re-combine the detailed data in the literature review tables in Annex 1 by collapsing the categories of gear types listed above (page 5) to five major categories, and collapsing the habitat types to six megahabitat/substrate types (Table 3). In most cases for which empirical data were available, these combinations resulted in samples sizes sufficient to derive useful means. However, it should be noted that several gear/habitat combinations have only one or two studies (n < 2) providing useable data on sensitivity and/or recovery levels.

It should also be noted that as a result of comments received at the SSC Groundfish Subcommittee meeting in Seattle in February 2004, the bottom habitat type "Biogenic" was subdivided into as many categories as practicable based on the amount of gear impacts literature available. Studies have been conducted on four major biogenic bottom types: shellfish reefs (mussels and oysters), macrophytes (mostly seagrasses), sponges, and corals. Other comments received at the February meeting included the suggestion that recovery levels be re-defined and calculated based on actual recovery time. Therefore, the existing literature summaries in Annex 1 were revised to show the above four biogenic subcategories for each of the megahabitat types (Estuarine, Shelf, etc) where appropriate, and recovery levels were presented as time in years (Table 3).

Two important general observations can be made concerning the biogenic habitats. First, most research has been done on trawls and dredges, as is the case generally for gear impacts research. Second, most of the values for both sensitivity and recovery are based on only one study (n=1). Clearly, much more work must be done before we have a good understanding of how the full range fishing gear types impact the many kinds of biogenic habitats. Nonetheless, research has been done on several major biogenic habitat types, particularly on the continental shelf, and some trends appear to be emerging. For example, dredges and trawls appear to be nearly equally damaging to biogenic habitats on the shelf regardless of the kind of biogenic bottom. And recovery times can be substantial for those habitats dominated by long-lived species; e.g., see Slope, Corals entry.

Two gear by habitat combinations in Table 3 warrant further comment because they show very low impacts of gear types that have been shown to be quite damaging on some biogenic bottoms. The impact of bottom trawls in estuarine macrophyte habitats is shown as "0.0, SE=0.0, n=3" for sensitivity and recovery. Although these means are based on three studies, they probably do not represent the situation for estuarine macrophytes generally. The three studies were all done on turtle grass (*Thalassia testudinum)* using a relatively light-weight (75 kg) trawl with the footrope rigged with rollers designed for catching shrimp in seagrasses. Turtle grass has leaves that range from several centimeters to a meter or so long and they are quite flexible, capable of lying nearly flush against the substrate in tidal currents. Hence, it may be expected that this type of gear could move above the turtle grass with minimal impact. The authors of these studies noted that certain gear specifications are needed to minimize damage to seagrasses. Hence, these studies should not be interpreted to represent the range of macrophyte and gear type combinations that may occur on the west coast.

The second gear by habitat combination that warrants comment is dredges in estuarine shellfish habitats, where sensitivity and recovery values were also quite low. All studies to date have been done on previously harvested oyster reefs where the natural vertical structure probably had already been greatly reduced. Oyster reefs that have not been harvested can have vertical relief ranging from < 1 m to several meters. Mechanical harvesting gears (whether hand-held or towed under power) typically used to harvest oysters are capable of greatly reducing this vertical structure because their effect is to destroy the natural aggregated nature of the reef, typically resulting in a reef that largely consists of individual oysters lying flat on the bottom. The studies summarized in Table 3 indicate that once the vertical structure of a reef is destroyed, further dredging apparently has only minimal impact on reef characteristics, including productivity. This is an important finding, but as in the case of the three trawl studies on one kind of seagrass, must not be pressed too far.

In conclusion, it should be emphasized that we only have a preliminary understanding of how fishing gear impacts biogenic habitats. Some trends are emerging, but further consideration of the two gear/habitat combinations that departed from general trends should be a warning that the relationships involved can be quite complex.

Table 3. Summary of mean sensitivity levels and recovery times for all combinations of five major gear types and bottom habitat types (i.e. three megahabitats, two induration types [hard and soft] and biogenic) for which empirical data were available.

Sensitivity Levels (range: 0 to 3)

Megahabitat, Induration, Meso/macrohabitat	**Habitat Code**	**Dredges**	**Bottom Trawls**	**Nets**	**Pots & Traps**	**Hook & Line**
Estuarine, Biogenic/Macrophytes		**2.9 (SE=0.07 , n=4)**	**0.0 (SE=0.00, n=3)**	(nd)	(nd)	(nd)
Estuarine, Biogenic/Shellfish		**0.9 (SE=0.93, n=3)**	(nd)	(nd)	(nd)	(nd)

Estuarine, Soft		**1.3 (SE=0.34, n=9)**	**0.7 (SE=0.25, n=7)**	(nd)	(nd)	(nd)
Shelf, Biogenic/Macrophytes		**2.8 (SE= , n=1)**	**2.0 (SE= , n=1)**	(nd)	(nd)	(nd)
Shelf, Biogenic/Shellfish		**1.0 (SE= , n=1)**	**1.0 (SE= , n=1)**	(nd)	**0.8 (SE= , n=1)**	(nd)
Shelf, Biogenic/Sponges		(nd)	**2.2 (SE=0.15 , n=2)**	(nd)	(nd)	(nd)
Shelf, Biogenic/Corals		(nd)	**1.0 (SE= , n=1)**	(nd)	(nd)	(nd)
Shelf, Hard, Exposure	She	**1.7 (SE=0.40, n=3)**	**2.5 (SE=0.50, n=2)**	(nd)	**0.3 (SE=0.30, n=2)**	(nd)
Shelf, Soft	Ss_u	**1.0 (SE=0.10, n=22)**	**1.2 (SE=0.14, n=29)**	(nd)	(nd)	(nd)
Slope, Biogenic, Sponges		(nd)	**3.0 (SE=0.00 , n=2)**	(nd)	(nd)	(nd)
Slope, Biogenic, Corals		(nd)	**3.0 (SE=0.00 , n=2)**	(nd)	(nd)	(nd)
Slope, Soft	Fs_u	(nd)	**1.0 (SE= , n=1)**	(nd)	(nd)	(nd)

Recovery Time (years)

Megahabitat, Induration, Meso/macrohabitat	Habitat Code	Dredges	Bottom Trawls	Nets	Pots & Traps	Hook & Line
Estuarine, Biogenic/Macrophytes		**3.8 (SE=1.17, n=3)**	**0.0 (SE=0.00, n=3)**	(nd)	(nd)	(nd)

Estuarine, Biogenic/Shellfish		**0.0 (SE=0.00, n=2)**	(nd)	(nd)	(nd)	(nd)
Estuarine, Soft		**0.4 (SE=0.17, n=8)**	**0.2 (SE=0.07, n=6)**	(nd)	(nd)	(nd)
Shelf, Biogenic/Macrophytes		**4.0+ (SE= , n=1)**	**3.0 (SE= , n=1)**	(nd)	(nd)	(nd)
Shelf, Biogenic/Shellfish		(nd)	(nd)	(nd)	**0.1 (SE= , n=1)**	(nd)
Shelf, Biogenic/Sponges		(nd)	**1.3 (SE=0.25 , n=2)**	(nd)	(nd)	(nd)
Shelf, Biogenic/Corals		(nd)	**1.0 (SE= , n=1)**	(nd)	(nd)	(nd)
Shelf, Hard, Exposure	She	(nd)	(nd)	(nd)	**0.0 (SE= , n=1)**	(nd)
Shelf, Soft	Ss_u	**0.5 (SE=0.17, n=9)**	**0.4 (SE=0.18, n=8)**	(nd)	(nd)	(nd)
Slope, Biogenic, Sponges		(nd)	(nd)	(nd)	(nd)	(nd)
Slope, Biogenic, Corals		(nd)	**7.0+ (SE= , n=1)**	(nd)	(nd)	(nd)
Slope, Soft	Fs_u	(nd)	(nd)	(nd)	(nd)	(nd)

Table 4 below is a first-draft "sensitivity matrix" and Table 5 is a first draft "recovery matrix." Each impact level is expressed as a range, which represents plus or minus one standard error around the mean for the values based on empirical data and plus or minus 50% of the mean for the derived values. The following 4-step protocol was used to derive the levels in both tables.

1) Empirical data were used as the starting point for all gear x habitat combinations, when available.

2) Empirical data were analyzed for trends in relative impacts by major gear types across all habitats and by habitat for all gear types.

3) Expert opinion and/or theoretical considerations were used to determine relative impacts for gear x habitat combinations where no empirical data were available. This was done by assigning impact levels across a range of gear x habitat cells following the general trends identified in steps 2 and 3 and reducing the impact level by approximately 50% at each step along the trend gradient for gear and habitats.

4) When empirical data came from only one study or were apparently anomalous and departed strongly from the overall trends in impact levels (step 2), trend data were used.

The values in the two matrices are color-coded based on how they were determined. Those in cells highlighted in green are means calculated from the literature summaries in Annex 1 and summarized in Table 3; i.e. these are the empirical data derived from step 1 in the above protocol. Those in the un-highlighted cells were derived by adjusting the appropriate empirical literature values using the relative rankings of gear impacts determined in the present analysis as well as information in recent reviews (Auster and Langton 1999; Hamilton 2000; Barnette 2001; Johnson 2002; Morgan and Chuenpagdee 2003); using steps 2 and 3 in the above protocol. Those in the yellow highlighted cells were derived using step 4 above. Some example calculations are given below.

The present analysis (Table 3) suggests the following relative rankings of gear from highest to lowest impact: dredges > bottom trawls > pots & traps (no empirical data available for nets and hook & line gears). Although very little research exists, the various types of nets are generally considered to have much less impact on the seabed than dredges and trawls, and hook & line methods have the least impact (Hamilton 2000; Barnette 2001; Johnson 2002). Hence, the derived values reflect this relative ranking of impacts: dredges > trawls > nets > pots and traps > hook and line.

In addition to the relative gear rankings, the present analysis of empirical research also showed a nearly consistent ranking by substrate/macrohabitat type almost regardless of gear type from most adversely impacted to least: biogenic > hard bottom > soft sediment. This ranking is the same as that in two recent conceptual models of gear impacts by bottom type (Auster and Langton 1999; NRC 2002).

Inspection of Tables 4 and 5 shows that all values for the Basin and Ridge megahabitats, and most for the Slope are derived values and not means calculated from empirical values in the literature. This is because there has been very little research useful for the present analysis on gear impacts in water depths exceeding 200 m. Therefore, in most cases for both matrices, the values from the appropriate shelf substrate/macrohabitat categories were transferred without change to the Slope, Basin, and Ridge cells. It should be noted, however, that there are theoretical bases for adjusting values from these deeper habitats. Benthic communities in deeper waters where wind and waves do not disturb the seabed are probably less adapted to resisting and recovering from physical disturbances generally. No such adjustments, however, were attempted for the present analysis.

To illustrate the general process for obtaining the values given in Tables 4 and 5, consider the "Dredges" column in "Estuarine" habitats and the relative ranking of sensitivity by habitat type discussed above (biogenic > hard > soft). Note that the derived cell (dredges on estuarine hard bottom) was assigned a range of 0.9-2.6, which falls below the sensitivity range for biogenic habitat but above the range for soft sediments. In similar fashion, consider The empirical values for the sensitivity of "Shelf, Biogenic" habitat. The literature values reflect the ranking of dredges having the most impact (1.0-2.8), followed by trawls (1.4-2.2). There were no studies on nets, so it was assigned a value (0.9-1.8) less than Trawls but more than Pots and Traps for which there were empirical values (0.4-1.2). And Hook and Line was assigned the smallest range (0.0-0.9).

In similar fashion, moving across most rows in the two tables, note that the ranges reflect the relative rankings of impacts of gear types (dredges > trawls > nets > pots and traps > hook and line). It should be noted, however, that where empirical data departed from either of these trends (e.g. the effects of bottom trawls in estuarine habitats) the empirical data were used to control the derived values.

As noted above, the ranges given in the highlighted cells reflect plus or minus one standard error around the means for each gear-by-habitat combination given in Table 3. For example, the range of sensitivity for Bottom Trawls on Estuarine, Soft Sediments in Table 4 is 0.5-1.0 (column 4 and row 4). This is the mean (0.70) plus or minus the 0.25, the standard error around the mean given in Table 3 (column 4, row 3), rounded to the nearest 0.1 of a unit. All values in Tables 4 and 5 were rounded to the nearest tenth. The ranges given for the derived (un-highlighted) values represent approximately plus or minus 50% of the midpoint of each range. This range of variability was chosen because it is representative of the variability in those empirical means for which sample sizes (n values in Table 3) were 3 or more.

Table 4. Sensitivity level ranges for five major gear categories for all mapped habitat types. Sensitivity levels range from 0 to 3 (see Table 2 for descriptions). Values in green shaded cells are ranges from the literature, showing + or - one SE around the calculated means in Table 5. Others are derived values (see text for details).

MEGAHAB, SUBSTRATE, MESO/MACROHAB	Habitat Code	Dredges	Bottom Trawls	Nets	Pots & Traps	Hook & Line
Estuarine, Biogenic/Macrophytes		2.8-3.0 (n=4)	1.0-2.0 (n=3)	0.5-1.0	0.0-0.5	0.0-0.5
Estuarine, Biogenic/Shellfish		2.0-3.0 (n=3)	1.0-2.0	0.5-1.0	0.0-0.5	0.0-0.5
Estuarine, Hard		1.5-2.5	1.0-2.0	0.5-1.0	0.0-0.5	0.0-0.5
Estuarine, Soft		1.0-1.6 (n=9)	0.5-1.0 (n=7)	0.0-0.5	0.0-0.5	0.0-0.5
Shelf, Biogenic/Macrophytes		1.4-3.0 (n=1)	1.0-3.0 (n=1)	0.5-2.5	0.3-1.3	0.3-1.3
Shelf, Biogenic/Shellfish		1.4-3.0 (n=1)	1.4-2.2 (n=1)	0.9-1.8	0.4-1.2 (n=1)	0.2-1.0
Shelf, Biogenic/Sponges		2.0-3.0	2.0-2.4 (n=2)	0.9-1.8	0.4-1.2	0.2-1.0
Shelf, Biogenic/Corals		2.0-3.0	2.0-3.0 (n=1)	0.5-2.5	0.3-1.3	0.3-1.3
Shelf, Hard, Canyon Wall	Shc	1.3-2.1	2.0-3.0	0.8-1.6	0.0-0.6	0.0-0.6
Shelf, Hard, Exposure	She	1.3-2.1 (n=3)	2.0-3.0 (n=2)	0.8-1.6	0.0-0.6 (n=2)	0.0-0.6
Shelf, Hard, Ice-formed feature	Shi_b/p	1.3-2.1	2.0-3.0	0.8-1.6	0.0-0.6	0.0-0.6
Shelf, Soft	Ss_u	0.9-1.1 (n=22)	0.5-1.0 (n=29)	0.5-1.0	0.0-0.5	0.0-0.2
Shelf, Soft, Canyon Floor	Ssc/f_u	0.9-1.1	0.5-1.0	0.2-0.8	0.0-0.5	0.0-0.2
Shelf, Soft, Canyon Wall	Ssc_u	0.9-1.1	0.5-1.0	0.2-0.8	0.0-0.5	0.0-0.2
Shelf, Soft, Gully	Ssg	0.9-1.1	0.5-1.0	0.2-0.8	0.0-0.5	0.0-0.2
Shelf, Soft, Gully floor	Ssg/f	0.9-1.1	0.5-1.0	0.2-0.8	0.0-0.5	0.0-0.2
Shelf, Soft, Ice-formed feature	Ssi_o	0.9-1.1	0.5-1.0	0.2-0.8	0.0-0.5	0.0-0.2
Ridge, Biogenic		2.0-3.0	2.0-3.0	0.5-2.5	0.3-1.3	0.3-1.3
Ridge, Hard, Exposure	Rhe	1.3-2.1	2.0-3.0	0.8-1.6	0.0-0.6	0.0-0.6
Ridge, Soft	Rs_u	0.9-1.1	0.5-1.0	0.8-1.6	0.0-0.6	0.0-0.6
Slope, Biogenic/Sponges		2.5-3.0	2.5-3.0 (n=2)	1.0-2.0	0.5-1.0	0.5-1.0
Slope, Biogenic/Corals		2.5-3.0	2.5-3.0 (n=2)	1.0-2.0	0.5-1.0	0.5-1.0
Slope, Hard, Canyon Wall	Fhc	2.5-3.0	2.5-3.0	1.0-2.0	0.5-1.0	0.5-1.0

Slope, Hard, Canyon Floor	Fhc/f	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Slope, Hard, Exposure	Fhe	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Slope, Hard, Gully	Fhg	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Slope, Hard, Landslide	Fhl	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Slope, Soft	Fs_u	**1.0-2.0**	**0.5-1.5 (n=1)**	**0.5-1.0**	**0.2-0.6**	**0.2-0.6**
Slope, Soft, Canyon Floor	Fsc/f_u	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Slope, Soft, Canyon Wall	Fsc_u	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Slope, Soft, Gully	Fsg	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Slope, Soft, Gully floor	Fsg/f	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Slope, Soft, Landslide	Fsl	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Basin, Biogenic		**2.0-3.0**	**2.0-3.0**	**0.5-2.5**	**0.3-1.3**	**0.3-1.3**
Basin, Hard, Exposure	Bhe	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Basin, Soft	Bs_u	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Basin, Soft, Canyon Floor	Bsc/f_u	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Basin, Soft, Canyon Wall	Bsc_u	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Basin, Soft, Gully	Bsg	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Basin, Soft, Gully floor	Bsg/f_u	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Continental Rise, Biogenic		**2.0-3.0**	**2.0-3.0**	**0.5-2.5**	**0.3-1.3**	**0.3-1.3**
Continental Rise, Hard, Canyon Wall	Ahc	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Continental Rise, Hard, Exposure	Ahe	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Continental Rise, Soft	As_u	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Continental Rise, Soft, Canyon Floor	Asc/f_u	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Continental Rise, Soft, Canyon	Asc_u	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Continental Rise, Soft, Gully	Asg	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Continental Rise, Soft, Landslide	Asl	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**

Table 5. Recovery time (years) ranges for five major gear categories and all mapped habitat types. Values in green shaded cells are ranges from the literature, showing + or - one SE around the calculated means in Table 5. Others are derived values (see text for details).

MEGAHAB, SUBSTRATE, MESO/MACROHAB	Habitat Code	Dredges	Bottom Trawls	Nets	Pots & Traps	Hook & Line
Estuarine, Biogenic/Macrophytes		2.6-5.5 (n=3)	1.5-4.5	0.5-2.0	0.0-0.5	0.0-0.5
Estuarine, Biogenic/Shellfish		2.5-5.5	1.5-4.5	0.5-2.0	0.0-0.5	0.0-0.5
Estuarine, Hard		1.5-2.5	1.0-2.0	0.5-1.0	0.0-0.5	0.0-0.5
Estuarine, Soft		0.2-0.6 (n=8)	0.1-0.3 (n=6)	0.0-0.5	0.0-0.5	0.0-0.5
Shelf, Biogenic/Macrophytes		2.0-6.0 (n=1)	1.5-4.5 (n=1)	0.5-2.5	0.3-1.3	0.3-1.3
Shelf, Biogenic/Shellfish		2.0-6.0	1.0-3.0	0.5-1.5	0.0-0.2 (n=1)	0.0-0.2
Shelf, Biogenic/Sponges		2.0-3.0	1.0-1.6 (n=2)	0.5-1.5	0.4-1.2	0.2-1.0
Shelf, Biogenic/Corals		2.0-3.0	1.0-1.6	0.5-1.5	0.4-1.2	0.2-1.0
Shelf, Hard, Canyon Wall	Shc	1.0-3.0	1.0-2.0	0.5-1.5	0.0-0.5	0.0-0.5
Shelf, Hard, Exposure	She	1.0-3.0	1.0-2.0	0.5-1.5	0.0-0.1 (n=1)	0.0-0.5
Shelf, Hard, Ice-formed feature	Shi_b/p	1.0-3.0	1.0-2.0	0.5-1.5	0.0-0.5	0.0-0.5
Shelf, Soft	Ss_u	0.3-0.7 (n=9)	0.2-0.6 (n=8)	0.1-0.5	0.0-0.5	0.0-0.2
Shelf, Soft, Canyon Floor	Ssc/f_u	0.3-0.7	0.2-0.6	0.1-0.5	0.0-0.5	0.0-0.2
Shelf, Soft, Canyon Wall	Ssc_u	0.3-0.7	0.2-0.6	0.1-0.5	0.0-0.5	0.0-0.2
Shelf, Soft, Gully	Ssg	0.3-0.7	0.2-0.6	0.1-0.5	0.0-0.5	0.0-0.2
Shelf, Soft, Gully floor	Ssg/f	0.3-0.7	0.2-0.6	0.1-0.5	0.0-0.5	0.0-0.2
Shelf, Soft, Ice-formed feature	Ssi_o	0.3-0.7	0.2-0.6	0.1-0.5	0.0-0.5	0.0-0.2
Ridge, Biogenic		2.0-3.0	2.0-3.0	0.5-2.5	0.3-1.3	0.3-1.3
Ridge, Hard, Exposure	Rhe	1.3-2.1	2.0-3.0	0.8-1.6	0.0-0.6	0.0-0.6
Ridge, Soft	Rs_u	0.9-1.1	0.5-1.0	0.8-1.6	0.0-0.6	0.0-0.6
Slope, Biogenic/Sponges		3.5-10.5	3.5-10.5	2.0-8.0	0.0-3.0	0.0-3.0
Slope, Biogenic/Corals		3.5-10.5	3.5-10.5 (n=1)	2.0-8.0	0.0-3.0	0.0-3.0
Slope, Hard, Canyon Wall	Fhc	2.5-3.0	2.5-3.0	1.0-2.0	0.5-1.0	0.5-1.0

Slope, Hard, Canyon Floor	Fhc/f	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Slope, Hard, Exposure	Fhe	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Slope, Hard, Gully	Fhg	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Slope, Hard, Landslide	Fhl	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Slope, Soft	Fs_u	**1.0-2.0**	**1.0-2.0**	**0.5-1.0**	**0.2-0.6**	**0.2-0.6**
Slope, Soft, Canyon Floor	Fsc/f_u	**1.0-2.0**	**1.0-2.0**	**0.5-1.0**	**0.2-0.6**	**0.2-0.6**
Slope, Soft, Canyon Wall	Fsc_u	**1.0-2.0**	**1.0-2.0**	**0.5-1.0**	**0.2-0.6**	**0.2-0.6**
Slope, Soft, Gully	Fsg	**1.0-2.0**	**1.0-2.0**	**0.5-1.0**	**0.2-0.6**	**0.2-0.6**
Slope, Soft, Gully floor	Fsg/f	**1.0-2.0**	**1.0-2.0**	**0.5-1.0**	**0.2-0.6**	**0.2-0.6**
Slope, Soft, Landslide	Fsl	**1.0-2.0**	**1.0-2.0**	**0.5-1.0**	**0.2-0.6**	**0.2-0.6**
Basin, Biogenic		**3.5-10.5**	**3.5-10.5**	**2.0-8.0**	**0.0-3.0**	**0.0-3.0**
Basin, Hard, Exposure	Bhe	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Basin, Soft	Bs_u	**1.0-2.0**	**1.0-2.0**	**0.5-1.0**	**0.2-0.6**	**0.2-0.6**
Basin, Soft, Canyon Floor	Bsc/f_u	**1.0-2.0**	**1.0-2.0**	**0.5-1.0**	**0.2-0.6**	**0.2-0.6**
Basin, Soft, Canyon Wall	Bsc_u	**1.0-2.0**	**1.0-2.0**	**0.5-1.0**	**0.2-0.6**	**0.2-0.6**
Basin, Soft, Gully	Bsg	**1.0-2.0**	**1.0-2.0**	**0.5-1.0**	**0.2-0.6**	**0.2-0.6**
Basin, Soft, Gully floor	Bsg/f_u	**1.0-2.0**	**1.0-2.0**	**0.5-1.0**	**0.2-0.6**	**0.2-0.6**
Continental Rise, Biogenic		**3.5-10.5**	**3.5-10.5**	**2.0-8.0**	**0.0-3.0**	**0.0-3.0**
Continental Rise, Hard, Canyon Wall	Ahc	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Continental Rise, Hard, Exposure	Ahe	**2.5-3.0**	**2.5-3.0**	**1.0-2.0**	**0.5-1.0**	**0.5-1.0**
Continental Rise, Soft	As_u	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Continental Rise, Soft, Canyon Floor	Asc/f_u	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Continental Rise, Soft, Canyon	Asc_u	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Continental Rise, Soft, Gully	Asg	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**
Continental Rise, Soft, Landslide	Asl	**1.0-2.0**	**0.5.1.5**	**0.3-1.0**	**0.2-0.6**	**0.1-0.3**

4 DISCUSSION AND CONCLUSIONS

This analysis is a first attempt to quantify the sensitivity of bottom habitats to and recovery of bottom habitats from the impacts of different types of fishing gear that occur along the US west coast. The analysis was based on major literature reviews, particularly Johnson (2002) but also Watling and Norse (1998), Auster and Langton (1999), Dayton et al. (2002), National Research Council (2002), and Morgan and Chuenpagdee (2003). The resulting sensitivity and recovery values are presented in Tables 4 and 5. The intention is for these values, or values modified based on additional information and/or analysis, to be used in the Bayesian modeling process to identify fishing impacts and ways of preventing, minimizing or mitigating those impacts. Before proceeding to the modeling process, however, several topics warrant discussion.

First, it may be useful to discuss Tables 4 and 5 from the perspective of what this analysis does and does not aim to be. The values in all cells are given as ranges. As discussed, the ranges represent plus or minus one standard error around the mean for all values given. The magnitude of each range reflects the amount of uncertainty in a statistical sense, which is affected in large measure by the number of studies incorporated into each mean. For those gear-by-habitat combinations for which there were few studies, the ranges are generally greater compared to those that had relatively large "n" values; see Table 3 for statistics for each gear-by-habitat combination for which empirical data were available. The values presented in Tables 4 and 5 are adequate for use in the Bayesian modeling process, but they should not be pressed too far quantitatively.

This caveat is based on the paucity of empirical data for the overall analysis, but also the fact that an arbitrary scale of 0 to 3 was used to standardize the various metrics reported in the literature (Annex 1). Researchers have used a wide range of metrics to try to assess gear impacts, and the various ecological processes that determine EFH characteristics are not well understood. Hence, the present analysis should not be interpreted as a direct quantification of gear impacts that can be used to infer, for example, functional habitat characteristics related to EFH. The relative effects of gear types on some functional habitat characteristics may well be reflected in the ranges of values given in Tables 4 and 5, but they do not represent a direct quantification of any particular impact on habitat function. The relationship of EFH to various habitat characteristics is complicated and not well understood quantitatively.

Secondly, it was noted in the Introduction section that the literature consists largely of research in other areas. There is therefore a need to determine how studies in other parts of the world relate to impacts on habitats from fishing gears used on the Pacific coast. Only two studies from the Pacific were found that had useful information for the present analysis (see first two entries in Table A1.2). In order to develop a more complete picture of potential impacts, studies from other areas must be relied upon. This raises the question of how inferences can and/or should be drawn from studies in other areas. This is essentially a question of applicability that is relevant to all of the sciences: How representative are the findings from one study of situations in other areas or at other times?

All the major reviews on the impacts of fishing gear on fish habitat address this issue directly or implicitly. For example, the extensive international review and assessment of the impacts of trawling and dredging on seafloor habitats (National Research Council 2002) found that (p. 20): "The extensive primary literature and many review articles… reveal several generalities about the response of seafloor communities to trawling and dredging." In another review, Morgan and Chuenpagdee (2003) ranked gear types by their relative impacts based on the scientific literature as well as surveys of those involved in the research and management of fisheries. With respect to the utility of their findings to others, they state (p. v): "The methods demonstrated here can be applied to specific fishery management councils to catalyze both regional and national conversations on how to manage truly sustainable ecosystems for fishing and other societal values." Auster and Langton (1999) have taken what might be considered a first step towards a general theory of gear impacts based on habitat complexity, fishing intensity, and ecological theory. Their analysis essentially takes a global perspective based on the overall literature.

Three major facts support this kind of reasoning: (1) many of the same gear types are used in many different geographic areas of the world, (2) seafloor habitats worldwide have a variety of ecological similarities, particularly as related to water depth and substrate characteristics, and (3) many harvested species have broad geographic ranges. Therefore, it seems quite reasonable to infer impacts from studies in other areas so long as they are based on similar gear x habitat combinations. The present analysis considered only studies that involved gear types used on the west coast and the major habitat types that occur there.

Another topic that warrants discussion is the disparity between the number of sensitivity (n=89) and recovery (n=41) studies (see summary in Table 3). Clearly, most of the research has been done on short-term impacts (sensitivity) and there is a need to better understand how habitats recover from different types of impacts in order to better quantify the long-term and cumulative impacts of fishing gear. However, the overall trends for both sensitivity and recovery values relative to gear and habitat types were similar. Most studies showed that all habitat types were most sensitive (greatest short-term impact) to dredges, followed by trawls, then pots and traps (Table 3). A similar relative ranking occurred for recovery times. This does not negate the need for a better quantitative understanding of the recovery process but it does suggest that the recovery times are related to the level of the initial impacts.

A related topic that was not considered in the present analysis is the issue of fishing intensity, or frequency of disturbance of the bottom by fishing gear. Where available, relevant comments were recorded in the literature summary tables in Annex 1. However, there was no consideration of these data in the formulation of the sensitivity and recovery values in the impact tables. Two major reviews developed conceptual models incorporating fishing intensity to their assessment of gear impacts. Auster and Langton (1999) related "level of fishing effort" to changes in habitat characteristics, particularly habitat complexity. The National Research Council 2002 related "frequency of fishing disturbance" and "frequency of natural disturbance" to their overall effect on benthic communities in different kinds of substrates. These kinds of analyses recognize the fact that fishing intensity is an important consideration regardless of how gear impacts are assessed.

A final topic to consider for future research is the possibility of refining the substrate categories, which at present include only "soft," "hard" and "biogenic." For example, the impacts of fishing gear generally are very different when comparing mobile sands and stable muds with some biogenic structure, both being classified as "soft" sediments in the present analysis. It might, for example, be useful to incorporate information such as water depth and potential frequency of natural disturbance (e.g. storm waves). Even if the existing literature was not adequate for a quantification of the differences, ecological theory and/or conceptual models (National Research Council 2002, p. 23) would allow a semi-quantitative assessment.

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ANNEX 1: LITERATURE SUMMARIES

DRAFT 6 - Table A1.1. Summary of references on impacts of **ALL GEAR TYPES** on **ESTUARINE HABITATS**

Reference	Location	Megahabitat	Water Depth	Substrate Type	Macrohabitat	Habitat Code	Sensitivity Level	Sensitivity Comments	Recovery Time (years)	Recovery Comments	Study Design & Sampling Methods	Study Design & Gear Comments
Otter Trawls x Soft Sediment												
Gibbs et al. 1980	New South Wales, Australia	Estuarine	"shallow" estuary	Soft Sediment; sand, 0-30% mud	n/a	n/a	0, 0, 0, 0 (avg=0.0)	minor disturbance of sand; no significant differences between fished and control sites in any community characteristics measured	0, 0, 0, 0 (avg=0.0)	(no detrimental impact)	Smith-McIntyre grab samples	10-m otter trawl with 1 x 0.5 m boards and chain spiders; before & after seasonal prawn trawling and repeated experimental trawling for 1 wk
Smith et al. 1985	Long Island Sound, NY	Estuarine	?	Soft Sediment; sand, mud	n/a	n/a	1, 1, 0, 1 (avg=0.8)	tracks in sediment 1 to 6" deep; attraction of predators; suspension of epibenthos	0.1	tracks "naturalized" by tidal currents after ??; lobster burrow alterations "easily" repaired by lobsters	diver observations	otter trawl with 6' doors, 30-60' scissors, 60-110' extended wing nets, 3/8" chain footrope
Brylinsky et al. 1994	Bay of Fundy, NS	Estuarine	0 to 10+ m; intertidal (6 to 8 m tidal range)	Soft Sediment; mud (silt)	n/a	n/a	1, 1, 1, 1 (avg=1.0)	5 cm deep x 30 cm wide tracks in sediment; decrease in nematodes and diatoms; no effect on polychaetes	0.4	furrows 2 to 7 mo; 4 to 6 wk for nematodes; 1 mo for diatoms - quick recovery expected because of frequent natural distur-bance by storms and ice	core (?) samples of seabed	otter trawl, 18 m trawl, 220 kg doors, 29 cm rollers; experimental tows
DeAlteris et al. 1999	Narragansett Bay, RI	Estuarine	0 to 10+ m; 14 m	Soft Sediment; mud (also see sand)	n/a	n/a	1, 1, 1, 1 (avg=1.0)	otter trawl door tracks (5 to 10 cm) and berms (10 to 20 cm) formed	0.4	hand dug scars persisted >60 da	side scan sonar	otter trawl; observations with side scan sonar of otter trawl door tracks; divers monitored hand dug scars
DeAlteris et al. 1999	Narragansett Bay, RI	Estuarine	0 to 10+ m; 7 m	Soft Sediment; sand with sand waves (also see mud)	n/a	n/a	1, 0, 0, 0 (avg=0.3)	no tracks observed (but see mud)	0.2	hand dug scars recovered in 1 to 4 da	side scan sonar	otter trawl; sand in shallow areas eroded daily, gear impacts may be inconsequential
Cahoon et al. 2001	Pamlico River Estuary, North Carolina	Estuarine	?	Soft Sediment; (no grain size given)	n/a	n/a	0	"…no significant or consistent effect …on any of the soft-sediment organisms we studied."	0	(no effects)	replicate Ponar grabs in six areas, before and after trawling, and in areas known to be affected by shrimp and crab trawling and others unfished	"shrimp and crab trawl" rigged as used in commercial fishery
							Mean = 0.5 Std Err = 0.19 n=6		**Mean = 0.2 Std Err = 0.07 n=6**			
Beam Trawls x Soft Sediment												
Hall-Spencer et al. 1999	Gulf of Venice	Estuarine	25 m	Soft Sediment; sand and mud	n/a	n/a	1, 1, 3, 2 (avg=1.8)	decreased # of large, slow-moving epifauna (scallops, sea cucumbers), inc. # scavengers	(not studied)	none	video surveys 1 and 15 hr post trawling	3-m Rapido (toothed beam) trawl; five passes across study area
							Mean = 1.8 Std Err = n=1		**Mean = Std Err = n = 0**			
Otter Trawls x Biogenic, Macrophytes												
Futch and Beaumariage 1965; Meyer et al. 1991; Tabb 1958	Florida	Estuarine	0 to 10+ m; "shallow"	Biogenic; seagrass (*Thalassia*) *beds;* (sediment??)	n/a	n/a	0, 0, 0, 0 (avg=0.0)	removed some leaves and algae; no change in shoot density, blade number and length, or below ground biomass	0, 0, 0, 0 (avg=0.0)	(no detrimental impact)	?	"Tarpon Springs" & "St. Petersburg" shrimp roller trawls with 4.5 to 8 in rollers; 75 kg roller trawl with steel rollers
							Mean = 0.0 Std Err = n = 1		**Mean = 0.0 Std Err = n = 1**			
New Bedford/Scallop Dredges x Soft Sediment												
Eleftheriou & Robertson 1992	Loch Ewe, Scotland	Estuarine	5 m	Soft Sediment; sand	n/a	n/a	2, 1, 1, 1 (avg=1.3)	shallow furrows by teeth; no changes in infauna; crustaceans and sea stars increased; urchins, scallops, razor clams and other epifauna damaged or removed	(not studied)	?	photographic obser.; grab samples of epifauna and large infauna; samples taken before and after dredging	scallop dredge, 1.2 m wide with nine 12-cm long teeth, no chain bag; 25 tows in one area over 9-da period
Watliing et al. 2001	Damariscotta River, Maine	Estuarine	15 m	Soft Sediment; silty sand	n/a	n/a	1, 1, 2, 1 (avg=1.3)	tilled sediment to 9 cm; trenches 2 cm deep; decearse in fines and org. cont at surf, inc. at 5-9 cm; decreased macrofauna	0.5	sediments similar after 4 - 6 mo; no differences in macrofauna after 6 mo.	sediment samples collected before, immediately after, and 4 - 6 months after dredging	New Bedford style, 2 m wide with chain sweeps, no cutterbar; "intensive" experimental dredging at one site
							Mean = 1.3 Std Err = 0.0 n = 2		**Mean = 0.5 Std Err = n = 1**			
Hydraulic/Suction Dredges x Soft Sediment												

Kyte et al. 1975	Maine	Estuarine	intertidal	Soft Sediment; mud	n/a	n/a	0, 0, 0, 1 (avg=0.3)	turbidity plumes, limited effects on infauna	0.5	rapid recruitment of benthic organisms	water samples and sediment/benthos (cores?); sampled prior to dredging, during, and after 10 mo.	escalator dredge
Peterson et al. 1987	Back Sound, North Carolina	Estuarine	<10 m	Soft Sediment; sand	n/a	n/a	0	no significant impacts for any metric measured	0	(no impacts)	measured clam recruitment, scallop densities, macrofaunal benthos; control and treatment, up to 4 yr post-exp	hydraulic-like clam harvester
Hall et al. 1990	sea loch, Ireland	Estuarine	7 m	Soft Sediment; fine sand	n/a	n/a	3	trenches 0.25 m deep, some holes 0.6 m deep immediately after dredging; 60% reduction in infauna density, 24% loss of species	0.2	all dredge-caused sediment features gone after 40 da; infaunal recovery within 40 da; quick recovery probably because of winter storms in area	diver observations; sediment/benthos samples before, after, and 40 da after	suction dredging for razor clams; experimental dredging for 5 hr to simulate commercial fishing
Wynberg & Branch 1994	Langebaan Lagoon, South Africa	Estuarine	intertidal	Soft Sediment; sand	n/a	n/a	2	up to 75% decreases in some metrics for micro-, meio-, and macrofauna	1.5	recovery of bacteria within weeks, meiofauna 4 mos, macrofauna still some diffs after 18 mos	sample micro-, meio-, and macrofauna up to 18 mos post-exp	experimental fishing with suction dredge used for prawns, replicate sites and controls
Maier et al. 1995	South Carolina	Estuarine	intertidal creeks	Soft Sediment; muddy sand	n/a	n/a	0, 0, 0, 0 (avg=0.0)	short-term turbidity plumes; no significant changes in dominant taxa or abundances	0, 0, 0, 0 (avg=0.0)	(no measured impact)	turbidity levels and benthic infauna (cores?); samples before, during, and 2 wk after dredging	mechanical escalator dredge
Kaiser et al. 1996	southeastern England	Estuarine	intertidal	Soft Sediment; muddy sand	n/a	n/a	1, 1, 2, 2 (avg=1.5)	large amounts of sand re-suspension; sig diffs in total infaunal numbers	0.6	"complete recovery" of sediments and benthos after 7 mo	sediment/benchos samples (cores?) taken before, 3 hr after, and 7 mo after in impacted area and control site	suction dredging for manila clams; experimental dredging to simulate commercial fishing
Hall & Harding 1997	Auchencairn Bay, Scotland	Estuarine	intertidal	Soft Sediment; sand	n/a	n/a	2	up to about 50% decrease in some macrofaunal metrics	0.2	approached full recovery within 56 da	sampled macrofauna for up to 56 da post-exp	experimental fishing for cockles with hydraulic suction (and mechani-cal/tractor - see below) in replicate plots and control areas
							Mean = 1.3 Std Err = 0.44 n = 7		**Mean = 0.4 Std Err=0.20 n = 7**			
New Bedford/Scallop Dredges x Biogenic, Macrophytes												
Fonseca et al. 1984	Beaufort, North Carolina	Estuarine	intertidal, shallow subtidal	Biogenic; Soft Sediment; eelgrass beds in muddy sand	n/a	n/a	3, 3, 3, 2 (avg=2.8)	sig decreases in eelgrass biomass and shoot density at both sites, with reduction to ~0 at 30 times site	(not studied)	(no long-term sampling)	sampling of eelgrass	hand-operated scallop dredge, 0.65 m wide, 13 kg, no teeth; experimental dredging at two sites with diff intensity: 0, 15, 30 tows
							Mean = 2.8 Std Err = n = 1		**Mean = Std Err = n =**			
Hydraulic/Suction Dredges x Biogenic, Macrophytes												
Godcharles 1971	Tampa Bay, Florida	Estuarine	?	Biogenic, Soft Sediment; seagrasses, algae, sand	n/a	n/a	3, 3, 3, 2 (avg=2.8)	trenches 5 in deep; all vegetation in path uprooted leaving bare sand	1.5	trenches persisted 1 - 86 da; some sediments still altered after 500 da; authors recommended complete prohitbition of dredging in seagrasses with algae	diver observations	escalator dredge; experimental
Peterson et al. 1987	Back Sound, North Carolina	Estuarine	<10 m	Biogenic; eelgrass and shoalgrass	n/a	n/a	3	seagrass density decreased by 65% in some areas; decreased bay scallop densities	5	seagrass density still 35% lower after 4 yr	measured seagrass damage, clam recruitment, macrofaunal benthos; control and treatment, up to 4 yr post-exp	hydraulic-like clam harvester
Orth 1998	Chincoteague Bay, Virginia	Estuarine	?	Biogenic; Soft Sediment; seagrass beds	n/a	n/a	3, 3, 3, 3 (avg=3.0)	circular "scars" with loss of >50% seagrass cover	5	re-growth minimal after 2 yr; authors estimated 5 or more yr for recovery	diver observations	escalator dredge
							Mean = 2.9 Std Err = 0.07 n = 3		**Mean = 3.8 Std Err = 1.17 n = 3**			
Oyster Dredges/Mechanical Dredges x Biogenic, Oyster Reefs												

Langan 1998	Piscataqua River, New Hampshire and Maine	Estuarine	<10 m	Biogenic; Hard; oyster reef	n/a	n/a	0, 0, 0, 0 (avg=0.0)	temporary turbidity plume; no sig diffs in infauna; oyster size larger in un-dredged area; (no exam of reef structure?)	0, 0, 0, 0 (avg=0.0)	(no serious impacts)	water samples and sediment/benthos and oyster samples in fished (ME) and unfished (NH) areas of same oyster reef	oyster dredge, 30 in wide, 60 lbs, 2-in teeth, chain mesh bag; fished (ME) vs unfished (NH) areas of same oyster reef sampled
Lenihan and Peterson 1998	Neuse River, North Carolina	Estuarine	3 - 6 m	Biogenic; Hard; oyster reef	n/a	n/a	3, 3, 2, 3 (avg=2.8)	reduction in reef height by about 30 cm in dredged areas	(not studied)	(no long-term sampling)	measured reef height and ?	oyster dredge; experimental dredging; compared dredged and un-dredged reefs
Powell et al. 2001	Delaware Bay, New Jersey	Estuarine	< 10 m	Biogenic; Hard; oyster reef	n/a	n/a	0	no significant impacts for any metric measured	0	(no impacts)	repicate dredge samples taken up to several months after exp dredgeing; measured several oyster metrics (no non-oyter metrics)	exp dredging with commercial oyster dredges; 4 sites, 2 exp & 2 control
							mean = 0.9 Std Err = 0.93 n = 3		**Mean = 0.0 Std Err = 0.0 n = 2**			
Hand/Mechanical x Soft Sediment												
Peterson et al. 1987	Back Sound, North Carolina	Estuarine	<10 m	Soft Sediment; sand	n/a	n/a	0	no significant impacts for any metric measured	0	(no impacts)	measured clam recruitment, macrofaunal benthos; control and treatment, up to 4 yr post-exp	Hand/clam rake
Wynberg & Branch 1994	Langebaan Lagoon, South Africa	Estuarine	intertidal	Soft Sediment; sand	n/a	n/a	2	up to 75% decreases in some metrics for micro-, meio-, and macrofauna	1.5	recovery of bacteria within weeks, meiofauna 4 mos, macrofauna still some diffs after 18 mos	sample micro-, meio-, and macrofauna up to 18 mos post-exp	experimental fishing with hand rake (and suction pump - see above) used for prawns, replicate sites and controls
Brown & Wilson 1997	Lowes Cove, Maine	Estuarine	intertidal	Soft Sediment; mud	n/a	n/a	2	up to about 50% decrease in some macrofaunal metrics	(not studied)	(not designed to study recovery)	sampled macrofauna in un-dug, low intensity, and high intensity areas over 2.5 mo period	experimental fishing with clam rake at low and high intensities over 2.5 mo period
Hall & Harding 1997	Auchencairn Bay, Scotland	Estuarine	intertidal	Soft Sediment; sand	n/a	n/a	2	up to about 50% decrease in some macrofaunal metrics	0.2	approached full recovery within 56 da	sampled macrofauna for up to 56 da post-exp	experimental fishing for cockles with tractor (mechanical) dredge (and hydraulic suction- see above) in replicate plots and control areas
							mean = 1.5 Std Err = 0.50 n = 4		**Mean = 0.9 Std Err=0.53 n = 3**			
Hand/Mechanical x Biogenic, Macrophpytes												
Peterson et al. 1983	North Carolina	Estuarine	<10 m	Biogenic; eelgrass and shoalgrass	n/a	n/a	3	bull rake removed 89% of shoots and 83% roots; pea digger 55% and 37%	(not studied)	(no long-term sampling)	measured seagrass damage only	Hand/mechanical; clam raking with bull rakes and pea digger rakes
Peterson et al. 1987	Back Sound, North Carolina	Estuarine	<10 m	Biogenic; eelgrass and shoalgrass	n/a	n/a	1	seagrass density decreased by 25%; no effects on other metrics	1	full recovery of seagrasses within 1 yr	measured seagrass damage, clam recruitment, macrofaunal benthos; control and treatment, up to 4 yr post-exp	Hand/clam rake
							Mean = 2.0 Std Err=1.00 n = 2		**Mean = 1.0 Std Err = n = 1**			

DRAFT 6 - Table A1.2. Summary of references on impacts of **TRAWLS** on **SHELF HABITATS**

Reference	Location	Megahabitat	Water Depth	Substrate Type	Macrohabitat	Habitat Code	Sensitivity Level	Sensitivity Comments	Recovery Time (years)	Recovery Comments	Study Design & Sampling Methods
								Otter Trawls x Soft Sediment			
Engel & Kvitek 1998	**central California**	**Shelf**	**180 m**	**Soft Sediment; mud, sand, gravel**	**n/a**	**Ss_u**	**1, 1, 2, 1 (avg=1.3)**	**higher densities of all dom epifauna in lightly fished areas; some invert prey spp higher in heavily fished areas**	**(not studied)**	**(short-term study)**	**still and video; grab samples; fish stomachs**
High 1998	**Pacific NW USA**	**Shelf**	**?**	**Soft Sediment; "various"**	**n/a**	**Ss_u**	**1**	**trawl marks visible; benthic fauna and rocks dislodged**	**(not studied)**	**(short-term study)**	**diver observations**
Gibbs et al. 1980	New South Wales, Australia	Shelf	10 m	Soft Sediment; sand	n/a	PC 915	0, 0, 0, 0 (avg=0)	infauna at low densities but no difference detected pre- and post-trawl	0, 0, 0, 0 (avg=0)	(short-term study)	grab samples of infauna pre- and post-trawl; underwater observations
Harris & Poiner 1991	Gulf of Carpentaria, Australia	Shelf	17-21 m	Soft Sediment; mud	n/a	Ss_u	2, 1, 2, 2 (avg=1.8)	>50% reduction in total fish abundances, but some spp inc, some decreased little	(not studied)	**This study attempted to show persistent differences due to continued trawling, which might be relevant for some management decisions.**	comparison of 1964 and 1985/86 data on demersal fish
Mayer et al. 1991	Gulf of Maine, Maine	Shelf	20 m	Soft Sediment; mud	n/a	Ss_u	1, 0, 0, 1 (avg=0.5)	furrows in sediments several cm deep; no sig diffs in infauna inside and out	0, 0, 0, 0 (avg=0.0)	(no sig effects; short-term study)	sediment/benthos, cores; sampled inside and outside trawl track before and 1 da after
Rumohr & Krost 1991	Western Baltic Sea	Shelf	?	Soft Sediment; sand	n/a	Ss_u	1	observed shell damage to ocean quahogs	(not studied)	(short-term study)	samples of bivalves
Prena et al. 1996	Grand Banks, Canda	Shelf	?	Soft Sediment; sand	n/a	Ss_u	1, 2, 1 (avg=1.3)	25% decrease in epifauna biomass in trawled area; some damage to brittle stars and urchins; no effect on molluscs	1	(assumed "recovery" within 1 yr or minor effects)	sampled infauna, epifauna (sled) and observations
Schwinghamer et al. 1998 (physical effects); Prena et al. 1999 & Kenching-ton et al. 2001 (biological effects)	Grand Banks, New Foundland	Shelf	120-146 m	Soft Sediment; fine and medium sand	n/a	Ss_u	1, 1, 1, 2 (avg=1.3)	trawl marks visible, trawling smoothed the bottom, less hummocky; sig diffs in various epifauna characteristics	1	trawl marks gone after 1 yr;"little long-term effects on infauna"; (persistent?) decreases in sand dol-lars, brittle stars, crabs, urchins after trawling;	video observations, epibenthic sled, grabs; multiple samples over 3 yr period
Tuck et al. 1998	Scottish Sea, Scotland	Shelf	30-40 m	Soft Sediment; mud	n/a	Ss_u	1, 1, 1, 1 (avg=1.0)	species richness sig higher after 16 mo and throughout recovery 18 mo in fished areas; abundance higher then lower in fished areas	1	(minor sig but complex effects)	"biological surveys" of infauna, sampled after 5, 10, 16 mo after initiation of trawling, then 6, 12, 18 mo after end of trawling in fished and unfished areas
Fridd et al. 1999	North Sea	Shelf	55-80 m	Soft Sediment; mud, sand	n/a	Ss_u	1, 0, 1, 1 (avg=0.8)	heavy fishing decreased some taxa, but increased some opportunistic taxa - study started with a priori predictions and tested them by taxa	(not studied)	(study not directly designed to assess recovery, but did suggest persistence of benthos even with heavy trawling)	grab sampling over 27 yr period in fished areas
Bergman & Van Santbrink 2000	North Sea	Shelf	30 -50 m	Soft Sediment; sand, silty sand	n/a	Ss_u	1, 1, 1, 2 (avg=1.3)	mortality of various taxa ranged from 0 to 52%, with average about ~20%	(not studied)	(short-term study)	grab or corer(?); sampled before tow and within 2 days after
Hansson et al. 2000	Sweden	Shelf	75-90 m	Soft Sediment; clay	n/a	PC 915	1, 1, 1 (avg=1.0)	differential responses by taxa, but some decrease in most	(not studied)	(short-term study)	grab sampling before and 5-9 mo after trawling in area closed to fishing for 6 yr
McConnaughey, et al. 2000	eastern Bering Sea, Alaska	Shelf	44-52 m	Soft Sediment; sand	n/a	Ss_u	1	epifauna less abundant and less diverse in fished; infauna with mixed responses, some less	(not studied)	(study designed to fished vs unfished areas)	sampled epifauna with 34 m otter trawl
Moran & Stephenson 2000	northwest Australia	Shelf		Soft Sediment; sand(?)	n/a	Ss_u	2, 2, 2, 2 (avg=2.0)	benthic densities decreased exponentially with # tows, 4 tows=50% reduction	(not studied)	(short-term study)	video camera on sled; multiple samples over several days(?)

Sanchez et al. 2000	Catalan coast, Spain	Shelf	30-40 m	Soft Sediment; mud	n/a	Ss_u	1, 1, 0, 1 (avg=0.8)	minor sig diffs in some infaunal characteristics; furrows visible in side scan images	0	(minor sig effects; short-term study)	benthos, van Veen grab, side scan sonar; sampled over time after trawling (hrs): 0, 24, 102, 150
Drabsch et al. 2001	South Australia	Shelf	20 m	Soft Sediment; fine silt, sand	n/a	Ss_u	1, 1, 2, 2 (avg=1.5)	28% loss of epifauna; some infauna losses; board marks on seabed	(not studied)	(short-term study)	grab or corer(?); sampled before tows and within 3 wks after
							Mean = 1.1 **Std Err = 0.12** **n = 16**		**Mean = 0.6** **Std Err = 0.25** **n = 5**		
								Beam Trawls x Soft Sediment			
de Groot and Apeldoorn 1971	southern North Sea	Shelf	20 m	Soft Sediment; sand	n/a	Ss_u	2, 2, 2 (avg=2.0)	sessile organisms (e.g. hydroids, tube worms, bivalves, echinoids) badly damaged; mobile epifauna not affected	(not studied)	(short-term study)	diver observations
de Groot 1984	North Sea	Shelf	?	Soft Sediment; sand	n/a	Ss_u	2, 2, 1 (avg=1.7)	trawling removed "high numbers" of hydroids	(not studied)	(short-term study)	diver observations
Margetts & Bridger 1971	English Channel	Shelf	22 m	Soft Sediment; sand, mud/sand	n/a	Ss_u	1, 1, 1, 1 (avg=1.0)	left 15 mm deep furrows and smoothed bottom roughness in some areas	(not studied)	(short-term study)	underwater video; obs of physical effects only
Fonteyne 2000	Goote Bank, Belgium and Netherlands	Shelf	20-30 m	Soft Sediment; sand, silt	n/a	Ss_u	1, 1, 1, 1 (avg=1.0)	shallow furrows, sediment hardness affected	(not studied)	(short-term study)	side scan sonar, sediment physical measurements; made up to 52 hr after trawling
Bergman et al. 1990, Bergman & Hup 1992	North Sea	Shelf	30 m	Soft Sediment; sand	n/a	PC 915	1, 1, 2, 3 (avg=1.8)	up to 65% decrease in some epi and tube dwelling taxa, but no effect on many, some increased	(not studied)	(short-term study)	grab and trawl sampling of epifauna; sampled before and up to 16 hr after
Philippart 1998	North Sea	Shelf	variable	Soft Sediment	n/a	PC 915	1, 1, 2, 1 (avg=1.3)	beam trawl much more effective at catching large epifauna, up to 10x for some	(not studied)	(not designed to determine recovery level)	analyzed bycatch data as fishery changed trawl types
Kaiser & Spencer 1996, Kaiser et al. 1996, 1998, 1999	Irish Sea	Shelf	12-35 m	Soft Sediment; sand, sand with gravel and shell	n/a	Ss_u	1, 2, 2 (avg=1.7)	up to 54% reduction in species numbers and abundances in some areas; losses of epi- and infauna	0.5	differences between sites detectable only up to 6 mo	bottom sampling and observations over time (sampling schedule??)
Santbrink & Bergman 1994	North Sea, Netherlands	Shelf	?	Soft Sediment; very fine sand	n/a	Ss_u	2, 2, 2 (avg=2.0)	mortality of various taxa ranged from 4 to ~100%: echinoderms low, larger molluscs 12-85%, epifaunal crustaceans 30-74%, most annelids unaffected; fish scavengers attracted	(not studied)	(short-term study)	infauna sampling; compared before and after trawling
Jennings et al. 2001a, b	eastern North Sea	Shelf	40-75 m	Soft Sediment; mud to sand	n/a	Ss_u	2	in one area fishing intensity sig neg correlated with infaunal prod & biomass ("dramatic reductions"), no sig with epifauna; no sig correl in second area	(not studied)	(not designed to determine recovery level)	sampled epifauna with small beam trawl, infauna with anchor dredge
Jennings et al. 2002	central North Sea	Shelf	50-75 m	Soft Sediment; sandy, muddy sand	n/a	Ss_u	0	no sig relation between production of small infauna, esp polychaetes (assumed to be fish prey items)	(not studied)	(not designed to determine recovery level)	sampled infauna at nine sites with replicate NIOZ corer
Schratzberger et al. 2002a	North Sea	Shelf	39 and 59 m	Soft Sediment; muddy sand	na	Ss_u	1	some changes in meiofaunal community structure; no sig effects on diversity or biomass	0	(recovery assumed fast because only minor impacts)	sampled meiofauna with corer from 1 to 392 days post-exp trawling

Schratzberger et al. 2002b	North Sea	Shelf	59 m	Soft Sediment; mud, muddy sand	n/a	Ss_u	1, 0, 0, 1 (avg=0.5)	minor decreases at some sites attributed to trawling	(not studied)	(short-term study)	core sampling before and after trawling, meiofauna only
							Mean = 1.3 **Std Err = 0.19** **n = 12**		**Mean = 0.3** **Std Err = 0.25** **n = 2**		
<u>Shrimp Trawls x Soft Sediment</u>											
Ball et al. 1999	Western Irish Sea	Shelf	75 m	Soft Sediment; mud	n/a	Ss_u	1, 1, 2, 1 (avg=1.3)	fewer spp & abundances, and dominance by opportunists in fished area; many more spp & larger individuals of some taxa in unfished area	(not studied)	**This study attempted to show persistent differences due to continued trawling, which might be relevant for some management decisions.**	benthos, grab; sampled before and 24 hr after trawling at fished site
							Mean = 1.3 **Std Err =** **n = 1**		**Mean =** **Std Err =** **n =**		
<u>Otter Trawls x Hard Bottom</u>											
Auster et al. 1996; Lindholm et al. 1999	Gulf of Maine, Maine	Shelf	94 m	Hard; Boulder	n/a	She	3, 3, 3, 3 (avg=3.0)	abundances of several taxa "greatly reduced" or completely absent; boulders apparently moved	(not studied)	(not designed to determine recovery level)	submersible observation in 1987 and 1993, after 6 yr of trawling by large gear
							Mean = 3.0 **Std Err =** **n = 1**		**Mean =** **Std Err =** **n =**		
<u>Beam Trawls x Hard Bottom</u>											
Kaiser & Spencer 1994	Irish Sea	Shelf	32 m	Hard; Gravel, Cobble	n/a	She	2	density of epifauna reduced by 50%	(not studied)	(not designed to determine recovery level)	diver observations
							Mean=2.0 **Std Err =** **n = 1**		**Mean =** **Std Err =** **n =**		
<u>Otter Trawls x Biogenic, Sponges</u>											
Van Dolah et al. 1987	Atlantic, Georgia	Shelf	20 m	Biogenic; sponges and octocorals; Hard; gravel, cobble	n/a		2, 2, 3, 2 (avg=2.3)	heavy damage to barrel sponges, slight damage to corals	1	all epifauna recovered after 12 months	diver observations
Freese 2001	Gulf of Alaska	Shelf	~200 m	Biogenic; sponges	n/a		2	30% sponges badly damaged, 16% reduction in abundance; boulders moved and furrows in bottom	1.5	after 1 yr: 21% less sponges in trawl tracks, little recovery evident	submersible surveys immediately after trawling and 1 yr post
							Mean = 2.2 **Std Err = 0.15** **n =2**		**Mean = 1.3** **Std Err = 0.25** **n = 2**		
<u>Otter Trawls x Biogenic, Corals</u>											
Van Dolah et al. 1987	Atlantic, Georgia	Shelf	20 m	Biogenic; sponges and octocorals; Hard; gravel, cobble	n/a		1	heavy damage to barrel sponges, slight damage to corals	1	all epifauna recovered after 12 months	diver observations
							Mean = 1.0 **Std Err =** **n = 1**		**Mean = 1.0** **Std Err =** **n = 1**		
<u>Otter Trawls x Biogenic, Mussels</u>											
Magorrian 1995	Strangford Lough, Northern Ireland	Shelf	?	Biogenic; mussel beds (*Modiolus*)	n/a		1	mussel beds disconnected by trawling, reductions in epifauna	(not studied)	(short-term study)	side scan sonar
							Mean = 1.0 **Std Err =** **n =1**		**Mean =** **Std Err =** **n =**		
<u>Otter Trawls x Biogenic, Macrophytes</u>											
Guillen et al. 1994	Western Mediterranean	Shelf	?	Biogenic; seagrass meadow (*Posidonia*)	n/a		2	monitored seagrass densities	3	seagrass density had increased 6-fold after 3 years	noted 45% loss of seagrass meadows due to trawling

	Mean = 2.0 **Std Err =** **n = 1**		**Mean = 3.0** **Std Err =** **n = 1**		

Study Design & Gear Comments
compared lightly and heavily fished areas
?
otter trawl; area trawled repeatedly for one week
otter trawls used for prawns; compared before data after 20 yr of fishing
otter trawl, 18 m footrope, 90 kg doors, with tickler chains; one tow
otter trawl; experimental trawling
otter trawl; experimental trawling 12 times annually for 3 yr
otter trawl, Engel 145 with 1250 kg oval doors, 46 cm rockhopper gear; many experimental tows in area closed to fishing for 1 - 2 yr
otter trawl, no net, with rock hopper gear; experimental trawling in area closed to fishing for 30 yr, 1 tow per mo for 16 mo
otter trawls used for prawns; compared 27-yr series of data during light, mod, heavy fishing
otter tawl, (size?); single experimental sweep
otter (shrimp) trawl, 14 m groundrope, 125 kg boards; experimental trawling (# tows, etc?)
studied different areas representing unfished (closed) and heavily fished with otter trawls
otter trawl, (size etc?); experimenal trawling of short-term (days) multiple tows

otter trawl, (size etc?); experimenal trawling of one or two tows at multiple sites
otter trawl; experimental trawling in non-fished area
beam trawl; site hauled once
beam trawl; observations of immediate effects of trawl
beam trawl, 9.1 m wide; experimental trawling
beam trawl, 4 m wide with tickler chain; experimental trawling
beam trawl, 12 m, 7000 kg with ticklers; repeated exp trawling to cover study site 3 times
beam trawl vs otter trawl
beam trawl, 4 m, 3.5 tonnes with chain matrix; experimental tows, 10-12 passes
beam trawl; experimental trawling
studied two areas, each with wide range of intensities of beam trawling
sampled nine sites representing 17.5-fold range of beam trawling intensities (from 0.35 to 6.14 times/yr disturbance)
sampled two sites after 25 experimental tows with beam trawl

beam trawl, 4 m beam, 80 mm mesh and chain matrix; experimental trawling to simulate "lightly fished"
shrimp bottom trawl; "heavily" fished site vs unfished for 50 yr site near shipwreck
otter trawls, etc; assumed "large" trawl gear effects by before/after obs, 1987 & 1993
beam trawls; 10 hauls with 4 m and 3 hauls with 2 m beam trawls, catches compared
otter trawl, roller-rigged; area trawled once
experimental trawl tows with Nor'eastern bottom trawl with 0.45 m rockhopper discs
otter trawl, roller-rigged; area trawled once
otter trawls; pre- and post-impact study
otter trawls; studied recovery of seagrasses after trawling stopped by artificial reefs

DRAFT 6 - Table A1.3. Summary of references on impacts of **DREDGES** on **SHELF HABITATS**

Reference	Location	Megahabitat	Water Depth	Substrate Type	Macrohabitat	Habitat Code	Sensitivity Level	Sensitivity Comments	Recovery Level	Recovery Comments	Study Design & Sampling Methods
New Bedford/Scallop Dredges x Soft Sediment											
Caddy 1968	Northumberland Strait, Gulf of St. Lawrence, Canada	Shelf	20 m	Soft Sediment; mud, sand	n/a	Ss_u	1, 0, 1, 1 (avg=0.8)	2 cm deep tracks, ridges, dislodged shells in dredge tracks	(not studied)	(short-term study)	diver observations
Butcher et al. 1981	Jervis Bay, New South Wales, Australia	Shelf	13 m	Soft Sediment; sand	n/a	Ss_u	1, 1, 1, 1 (avg=1.0)	smoothed sand ripples	(not studied)	(short-term study)	diver obs of physical effects only
Langton and Robinson 1990	Fippennies Ledge, Atlantic, Maine	Shelf	56-84 m	Soft Sediment; silty sand, some gravel and shell	n/a	Ss_u	1, 2, 2, 2 (avg=1.8)	sediment coarser after dredging; disruption of amphipod tube mats	1.5	scallops, burrowing anemones, tube polychaets decreased significantly after dredging (1 yr?)	submersible obs and photos; before and 1 yr after
Mayer et al. 1991	Atlantic, Maine	Shelf	8 m	Soft Sediment; mud with sand, shell	n/a	Ss_u	1, 2, 1, 1 (avg=1.3)	decrease in fines and org content at surface, increase at 5-9 cm depth; sediment diatoms disrupted, microbial biomass increased after dredging	(not studied)	(short-term study)	core samples; sampled before and 1 day after tow
Eleftheriou and Robertson 1992	Scotland	Shelf	5 m	Soft Sediment; sand	n/a	Ss_u	1, 1, 1 (avg=1.0)	numbers increased with increasing tows, biomass decreased; some polychaetes, urchins and sand eels affected most	(not studied)	(short-term study)	sampled benthic fauna at 1-5 da and 9 da
Black and Parry 1994, 1999	Port Phillip Bay, SE Australia	Shelf	15 m	Soft Sediment; muddy sand	n/a	Ss_u	1, 1, 0, 1 (avg=0.8)	sediment plume; smoothing of seafloor; disturbance up to 6 cm deep in sediments	(not studied)	(short-term study?)	diver observations (?); short-term (?)
Thrush et al. 1995	Mercury Bay, New Zealand	Shelf	24 m	Soft Sediment; coarse sand; "high energy site"	n/a	Ss_u	1, 1, 1, 1 (avg=1.0)	smoothed ripples and infaunal tubes, tracks 2-3 cm deep; reduced densities of common taxa and taxa richness; some community-level changes	0.5	partial recovery after 3 mo in benthic community and pops of some dominant taxa	diver obs and core samples; before and up to 3 mo after dredging
Auster et al. 1996	Stellwagen Bank, Atlantic, Massachusetts	Shelf	20-55 m	Soft Sediment; sand with ripples	n/a	Ss_u	1, 1, 1, 2 (avg=1.3)	sand ripples smoothed, dispersal of shell	1	physical effects only; ripples restored by storms, within 1 yr (?)	side scan sonar surveys
Currie and Parry 1996, 1999	Port Phillip Bay, SE Australia	Shelf	15 m	Soft Sediment; muddy sand	n/a	Ss_u	1, 1, 2, 1 (avg=1.3)	smoothed sand ripples and biogenic mounds; tracks up to 25 cm deep; sig decreases in several taxa; inc in some opportunistic taxa	0.8	tracks gone after 6 mo, ripples re-formed 5 da after dredging after a storm; biogenic mounds re-formed after 6 mo; most spp recovered within 6 mo, some not after 14 mo; annual recruitment 6 mo after exp caused non-sig diffs in most pops	diver obs (?); infauna sampling; monitored up to 14 mo post dredging
Kaiser et al. 1996a	Irish Sea	Shelf	?	Soft Sediment; ? sand, ? gravel	n/a	Ss_u	1, 1, 1 (avg=1.0)	reduced abundances of most species; impacts of both gears similar	(not studied)	(short-term study)	"benthic" samples
Bradshaw et al. 2000	Irish Sea	Shelf	25-40 m	Soft Sediment; sand, mud, gravel	n/a	Ss_u	2, 1, 3, 1 (avg=1.8)	(apparently pops of many common taxa had been decreased by "towed gear" fishing)	?	many epifaunal spp increased significantly in abundance… including brittle stars, a spider crab, scallops, hermit crabs, one sea star	diver obs; multiple surveys over 10 yr period (1989-1998) after area closed to fishing - a long-term, observational "recovery" study
Bradshaw et al. 2001	Irish Sea	Shelf	25-40 m	Soft Sediment; sand, mud, gravel	n/a	Ss_u	1, 1, 0, 1 (avg=0.8)	some diffs in taxa (see recovery notes) but no sig differences in spp richness among plots	?	after 3-9 yr, encrusting epibenthic taxa more common in dredged areas, upright taxa more common in undredged; no sig diffs or clear trends for infauna	diver obs, grab samples 2 times annually for 10 yr (?)

Bradshaw et al. 2002	Irish Sea	Shelf	?	Soft Sediment; sand, gravel	n/a	Ss_u	2, 1, 3, 1 (avg=1.8)	taxa that decreased over time: brittlestars, hydroids, bryozoans, barnacles; taxa that increased: large tunicates, crabs, shrimp, lobsters, whelks, seastars; length of fishing time rather than fishing intensity most important	?	recovery level estimated by comparing areas fished at different intensities, over long-term	compared recent benthic data from 7 sites exposed to different levels of fishing effort to data collected 50-60 yr earlier when scallop fishing was limited
Alves et al. 2003	eastern Atlantic, southern Portugal	Shelf	7-9 m	Soft Sediment	n/a	Ss_u	1.5	significant decreases in abundance, taxonomic richness, and biomass; most <50% ?	(not studied)	(short-term study)	before-after experimental dredge tows in different seasons; core and quadrat samples of meio- and macroinfauna
Gaspar et al. 2003	eastern Atlantic, southern Portugal	Shelf	5-12 m	Soft Sediment; sand, sandy mud	n/a	Ss_u	1	"damage and mortality relatively low"; scavengers attracted to site	(not studied)	(short-term study)	experimental tows with dredge; sampled immediately after and up to 24 hr after
Sullivan et al. 2003	Atlantic, New York Bight	Shelf	45-88 m	Soft Sediment; sand	n/a	Ss_u	0	no sig diffs in any areas	0	some short-term increase in juvenile fish recruits, but no diffs in other metrics (except those related to storm events)	underwater video surveys of seabed; suction sampling of infauna; beam trawl sampling of young-of-year flatfish
							Mean = 1.2 Std Err = 0.10 n = 16		**Mean = 0.8 Std Err = 0.25 n = 5**		
							Hydraulic Dredges x Soft Sediment				
Meyer et al. 1981	Atlantic, New York	Shelf	11 m	Soft Sediment; silty sand	n/a	Ss_u	1, 0, 1, 1 (avg=0.8)	20 cm deep trenches formed; attracted predators preying on damaged and exposed infauna	0.1	within 24 hr predator numbers appeared back to normal; (no data on recovery of infauna)	diver observations
MacKenzie 1982	Atlantic, New Jersey	Shelf	37 m	Soft Sediment; fine to medium sand	n/a	Ss_u	0, 0, 0, 0 (avg=0)	no sig diffs in any areas	0	designed to estimate recovery by comparing areas with different fishing intensities; "no lasting effcts…"	sampled benthic infauna in areas with diff fishing levels: none, active for 2 yr, fished then abandoned (for ?? yr)
Medcof and Caddy 1971	Southern Nova Scotia	Shelf	7-12 m	Soft Sediment; sand, sand-mud	n/a	Ss_u	1, 1, 1, 1 (avg=1.0)	physical effects only; avg 20 cm deep furrows by hydraulic, 3-10 mechanical	(not studied)	(short-term study only)	diver and manned submersible observations
Murawski and Serchuk 1989	mid-Atantic, NJ-NY	Shelf	?	Soft Sediment; mud, sand, gravel	n/a	Ss_u	1, 1, 1, 1 (avg=1.0)	trenches cut, deeper by hydraulic dredge; sand dollars, crustaceans, worms "substantially disrupted"; attraction of sea stars, fish to trenches	(not studied)	(short-term study only); sand dollars appear to recover quickly	manned submersible observations
Pranovi and Giovanardi 1994	Venice Lagoon, Adriatic Sea, Italy	Shelf	1.5-2 m	Soft Sediment;	n/a	Ss_u	1, 1, 1, 1 (avg=1.0)	8-10 cm deep furrows; some sig decreases in infauna, non-sig in some areas	0.3	densities recovered in 2 mo, but not biomass	sediment/infauna samples by divers; sampled immediately after tows, 3-wk intervals for 2 mo
Tuck et al. 2000	Outer Hebrides, Scotland	Shelf	2-5 m	Soft Sediment; fine to medium sand; (tidal currents up to 3 knots in area)	n/a	Ss_u	1, 1, 1, 1 (avg=1.0)	sediment fluidized to 30 cm depth; sig decrease in infaunal spp richness and total abundances, polychaetes most affected	0.2	benthos "recovered completely" within 11 wks	core samples, diver observations, video; sampled before, during, and up to 11 wks after tows
							Mean = 0.8 Std Err = 0.16 n = 6		**Mean = 0.2 Std Err = 0.06 n = 4**		
							New Bedford/Scallop Dredges x Hard				
Caddy 1973	Chaleur Bay, Gulf of St. Lawrence, Canada	Shelf	40-50 m	Hard (Mixed); sand over gravel, some boulders	n/a	She	3, 2, 2, 3 (avg=2.5)	rocks overturned, dislodged or plowed along bottom	(not studied)	(short-term study)	manned submersible observations

Collie et al. 1996, 1997	Georges Bank, Massachusetts	Shelf	?	Hard; gravel pavement	n/a	She	2, 0, 2, 1 (avg=1.3)	unfished areas with more epifauna, higher densities, species numbers and biomass of some infauna; different species composition also	(not studied)	best interpreted as study of chronic effects of different fishing intensities	observations and benthic samples; assessed cumulative impacts of scallop dredging by comparing fished to unfished sites
Veale et al. 2000	Irish Sea	Shelf	20-67 m	Hard (Mixed); sand overlain by pebbles, cobble, boulders, shell	n/a	She	1, 1, 2, 1 (avg=1.3)	decreases in spp diversity and total abundances with increasing fishing effort	(not studied)	best interpreted as study of chronic effects of different fishing intensities	compared bycatch from fishing grounds exposed to different fishing intensities
							Mean = 1.7 Sts Err = 0.40 n = 3				
							New Bedford/Scallop Dredges x Biogenic, Shellfish				
Brown 1989	Strangford Lough, Northern Ireland	Shelf	?	Biogenic; mussel (*Modiolus*) beds	n/a		1	mussels are bycatch in dredges	?	concern that it would take "extended period" for recovery	compared benthic survey data from before and after initiation (8 yr) of scallop fishery
							Mean = 1.0 Std Err = n = 1		**Mean = Std Err = n =**		
							New Bedford/Scallop Dredges x Biogenic, Macrophytes				
Hall-Spencer and Moore 2000	Clyde Sea, Scotland	Shelf	10-15 m	Biogenic (maerl); calcareous red algae, sand, mud, cobble, boulders	n/a		3, 3, 2, 3 (avg=2.8)	rocks overturned, dislodged or plowed along bottom; tracks still visible after 2.5 yr in some areas; damage to many taxa	5	epifauna most impacted, infauna less so; taxa with regular recruitment recovered most quickly; some large epifauna did not recover after 4 yr	video monitoring by divers 2-4 times per year for 4 yr
							Mean = 2.8 Std Err = n = 1		**Mean = 5 Std Err = n = 1**		

Study Design & Gear Comments
New Bedford scallop dredge, 2.4 m wide, 0.36 m height, chain sweep, no teeth; obs in fished area
toothed scallop dredge
New Bedford scallop dredge; obs made in area with "heavy commercial dredging"
New Bedford scallop dredge; one experimental tow
scallop dredge; several tows over same track for 9 days
toothed scallop dredge; experimental towing repeatedly over 3-da periood in area not fished for 3 yr
toothed scallop dredge; experimental dredging at 2 sites, one fished
New Bedford scallop dredge; experimental tows
toothed scallop dredge; experimental towing repeatedly over 3-da period in area not fished for 3 yr
scallop dredge and beam trawl, experimentally fished together; 10 tows of each
commercially dredged area closed to fishing in 1989
scallop dredge; experimental dredging in and out of closed area (since 1989), and control sites; 10 tows along each line every 2 mo for 5 yr

(studied area mostly impacted by scallop dredging; see Sampling Methods notes)
Portugese toothed clam dredge (similar impact to scallop dredge?)
"commercial dredge" (clam dredge as Alves et al 2003?)
pre- and post-impact (up to 1 yr) study of experimental scallop dredging (New Bedford style, 4.6 m) at multiple sites including some in closed areas
hydraulic dredge, 4 ft wide; experimental tows in surf clam bed
hydraulic dredge; active ocean quahog fishing areas
hydraulic dredges and toothed mechanical dredges; experimental tows
hydraulic and scallop dredges; experimental tows
hyrdaulic dredge, 2.7 m wide; experimental tows inside and outside commercial fishing areas
hydraulic dredge; experimental tows
New Bedford scallop dredge, 2.4 m wide, 0.36 m height, chain sweep, no teeth, 1300 lbs; obs in fished area

(studied area mostly impacted by scallop dredging; see Sampling Methods notes)
(studied area mostly impacted by scallop dredging; see Sampling Methods notes)
scallop dredging; reivew paper assessing survey data
toothed scallop dredge; experimental dredging in area fished for 40 yr and unfished area

DRAFT 6 - Table A1.4. Summary of references on impacts of **MULTIPLE MOBILE GEARS** (DREDGES, TRAWLS, etc) on **SHELF HABITATS**

Reference	Location	Megahabitat	Water Depth	Substrate Type	Macrohabitat	Habitat Code	Sensitivity Level	Sensitivity Comments	Recovery Time (years)	Recovery Comments	Study Design & Sampling Methods	Study Design & Gear Comments
Multiple gears (trawls+dredges) x Soft Sediment												
Hall et al. 1993	Turbot Bank, North Sea	Shelf	80 m	Soft Sediment; coarse sand	n/a	Ss_u	0, 0, 0, 1 (avg=0.3)	no sig differences in benthos, except associated with sediment characteristics	(not studied)	n/a	sampled along gradient of fishing intensity based on distance from shipwrecks; grab sampling	otter trawls and dredges mainly
Auster et al. 1996	Swans Island Cons Area; Gulf of Maine	Shelf	30-40 m	Soft Sediment; sand, shell, cobble	n/a	Ss_u	2, 1, 2, 2 (avg=1.8)	some epifauna and biogenic structure such as depressions and debris less common outside cons area	(not studied)	(sensitivity comments also relevant here, but no easy way to quantify?)	in vs. out of Cons. Area closed for 10 yr; ROV, video transects	otter trawls and dredges mainly
Auster et al. 1996	Stellwagen Bank, Massachusetts	Shelf	32-43 m	Soft Sediment; sand, shell	n/a	Ss_u	1, 1, 2, 1 (avg=1.3)	loss of some hydroids, algae, and shrimp by fishing gear	(not studied)	n/a	ROV observations	otter trawls and dredges mainly
Thrush et al. 1998	Hauraki Gulf, New Zealand	Shelf	17-35 m	Soft Sediment; mud, sand	n/a	Ss_u	2, 1, 2, 1 (avg=1.5)	various changes to infauna (spp #, densities), and density of large epifauna; overall 15-20% of differences attributed to fishing	(not studied)	n/a	sampled 18 sites over wide gradient of fishing intensity; sampled with video, corer, grab, dredge	otter trawls and dredges mainly?
Almeida et al. 2000	Closed Area II, Georges Bank, Massachusetts	Shelf	?	Soft Sediment; sand	n/a	Ss_u	1, 0, 1, 1 (avg=0.8)	some fish spp more abundant inside; scallops larger inside; sponges more abundant inside; other benthic characters similar	(not studied)	(sensitivity comments also relevant here, but no easy way to quantify?)	in vs out after 4.5 yr closed; sampling of seabed, fish, and observations	otter trawls and dredges mainly
Collie et al. 2000	Georges Bank, Massachusetts	Shelf	42-90 m	Soft Sediment; sand (also gravel, see below)	n/a	Ss_u	1.5	colonial epifauna "conspicuously less abundant" in fished areas	(not studied)	(not designed to assess recovery)	compared fished vs non-fished areas; analyzed video and still photos of seabed in both areas	trawls and scallop dredges
Kaiser et al. 2000b	Devon coast, England	Shelf	15-70 m	Soft Sediment; fine to coarse sand	n/a	Ss_u	2, 1, 2, 1 (avg=1.5)	sig differences in some epi- and infauna among areas related to fishing; higher biomass and abundances of hydroids, soft	(not studied)	(sensitivity comments also relevant here, but no easy way to quantify?)	compared areas of high, medium and low fishing intensity; sampled with grab, beam trawl, dredge	otter trawls and dredges mainly
							Mean = 1.2 **Std Err = 0.20** **n = 7**		**Mean =** **Std Err =** **n =**			
Multiple gears (trawls+dredges) x Hard Bottom												
Valentine and Lough 1991	Georges Bank, Massachusetts	Shelf	?	Hard Bottom; gravel and sand	n/a	She	2, 1, 2, 2 (avg=1.8)	unfished areas with boulders had abundant epifauna; smoother bottom and sparse epifauna in fished areas	(not studied)	n/a	correlated impacts with evidence of gear impacts on seabed; side scan sonar and submersible observations	otter trawls and dredges mainly
Auster et al. 1996	Swans Island Cons Area; Gulf of Maine	Shelf	30-40 m	Hard Bottom; shell, cobble	n/a	She	2, 2, 2, 2 (avg=2.0)	some epifauna and biogenic structure such as depressions and debris less common outside cons area	(not studied)	(sensitivity comments also relevant here, but no easy way to quantify?)	in vs. out of Cons. Area closed for 10 yr; ROV, video transects	otter trawls and dredges mainly
Collie et al. 1997	Georges Bank, Massachusetts	Shelf	40-90 m	Hard Bottom; gravel, cobble	n/a	She	1, 0, 2, 2 (avg=1.3)	closed area had higher numbers, biomass and species richness; closed area also had more "bushy" organisms, giving more structure to bottom	(not studied)	(sensitivity comments also relevant here, but no easy way to quantify?)	in vs. out of area closed to fishing	scallop dredges, otter trawls
Collie et al. 2000	Georges Bank, Massachusetts	Shelf	42-90 m	Hard Bottom; gravel (also soft sediment, see	n/a	She	1	colonial epifauna "conspicuously less abundant" in fished areas	(not studied)	(not designed to assess recovery)	compared fished vs non-fished areas; analyzed video and still photos of seabed in both areas	trawls and scallop dredges
							Mean = 1.7 **Std Err = 0.16** **n = 4**		**Mean =** **Std Err =** **n =**			

DRAFT 6 - Table A1.5. Summary of references on impacts of **POTS AND TRAPS** on **SHELF HABITATS**

Reference	Location	Megahabitat	Water Depth	Substrate Type	Macrohabitat	Habitat Code	Sensitivity Level	Sensitivity Comments	Recovery Time (years)	Recovery Comments	Study Design & Sampling Methods	Study Design & Gear Comments
Pots and Traps x Biogenic, Shellfish												
Eno et al. 2001	Great Britain	Shelf	14-23 m	Biogenic; mud with sea pens	n/a		1, 0, 1, 1 (avg=0.8)	bending and uprooting of sea pens	0.1	sea pens recovered within 6 da	diver observations	experimental setting and retrieval of pots at one site
							Mean = 0.8 SE = n = 1		**Mean = 0.8 SE = n = 1**			
Pots and Traps x Hard Bottom												
Eno et al. 2001	Great Britain	Shelf	14-23 m	limestone slabs, boulders	n/a	She	1, 0, 0, 1 (avg=0.5)	bending of sea pens	0, 0, 0 (avg=0.0)		diver observations	experimental setting and retrieval of three types of pots at one site
Eno et al. 2001	Great Britain	Shelf	14-23 m	rock	n/a	She	0, 0, 0, 0 (avg=0.0)	no damage	0, 0, 0, 0 (avg=0.0)	n/a	diver observations	experimental setting and retrieval of pots at five sites
							Mean = 0.3 SE = 0.3 n = 2		**Mean = 0.0 SE = 0 n = 2**			

DRAFT 6 - Table A1.6. Summary of references on impacts of **TRAWLS** on **SLOPE HABITATS**

Reference	Location	Megahabitat	Water Depth	Substrate Type	Macrohabitat	Habitat Code	Sensitivity Level	Sensitivity Comments	Recovery Time (years)	Recovery Comments	Study Design & Sampling Methods	Study Design & Gear Comments
Otter Trawls x Soft Sediment												
Cryer et al. 2002	Western Bay of Plenty, New Zealand	Slope	205-595 m	Soft Sediment; mixed, mostly soft-bottoms	Slope, Soft Sediment	Fs_u	1	fishing intensity negatively correlated with species richness and density of 15 spp, but positively to 6 spp, mostly opportunistic scavengers; overall 11-40% of changes attributed to fishing	(not studied)	Not studied - rather, the relation of benthic invert communities to different intensities of fishing was studied	66 research trawls in areas with known different fishing intensities	otter trawls used to catch demersal fish and lobsters (scampi)
							Mean = 1.0 Std Err = n = 1		**Mean = Std Err = n =**			
Otter Trawls x Hard Bottom												
Otter Trawls x Biogenic, Sponges												
Freese et al. 1999	eastern Gulf of Alaska	Slope	206-274 m	Hard Bottom; pebble, cobble, boulders	Slope, Hard, Biogenic, Sponges		3	boulders displaced; large epifauna removed or damaged; sig decreases in sponges and anthozoans but not in motile invertebrates	(not studied)	(not studied)	8 tows; manned submersible observations and video along trawl path	Nor'eastern trawl rigged with rockhopper roller gear
Koslow et al. 2001	Pacific Ocean, southern Tasmania	Slope (seamounts)	660-1700 m	Mixed Hard Bottom; ranging from mud to rock	Slope, Hard, Biogenic, Sponges (and corals)		3	trawling had "effectively removed the reef aggregate" organisms	(not studied)	(not studied)	Differences between fished areas and unfished areas (MPA?) sampled; sampled seabed with Lewis dredge, photos along transects, droplines and traps;	trawls (otter?) for orange roughy fishery
							Mean = 3.0 Std Err =0.0 n = 2		**Mean = Std Err = n =**			
Otter Trawls x Biogenic, Corals												
Koslow et al. 2001	Pacific Ocean, southern Tasmania	Slope (seamounts)	660-1700 m	Mixed Hard Bottom; ranging from mud to rock	Slope, Hard, Biogenic, Corals (and sponges)		3	trawling had "effectively removed the reef aggregate" organisms; large bycatches of corals noted early on in fishery by fishermen	(not studied)	(not studied)	Differences between fished areas and unfished areas (MPA?) sampled; sampled seabed with Lewis dredge, photos along transects, droplines and traps;	trawls (otter?) for orange roughy fishery
Krieger 2002	Gulf of Alaska	Slope	260, 365 m	Hard Bottom; pebble, cobble, boulders	Slope, Hard, Biogenic, Corals		3	moved boulders, broken corals common in trawl path	> 7	5 of 13 large coral colonies still missing >95% of branches; 27% of corals in path detached; no young corals had re-populated the trawled area	manned submersible observations and video in 1997, 7 years after a 1990 otter trawl tow	Nor'eastern trawl rigged with rockhopper roller gear, 998 kg doors, ~15 m spread; trawl had removed large quantities of deepwater corals

Appendix 11

Pilot Project to Profile West Coast Fishing Effort based on the Practical Experience of Fishermen

Final Report

Pilot Project to Profile West Coast Fishing Effort Based on the Practical Experience of Fishermen

A collaborative project by members of the commercial fishing community, the fisheries management community, and the scientific community:
Tim Athens
Allison Bailey
Flaxen Conway
Steve Copps
Randy Fisher
Marion Larkin
Scott McMullen
Fran Recht

Report submitted by
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January 13, 2004

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Section 1 - Background and Rationale

The ad hoc Groundfish Habitat Technical Review Committee (TRC), was created by the Pacific Fishery Management Council (Council) to review and guide the scientific assessment process for the Pacific Groundfish Essential Fish Habitat Environmental Impact Statement (EFH EIS).

To evaluate the status of habitat, a "risk assessment methodology" is being developed with oversight from the TRC. [1] A graphical description of the process for determining Essential Fish Habitat and associated conservation policies is included in appendix 1. One of the elements considered in this risk assessment is the amount and location of fishing effort over time.

The TRC, at their February 19-20, 2003 meeting, reviewed the results of a fishing effort model that was produced for the Pacific State Marine Fisheries Commission (PSMFC) by Ecotrust. The TRC was concerned about some of the assumptions in the model and recommended that, among other comparisons, experience-based information from fishermen be compiled for comparison with the Ecotrust product.

The methodology for responding to the TRC direction is described in the following sections. It was derived through an experimental process in which an initial pilot project was carried out in Washington State and then reviewed by the Council (and committees) and others with appropriate expertise in fisheries, management, and social sciences. The ultimate study design is the result of collaboration between PSMFC, NOAA Fisheries, Oregon Sea Grant, and commercial fishing representatives from the three coastal states. Final review and endorsement for this methodology was given by the TRC on August 4, 2003.

There are three main objectives for this pilot project:

Objective 1: To gather and produce a compilation of experienced-based information to indicate fishing effort location by gear type for areas off the West Coast over time.

Objective 2: To design and conduct this project collaboratively as a partnership with the fishing community, the fisheries management community, and the scientific community.

Objective 3: Gain experience in developing useful products for application in fisheries management that are based entirely on experience-based information.

Although the TRC recommendation focused on developing a product for comparison with the Ecotrust data, this project was designed to develop a discrete data set that could potentially be used independently. The results will be subjected to the scrutiny of the Council system (including the TRC and Scientific and Statistical Committee) and may potentially become part of the universe of available fishing effort data that, among other things, includes logbooks, observer data, and the Ecotrust model.

Section 2 - Project Design and Methodology

2.1 - Collaborative Design

This project was designed collaboratively. Collaboration has been defined as the "pooling of appreciations and resources by two or more stakeholders to solve a set of problems which neither can solve individually (Howell 1982)." The problem in this case was to not only gather experience-based information on fishing effort, but also to produce a scientifically defensible product that truly represented the experience of fishermen and would/could be useful to fishery managers. An addition goal was to conduct the project in a manner that built or strengthened relationships between all partners.

The collaborative team that was assembled for this project included representatives from the fishing, scientific, and management communities. To account for coastal diversity, stakeholders within the commercial fishing community were further stratified by geographic consideration. A collaborative team was developed to include these stakeholders as follows:

Commercial Fishing Community - Marion Larkin, Washington; Scott McMullen, Oregon; and, Tim Athens, California. Taken together, each of the three coastal states is represented. These fishermen sit on the TRC by appointment from their respective State fisheries agencies based on their representative knowledge of the fishing industry in their geographic area of expertise.

Scientific Community - Allison Bailey, Senior GIS Analyst, TerraLogic GIS; Flaxen Conway, Extension Community Outreach Specialist, Oregon Sea Grant; Randy Fisher, Executive Director, Pacific States Marine Fisheries Commission, Fran Recht, Habitat Program Manager, Pacific States Marine Fisheries Commission.

Fisheries Management Community - Steve Copps, Senior Policy Analyst, NOAA Fisheries, Northwest Region.

The collaborative team held a series of meetings to refine the objectives of the project and develop a responsive process. An initial work plan and preliminary results from the pilot project that was conducted for areas north of Destruction Island, trawl gear only, were presented at the June, 2003 Council meeting (see appendix 6). Following this meeting, the collaborative team was expanded to include the members listed above.

The collaborative team reformulated the work plan based on the experience gained during the initial pilot project and input gained during review. At their August 4, 2003 phone conference meeting, the TRC agreed that the project should continue based on the methodology described in this document. Due to funding limitations, the project would be initiated in a limited geographical area (the area chosen represented that covered by one nautical chart that spanned the distance from Yaquina Bay to the Columbia River in Oregon [NOAA chart number 18520]). Expansion of the project will be considered in light of TRC and Council comments on the results and based on available funds.

2.2 – Fishing Effort Information Gathered

This project was designed to gather information on four parameters / fundamental elements that describe fishing effort: time, gear type, area, and intensity. The focus session approach described in the following sections is time consuming and necessitates significant pre-planning to ensure that basic goals are met within allotted time and budget. To account for this, and in consideration of the overall goals of the EFH analysis, categories were established within each of the elements that were thought to be most representative of broad patterns of fishing effort. Of particular concern for this study is the need to produce comparable results from different areas of the coast with different fleet characteristics. The categories were chosen based on the collective experience of the collaborative team and the comments received through review.

Time

Information on time was focused into three time periods or "eras." The time periods chosen by the team were those that corresponded to the relative levels of trawl regulation that has influenced effort patterns:

Era #1 = 1986-1999 (least regulations)
Era #2 = 2000-2002 (more regulations)
Era #3 = 2003 – present (most regulations)

We speculated that it might be difficult for any group to focus their attention on such a wide range of years. The facilitator and lead fisherman consultant asked the group of fishermen consultants to come up with a "representative" or "average" year within each era.

Additionally it was anticipated that in order to think about fishing effort, it might be necessary to talk about season differences. The collaboration team was unsure if each of these representative / average years needed to be split into two or three seasonal periods: winter and summer, or winter, summer, and the transitional season (fall/spring). Once again, the facilitator led the fishermen consultant group through a process to define appropriate seasons to discuss each gear type. Each era was subdivided to reflect seasonal variation in effort patterns by:

Winter
Summer
Transition (spring and fall)

Gear Type

Information on gear type was focused into trawl gear and fixed gear and further subdivided into 7 gear types. Gear types were chosen based on fisheries that have been prosecuted within the study area. It should be noted that the gear types could have been further divided. The collaborative team decided that these listed gear types best corresponded to the level of information we currently have on gear effects. Also, this list would likely be different if expanded into other regions. Lastly, during the focus sessions, the fishermen consultants found it useful to add information on the target species, which was recorded and is shown in the results section of this report within the tables under the "habitat/fishery" column and in the focus session flipchart notes.

Trawl Gear
- large foot rope [groundfish]
- small foot rope [groundfish]

pelagic [pelagic rockfish excluding hake]
pink shrimp

Fixed Gear
bottom long line
pot gear
- crab pot
- groundfish pot

Area
It should be noted that the fishermen consultants were not asked to provide proprietary information at the level of the individual tow or set. Rather, they were to capture the broad area patterns they experienced the fleet working in and would best reflect the other information parameters such as gear type, time, and intensity.

The project's end product was to be a variety of areas drawn on the nautical chart maps (and available electronically through the GIS database). These mapped areas would represent the fishermen consultants' knowledge of where fishing effort had occurred during the various time periods or seasons for the various gear types. These areas, called 'polygons,' would likely be discrete areas of different sizes and shapes and would not be limited to statistical area grids normally used to capture fishing effort information. Rather, they would likely coincide with depth contours, bottom types, or other factors that represent fishermen's experiences and observations.

Other than being restricted to the NOAA chart that defined the study area, the fishermen consultants were given complete freedom to define the areas in which fishing took place. The fishermen consultants were provided with several copies of the same NOAA chart they typically use for navigation and selection of fishing areas on the north coast of Oregon. They were asked to use the information on the chart (bathymetry, lat/long) to recollect and draw in the areas where the fleet fishes (stratified by gear type, era, and intensity). The information was drawn on transparent chart overlays and later input into GIS.

Intensity
While the project was primarily designed to collect spatial information about fishing effort, an attempt was made to collect information about the intensity of fishing effort for each gear type as it related to the areas fished. Each map created would display this information as well.

It is important to note that because of practical limitations on this project, it was unrealistic to expect to get detailed information down to the level of "the number of tows per year for a given area," etc. Rather, to achieve the overall goals of the project, we gathered information on one factor (which we called "c"; see directly below) of intensity -- an estimate of the average number of boats per day for that season, for that gear type in that polygon.

We also, where possible, gathered information that could -- at a later date -- further flesh out the concept of intensity. For example, we assumed that an improved estimate of intensity might be the product of three factors (a x b x c) where, *say for the trawl fleet,*

a = average length of tow each fleet makes (a constant figure; noting the normal range),

b = average number of tows per day each fleet makes (a constant figure; noting the normal range), and
c = the average number of boats per day for the season in each polygon (a variable figure; noting the normal range when possible).

Similar, but fixed-gear-appropriate parameters were used for that fleet. The specific questions that the fishermen consultants were asked in order to gain information on effort intensity is described more fully in Appendix 9.

2.3 Preparing for the Focus Sessions

The collaborative team established a multi-step process to gather and process the information. This process began with the selection and recruitment of fishermen consultants, continued with structured group focus sessions, and culminated in a set of independent GIS data layers.

Selection and Recruitment

The selection and recruitment process consisted of identifying and procuring the services of appropriate fishermen consultants to participate in the project. This was a three-step process: identification and screening, making initial contact, and validating commitment to participate.

These fishermen consultants functioned as our key informants (Bernard, 2002) - people who were highly knowledgeable about commercial fishing operations and locations, and who were willing and able to share the information necessary.

Screening criteria were developed by the collaborative team to ensure that the sum total of the fishermen consultants who provided the information on fishing effort represented a large body of knowledge and experience, and were willing and able to function appropriately to achieve the goals of the project. The screening criteria were:

- must be practical experts who can speak from their own experience and knowledge;
- must have roughly 20 years experience in commercial fishing on the west coast, with a high percentage of this experience gained within the region they are supplying information on;
- must have good practical knowledge of the fleet's operations (know the area, know the gear types, know the fisheries);
- must be able to work well with others in a small but diverse group; and,
- must possess a willingness to participate openly and honestly and have an ability to follow through with this project.

A list of potential key informants was derived from a list of federal groundfish permit holders (obtained from the NMFS web site) and other sources. The lead fisherman consultant then worked through the list for the best fit based on the screening criteria, professional knowledge, and references from other key informers within the region.

The lead fisherman consultant made initial contact, by phone or in person, with approximately 45 fishermen who fit the criteria. Due to the nature of commercial fishing, most contact was made outside of the typical 9-5 workday and often resulted in leaving messages and follow up calls. Once contact was established, the potential recruit was presented with a quick summary of the project background and rationale, and the selection criteria and why they were being asked to serve as a fisherman consultant. The discussion that followed allowed an assessment of that person's interest in participating. If there was interest, the call was completed by providing information about compensation, gathering correct contact information, and explaining the next steps.

The third step involved the mailing of the recruitment package and a follow up call or visit. The recruitment package included a personalized letter from the lead fisherman, a 3-page summary of the project, a sample map (that showed arbitrarily drawn fishing areas), and a contract for them to sign (a formal agreement with the PSMFC documenting that they would be paid consultants, met the screening criteria, and would abide by the standards established for the project). The follow-up calls were used to go over the project design, the location of the meeting, and the expectations.

Group Focus Session Approach

The collaborative team made the decision to use a group focus session methodology instead of other available techniques such as conducting individual interviews with fishermen. A group focus session is a tool developed by social scientists to collect information from a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research (Powell et. al. 1996, Butler et. al. 1995). Group interviews and focus sessions have been used by many researchers over the years to collect information on reported experiences, obtain information about complex topics, discover new research questions, explore a range of perceptions regarding a topic, and generate feedback from others in the group (Agar 1995, Bloore et al. 2001, Trotter and Schensul 1998). Rigorous standards and protocols were developed to discipline the focus sessions and are discussed in the sections that follow.

Specific roles and responsibilities were assigned prior to focus sessions to ensure that the right information would be gathered according to proper technical specifications and that the information could be gathered consistently among group focus sessions from diverse areas of the coast. The roles were:

Fishermen Consultant: Responsible for supplying experience-based knowledge according to parameters defined for the project. Requisite skills are described above. Twenty-five Oregon fishermen fulfilled this role.

Lead Fisherman Consultant: Responsible for selection and recruitment and supporting the facilitator in presenting information on the overall goals of the project. During the trawl focus session the Lead Fisherman Consultant also supplied his own experience-based information on fishing effort along with the other fishermen consultants. Scott McMullen fulfilled this role.

Recorder: Responsible for providing appropriate charts and digitizing the information supplied by the fishermen consultants. The recorder was required to be technically proficient with GIS and have sufficient knowledge about the information parameters and fishery as to allow for fluent and timely transcription of consultant input into GIS. A key role played at the focus sessions was to listen and observe, allowing for accurate and thorough digitizing later. Allison Bailey fulfilled this role.

Facilitator: As the process designer and manager of the focus sessions, the facilitator had the ultimate responsibility to make sure that the information gathered from the group focus sessions was done in a consistent manner according the standards and protocols of the project design. The facilitator was required to be knowledgeable about the goals of the project; skilled at listening and extracting relevant information; clear at explaining how the session would work; good at managing the process; and good at developing and maintaining a rapport with the group (trusted). The facilitator was responsible for maintaining neutrality, drawing out diverse perspectives, and keeping the conversation on course. Flaxen Conway fulfilled this role.

Other Roles: The project manager for the EFH EIS was at the group focus session to respond to group questions regarding project goals and potential outcomes of the EFH EIS or other sources of effort information. Steve Copps fulfilled this role.

<u>Consistency Standards</u>
An important goal of the project was to achieve accurate and comparable results from multiple and potentially diverse group focus sessions should the geographic extent of the project be expanded. Fishermen consultants at all the focus groups were required to have a similar understanding of the project that included the objectives and protocols for participation. They were required to provide information openly and honestly and according to pre-established standards. To achieve these aims, the collaborative team derived a set of directions that each of the fishermen consultants was on briefed during recruitment and again during the focus session. The intent of these 'up-front' preparations was to fully disclose the standards before information on fishing effort was shared and assure that no "new" directions be delivered while the sessions were in progress (see Appendix 4).

<u>Geographical Distribution</u>
In order to test the conceptual underpinnings of the methodology, and in consideration of the broader time and budget constraints of the EFH EIS, the project was carried out on a relatively small scale. Ideally, the project would be completed for the entire coast to match the geographic extent of the EFH work and the Ecotrust product. However, we began with the area represented by NOAA Chart 18520, the northern most NOAA chart for Oregon, covering the area between Yaquina Bay and the Columbia River.

<u>Group Focus Sessions by Gear Grouping</u>
The collaborative team determined that completing the effort and intensity information for one full chart for each of the seven gear types would not be feasible within an eight-hour day. Gear types were broken into two broad categories of "trawl" and "fixed gear" (bottom longline and pot). A full day was allocated for each gear category.

2.4 Gathering and Processing the Information
The multi-step process that resulted in fishermen's information being recorded and transformed to a digital product is described in this section.

<u>Group Focus Sessions Implementation</u>
The agenda for each focus session was the same:

Welcome, Introductions	*Lead Fishermen Consultant (LFC)*
Today's Session	*Facilitator*
Quick Refresher on this Project	*LFC and Facilitator*
Assumptions / Definitions	*Facilitator and All*
Mapping & Intensity	*Facilitator, Recorder, and All*
What Happens with this Info	*LFC, Facilitator, and EFH EIS Project Manager*
Session Evaluation	*Facilitator*

The "welcome and introductions" topic followed the Lead Fishermen Consultant's "talking points" (see Appendix 2). The "today's session" topic consisted mostly of housekeeping, previewing the day's process, and going over the session ground rules. The "quick refresher on this project" topic reviewed the recruitment package information and visit.

The "assumptions and definitions" topic was designed to give the fishermen consultants an opportunity to further define the information categories that would be used throughout the day. In a facilitated discussion, the fishermen consultants defined the information categories in order to stabilize the terms they would use to categorize the information they would provide.

This facilitated discussion led the group through a series of questions:

1. What do you mean when you say a "representative or average year" within each of the three eras? For example, give us some characteristics of what you will be thinking of when you think about the fleet during the era and drawing maps where the fleet fished during that era.

2. Define "fleet"? Who/what do you mean when you say the __________ fleet (for example, large footrope or bottom longline)? Again, give us some characteristics about this fleet (size / kinds of vessels, types of gear, limitations, regulations, permits, etc.).

3. For each of these fleets, define what you mean by seasons in this representative/average year **for each fleet:**

   Winter = __________ to __________.
   Summer = __________ to __________.
   Transition (Spring/Fall) = ________ to ________ / ________ to _______.

This series of questions was designed to assist fishermen consultants to consciously think about the assumptions that they would be making in the context of the fleets, eras, and mapping of effort throughout the session. As such it wasn't designed to produce data but rather to function as a helpful tool to self-control <u>their</u> input throughout the long day.

<u>Creating the Digitized Maps</u>

There were three stages involved in producing a final map: 1) fishermen consultants drawing polygons on the NOAA chart to represent fished areas by gear type, era, and season; 2) fishermen consultants defining and assigning intensity for each of the polygons; and, 3) digitizing the information.

Working with permanent markers on clear sheets of acetate over the nautical chart, the fishermen consultants (working as a large group or several small groups) drew polygons for each fished area where marked differences in intensity was recalled. Separate maps were produced for each era, season, and gear type. Some maps covered multiple eras and/or multiple seasons for the fleet depending on the remembrance of the fishermen consultants. Polygons were numbered and before the map was turned over to the recorder, the map was reviewed and checked for accuracy and completion.

Defining and gathering information on intensity was challenging and time consuming. The facilitator led a large group discussion where fishermen consultants responded to a series of question to capture the needed information (see appendix 9).

Some of the information gathered was on factors that would be "held as constant" when considering effort (e.g. average length of tow, average number of tows per day, average number of pots per string, numbers of strings run for day, etc.). However, once that was complete, the group moved to viewing each map and then assigning a value to the third (variable) factor, "c" – average number of boats per day for the season -- to each polygon. This was recorded in tabular form for each numbered polygon (see results). Data from the tables was subsequently entered into GIS.

2.5 Learning How to Utilize Fishermen's Knowledge

It is widely recognized that the experience-based knowledge of fishermen is underutilized as a source of data for fisheries management. Despite this realization, collection of such knowledge in a systematic way for incorporation into fisheries management decision-making is atypical (Conway and Gilden, 2002). For this reason, one of the important goals of this project was to take advantage of the direction from the TRC to gain experience in developing experience-based products that might be utilized for this purpose.

Gathering data from fishermen necessarily involves data collection procedures that are typically rooted in the social science disciplines and may be somewhat unfamiliar to the traditional fisheries management process. Sampling theory as manifested in the social sciences often relies on recruitment of highly experienced "key informants" from which to gather information. This project utilized key-informant methodology well and was designed by a collaborative team of fishermen, scientists, and managers, and was reviewed by many reputable researchers, practitioners, and managers.

At the end of each group focus session, the facilitator led the group through a quick but informative session evaluation, with the goal of learning about what the fishermen consultants liked about the session, and what they thought should be changed for future sessions.

The discussion section of this report presents some of the "lessons learned." These relate not only to the information that was collected, but also to the design and implementation of a collaborative project, and the development of products for application in fisheries management. It is the hope of the collaborative team that the lessons learned through this project will open the door to an improved understanding of how to gather experience-based knowledge in a practical, timely, and sufficient manner so that it can be confidently incorporated into the universe of available data for management decisions.

Section 3 - Results
Participants
The focus sessions took place on October 8, 2003 for trawl gear fishermen and October 9, 2003 for fixed gear fishermen. Nine fixed gear fishermen and seventeen trawl fishermen, each of who met the standards for participation, served as fishermen consultants. The estimated total years of fishing experience for the group was 736—with mean experience level of 28.3 years. Every fisherman questioned had participated in multiple fisheries over their careers. Most of the fishermen consultants had considerable experience in two or more of the following fisheries:

Dungeness crab
Pink Shrimp trawl
Groundfish bottom trawl
Groundfish midwater trawl
Whiting midwater trawl
Halibut longline
Sablefish longline
Sablefish pot
Salmon troll
Alaska King & Tanner crab
Rockfish longline

All had gained their experience fishing on the West Coast and in Alaska. All had at least 15 years of recent experience in the fishing grounds located on Chart # 18520 (Yaquina Head to Columbia River, Oregon). However, many indicated that they spend less time on the ocean now than they did earlier in their careers. Their estimated number of days at sea per year ranged from an average of 200 to 300 several decades ago to less than 100 now, primarily due to increased regulation.

The quick evaluation at the end of each group focus session yielded insights into what the fishermen consultants thought should be changed for future sessions and what they liked about the session, including their interest and desire to do additional work with the project.

Products
Attached to this report (or on the accompanying compact disk) are the thirty maps that resulted from the group focus sessions with separate maps for each appropriate combination of gear type, era, and season. Some maps represent multiple eras and/or multiple seasons where applicable.

Distinct polygons on each chart represent where the fleet fished. Each polygon was given a number as an identifier only. The intensity of the fishing effort (the estimated average number of boats per day for the season) is indicated by the graded color scheme. Intensity values are independent of the size of the polygon. For example, two polygons that are vastly differing in size may both be shaded with the same fishing intensity color, indicating that a similar number of boats might be found in both polygons.

Each map has a corresponding table that provides, in text form, the same intensity information presented on the maps (except that the location is indicated only by polygon number). These tables provide information on the habitat/fishery, the estimated average number of boats per day for the season (and, in most cases, the normal range) for that particular fishing gear, era, and season (see appendix 8).

Section 4 - Discussion and Conclusions

A draft report was presented to the TRC at their November meeting. This report (dated December 23, 2003) incorporates input from the review of the TRC and the fishermen consultants who participated in the project. The maps and tables capture the information provided by the fishermen consultants. This discussion and conclusion relate primarily to the lessons learned in design and implementation of this pilot project. These lessons are grouped with regard to each objective of the project. A comparison analysis of the data (e.g. comparison with substrate GIS maps, etc.) is being conducted by TerraLogic. That analysis will provide lessons learned with regard to the accuracy or comparability of this information. The results of this analysis and any others that are done to compare distribution of fishing effort will be posted on Pacific Fishery Management Council website: www.pcouncil.org under the Groundfish Essential Fish Habitat section.

Discussion related to Objective 1-- Gathering and Producing a Compilation of Experienced-Based Information

The standards and protocols for the project were essential in producing what – in the collaborative team's opinion – is most likely a reliable and accurate product. The selection and recruitment process and the quality of the dialog during the sessions were particularly important to this perception.

Content

Discussion related to this objective can be categorized by process and content. Content issues, specifically related to interpretation of the information that was generated on this project, will require further analysis such as the one being conducted by TerraLogic. Such analyses may include:

- comparison in GIS of the trawl effort information to that derived from logbook data and from the Ecotrust model; and,
- comparison in GIS of the fixed gear effort information to the effort information from the Ecotrust model.

However, even a cursory perusal of the maps and tables show that the fishermen consultants noted significant differences in the location of the fleet's fishing effort as defined by the gear type, seasons, and time frames of the project design. They felt confident that their pooled knowledge of the location of the fleet's fishing effort presented a good picture of the areas where fishing actually occurred. They were comfortable with the gear type parameter, though during the discussion they found it easiest to think of specific fisheries and then 'combine' them into an overall picture of effort by gear type. For example, fishermen consultants discussed where the rockfish effort occurred then mapped this information in aggregate also considering other large footrope fisheries. They were less comfortable with the time period parameter, particularly the first era which was—possibly in retrospect—too long to have captured changes due to many and diverse factors.

Although the fishermen consultants also captured and shared information on the intensity with which the fleets fished, both they and the collaborative team struggled with how best to measure this parameter. The information on the maps represents the estimated number of boats per day for the season, yet information was also captured about such factors as length of tow, number of pots, length of lines, etc. (see appendix 9).

Because the data generated by this project is limited to one geographic area, it is impossible to test the comparability of results from diverse areas of the coast. This was an important issue that was raised by the PFMC's Scientific and Statistical Committee, and the collaborative team took several steps to foster comparability and consistency. The collaborative team believes that, based on this experience, the consistency standards could be properly administered to ensure comparability in other areas of the coast. Pending further review and the availability of funds, the project may be expanded to cover other areas of the coast. If the results of this study are consistent with logbook information for the trawl fishery, subsequent iterations may reasonably be limited to fixed gear.

Process

Regarding the process of implementing this project, several lessons were learned that could be used to tune the methodology based on the goals of the end-users. Throughout the design of the project there was a tension in developing information that would be most useful for the EFH EIS and the pragmatic issues associated with collecting information using a group focus session approach. Compromise between these competing objectives required categorization of information parameters that in some cases prohibited the direct use of all the finer-scale information that the fishermen consultants possess.

For example 'trawl gear' was grouped into 4 categories even though information could also have been mapped based on specific fisheries within each gear type. Similarly, time was divided into three eras and further sub-divided into three seasons. Time could clearly be categorized into more or less eras. The trade-off is that more divisions of any parameter would add work and time to the group focus session, unless savings can be found elsewhere. While the fishermen expressed discomfort (particularly with the length of the first era and the fact that effort patterns underwent shifts within the era as a result of market and regulatory forces), they were able to articulate and agree as a group on referenced characteristics for an "average or representative year," and complete their work within the 8-hour day. The referenced characteristics of the representative year or their definition of each particular fleet were captured on flip charts (see appendix 7). These notes primarily served participants throughout the day as a reference for the mapping exercise. However, this finer scale information was captured and could be generalized, grouped, or used in other appropriate ways (one example being the characteristics of Era 1 [see appendix 7]). Since the choice of categories is the main limitation on the product, those categories that are critically important to the end-user and must be carefully considered prior to implementation. If this project is to be continued, the adequacy of the categories chosen by the collaborative team should be reviewed.

An important lesson learned by the group is a significant amount of up-front planning was necessary to accomplish all of the desired objectives within an eight-hour focus session. The collaborative team invested hundreds of hours in designing and refining the project. These preparatory steps were essential and the time invested up-front allow us to "go fast" in the actual sessions and successfully capture the information from the fishermen consultants in two eight-hour days. The time invested in the selection, recruitment and orientation of the fishermen consultants prior to the focus sessions resulted in the fishermen requiring only a brief orientation during the meeting.

Even with this intense planning and preparation, the eight hours for the session was marginally sufficient. We were fortunate not to experience any unforeseen circumstances that would almost certainly have resulted in a longer session or an incomplete data set.

Discussion related to Objective 2 -- Collaborative Design and Implementation

The collaborative nature of the project design process was essential to incorporate the expertise necessary to achieve the objectives for this study. The relevant expertise included practical knowledge of the various fisheries, research techniques (from both the social science and natural resource disciplines), awareness of potential end-uses for managers, and expertise in GIS software.

The selection and recruitment process was essential to having the right people involved. Management of the process by a respected fisherman who functioned as a key informer played an important role in the quality of the consultants who were successfully recruited because of his professionalism, style of communication (engaging, open, honest, and willing to talk and listen), and the fact that he had much in common with those he was asking to participate (years of experience at sea, experience with the ups and downs of fishermen/management relations, etc.).

Other factors that influenced the recruitment process were weather, meeting location, and communication by the lead fisherman consultant. Weather strongly influences fishing activity. Bad weather on the days of the focus sessions worked ironically to the advantage of the project by preventing fishermen from being out at sea and otherwise unavailable. The location of the meeting was established strategically to be in close proximity to participants.

Discussion Related to Objective 3: Gaining Experience in the Utilization of Fishermen's Knowledge

The extent to which the information is actually utilized by scientists and managers remains to be seen but will become more evident with further analysis and comparisons to other sources of effort information.

All of the fisherman consultants exhibited a strong desire to participate in the study, with most expressing optimism that their input might eventually be used in the management process. It should be noted that the small amount of compensation provided for the day ($300 to cover both time and expenses) was not the notable factor that determined participation. Rather, during the recruitment almost all of the fishermen got excited about the prospects of the project and agreed to participate (if they were available) without even knowing about the compensation to be provided. Such willingness seems to indicate that the amount of money was not the factor that determined interest in participation in this project. The amount of money necessary, in absence of the motivation to participate in and of itself, was never tested.

The facilitated group focus session appears to be a reliable method of recording fishermen's knowledge. The dynamic afforded by the focus session allowed the fishermen to interact and build on each other's knowledge and ostensibly improve the amount and quality of information that was generated. This also helped maintain interest and enthusiasm throughout the day by all involved. Separating fishermen by gear type groups (trawl versus fixed and sometimes further subdividing within gear types) was helpful in creating a conducive and safe environment for sharing information and for assuring information was compatible so it could be built upon.

On a practical level, it is also clear that information from fishermen can be collected following a specific and documented methodology; that this information can be mapped on nautical charts in discrete ways, and that this mapped information can be reliably transferred to a digital format and utilized in a GIS-based system for analysis. It is also apparent that, due to the defined and documented methodology, this project could be replicated elsewhere or with fishermen in the same area, or using different parameters for information synthesis, for comparison and research purposes.

Section 6 - References

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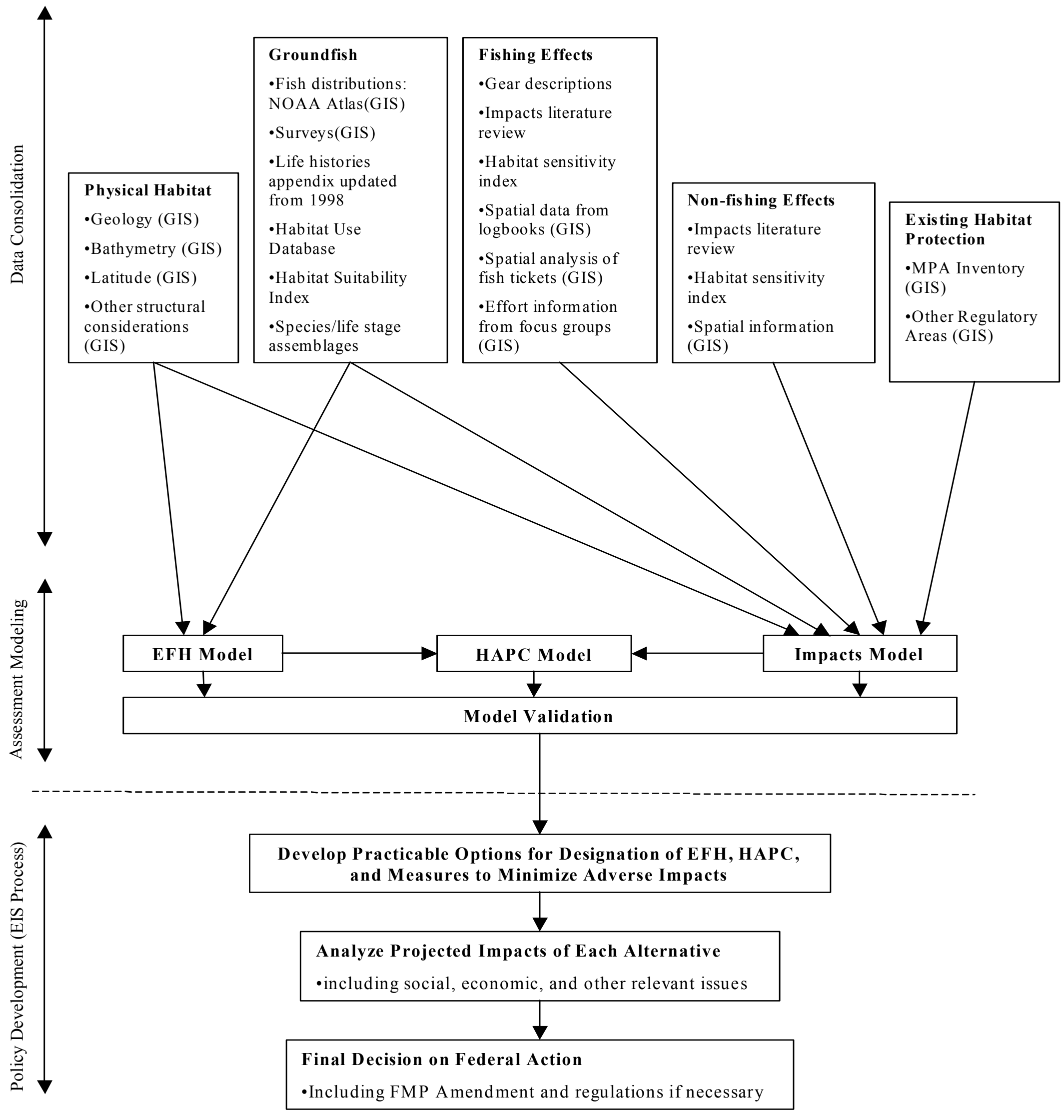
Section 7 - Acknowledgments

The collaborative team would like to thank the following people for their contributions to the design of this project: Susan Abbot-Jamison, NOAA Fisheries; Dave Colpo, Pacific States Marine Fisheries Commission; Guy Fleischer, Northwest Fisheries Science Center; Ginny Goblirsch, Oregon Sea Grant Extension; Jennifer Gilden, Pacific Fishery Management Council; Jamie Goen, NOAA Fisheries, Northwest Region; Lori Cramer, OSU Dept. of Sociology; Court Smith, OSU Dept. of Anthropology; Jennifer Langdon Pollock, Pacific States Marine Fisheries Commission; Graeme Parkes, Marine Resources Assessment Group; Ed Backus, Ecotrust; the Pacific Fishery Management Council (and committees). The collaborative team would also like to extend a heartfelt thanks to the 27 fishermen consultants who participated in the project.

Financial support for this project was provided by NOAA Fisheries, Northwest Region; Pacific States Marine Fisheries Commission; and, Oregon Sea Grant Extension.

Appendix 1 - EFH EIS Background

Draft Decisionmaking Framework for Pacific Coast Groundfish Essential Fish Habitat Environmental Impact Statement (modified from the draft presented at the April, 2002 Council meeting)



Appendix 2 – Lead Fisherman Consultant's Talking Points

[Self-introduction] Thanks to everyone for being there. Note that we have a tremendous amount of experience in the room, perhaps 300 years of on the ground experience represented today. State that they have been selected based on their long experience in the fishing industry, their knowledge of the grounds we are going to look at today, and their willingness to work together to record the information.

Mention the personal excitement about the possibilities of capturing fishermen's knowledge and recording it in a way that may allow it to be used in the management process—noting that one of our (fishermen's) complaints over the years is that the management system didn't have a way to use our experience- based information. If we pull this off, we will have showed a way to do this. There is no guarantee that our work will get used, but this is a first step that needs to be taken if we are ever going to have our experience and knowledge captured for use. Even if this isn't used we may be paving the way for future

Confirm that there are no predetermined outcomes…we are after the best fishing effort information available. Note that we are not looking for anyone to provide information on a special tow or set that would compromise a business secret, but we are looking for a consensus on patterns of where the fleet fishes.

Remind people to please turn in their completed contracts if you haven't' already. Note your awareness that those in the room are doing this because they care enough to want decisions made on good information, but that we do want to cover their costs for being with us today. Recognize that this isn't a great deal of money, but that it is acknowledgment that NOAA Fisheries and Pacific States Marine Fisheries Commission is providing some recognition for the value of their time.

Note the important background role that a couple of people in the room are taking. "Steve Copps is from NOAA Fisheries; he has been a big supporter of this project to use fishermen's experience based knowledge. Allison Bailey is a GIS specialist who is here to record the information you produce. She will digitize the info into electronic chart layers.

Flaxen Conway is here to help us do this process ~~in~~ a scientifically valid way so that what we produce can be used. And since we have a lot of ground to go over, she is also here as a facilitator to keep us on track and make sure we get through it.

Ask people to introduce themselves, noting the fisheries they participate in and home ports.

Appendix 3 - Facilitator's Talking Points
(ground rules, etc.)

Housekeeping
- bathrooms
- food
- smoke breaks
- conditions for using this meeting site

What we need to accomplish in today's session
- draw maps related to 1 nautical chart
- 1 each for a "representative year" in each of three eras (1-3 seasons in that representative year)
- for all gear types
- THAT'S ___ maps...and we want to assign a relative value for intensity for each polygon drawn on these maps... SO WE'VE GOT **A LOT** TO DO!
- We need to get this done in an effective manner
- we don't have a lot of time

_ I'll be pushing to keep us going and moving ahead

We need to get this done is a fair, open, and honest way...feel tired but good at the end. Our rules of playing well together today are simple:

-build on what others have said...don't just repeat things over
-let someone finish what they have to say...don't interrupt
-everyone is expected to participate fully...several perspectives can be combined to give an accurate picture
-speak up if we don't capture your input correctly
-agree to disagree...and do it respectfully
-take care of your bodily functions...but we will have breaks in the am & pm
-cell phones on vibrate or silent please
-confidentiality (what you hear here, stays here. The data will become public knowledge...but who said what when and who was here will not).

_ So, it's a lot...and we'll be bushed at the end of the day...so let's get going.

Appendix 4 – Consistency Standards

Full Disclosure Standards: Through the recruitment process and during the focus sessions, the investigators shall practice full disclosure in potential uses of the fishing effort information being collected in this project. The fishermen consultants will be brought to a common understanding of the goals and objectives for the project and the group focus sessions, as well as relevant background. This information is the same for all the group focus sessions regardless of geographical area or gear category and is specifically designed to disclose potential uses of the information the fishermen will be providing.

Standards of Openness: For results from multiple group focus sessions to be comparable and acceptable as a reliable representation of experiential data, consultants are required to open and honest in sharing information on fishing effort.

Recording Standards: All of the information from all of the group focus sessions will technically be recorded in exactly the same way. The recorder will project (or otherwise make available) digitized nautical charts and interpretive tables. The charts will be the same ones that are predominantly used by the fleet in the appropriate geographical area to conduct fishing operations. The consultants will then guide the recorder to digitally mark up the charts and tables according to the goals and information parameters of the project. GIS technology gives the recorder considerable flexibility to respond to consultant requests for altering the display (i.e. changing scale, moving information to the background or foreground, etc.). A brief written summary (included in the recruitment package) and verbal presentation by the recorder (at the beginning of each focus session) will explain in an appropriate level of detail:

- an overview of what GIS is;
- the technical capabilities for the group focus sessions;
- the information that will be entered into the GIS;
- the chart legend that will be applied to interpret the GIS data (color schemes and patterns to differentiate between information types); and,
- review procedures to ensure the final GIS product represents the information provided by the consultants.

(Note: the methodology section of this report describes the methods used to implement the group focus sessions. Please see this section for exact details of how the group focus sessions were facilitated and recorded).

Information Standards: It is a considerable challenge to ensure information that is collected from geographically diverse group focus sessions is comparable. To address this challenge, limits will be imposed on the categories of information and the means by which it is collected. Fishing effort will be categorized by time, gear, intensity, and area. Limits for each of the categories will be discussed at the recruitment visit and at the beginning of each group focus sessions (and brought up by the facilitator as necessary).

Appendix 5 - Sample Contract

Fisherman Consultant/Participant Agreement
Cooperative Fishing Effort Pilot Project

Pacific States Marine Fisheries Commission
45 SE 82nd Ave Suite 100
Gladstone, Oregon 97027-2522

PSMFC JOB NO.

LEGAL NAME:
TAX ID/SOCIAL SECURITY NO:
ADDRESS:
PHONE NO.:
FAX NO:

Pilot Project to Profile West Coast Fishing Effort Based on the Practical Experience of Fishermen

(To be filled out by PSMFC)

DATE OF COMPLETION:________________________

APPROVED BY:_______________________________

SERVICES TO BE PERFORMED: Receive briefing on project orally, read background material, fully participate in a one day meeting and supply information from my experiences of fleet fishing location and effort according to parameters defined for the project.
CONTRACT AMOUNT: $300 (includes time and expenses)
TOTAL AMOUNT DUE UPON COMPLETION OF SERVICE: $ 300

CERTIFICATIONS:
I am willing to speak about my experience and knowledge.

I have about 20 years experience in commercial fishing on the West Coast, with much of this experience gained within Oregon.

I have good practical knowledge of the fleet's operations. I know the area, know the gear types, know the fisheries.

I will participate openly and honestly in this work.

I will read background information to prepare for the meeting and will attend the all day group session. I will help map and discuss fleet effort.

I understand that the information that I provide will be used by NMFS and other entities as a representation of fishing effort based on practical experience and that this information will become the property of the Pacific States Marine Fisheries Commission.

I am an independent contractor and understand that no insurance is being provided and that I shall be responsible for payment of all applicable federal, state, and local taxes and fees which may become due and owing by reason of this agreement.

Signature ____
Date ____________________

Appendix 6 - Initial Pilot (Trawl Effort North of Destruction)
Brief description (by Marion Larkin) of the pilot of the initial project design in Washington:

The program was explained individually by phone to trawl fishers who have extensive experience fishing the northern coastal waters of Washington. Through this process five fishermen were found who were willing to participate in the pilot program. Selection was based somewhat their availability in one port but more importantly, on their experience, integrity, and willingness to participate. All fishers know each other, know the other fishers who fish the area, felt they knew of and could represent the areas they did not fish. All fish now from the Port of Bellingham; some have fished the coast from the Bering Sea to Bodega Bay California. Fishers had fished the entire charted area for years and had extensive knowledge.

A meeting room with a large table was arranged, charts taped to the table along it's length in varying scales to allow participants to refer and study areas under discussion while the facilitator/participant (Marion) and one other fisher with a stead hand roughed in the outlines of areas of distinct fishing patterns onto a master/working chart. Work progressed from the larger areas of most homogeneity to the more complex. Pencil and eraser kept the process simple and fluid.

We decided to first define areas in which the bottom required but one gear to be utilized; rough bottom where roller bottom gear was required. This encompassed the rocky bottom where a directed rockfish, lingcod and petrale fishery had occurred. If an argument could be made about differing effort levels, subsets where created which allowed large seasonal patterns to be represented such as a dover sole fishery in the winter, rockfish fishery mostly in the summer and so on. For example - in the charted area, roller gear is used exclusively in the winter months outside 100 fm in prosecution of the dover, sable and thornyhead fishery. There are areas where winter petrale fishing also take place outside 100 fm within this area. Although a distinct fishery, it uses the same gear, occurs simultaneously with the dover sole fishery (has similar seasonal pattern) and similar effort levels. More work is yet to be done to define extremely high effort areas targeting rock and ling. In some cases these are very small areas but most highly used. We did not get into this detail.

The next process was to define areas where small footrope was useable. This is not to say that this is the gear always used but rather that it could be used there. Pelagic gear use areas was very roughly defined by inclusion in gear used in the large footrope/roller gear fisheries. Further work is needed to define sub-areas of highest use.

The final stage assigned fishing intensity levels to areas, fine tuned boundaries, and took a final look at the results. From this, using the same chart as draft, felt pen finalized the process. We found it helpful if a sub-set of the group worked on areas which took some thinking and then brought the discussion back for general discussion. This took place as a natural part of the group dynamics or through suggestion by the facilitator. Group discussion in some instances helped to refresh memories, aided in reaching consensus and is a very important part of the process.

This pilot charting took roughly 6 hours of group effort and another hour of review by the facilitator (Larkin)

Appendix 7 – Sample Flip Chart Notes
This information is directly transcribed from part of the flipchart notes taken at the fixed gear focus session. They are shared as an example and for information. (Flip chart notes are available for the trawl gear session as well. *Note: review from the fishermen consultants who participated in the focus sessions confirmed that for the trawl fleet, the seasons designated relate to approximately 90% of the fleet.*)

Defining a Representative Year for Each Era -- FIXED

Note: The idea for all of the "defining" areas of the process was for the fishermen consultants to define the strata within the various information parameters to help them develop characterizations they could recall throughout the session. So this wasn't designed to necessarily produce data, but rather to function as a way to discipline their input throughout the long day.

Era #1 [1986-1999]

Note: This was a tough thing to do, given so many years and so many changes that occurred over this era. The group shared their thoughts about milestones in this era and therefore qualities to consider when thinking about this era while doing their mapping and intensity recording.

Pre-ground fish limited entry = lots more people in the fishery
No El Niño
Wide range of management regulations re: groundfish over this era
Less effort per vessel re: crab
Prices more stable (albeit low) for crab
Bad weather kept people on the beach (on shore)
Generally, not as many quotas – short term derby (larger quotas = increased fishing and increased length of fishing season)
Limited entry for crab happened during this era
Japanese markets increased

Era #2 [2000-2002]

Similar to present
Phasing in more regulations
Observers came on the scene
No restricted fishing areas
Quotas low re: groundfish
More gear per vessel re: crab
Discussions about pot limits / vessels started happening. Led to more effort in Era #3

Era #3 [present]

Stable effort due to regulations re: groundfish
Prices jump around a lot
More effort re: crab
Limited areas to fish
Fish no matter the weather (bad weather doesn't keep you on the beach anymore)

Defining Seasons within Each of These Representative Years

__Longline (LL) Fleet

	Era #1	Era #2	Era #3
Groundfish			
Winter:	None	None	Sablefish open year-round
Summer:	June through September	August through September (shorter season)	April through October
Transition:	April and October	No transition	No transition
Halibut	Note: Change in hook shape = more effective; kills less non-target species	Still a derby, summer only	
Summer Only	Four 12-day openings May through August	Made the change to four 10-hr openings	Four 10-hr openings June through August

__Groundfish Pot (GP) Fleet

	Era #1	Era #2	Era #3
Winter:	None	None	None
Summer:	May through August	April through October	April through October
Transition:	October	Just try not to affect other fisheries.	

__Crab Pot (CP) Fleet

	Era #1	Era #2	Era #3
Winter:	December through February	December through February	90% is caught December through February
Summer:	April through July	April through July	April through July
Transition:	March and August	March and August	March and August

Define the Fleet – FIXED

Note: beginning of Era #1, open access (no permits) there were around 700 vessels (max). By the end of Era #1, 7 days after limited entry, there were 160 boats (LL) and 33 boats (GP).

<u>Bottom Longline Fleet (LL)</u>

With Halibut, the hooks on the bottom all eras
Longline crabbing stopped in Era #1.

Era #1

Gear modifications – hooks laid on bottom
Lots of gear lost
Just long-lined at the beginning
There were tiered levels (open access)
Lots of big Seattle boats used to come down
There were 12-15 [mid 50' – 60' range] boats. Then salmon trollers got involved [40' boats. By the end of this era, the range was 40'-60' boats.
More processing options.

Era #2

Gear modifications – By this era line/hooks floating
Somewhat less gear loss
Do variety of gears
Stopped tiered levels; slowed open access
Lots of big Seattle boats still coming down
Generally 45-65' boats
The ability to combine/stack permits resulted in bigger boats; increased boat size resulted in increased effort

Era #3

Gear modifications – now all line/hooks floating
More relaxed controlled fishing.
Less gear loss, less crew, less time, less gear.
Limited open access
Less big Seattle boats coming down; sold permits
Generally 45-65' boats
The ability to combine/stack permits resulted in bigger boats (90'); less smaller boats
Combined/stacked permits
Limited processing options

<u>Groundfish Pot Fleet (GP)</u>

Generally bigger boats 40'-115' (60-80' average)

Era #1

Most pots used
Used to fish year round, or close to it, several months
More gear loss
Big operations w/lots of traps
Lots of gear conflicts
No grading
Most processing options

Era #2

With quotas there became less pots
Somewhat less gears loss
Less traps
Gear conflicts taper
Grading begins
Limited processing options

Era #3

Use less pots
Lots less gear loss
Least traps
Lots less gear conflicts
Traps modified (escape rings) = grading done in pots in the ocean
Still limited processing options

<u>Crab Pot Fleet (CP)</u>

Era #1

More day boats
Weather plays big role
Least amount of effort
Less thievery / gear lost
More, smaller boats
More processing options
Longer fishery
Limited entry starts

<u>Crab Pot Fleet (CP)</u>

Era #2

More effort, more crew, more attitude
More day boats
More gear loss
More seasonal limits
Less processing options

Weather playing less of a role…more apt to go out despite the weather

Era #3

Most effort/vessels
Most thievery
Most gear lost
Lots of day boats; more boats period. Bigger and smaller, port dependent.
Fish despite weather; hang on for dear life
Limited processing options.

Appendix 8 - Example Intensity Table

Trawl Gear Table

Gear: **LF**
Era Number: **1**
Season: **Winter**

Polygon No.	Habitat / Fishery	Ave. No. of Boats per Day for the Season	[Note, normal days / range depended on the quota] Normal Range (Min.)	Normal Range (Max.)
1	Hardbottom	1		
2	Hardbottom	2.5	2	3
3	Deep Water & Complex	14	8	20
4	Complex	3	1	10
5	Hardbottom	1.5	.5	5
6	Complex	1.5	.5	5
7	Complex	1.5	1	5
8	Hardbottom	1	.5	2
9	Complex	2	1	4
10	Hardbottom	2.5	2	6
11	Hardbottom	2.5	2	6
12	Hardbottom	1.5	1	2
14	Complex	6	3	9

(NOTE: 1 boat/day is a lot for a rock cod spot)

Appendix 9 - Questions for Facilitated Discussion on Intensity

A. Trawl Focus Session

For each part of the *trawl fleet, for each era and each season,* relative effort intensity is the product of three factors (a x b x c) as described below:
a = average length of tow this fleet makes (a constant figure; making note of the normal range whenever possible),

What is the average and normal range for?

	Average			*Normal Range*		
	Era 1	**Era 2**	**Era 3**	**Era 1**	**Era 2**	**Era 3**
LF =						
SF =						
PE=						
PS =						

b = average number of tows per day this fleet makes (a constant figure; making note of the normal range whenever possible),

What is the average and normal range for:

	Average			*Normal Range*		
	Era 1	**Era 2**	**Era 3**	**Era 1**	**Era 2**	**Era 3**
LF =						
SF =						
PE=						
PS =						

Then, for the last one – c – for each map (each era, each season, and each gear type) please work together to give me a figure (for each polygon) related to the average number of boats per day for the season (no constant; making note of the normal range when possible).

B. Fixed Gear Focus Session

For *the longline fleet*, intensity as the product of the three factors (a x b x c) as described below:
a = average length of groundline per set for this fleet (a constant; making note of the normal range and the average spacing of the hooks on that average length of groundline),

What is the average length (and normal range) of groundline?

	Average			*Normal Range*		
	Era 1	**Era 2**	**Era 3**	**Era 1**	**Era 2**	**Era 3**
BLL =						

What is the average (and normal range) for the spacing of the hooks?

	Average			***Normal Range***		
	Era 1	**Era 2**	**Era 3**	**Era 1**	**Era 2**	**Era 3**
BLL =						

b = average number of sets per day for this fleet (a constant; making note of the normal range if possible)

What is the average (and normal range) number of tubs/hooks per day?

	Average			***Normal Range***		
	Era 1	**Era 2**	**Era 3**	**Era 1**	**Era 2**	**Era 3**
BLL =						

For *the pot fleet* (both groundfish and crab), we will be looking at intensity as a x b x c, where a, b, & c, are defined as:

a = average number of pots per string in this fleet (a constant; making note of the normal range and the average distance between traps and the average length of ground line),

What is the average number of pots per string (and normal range)?

	Average			***Normal Range***		
	Era 1	**Era 2**	**Era 3**	**Era 1**	**Era 2**	**Era 3**
GP =						
CP =						

What is the average distance between traps (and normal range)?

	Average			***Normal Range***		
	Era 1	**Era 2**	**Era 3**	**Era 1**	**Era 2**	**Era 3**
GP =						
CP =						

What is the average length of groundline (and normal range)?

	Average			***Normal Range***		
	Era 1	**Era 2**	**Era 3**	**Era 1**	**Era 2**	**Era 3**
GP =						
CP =						

b = average number of strings ran per day by an average boat (a constant; making note of the normal range),

What is the average number of strings ran per day (and normal range)?

	Average			*Normal Range*		
	Era 1	**Era 2**	**Era 3**	**Era 1**	**Era 2**	**Era 3**
GP =						
CP =						

Then, for the last one – c – for each map (each era, each season, each gear type) please work together to give me a figure (for each polygon) related to the average number of boats per day for the season (no constant; making note of the normal range when possible).

GENERAL NOTE:

1 boat in 3 days = .34 boats/day for the season
1 boat in 4 days = .25 boats/day for the season
1 boat in 5 days = 0.20 boats/day for the season
1 boat in 7 days = 0.14 boats/day for the season
1 boat in 10 days = 0.10 boats/day for the season
2 boats in 10 days = 0.20 boats/day for the season
3 boats in 10 days = 0.30 boats/day for the season
1 boat in 15 days = 0.067 boats/day for the season
1 boat in 60 days = 0.0167 boats/day for the season

More information on this assessment methodology is available on the Council's web site at http://www.pcouncil.org/habitat/habback.html.

Appendix 12

Fishing Effort GIS Data Assessment for Groundfish Essential Fish Habitat

Final Report

Fishing Effort GIS Data Assessment for Groundfish Essential Fish Habitat

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1. Introduction

Spatial delineation of fishing effort data is a necessary component of the modeling and analysis for the West Coast EFH EIS. There are several potential data sets to provide this information for the BBN impacts models. Each data set has its own strengths and limitations, especially concerning geographic coverage, gear type(s), temporal coverage, and data source(s). Now that these effort data have been compiled into one location, we are able to explore the data and perform comparisons between the various data sets.

This document describes the initial fishing effort data comparisons and review that have been completed by TerraLogic GIS in response questions from the Technical Review Committee (TRC) in November 2003. Three fishing effort data sources were used in these comparisons: (1) Trawl logbook data from PACFIN, 1987-2002, (2) Ecotrust's fishing effort model output, 1997 and 2000 (Sholz 2003), and (3) Focus group data gathered from fishermen for a single nautical chart off Oregon (18520) during three eras, 1986-1999, 2000-2002, 2003 (Bailey et al. 2004). The comparison of these three fishing effort data sets is made difficult by the variation in their spatial resolution, temporal resolution, and attribution (gear types and intensity measures). Table 1 summarizes the key characteristics of each data set.

In order to use time and budget resources most effectively, we prioritized the comparisons between the focus group data and the other two data sources. The third possible comparison, between Ecotrust data and trawl logbook data, was not undertaken because the logbook data were available to Ecotrust for their model development, whereas the other pairs of data sets were developed independently. However, if resources and priorities allow, this third comparison could be completed.

The general goals of these comparisons were to determine the extent of spatial correspondence between various data sets. The comparisons serve to answer two distinct questions:

(1) Are the spatial locations of these fishing effort data sources coincident and consistent with each other, and,

(2) are the estimates of the magnitude of area affected by fishing similar, whether or not they are they are spatially coincident?

A third question -- are the levels of intensity of fishing effort in areas of spatial coincidence consistent with each other -- has not been addressed at this stage of the analysis.

In addition to the comparisons between fishing effort data sources, we also explored the spatial and temporal characteristics of the trawl logbook data, and we investigated the relationship between the focus group polygons and geologic bottom type.

We realize that there are many more analyses that could be undertaken, particularly comparisons of intensity between data sources. Nonetheless, we provide these results as an informative initial comparison and exploration of these various data sets.

Table 1: Characteristics of Fishing Effort Data Sets

Data Set	Extent	Spatial Resolution	Gear Types	Temporal Attributes	Intensity Measure	Catch Measure
Oregon Fishermen's Focus Group	Northern coast of Oregon from Newport to Columbia River (NOAA Chart 18520)	Polygons delineated by fishermen on 1:185,238 scale chart	Trawl: Large Footrope Small Footrope Pelagic Pink Shrimp Fixed: Crab Pot Groundfish Pot Longline	Data by Era: Era 1 (1986-1999) Era 2 (2000-2002) Era 3 (2003) Data by Season: Summer Transition Winter	Average number of boats per day by polygon Average tows per boat Average hours per tow	None
Ecotrust Model	West Coast (OR, WA, and CA)	9 x 9 km blocks	Trawl: Trawl Fixed: Pot/Trap Longline Hook and Line Other Gear	Model results summarized by year: 1997 2000	None – Catch used as a proxy for intensity	Pounds caught per year by 9 km block Revenue per year by 9 km block
Trawl Logbook	West Coast (OR, WA, and CA)	Original data source are set points for each tow. These set points are then assigned to the Trawl Logbook Blocks (mostly 10 minute blocks with others of various size). All effort from any given tow is assigned to the block in which the set point occurs.	Trawl: Flatfish Groundfish Roller Other Midwater	Set point data for each tow from 1987 – 2002 *All records contain tow year, but only 57% contain actual date of tow. Therefore, data can be summarized by year or years however they cannot be summarized by seasons within years.	Number of tows Tow duration	Pounds caught per tow

2.1 Comparison of Ecotrust Effort Model and Focus Group Data

In order to compare the focus group data to the Ecotrust data, we generalized the focus group data to the 9 x 9 km blocks, the same spatial resolution as the Ecotrust effort model blocks. In addition, because the Ecotrust data is summarized by year, focus group polygons for all seasons within a one gear type and era were combined. Table 2 shows the total area of each focus group gear type and the increase in total area when generalizing the focus group polygons to the 9 km blocks.

Table 2: Focus Group Polygon and Block Area Summaries

Focus Group Era	Focus Group Gear Type	Area (square km)		Percent Area Increase
		Focus Group polygons	Focus Group blocks	
	Crab Pot	5438.0	7400.6	36.1%
	Groundfish Pot	127.0	729.0	474.2%
	Longline	5354.7	9315.1	74.0%
1	Large Footrope Trawl	9224.8	12312.1	33.5%
	Small Footrope Trawl	4046.4	11667.4	188.3%
	Pelagic Trawl	770.3	3159.0	310.1%
	Pink Shrimp Trawl	3855.3	6642.0	72.3%
	Crab Pot	1753.3	7400.6	322.1%
	Groundfish Pot	7368.5	11502.1	56.1%
	Longline	5929.6	8667.1	46.2%
2	Large Footrope Trawl	8462.5	12231.1	44.5%
	Small Footrope Trawl	8201.7	11667.4	42.3%
	Pelagic Trawl	435.8	1296.0	197.4%
	Pink Shrimp Trawl	3855.3	6642.0	72.3%

Once both data sets were in the same spatial and temporal context, the comparison was performed as a simple presence/absence analysis. The blocks that were intersected by focus group effort polygons, were counted as focus group blocks. Blocks that were assigned catch by the Ecotrust model, were counted as Ecotrust blocks. Any blocks that had both Ecotrust and focus group effort, were counted as coincident blocks. For purposes of this presence/absence analysis, an area of "effort" is any area where fishing occurred, regardless of its level of intensity.

Comparisons were made within corresponding gear type and era/year. Analysis was limited spatially to the boundaries of the chart used in the focus group sessions, NOAA chart 18520, an area of approximately 115 km by 190 km. Table 3 lists the comparisons performed and summarizes the number of blocks (and area) for each data source as well as the coincident blocks.

Table 3: Block summaries for focus group, Ecotrust and coincident blocks.

Focus Group Era	Eco-Trust Year	Focus Group Gear Type	Ecotrust Gear Type	Number of Blocks * (Area in km²)		
				Focus Group	Ecotrust	Coincident
1	1997	Groundfish Pot	Pot/Trap	9 (729.0)	9 (729.0)	0 (0)
		Longline	Longline	115 (9315.1)	36 (2916.0)	16 (1296.0)
		Large Footrope Trawl	Trawl	152 (12312.11)	148 (11960.4)	117 (9477.1)
		Small Footrope Trawl		155 (11667.4)	148 (11960.4)	109 (8801.3)
		Pelagic Trawl		39 (3159.0)	148 (11960.4)	28 (2268.0)
2	2000	Groundfish Pot	Pot/Trap	142 (11502.1)	14 (1134.0)	3 (243.0)
		Longline	Longline	107 (8667.1)	28 (2268.0)	9 (729.0)
		Large Footrope Trawl	Trawl	151 (12231.1)	119 (9611.3)	90 (7290.1)
		Small Footrope Trawl		155 (11667.4)	119 (9611.3)	101 (8153.3)
		Pelagic Trawl		16 (1296.0)	119 (9611.3)	11 (891.0)

* 307 blocks within study area.

To visualize the distribution of these two data sets, maps showing the focus group blocks, Ecotrust blocks, and coincident blocks by era and gear type have been developed and are provided in Appendix A.

The total area affected by fixed gear fishing (groundfish pot, longline) as predicted by the Ecotrust model, is generally much smaller than the total area affected by fixed gear as delineated by the fishermen's focus group. Spatial coincidence between the two data sources for fixed gear is also fairly low. For bottom trawl gear, the area estimates are much more similar and spatial coincidence is greater between the two data sources.

2.2 Comparison of Trawl Logbook Data and Focus Group Data

Analogous to the comparison with the Ecotrust data, we generalized the focus group effort data to the same spatial resolution as the trawl logbook blocks. The comparison was performed as a simple presence/absence analysis. The logbook blocks that were intersected by focus group effort polygons, were counted as focus group polygons.

Blocks that had logbook effort, were counted as logbook polygons. Any blocks that had both logbook and focus group effort, were counted as coincident polygons.

Trawl logbook data that had no block number or lat/long coordinate were excluded from the analysis. A total of 668,047 logbook records, from 1987 to 2002 were included in the analysis. Five gear types are available in the Pacfin logbook data: Flatfish Trawl (FFT), Groundfish Trawl (GFT), Roller Trawl (RLT), Other Trawl (OTW), and Midwater Trawl (MDT). With these categories, we are unable to distinguish large footrope trawl tows from small footrope trawl tows, so they were both compared to the four bottom trawl types (FFT, GFT, RLT, OTW). The pelagic trawl data from the focus group were compared to Midwater Trawl (MDT). The pink shrimp trawl had no corresponding gear type in the logbook data.

For the era comparisons, all logbook tows from 1987 to 1999 were combined for the comparison with focus group Era 1 data. Similarly, logbook tows from 2000 to 2002 were compared with Era 2 data. Table 4 shows the block count comparison.

Table 4: Block summaries for focus group, logbook, and coincident blocks

Focus Group Era	Logbook Years	Focus Group Gear Type	Logbook Gear	Number of Blocks (76 total)		
				Focus Group	Trawl Logbook	Coincident
1	1987-1999	Large Footrope Trawl	Bottom Trawl	63	76	63
		Small Footrope Trawl		51	76	51
		Pelagic Trawl	Midwater	23	69	23
2	2000-2002	Large Footrope Trawl	Bottom Trawl	64	76	64
		Small Footrope Trawl		51	76	51
		Pelagic Trawl	Midwater	9	57	8

The presence/absence analysis with the logbook data is somewhat limited because all or nearly all of the logbook blocks in the study area have had some effort during the two time periods. Therefore, for visualization we included an intensity measure for the logbook data. We calculated the total duration of tows for each year by block, and then averaged this value for all years in the era. Maps showing these logbook and focus group blocks, as well as focus group polygons are attached in Appendix B.

Because the large size of the logbook blocks may obscure finer scale spatial patterns, we also compared the focus group polygon boundaries to set point locations. Distinct boundaries delineated by the fishermen in the focus group are clearly exhibited in the logbook set points, particularly the deepwater boundary of the large footrope gear and some shallower areas delineated for small footrope gear (Figure 1 and 2).

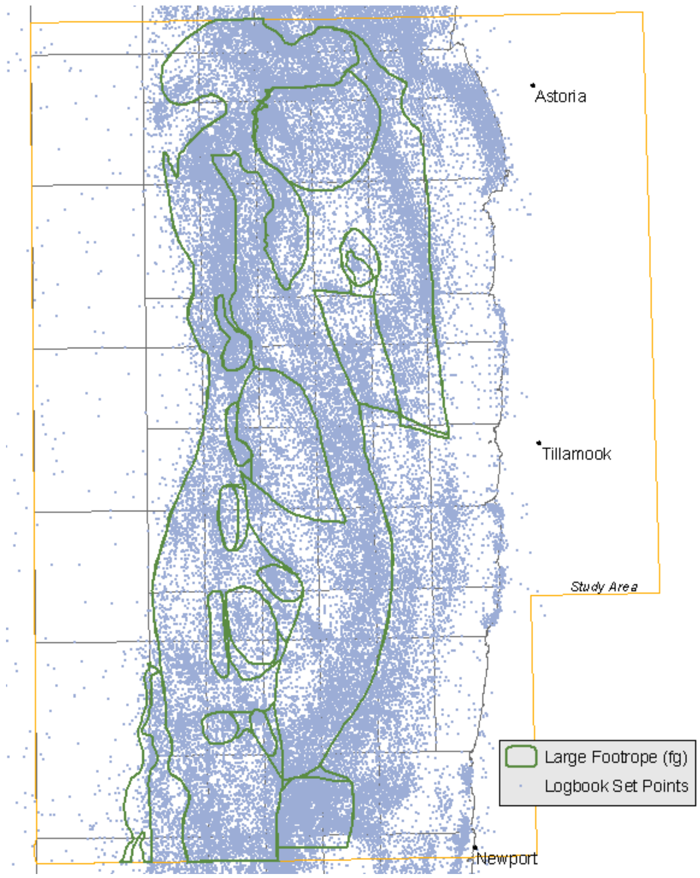

Figure 1: Trawl Logbook Bottom Trawl Set Points compared to Focus Group Large Footrope Polygons

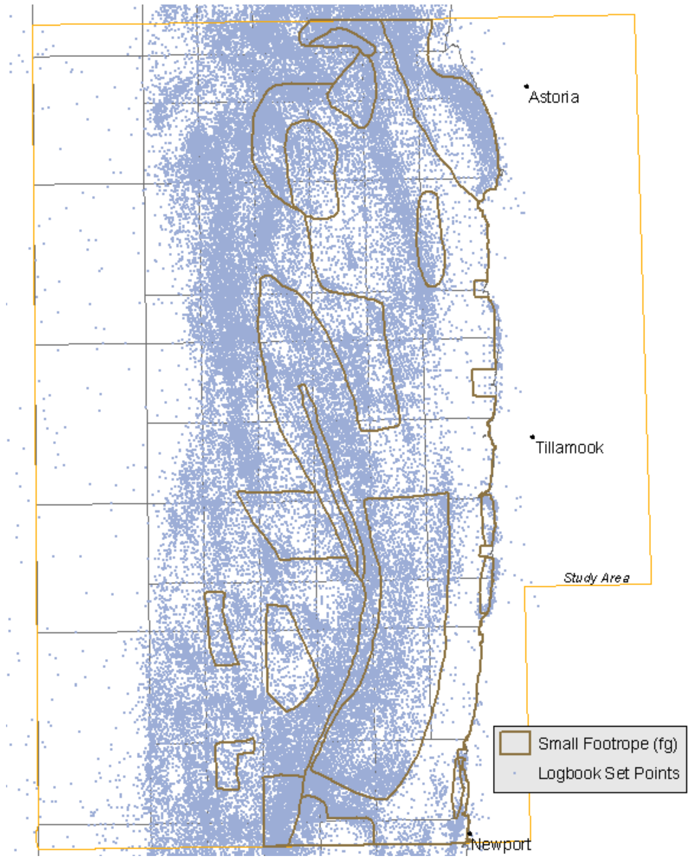

Figure 2: Trawl Logbook Bottom Trawl Set Points compared to Focus Group Small Footrope Polygons

The focus group data for pelagic trawls is less consistent with the logbook data than the bottom trawl data. It does not delineate the same areal extent as the logbook data, however, it does appear to locate areas with a higher concentration of midwater trawl set points (Figure 3).

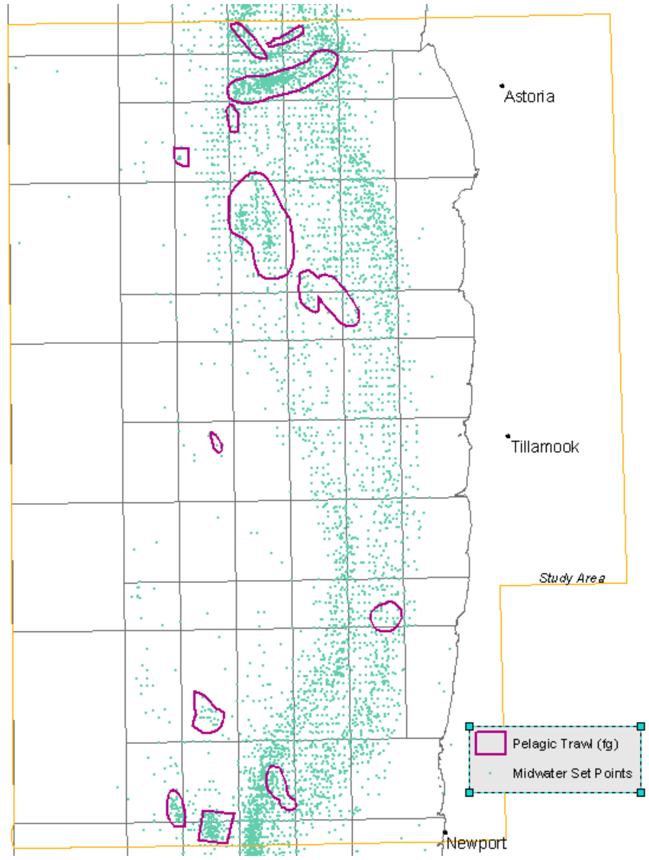

Figure 3: Trawl Logbook Midwater Trawl Set Points compared to Focus Group Pelagic Trawl Polygons

3. Spatial and Temporal Distribution of Trawl Logbook Effort

For a unique view of the changes over time in logbook effort, we created a map of the study area's logbook blocks with bar graphs depicting the total tow duration (in hours) by year in each block (Figure 4). This map depicts both the spatial and temporal distribution of trawl fishing effort in the same area covered by the Oregon focus group maps. At a glance, one can see general spatial distribution of fishing effort, as well as the change in intensity over time. We intend to create a series of maps like this one that depict the logbook blocks for the entire West Coast. In addition, because these data are available coastwide and have a range of time periods, this metric, total duration of all tows by year, will be provided as a preliminary input for the BBN impacts model.

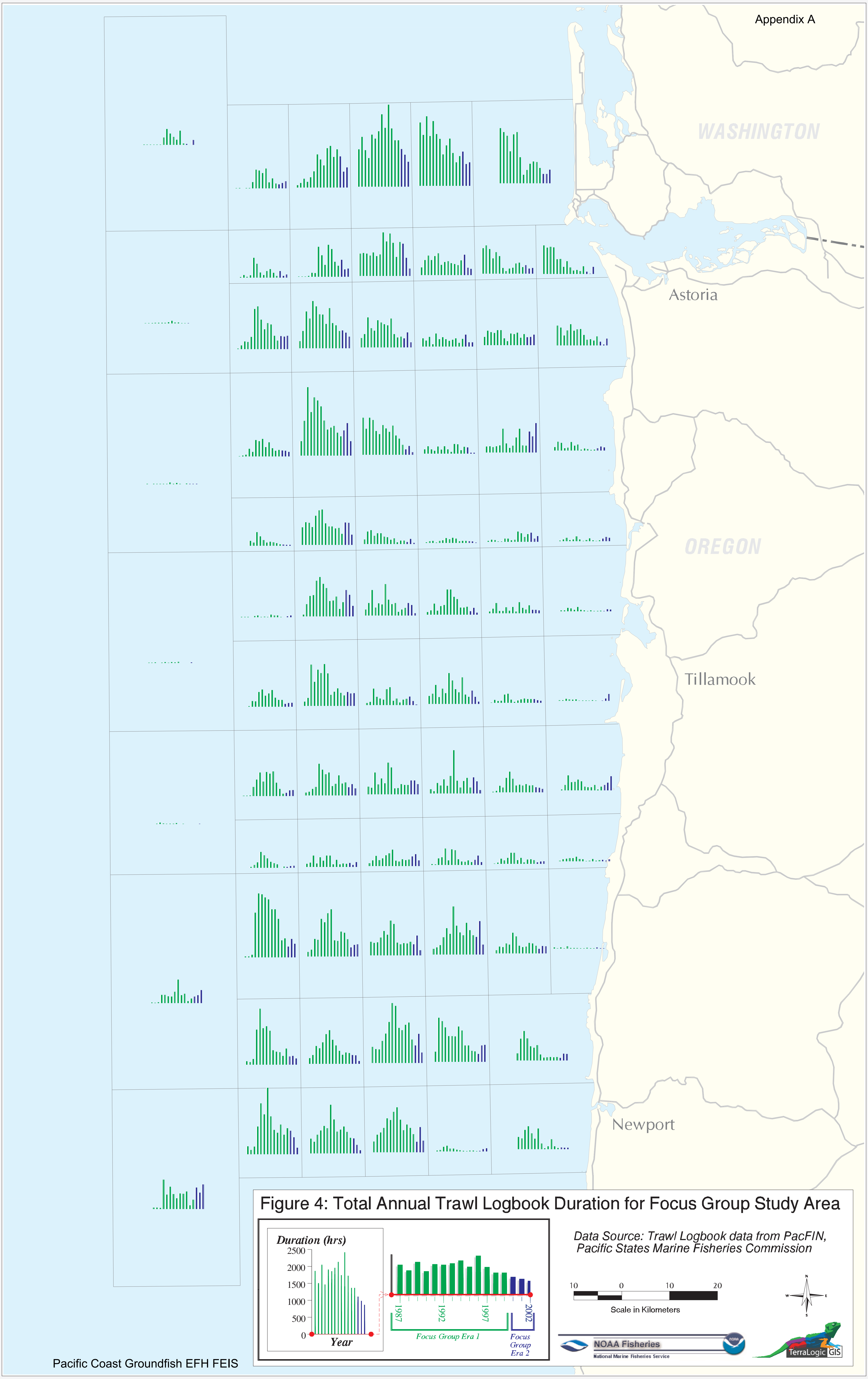

Figure 4: Total Annual Trawl Logbook Duration for Focus Group Study Area

Data Source: Trawl Logbook data from PacFIN, Pacific States Marine Fisheries Commission

4. Overlay of Focus Group Data with Geological Habitat

Focus group polygons were also overlaid with the geologic habitat data to look for habitat-specific patterns of fishing effort. Table 5 shows the total area covered by each geologic type within the study area (Table 5).

Table 5: Geologic Habitats Occurring in Focus Group Study Area

Habitat Type	Area (km2)	Percent of Total Area
Sedimentary Shelf	7350.67	36.65%
Sedimentary Slope	5820.34	29.02%
Sedimentary Ridge	3249.53	16.20%
Sedimentary Basin	1824.53	9.10%
Rocky Ridge	787.14	3.92%
Sedimentary Slope Canyon Wall	289.03	1.44%
Sedimentary Slope Canyon Floor	224.09	1.12%
Rocky Shelf	219.39	1.09%
Rocky Slope Canyon Wall	91.29	0.46%
Rocky Slope	66.73	0.33%
Sedimentary Shelf Canyon Wall	54.47	0.27%
Rocky Basin	21.89	0.11%
Sedimentary Shelf Canyon Floor	14.49	0.07%
Sedimentary Slope Gully	12.64	0.06%
Sedimentary Slope Landslide	11.92	0.06%
Rocky Slope Landslide	8.26	0.04%
Rocky Slope Canyon Floor	8.09	0.04%
Rocky Slope Gully	1.08	0.01%
Sedimentary Shelf Gully	0.70	0.00%
Island	0.09	0.00%

These results allow comparison of the habitats impacted by specific gear types to the overall coverage of each habitat type. The results from the focus group polygons and habitat overlays are shown in Table 6 (fixed gear) and Table 7 (trawl gear).

Table 6: Habitat Type Area by Focus Group Fixed Gear Polygons

Gear	Era	Season	Area (km2)	% of Total Area	Habitat Type
Crab Pot	1	Summer	2436.18	94.6%	Sedimentary Shelf
			45.92	1.8%	Sedimentary Slope
			42.81	1.7%	
			34.54	1.3%	Rocky Shelf
			12.15	0.5%	Sedimentary Shelf Canyon Wall
			1.60	0.1%	Rocky Slope
			1.10	0.0%	Sedimentary Slope Canyon Wall
			0.53	0.0%	Sedimentary Ridge
			0.08	0.0%	Island
Crab Pot	1	Transition	4041.88	94.5%	Sedimentary Shelf
			127.87	3.0%	
			45.93	1.1%	Sedimentary Slope
			45.59	1.1%	Rocky Shelf
			12.15	0.3%	Sedimentary Shelf Canyon Wall
			1.60	0.0%	Rocky Slope
			1.10	0.0%	Sedimentary Slope Canyon Wall
			0.53	0.0%	Sedimentary Ridge
			0.08	0.0%	Island
Crab Pot	1	Winter	5186.44	95.4%	Sedimentary Shelf
			127.87	2.4%	
			61.08	1.1%	Rocky Shelf
			45.93	0.8%	Sedimentary Slope
			12.15	0.2%	Sedimentary Shelf Canyon Wall
			1.60	0.0%	Rocky Slope
			1.10	0.0%	Sedimentary Slope Canyon Wall
			0.53	0.0%	Sedimentary Ridge
			0.08	0.0%	Island
Crab Pot	2 & 3	Summer	2436.18	94.6%	Sedimentary Shelf
			45.92	1.8%	Sedimentary Slope
			42.81	1.7%	
			34.54	1.3%	Rocky Shelf
			12.15	0.5%	Sedimentary Shelf Canyon Wall
			1.60	0.1%	Rocky Slope
			1.10	0.0%	Sedimentary Slope Canyon Wall
			0.53	0.0%	Sedimentary Ridge
			0.08	0.0%	Island
Crab Pot	2 & 3	Transition	5186.44	95.4%	Sedimentary Shelf
			127.87	2.4%	
			61.08	1.1%	Rocky Shelf
			45.93	0.8%	Sedimentary Slope
			12.15	0.2%	Sedimentary Shelf Canyon Wall
			1.60	0.0%	Rocky Slope
			1.10	0.0%	Sedimentary Slope Canyon Wall
			0.53	0.0%	Sedimentary Ridge
			0.08	0.0%	Island
Crab Pot	2 & 3	Winter	5186.44	95.4%	Sedimentary Shelf
			127.87	2.4%	
			61.08	1.1%	Rocky Shelf

Gear	Era	Season	Area (km2)	% of Total Area	Habitat Type
			45.93	0.8%	Sedimentary Slope
			12.15	0.2%	Sedimentary Shelf Canyon Wall
			1.60	0.0%	Rocky Slope
			1.10	0.0%	Sedimentary Slope Canyon Wall
			0.53	0.0%	Sedimentary Ridge
			0.08	0.0%	Island
Groundfish Pot	1	Summer	49.83	39.2%	Sedimentary Slope Canyon Wall
			39.22	30.9%	Sedimentary Slope
			13.46	10.6%	Rocky Slope Canyon Wall
			9.17	7.2%	Sedimentary Slope Canyon Floor
			6.31	5.0%	Sedimentary Slope Landslide
			4.72	3.7%	Rocky Slope Landslide
			3.10	2.4%	Rocky Slope
			1.15	0.9%	Sedimentary Shelf Canyon Wall
Groundfish Pot	2	Summer	4073.71	55.3%	Sedimentary Slope
			1719.98	23.3%	Sedimentary Ridge
			358.51	4.9%	Rocky Ridge
			311.49	4.2%	Sedimentary Basin
			246.92	3.4%	Sedimentary Shelf
			244.16	3.3%	Sedimentary Slope Canyon Wall
			182.59	2.5%	Sedimentary Slope Canyon Floor
			74.41	1.0%	Rocky Slope Canyon Wall
			39.40	0.5%	Rocky Slope
			38.98	0.5%	Sedimentary Shelf Canyon Wall
			20.63	0.3%	Rocky Shelf
			14.49	0.2%	Sedimentary Shelf Canyon Floor
			11.98	0.2%	Sedimentary Slope Gully
			11.55	0.2%	Sedimentary Slope Landslide
			8.26	0.1%	Rocky Slope Landslide
			7.48	0.1%	Rocky Slope Canyon Floor
			3.00	0.0%	Rocky Basin
			0.91	0.0%	Rocky Slope Gully
Groundfish Pot	3	Summer	4097.49	56.1%	Sedimentary Slope
			1719.98	23.6%	Sedimentary Ridge
			358.51	4.9%	Rocky Ridge
			311.49	4.3%	Sedimentary Basin
			244.16	3.3%	Sedimentary Slope Canyon Wall
			182.59	2.5%	Sedimentary Slope Canyon Floor
			161.44	2.2%	Sedimentary Shelf
			74.41	1.0%	Rocky Slope Canyon Wall
			45.87	0.6%	Sedimentary Shelf Canyon Wall
			39.49	0.5%	Rocky Slope
			14.49	0.2%	Sedimentary Shelf Canyon Floor
			11.98	0.2%	Sedimentary Slope Gully
			11.55	0.2%	Sedimentary Slope Landslide
			8.26	0.1%	Rocky Slope Landslide
			7.48	0.1%	Rocky Slope Canyon Floor
			6.69	0.1%	Rocky Shelf
			3.00	0.0%	Rocky Basin
			0.91	0.0%	Rocky Slope Gully

Gear	Era	Season	Area (km2)	% of Total Area	Habitat Type
Longline	1	Summer	3673.69	68.6%	Sedimentary Slope
			784.25	14.6%	Sedimentary Ridge
			373.14	7.0%	Sedimentary Shelf
			131.10	2.4%	Rocky Shelf
			126.27	2.4%	Rocky Ridge
			76.72	1.4%	Sedimentary Slope Canyon Wall
			47.17	0.9%	Sedimentary Basin
			30.88	0.6%	Rocky Slope
			29.04	0.5%	Sedimentary Slope Canyon Floor
			23.57	0.4%	Rocky Slope Canyon Wall
			18.30	0.3%	Sedimentary Shelf Canyon Wall
			14.37	0.3%	Sedimentary Shelf Canyon Floor
			8.53	0.2%	Sedimentary Slope Gully
			7.39	0.1%	Rocky Slope Landslide
			6.99	0.1%	Sedimentary Slope Landslide
			1.60	0.0%	Rocky Basin
			1.06	0.0%	Rocky Slope Gully
			0.65	0.0%	Sedimentary Shelf Gully
			0.01	0.0%	Rocky Slope Canyon Floor
Longline	1	Transition	3570.77	68.9%	Sedimentary Slope
			784.25	15.1%	Sedimentary Ridge
			342.85	6.6%	Sedimentary Shelf
			126.27	2.4%	Rocky Ridge
			92.98	1.8%	Rocky Shelf
			75.07	1.4%	Sedimentary Slope Canyon Wall
			47.17	0.9%	Sedimentary Basin
			29.28	0.6%	Rocky Slope
			29.04	0.6%	Sedimentary Slope Canyon Floor
			23.57	0.5%	Rocky Slope Canyon Wall
			18.30	0.4%	Sedimentary Shelf Canyon Wall
			14.37	0.3%	Sedimentary Shelf Canyon Floor
			8.53	0.2%	Sedimentary Slope Gully
			7.39	0.1%	Rocky Slope Landslide
			6.99	0.1%	Sedimentary Slope Landslide
			1.60	0.0%	Rocky Basin
			1.06	0.0%	Rocky Slope Gully
			0.65	0.0%	Sedimentary Shelf Gully
			0.01	0.0%	Rocky Slope Canyon Floor
Longline	2	Summer	3780.06	63.7%	Sedimentary Slope
			791.76	13.4%	Sedimentary Shelf
			621.42	10.5%	Sedimentary Ridge
			179.74	3.0%	Sedimentary Slope Canyon Wall
			136.50	2.3%	Sedimentary Slope Canyon Floor
			122.90	2.1%	Rocky Ridge
			56.50	1.0%	Sedimentary Basin
			53.66	0.9%	Rocky Slope Canyon Wall
			50.12	0.8%	Rocky Shelf
			46.88	0.8%	Sedimentary Shelf Canyon Wall
			39.73	0.7%	Rocky Slope
			14.49	0.2%	Sedimentary Shelf Canyon Floor

Gear	Era	Season	Area (km2)	% of Total Area	Habitat Type
			11.92	0.2%	Sedimentary Slope Landslide
			11.24	0.2%	Sedimentary Slope Gully
			8.26	0.1%	Rocky Slope Landslide
			1.69	0.0%	Rocky Basin
			1.08	0.0%	Rocky Slope Gully
			0.94	0.0%	Rocky Slope Canyon Floor
			0.70	0.0%	Sedimentary Shelf Gully
Longline	2	Transition	3677.82	63.9%	Sedimentary Slope
			761.48	13.2%	Sedimentary Shelf
			621.42	10.8%	Sedimentary Ridge
			178.19	3.1%	Sedimentary Slope Canyon Wall
			136.50	2.4%	Sedimentary Slope Canyon Floor
			122.90	2.1%	Rocky Ridge
			56.50	1.0%	Sedimentary Basin
			53.66	0.9%	Rocky Slope Canyon Wall
			46.88	0.8%	Sedimentary Shelf Canyon Wall
			38.13	0.7%	Rocky Slope
			14.49	0.3%	Sedimentary Shelf Canyon Floor
			12.00	0.2%	Rocky Shelf
			11.92	0.2%	Sedimentary Slope Landslide
			11.24	0.2%	Sedimentary Slope Gully
			8.26	0.1%	Rocky Slope Landslide
			1.69	0.0%	Rocky Basin
			1.08	0.0%	Rocky Slope Gully
			0.94	0.0%	Rocky Slope Canyon Floor
			0.70	0.0%	Sedimentary Shelf Gully
Longline	3	Summer	3776.00	64.4%	Sedimentary Slope
			771.86	13.2%	Sedimentary Shelf
			621.42	10.6%	Sedimentary Ridge
			179.74	3.1%	Sedimentary Slope Canyon Wall
			136.50	2.3%	Sedimentary Slope Canyon Floor
			122.90	2.1%	Rocky Ridge
			56.50	1.0%	Sedimentary Basin
			53.66	0.9%	Rocky Slope Canyon Wall
			46.88	0.8%	Sedimentary Shelf Canyon Wall
			39.73	0.7%	Rocky Slope
			14.49	0.2%	Sedimentary Shelf Canyon Floor
			12.00	0.2%	Rocky Shelf
			11.92	0.2%	Sedimentary Slope Landslide
			11.24	0.2%	Sedimentary Slope Gully
			8.26	0.1%	Rocky Slope Landslide
			1.69	0.0%	Rocky Basin
			1.08	0.0%	Rocky Slope Gully
			0.94	0.0%	Rocky Slope Canyon Floor
			0.70	0.0%	Sedimentary Shelf Gully
Longline	3	Transition	3677.82	63.9%	Sedimentary Slope
			761.48	13.2%	Sedimentary Shelf
			621.42	10.8%	Sedimentary Ridge
			178.19	3.1%	Sedimentary Slope Canyon Wall
			136.50	2.4%	Sedimentary Slope Canyon Floor

Gear	Era	Season	Area (km2)	% of Total Area	Habitat Type
			122.90	2.1%	Rocky Ridge
			56.50	1.0%	Sedimentary Basin
			53.66	0.9%	Rocky Slope Canyon Wall
			46.88	0.8%	Sedimentary Shelf Canyon Wall
			38.13	0.7%	Rocky Slope
			14.49	0.3%	Sedimentary Shelf Canyon Floor
			12.00	0.2%	Rocky Shelf
			11.92	0.2%	Sedimentary Slope Landslide
			11.24	0.2%	Sedimentary Slope Gully
			8.26	0.1%	Rocky Slope Landslide
			1.69	0.0%	Rocky Basin
			1.08	0.0%	Rocky Slope Gully
			0.94	0.0%	Rocky Slope Canyon Floor
			0.70	0.0%	Sedimentary Shelf Gully

Table 7: Habitat Type Area by Focus Group Trawl Gear Polygons

Gear	Era	Season	Area (km2)	% of Total Area	Habitat Type
Large Footrope Trawl	1	Summer & Transition	4627.61	50.2%	Sedimentary Slope
			3146.40	34.1%	Sedimentary Shelf
			748.15	8.1%	Sedimentary Ridge
			151.42	1.6%	Sedimentary Slope Canyon Wall
			128.55	1.4%	Rocky Shelf
			103.27	1.1%	Sedimentary Slope Canyon Floor
			99.40	1.1%	Rocky Ridge
			54.47	0.6%	Sedimentary Shelf Canyon Wall
			46.84	0.5%	Rocky Slope
			35.91	0.4%	Sedimentary Basin
			32.30	0.4%	Rocky Slope Canyon Wall
			14.49	0.2%	Sedimentary Shelf Canyon Floor
			11.92	0.1%	Sedimentary Slope Landslide
			10.16	0.1%	Sedimentary Slope Gully
			8.26	0.1%	Rocky Slope Landslide
			1.60	0.0%	Rocky Basin
			1.07	0.0%	Rocky Slope Gully
			0.70	0.0%	Sedimentary Shelf Gully
			0.36	0.0%	Rocky Slope Canyon Floor
Large Footrope Trawl	1	Winter	2978.36	58.6%	Sedimentary Slope
			737.20	14.5%	Sedimentary Ridge
			683.62	13.5%	Sedimentary Shelf
			151.18	3.0%	Sedimentary Slope Canyon Wall
			119.27	2.3%	Rocky Shelf
			103.05	2.0%	Sedimentary Slope Canyon Floor
			98.45	1.9%	Rocky Ridge
			50.92	1.0%	Sedimentary Shelf Canyon Wall
			44.13	0.9%	Rocky Slope
			35.49	0.7%	Sedimentary Basin
			32.13	0.6%	Rocky Slope Canyon Wall
			14.49	0.3%	Sedimentary Shelf Canyon Floor

Gear	Era	Season	Area (km2)	% of Total Area	Habitat Type
			10.55	0.2%	Sedimentary Slope Landslide
			8.96	0.2%	Sedimentary Slope Gully
			8.26	0.2%	Rocky Slope Landslide
			1.60	0.0%	Rocky Basin
			0.83	0.0%	Rocky Slope Gully
			0.36	0.0%	Rocky Slope Canyon Floor
Large Footrope Trawl	2	Summer & Transition	4203.27	52.3%	Sedimentary Slope
			2663.18	33.2%	Sedimentary Shelf
			545.73	6.8%	Sedimentary Ridge
			151.19	1.9%	Sedimentary Slope Canyon Wall
			103.05	1.3%	Sedimentary Slope Canyon Floor
			86.93	1.1%	Rocky Ridge
			81.25	1.0%	Rocky Shelf
			54.47	0.7%	Sedimentary Shelf Canyon Wall
			35.49	0.4%	Sedimentary Basin
			32.13	0.4%	Rocky Slope Canyon Wall
			31.01	0.4%	Rocky Slope
			14.49	0.2%	Sedimentary Shelf Canyon Floor
			11.92	0.1%	Sedimentary Slope Landslide
			8.26	0.1%	Rocky Slope Landslide
			7.10	0.1%	Sedimentary Slope Gully
			1.60	0.0%	Rocky Basin
			0.70	0.0%	Sedimentary Shelf Gully
			0.49	0.0%	Rocky Slope Gully
			0.36	0.0%	Rocky Slope Canyon Floor
Large Footrope Trawl	2	Winter	2832.03	64.5%	Sedimentary Slope
			677.14	15.4%	Sedimentary Ridge
			258.09	5.9%	Sedimentary Shelf
			151.18	3.4%	Sedimentary Slope Canyon Wall
			105.68	2.4%	Rocky Ridge
			103.05	2.3%	Sedimentary Slope Canyon Floor
			71.83	1.6%	Rocky Shelf
			50.92	1.2%	Sedimentary Shelf Canyon Wall
			35.49	0.8%	Sedimentary Basin
			32.13	0.7%	Rocky Slope Canyon Wall
			30.34	0.7%	Rocky Slope
			14.49	0.3%	Sedimentary Shelf Canyon Floor
			10.55	0.2%	Sedimentary Slope Landslide
			8.96	0.2%	Sedimentary Slope Gully
			8.26	0.2%	Rocky Slope Landslide
			1.60	0.0%	Rocky Basin
			0.83	0.0%	Rocky Slope Gully
			0.36	0.0%	Rocky Slope Canyon Floor
Large Footrope Trawl	3	Winter	3505.89	65.6%	Sedimentary Slope
			1036.23	19.4%	Sedimentary Ridge
			201.35	3.8%	Rocky Ridge
			166.91	3.1%	Sedimentary Slope Canyon Wall
			146.80	2.7%	Sedimentary Slope Canyon Floor
			113.39	2.1%	Sedimentary Basin
			46.41	0.9%	Rocky Slope Canyon Wall

Gear	Era	Season	Area (km2)	% of Total Area	Habitat Type
			32.36	0.6%	Sedimentary Shelf
			29.63	0.6%	Rocky Slope
			22.54	0.4%	Sedimentary Shelf Canyon Wall
			14.40	0.3%	Sedimentary Shelf Canyon Floor
			11.93	0.2%	Sedimentary Slope Gully
			5.28	0.1%	Sedimentary Slope Landslide
			3.81	0.1%	Rocky Slope Landslide
			2.95	0.1%	Rocky Slope Canyon Floor
			1.76	0.0%	Rocky Basin
			0.89	0.0%	Rocky Slope Gully
			0.11	0.0%	Rocky Shelf
Small Footrope Trawl	1 & 2	Winter	1293.57	58.5%	Sedimentary Shelf
			885.28	40.1%	Sedimentary Slope
			14.85	0.7%	Sedimentary Shelf Canyon Wall
			8.22	0.4%	Rocky Slope
			7.36	0.3%	Sedimentary Ridge
			0.89	0.0%	Rocky Shelf
			0.00	0.0%	Rocky Ridge
Small Footrope Trawl	1	Summer & Transition	6319.87	77.1%	Sedimentary Shelf
			1685.37	20.5%	Sedimentary Slope
			150.98	1.8%	Rocky Shelf
			16.63	0.2%	Sedimentary Shelf Canyon Wall
			16.03	0.2%	Rocky Slope
			7.36	0.1%	Sedimentary Ridge
			2.16	0.0%	Sedimentary Slope Canyon Wall
			2.15	0.0%	
			0.59	0.0%	Sedimentary Shelf Gully
			0.45	0.0%	Sedimentary Slope Landslide
			0.08	0.0%	Island
			0.01	0.0%	Sedimentary Slope Gully
			0.00	0.0%	Rocky Ridge
Small Footrope Trawl	2	Summer	6319.87	83.4%	Sedimentary Shelf
			1070.32	14.1%	Sedimentary Slope
			150.98	2.0%	Rocky Shelf
			16.63	0.2%	Sedimentary Shelf Canyon Wall
			15.56	0.2%	Rocky Slope
			2.16	0.0%	Sedimentary Slope Canyon Wall
			2.15	0.0%	
			0.59	0.0%	Sedimentary Shelf Gully
			0.53	0.0%	Sedimentary Ridge
			0.45	0.0%	Sedimentary Slope Landslide
			0.08	0.0%	Island
			0.01	0.0%	Sedimentary Slope Gully
Small Footrope Trawl	3	Summer	1670.11	99.9%	Sedimentary Shelf
			0.64	0.0%	
			0.38	0.0%	Rocky Shelf
Small Footrope Trawl	3	Winter	2126.58	99.8%	Sedimentary Shelf
			4.64	0.2%	
			0.30	0.0%	Rocky Shelf
			0.00	0.0%	Island