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Groundfish Fisheries in St. Georges Bay

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1. Abstract - *Résumé*

Groundfish fisheries in St. Georges Bay have been directed at white hake, plaice, winter flounder and cod. Four main gear types are used, longlines, gillnets, otter trawls and seines. Seven unique fishery types were defined based on the species composition of the catches: four were directed at each of the main species and the remaining three yielded mixed catches of white hake and plaice, white hake and winter flounder, and white hake and cod. Longlines and gillnets were used mainly for the gadoid species, white hake and cod. Seines were used for white hake, plaice and cod while otter trawls were used for all four species. A preliminary analysis of catch rates for the four species was conducted. Several possible research topics are discussed.

Les pêches du poisson de fond dans la baie St. Georges sont dirigées vers la merluche blanche, la plie canadienne, la plie rouge et la morue. Quatre principaux types d'engin sont utilisés, soit la palangre, le filet maillant, le chalut à panneau et la seine. D'après la composition des prises selon l'espèce, on a défini sept types distincts de pêche : quatre types visaient chacune des principales espèces et les trois autres ont donné lieu à des prises mélangées, soit la merluche blanche et la plie canadienne, la merluche blanche et la plie rouge, et la merluche blanche et la morue. La palangre et le filet maillant ont servi principalement à la pêche des espèces gadoïdes, la merluche blanche et la morue. La seine a été utilisée pour la merluche blanche, la plie canadienne et la morue tandis que le chalut à panneau a été utilisé pour les quatre espèces. Une analyse préliminaire des taux de capture pour chacune des quatre espèces a été effectuée. Plusieurs sujets de recherche possibles sont traités dans le présent document.

2. Introduction

Groundfish fisheries in St. Georges Bay consist of a diverse combination of fishing gears and species. There are important interactions among the fisheries due to the multi-species nature of the catches, competition for fishing grounds among vessels, and differences in size selection of different fishing gears. A better understanding of these interactions would help in interpreting fishery catch and effort data in terms of trends in stock abundance and exploitation rates. This is particularly important for cod and hake fisheries in St. Georges Bay where these species are in a depressed state and require stock rebuilding. The multi-species and multi-gear nature of groundfish fisheries in St. Georges Bay is different from that for lobster and herring fisheries which are exploited in a single-species, single-gear manner.

This report describes the combination of species and fishing gears involved in the groundfish fisheries. We have examined the main fishing gears used, the species caught with each, and the evolution of gear/species combinations over the past 13 years (1985 - 1997). Fishery types are defined based on similarities in species composition of the landings. Catch rate indices of individual species are developed and are discussed in relation with changes in overall and local stock abundance. Some of the factors which have influenced these changes are discussed, but several questions remain unanswered. Improved understanding of the social and biological factors which influence the conduct of these fisheries will aid in the interpretation of fisheries data in relation to stock status and in formulating effective management measures. Within the context of the St. Georges Bay Ecosystem Project, the intent of this report is to provide industry stakeholders with information on recent changes in their fisheries.

This is a first draft of the report and it is hoped that it will stimulate the interest of readers and encourage further discussion using the GBEP listserver. Please don't hesitate to provide comments.

3. Data

The main source of information used in this report is the Department of Fisheries and Oceans purchase slip database which records individual trip landings from commercial marine fisheries in eastern Canada. The study area includes ports from Lismore N.S. at the western extreme, throughout St. Georges Bay and extending to Mabou Mines, Cape Breton at the eastern end (Figure 1). The study period includes 1985 to 1997, years for which purchase slip data are readily available. The purchase slip files record the CFV number of the vessel, the gear used, the port of landing, the date of landing, and the quantity of fish landed.

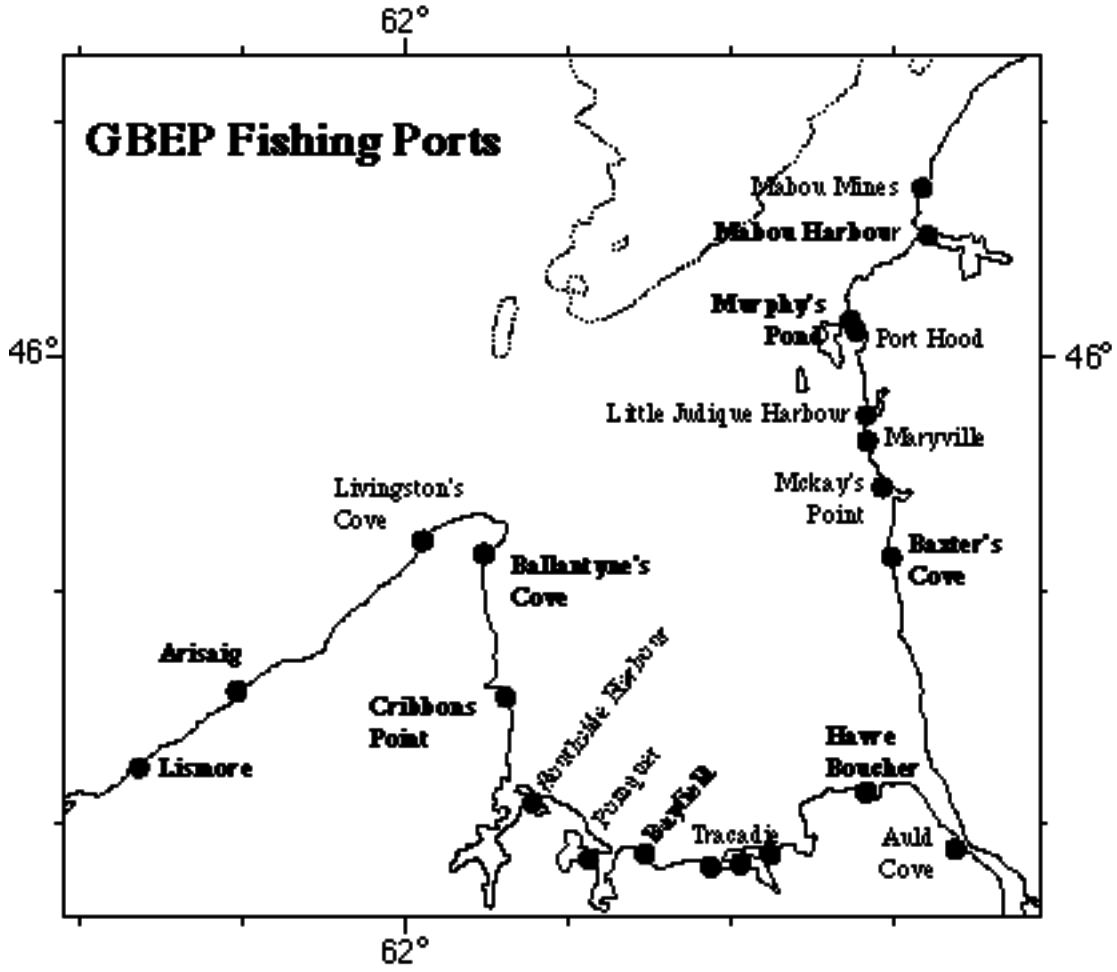

Figure 1: Fishing ports in the St. Georges Bay ecosystem project study area.

The number of slips was used here as a measure of the amount of fishing effort expended to catch the fish. The groundfish fishing trips in St. Georges Bay are almost all of one days duration, so the number of slips is an indication of the number of fishing days. The number of fishing sets or amount of fishing gear used in the trip is not recorded on the slip however. This information is normally recorded on fishing logbooks. Logbook data is available for mobile gear vessels (otter trawl and seine) since 1991, but it is not available for fixed gear vessels. A preliminary analysis of logbook data indicated little variation in the number of sets made per days fishing for mobile gear vessels. So, we are fairly comfortable in using the number of purchase slips as an indication of the amount of fishing effort.

Catch per unit effort has been traditionally used as a measure of fishing success and as an index of stock size. In this report we have used landings per purchase slip as a measure of catch per unit effort. Its relevance in terms of stock status is also discussed.

4. Groundfish Landings

4.1. Species

The principle groundfish species landed in St. Georges Bay are white hake, American plaice, winter flounder, and cod (Table 1). These four species are ranked 3, 5, 7, and 8 on the list of all species landed in the study area between 1985 - 97. This report will focus on fisheries for these four species. Other groundfish species reported in St. Georges Bay are dogfish, witch flounder, skate, haddock, yellowtail flounder, catfish (wolfish), halibut and Greenland halibut, however their landings have been very small and these will not be considered further.

Table 1: Landings of commercial marine species in St. Georges Bay, 1985 - 1997.

Species	Tonnes	Species	Tonnes
Herring	21817	Bar Clams	49
Lobsters	15013	Quahaugs Clams	33
White Hake	5561	Skate	28.8
Snow Crabs (Queen)	4480	Squid	17
Plaice	3436	Oysters (American)	17
Alewives (Gaspereau)	3089	Haddock	7
Winter Flounder	2916	Yellowtail	5
Cod	1335	Soft Shell Clams	2
Mackerel	902	Mussels	1
Rock Crabs	436	Shark, Unsp.	1
Scallops	379	Tomcod	1
Tuna, Bluefin	239	Catfish	0.3
Eels	179	Halibut	0.3
Dogfishes	146	Greenland Halibut (Turbot)	0.3
Greysole (Witch)	145	Salmon	0.1
Smelts	139	Striped Bass	0.1

4.2. Gear

Groundfish are caught with several fishing gears (Table 2). The main gears are stern and side otter trawl, longline, gillnet, and seine. All four have a continuous history of fishing in the area, and their landings will be considered further in this report. Other minor gears include handline, jiggers, pair seine, traps and pots.

Table 2: Fishing gears used to catch groundfish in St. Georges Bay. The amount of use of each gear is indicated by the number of purchase slips.

Gear Type	Code	N Slips
Bottom Otter Trawl (Stern)	12	8461
Longline	51	5867
Gillnet	41	3814
Danish and Scottish Seine	21, 22	3594
Bottom Otter Trawl (Side)	11	252
Hand Line (Baited)	59	149
Jigger	53	36
Pair Seine	33	22
Trap	61	16
Pot	62	2

The species composition of the landings varies among the different gears (Fig. 2). Otter trawls were used to catch winter flounder, white hake, and plaice. Longlines were used almost exclusively for white hake. Gillnets were used for white hake, cod, and for a brief period (1991) for winter flounder. Seines were used for plaice, cod, and white hake.

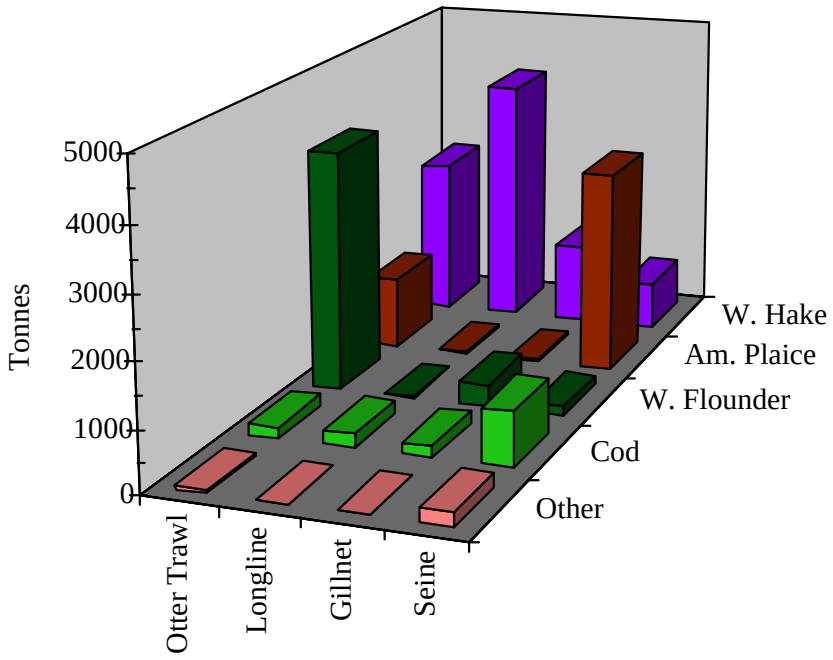

Figure 2: Groundfish landings in St. Georges Bay by four main gear categories, 1985 - 1997.

4.3. Ports

There are some 21 recognised fish offloading sites in the St. Georges Bay study area (Figure 1). Contiguous sites were regrouped into 9 "ports" to facilitate further analysis. These are listed in Table 3. The groupings were as follows. Lismore, Arisaig and Cribbons Point were treated as individual ports. Ballantyne's Cove and Livingston Cove were combined. Bayfield, Southside Harbour and Pomquet were combined. Havre Boucher, Tracadie, and Aulds Cove were combined. Baxter's Cove was grouped with Maryville and McKay's Point. Murphy's Pond included Little Judique Harbour and Port Hood. Finally, Mabou Harbour and Mabou Mines were combined.

The usage of these different fishing gears varies geographically (Table 3). Gillnets were used mainly from ports at the mouth of St. Georges Bay including Murphy's Pond, Mabou, Ballantyne's Cove, Arisaig, and Lismore. Longlines were used at Murphy's Pond, Harvre Boucher, Ballantyne's Cove, and Bayfield. Otter trawls were used from the western and central ports (Lismore, Arisaig, Ballantyne's Cove, Bayfield, and Harvre Boucher). Seines were used almost exclusively at Murphy's Pond with a moderate number of purchase slips coming from Ballantyne's Cove. It would be instructive to understand what influences the choice of fishing gear in different ports. Is it the type of fishing grounds available near the port, the species sought, or the development of local expertise with the different gears?

Table 3: Fishing gear usage (number of purchase slips) by fishing ports in the St. Georges Bay area, 1985 - 1997. The ports were grouped into the nine locations.

	Gillnet	Longline	Otter Trawl	Seine
LISMORE	199	19	2672	7
ARISAIG	223	3	1766	1
BALLANTYNE'S COVE	481	1232	1742	464
CRIBBONS POINT	72	53	31	0
BAYFIELD	125	769	1513	30
HAVRE BOUCHER	59	1608	866	0
BAXTER'S COVE	57	42	81	0
MABOU HARBOUR	657	46	0	55
MURPHY'S POND	1941	2095	42	3037

4.4. Effort

The total number of individual vessels participating in the St. Georges Bay groundfish fisheries varied between 88 and 137 annually between 1985 and 1994. The number of vessels fell to 47 in 1995 and to 39 in 1996 and 1997 respectively. The main reason for this decrease was probably the closure of the white hake fishery in January 1995.

Many of these vessels were involved in fisheries for species other than groundfish, e.g. lobster and herring. It was also possible to change fishing gear in mid-groundfish season. As a result, one vessel could use anywhere from one to all four main groundfish gears in a

single year. This flexibility was reduced in 1993 when vessel operators were required to choose between fixed or mobile gears for the groundfish season.

Closure of the white hake fishery had the greatest impact on the use of longlines and gillnets (Fig. 3). The number of vessels using otter trawl declined gradually over the 1985 - 1997 time period, but there remained over 20 otter trawl vessels in 1997. The number of vessels using seines remained relatively stable throughout the time period, between 10 - 20 per year. There were between 22 - 45 vessels using gillnets between 1985 - 1994, but this fell to 2 - 4 in the last 3 years. The number vessels using longlines varied between 25-54 during 1985-91, the increased to over 70 in 1992 - 1994. However, with the closure of the white hake fishery, this fell to 2 or 3 in the last 3 years. Of these vessels, 2 were participants in the DFO sentinel survey program.

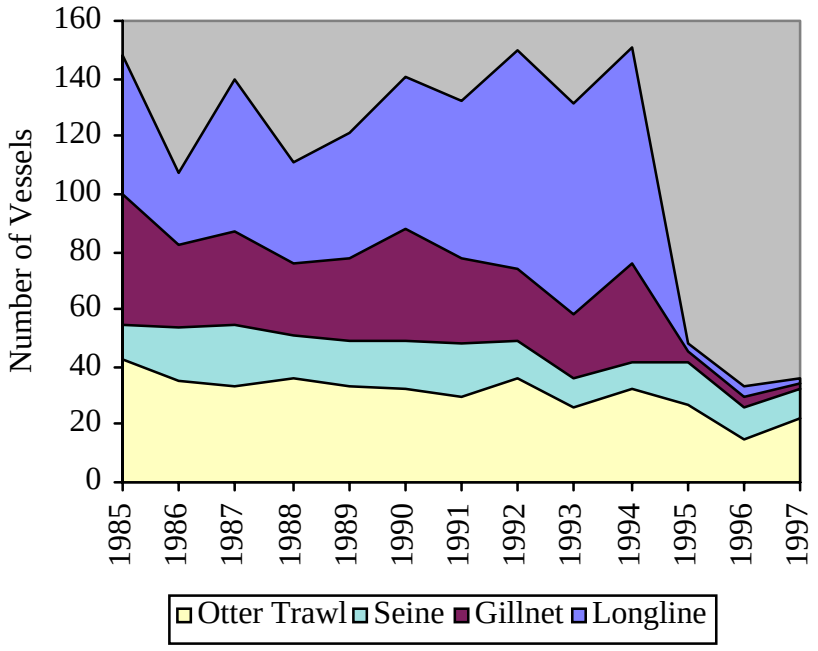

Figure 3: Numbers of vessels using the four main gear types in St. Georges Bay groundfish fisheries, 1985 - 1997. One vessel could use more than 1 gear in a single year.

Fishing gear use by individual vessels became more specialized in the 1990s. This is indicated by the decline in the index of multiple gear use (Fig. 4). This index is the ratio between the sum of the vessel-gear combinations divided by the number of individual vessels. The ratio is restricted to the range of 1 - 4. An annual value of 1 would result from each vessel using only 1 gear. The maximum value would result from each vessel using all 4 gears. The highest ratio occurred in 1985 (1.55). It declined to between 1.2 - 1.3 in 1986 - 1989, increased for 1 year to 1.35 in 1990, then declined to a minimum value of 1.1 in 1995. Relatively speaking, there is very little multiple gear use in the current groundfish fisheries in St. Georges Bay.

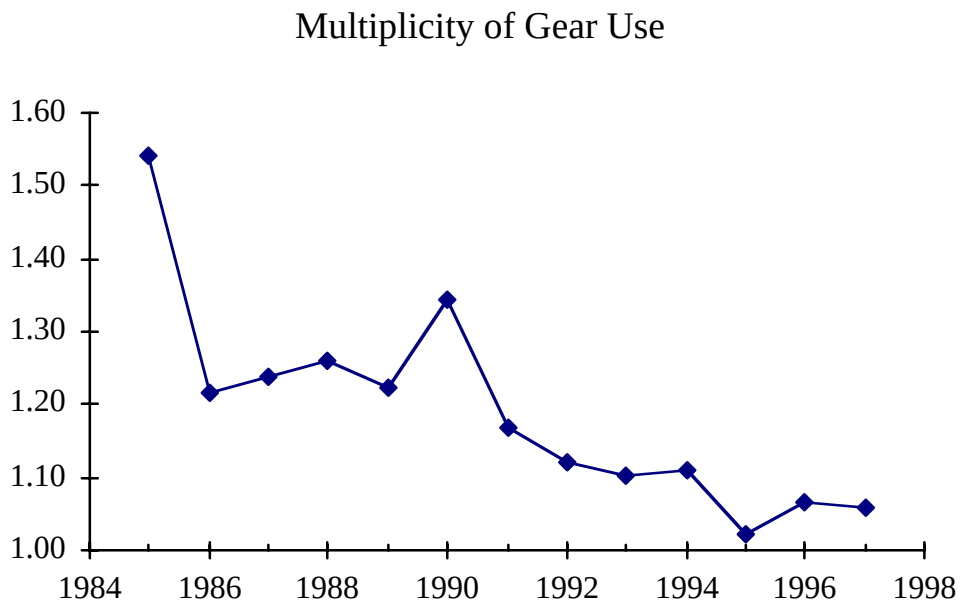

Figure 4: Index of multiple gear use in St. Georges Bay groundfish fisheries, 1985 - 1997. The index is the ratio of the sum of the number of vessel / gear combinations in a year divided by the number of individual vessels fishing in the year.

5. Fishery Definition

Understanding the dynamics of groundfish fisheries has important implications for fisheries management. It allows researchers to put in perspective the effects of removals from directed fisheries and by-catch fisheries. Directed fisheries are those that target one species. By-catches are also made of secondary species. These by-catches, however, may be important when the directed fishery is relatively large, or when the by-catch species is threatened. Management regulations have been put in place to limit the amount of by-catch. However, it is important that the by-catch limits reflect reasonable expected levels. If the limits are too low, then discarding of by-catch species is encouraged.

The species composition of landings reflects the mixture of species on the fishing grounds and the selectivity of the fishing gear used. Individual groundfish species occupy specific habitats defined by factors such as water temperature, bottom type, and water depth. Consequently, their spatial distributions reflect, to a certain extent, variations in their preferred habitats. Their spatial distributions also vary seasonally. Cod, plaice and white hake leave the Bay in the late fall and overwinter in deeper waters of the Laurentian Channel at the mouth of the Gulf of St. Lawrence. Winter flounder, on the other hand, are thought to overwinter in coastal estuaries. Some fisheries concentrate on migrating fish due to their more aggregated distribution. Others concentrate on feeding distributions. During the fishing season, cod and plaice tend to be found in deeper and colder water than white hake and winter flounder. But, there is considerable spatial

overlap among these species. Over the years, knowledge of these patterns allows fishers to predict the species mix of their catches based on their fishing location and timing.

Fishing gears are also selective, both of the size of fish and the species. The size of meshes in otter trawls, seines and gillnets, and the hook and bait sizes used on longlines will affect the sizes of individual fish caught. Larger meshes, hooks, and baits will catch larger fish. Plaice and winter flounder have smaller mouths than white hake and cod of the same size, and this results in few plaice and winter flounder being caught on longlines. Gillnets are normally used for cod and hake, possibly because the flatfish species remain closer to bottom. In summary, the type and size of gear will affect the size and species composition of the catches.

In this section of the report we describe the main fishery types in St. Georges Bay groundfish fisheries. These fishery types were defined based on the species composition of landings and the fishing gear used. Changes in the mix of fishery types during the study period are described as well as their geographic locations.

5.1. Methods

Fishing trips can be classified into fishery types using a technique called cluster analysis. For each fishing trip, the proportion of the total landing made up by each of the four species, white hake, plaice, winter flounder and cod, was calculated. Cluster analysis was then used group the trips into clusters based on the similarity in catch composition. For example, trips that landed a high proportion of cod and little of any other species were grouped together, trips with similar combinations of winter flounder and white hake were grouped together, and so on. In the end, a reduced number of fishery types was selected, in this case there were 7 fishery types.

A detailed explanation of the cluster analysis can be found here. For those more interested in the results, and how the fishery types were distributed among the fishing gears and years, click here.

5.1.1. K-means Clustering

The K-means clustering method was used for the St. Georges Bay purchase slip cluster analysis. This methods involves first specifying the number of clusters desired (k). The algorithm then selects k cluster seeds which are located approximately uniformly in the multi-dimensional space defined by the four species landings proportions. Each trip is then assigned to the nearest seed to form temporary clusters of trips. The cluster mean position is then calculated and used as new cluster seeds, and the trips are reallocated according to the new seeds. This process is repeated until no further change in the cluster seeds occurs.

Several other methods of cluster analysis are available. Two classes commonly used on small datasets (500 observations or less) are either agglomerative or divisive. The former begins with the individual observations and groups them together according to a pre-defined similarity index. The process continues until only one cluster remains. The divisive method works in the opposite direction, beginning with one observation and dividing the observations in more and more clusters. Neither method was feasible with the large number of purchase slips available, over 20,000. The computing time needed for agglomerative or divisive clustering was far too high to be practical.

5.1.2. Catch Composition

Cluster analysis works on observations distributed in a 4 - dimensional space defined by the proportions of the trip landing composed of the four species. The axes of the space range from 0 to 1 (or 0% to 100%). On any 2-dimensional plane, defined by the catch proportions of 2 species, the observations are restricted to a triangular space defined by the origin, the maximum value of the axis (1.0 or 100%), and a diagonal running from the two axis maxima (Fig. 4). Points running along the diagonal represent trips where only 2 species were landed (the proportions sum to 1.0). Points on either axis represent trips where there was no catch of one of the species. Points inside the triangular space are from trips where there was a mixture of landings of the 2 species plotted plus one or both of the other two species.

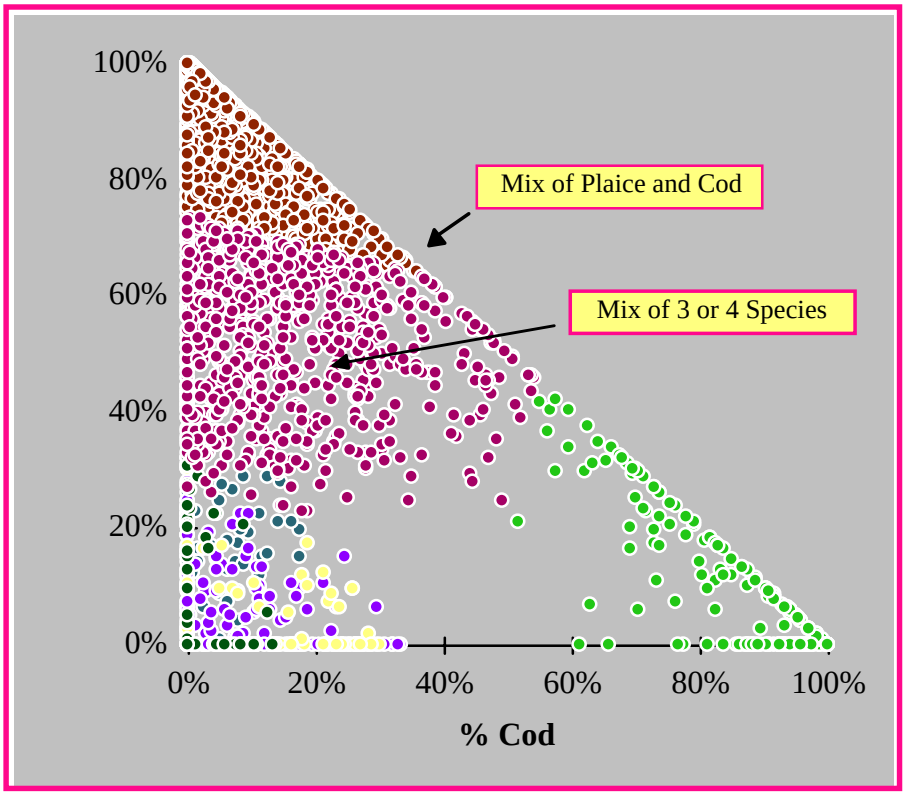

Figure 5: A scatterplot ot the proportions of plaice and cod in landings from seiners fishing in the St. Georges Bay area, 1985 - 1997. This is a 2-dimensional plane through the 4-dimensional space analysed with cluster analysis. The data points are colour-coded according to the cluster assigned.

The points plotted in Fig. 5 are colour coded according to their respective clusters. The brown points are for landings that were heavily weighted toward plaice, the green points were weighted toward cod. The wine coloured points had moderate to high proportions of plaice, moderate to low proportions of cod, and also catches of both white hake and winter flounder. The remaining clusters had low proportions of both cod and plaice.

5.1.3. Species Mix by Gear

The following figures present a scatterplot matrix for each fishing gear. These figures provide a rapid evaluation of the degree of species mixture in landings by the gears. The scatterplot martrix consists of several plots similar to that shown in Fig. 4. The axes are indicated by the labels on the diagonal of the figure and the overall figure is symmetrical. That is to say that the same plots are shown on opposite sides of the diagonal, only their axes are reversed.

Otter trawl landings had the highest degree of species mix of the four main gear types (Fig. 6). This is indicated by the large number of data points found in the center of the scatterplots, especially in the plots involving plaice, winter flounder, and white hake.

Most of the cod landings by otter trawls were less than 20% of the total landing for the trip. There appears to be a fairly strong association between winter flounder and white hake in an otter trawl fishery. This can be seen in the heavy distribution of data points along the diagonal of the scatterplot of these 2 species.

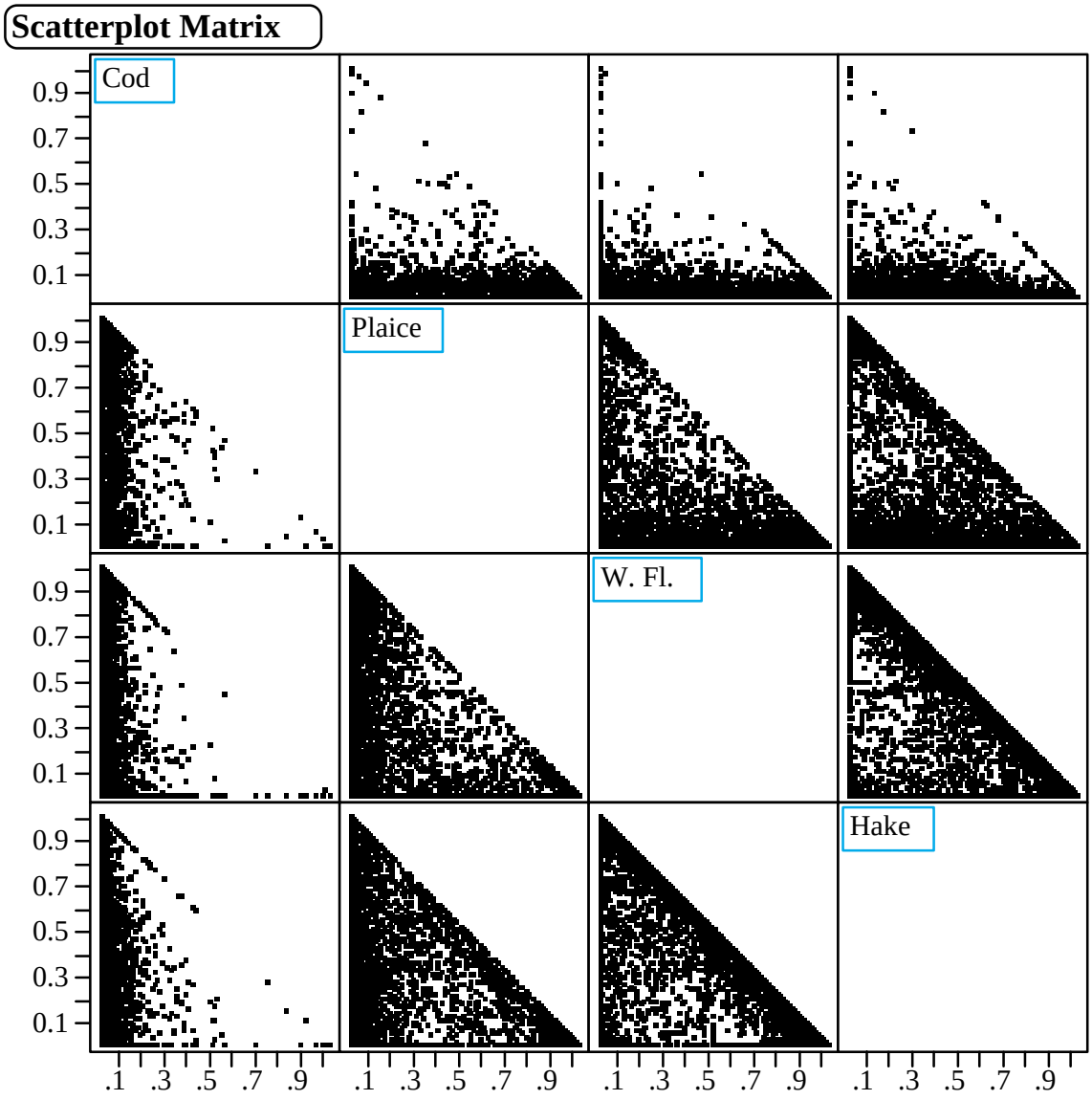

Figure 6: Scatterplot matrix of species compositions in landings by otter trawls. Each panel is a bi-variate plot comparing landings proportions of 2 species (see Fig. 5). The axes are indicated by labels in the diagonal of the matrix. The matrix is symmetrical, i.e. each panel is plotted twice with the axes reversed.

Plaice was the most important species in the seine landings (Fig. 7). Cod were generally less than 40% of the total landing on a trip by trip basis, and the same could be said for white hake. Winter flounder were not common in seine landings. A large number of landings by seines had a mixture of plaice, cod and white hake, as can be seen from the large clusters of points in the scatterplots of these 3 species.

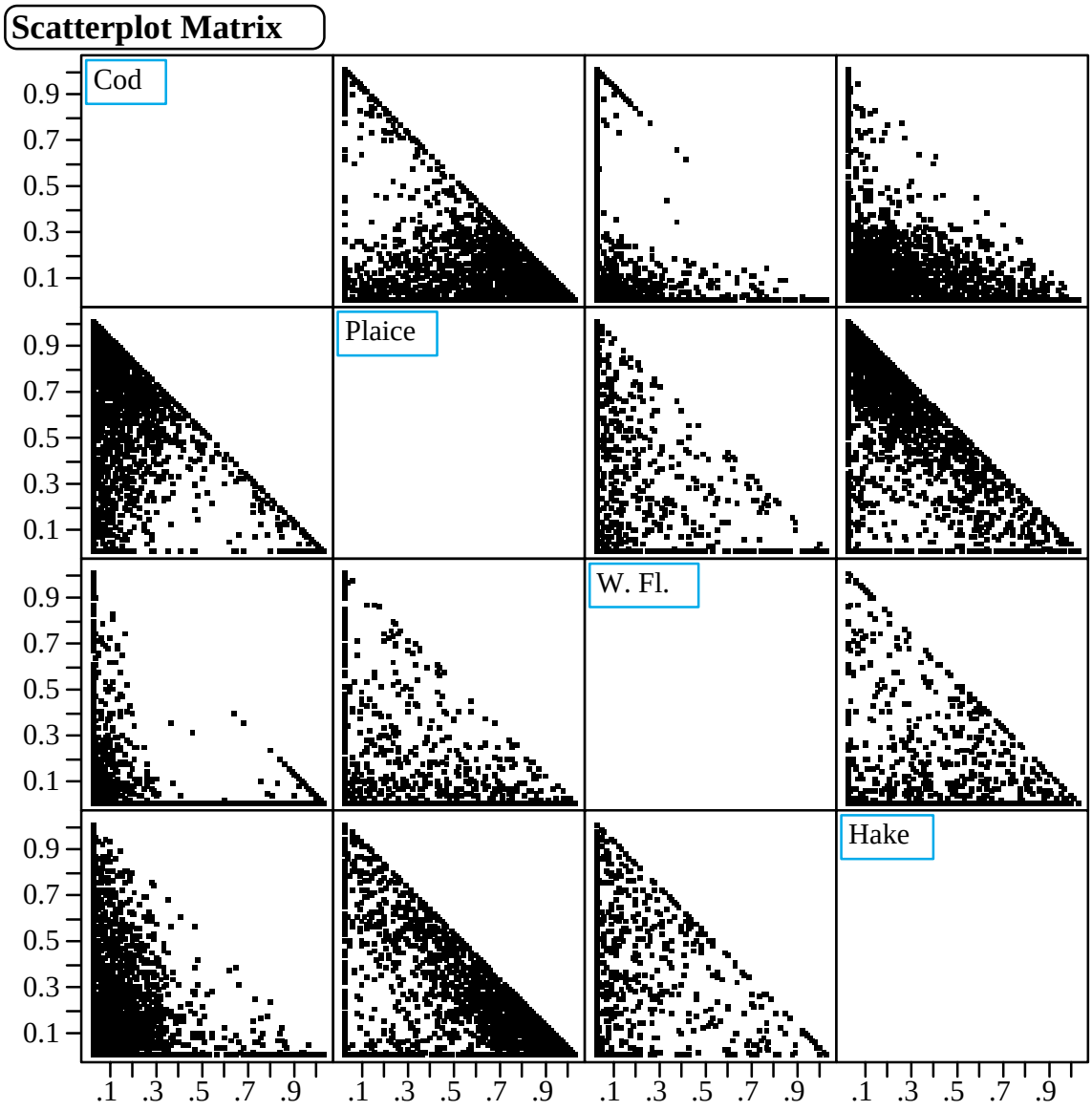

Figure 7: Scatterplot matrix of species compositions in landings by seines. Each panel is a bi-variate plot comparing landings proportions of 2 species (see Fig. 5). The axes are indicated by labels in the diagonal of the matrix. The matrix is symmetrical, i.e. each panel is plotted twice with the axes reversed.

Longline landings were composed mainly of white hake and cod (Fig. 8). White hake was often over 90% of the landing. A large number of trips were made up of cod and white hake only, and this can be seen from the heavy diagonal line of points in the white hake / cod scatterplots.

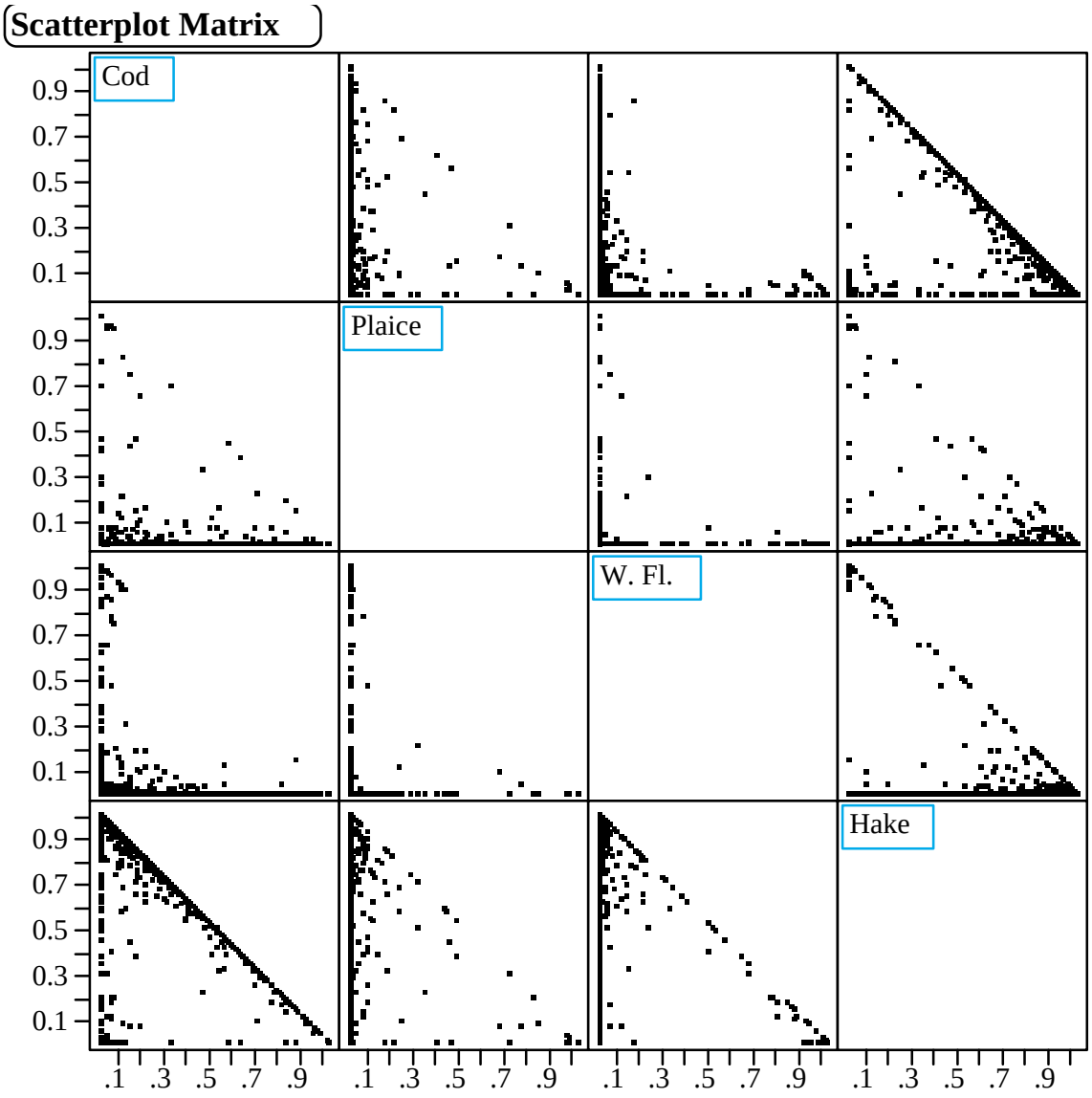

Figure 8: Scatterplot matrix of species compositions in landings by longlines. Each panel is a bi-variate plot comparing landings proportions of 2 species (see Fig. 4). The axes are indicated by labels in the diagonal of the matrix. The matrix is symmetrical, i.e. each panel is plotted twice with the axes reversed.

Gillnet landings were also relatively clean, meaning that there were not many cases where more than 2 species were landed in the same trip (Fig. 9). White hake was the main species caught. Cod and winter flounder were taken as by-catch with white hake, but rarely together in the same trips. Note the heavy diagonal line of points in both the white hake / cod and the white hake / winter flounder scatterplots. Another way to look at it is that when cod were taken as by-catch with white hake, winter flounder were not, and vice versa. This indicates that white hake habitat may overlap both cod and winter flounder habitat, but that cod and winter flounder do not overlap.

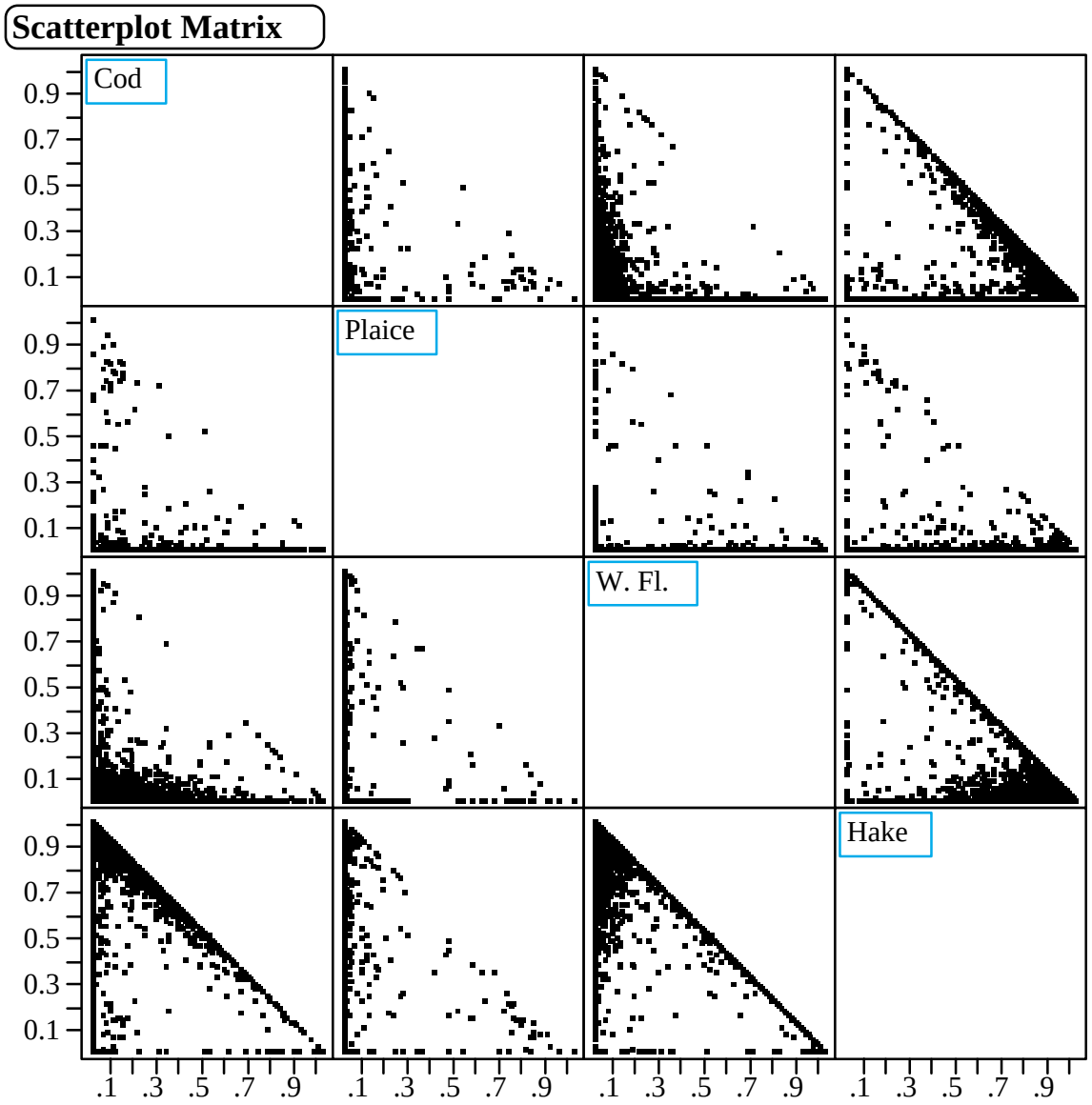

Figure 9: Scatterplot matrix of species compositions in landings by gillnets. Each panel is a bi-variate plot comparing landings proportions of 2 species (see Fig. 4). The axes are indicated by labels in the diagonal of the matrix. The matrix is symmetrical, i.e. each panel is plotted twice with the axes reversed.

5.2. Fishery Catch Composition

Seven fishery types were identified with the cluster analysis. Four of these had high percentages of one of the four main groundfish species (Fig. 10). The most common fishery type was dominated by white hake and it had a cluster with 8504 purchase slips. This was followed by a winter flounder fishery with 4479 slips. The plaice fishery had 3164 slips, and the smallest cluster was dominated by cod with 539 slips. The other 3 were mixed fisheries, each with white hake as an important component. One was a

mixture of white hake and winter flounder with 2631 slips. A second was a mixture of plaice and white hake with 1372 slips, and the third mixed fishery had white hake and cod with 1299 slips.

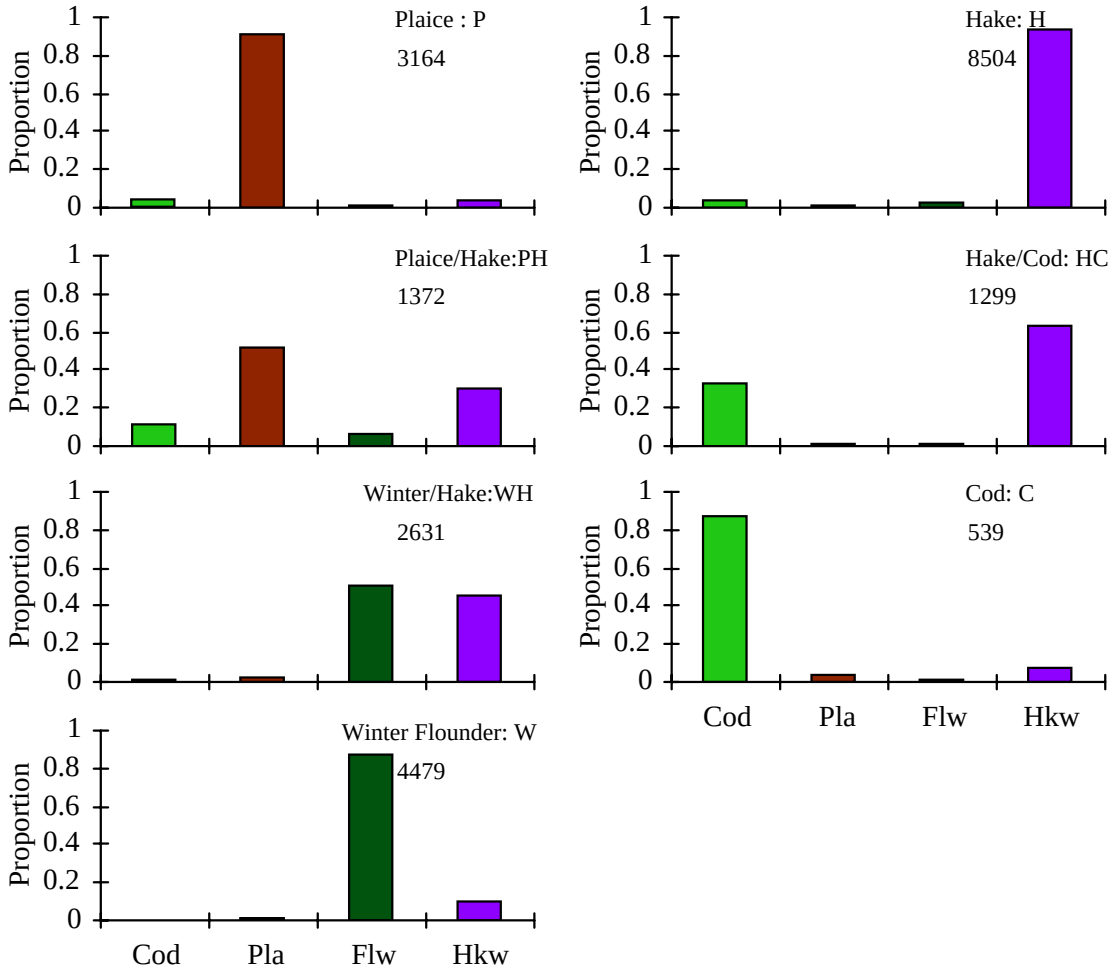

Figure 10: Average species compositions of seven groundfish fishery types in St. Georges Bay, identified with cluster analysis of purchase slip data, 1985 - 1997. Each panel is annotated with the name(s) of the dominant species, a label which is used to identify the cluster in subsequent figures, and the number of purchase slips in the cluster.

5.3. Fishery and Gear

The fishery types were not exploited equally by the different gears (Fig. 11). Gillnets were used primarily for the white hake fishery with fewer numbers of slips from the white hake/cod mixed fishery, the winter flounder fishery, and the winter flounder/white hake mixed fishery. Longlines were used almost exclusively for the white hake fishery with a relatively small number of white hake / cod mixed fishery and cod fishery cases. Otter trawls were used for a diverse set of fisheries. The main fishery was for winter flounder followed by the winter flounder / white hake fishery. There were also significant numbers of slips from the plaice, the plaice/white hake mixed, and the white hake fisheries. Seines were used mainly in the plaice and the plaice/white hake fisheries.

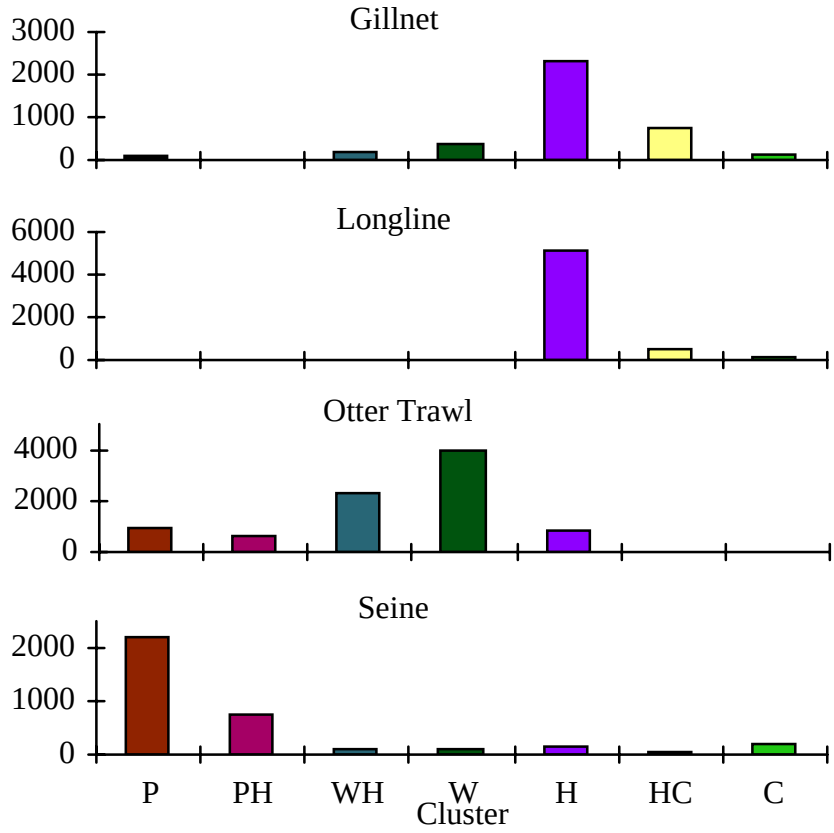

Figure 11: Distribution of fishery types among fishing gears in the St. Georges Bay groundfish fisheries, 1985 - 1997. The species compositions of the fishery types are shown in Fig. 8. The cluster labels are P: plaice, PH: plaice and white hake, WH: winter flounder/white hake, W: winter flounder, H: white hake, HC: white hake and cod, C: cod.

6. Changes in Fishing Strategies

Understanding factors which affect fishing strategies is important for interpreting catch rate information in terms of stock status and for anticipating how fishing fleets may react to changes in fisheries management measures. There were important changes in the range of fisheries prosecuted by groundfish fleets in St. Georges Bay during the study period and these are described in the following section along with some possible reasons for the changes. It will be important to receive input from local fishermen before drawing firm conclusions of the causes. Additional input is welcomed.

Some of the important changes in the management of fisheries in the southern Gulf of St. Lawrence are given below.

- the commercial cod fishery was closed on September 3, 1993.
- the closure of the hake fishery was announced in December, 1994 and affected the 1995 fishing year.
- Several significant changes to the fishery regulations were announced in 1993:
    - the minimum mesh size was increased from 108 (diamond) to 120 mm (square mesh) for mobile gears (<14 m (45 feet)) fishing in the Northumberland Strait area
    - a regulation to control excessive dumping/discarding of groundfish at sea was introduced requiring fishing vessels to land all groundfish caught (with some species excluded)
    - following the closure of the cod directed fishery (1/09/93), the minimum mesh size for mobile gears (<14 m (45 feet)) targeting hake in the Northumberland Strait was increased (again) to 130 mm (square mesh).
    - the fishing season for mobile gear in the eastern portion of the Northumberland Strait was adjusted to open on July 15 to allow hake to spawn.

6.1. Longline

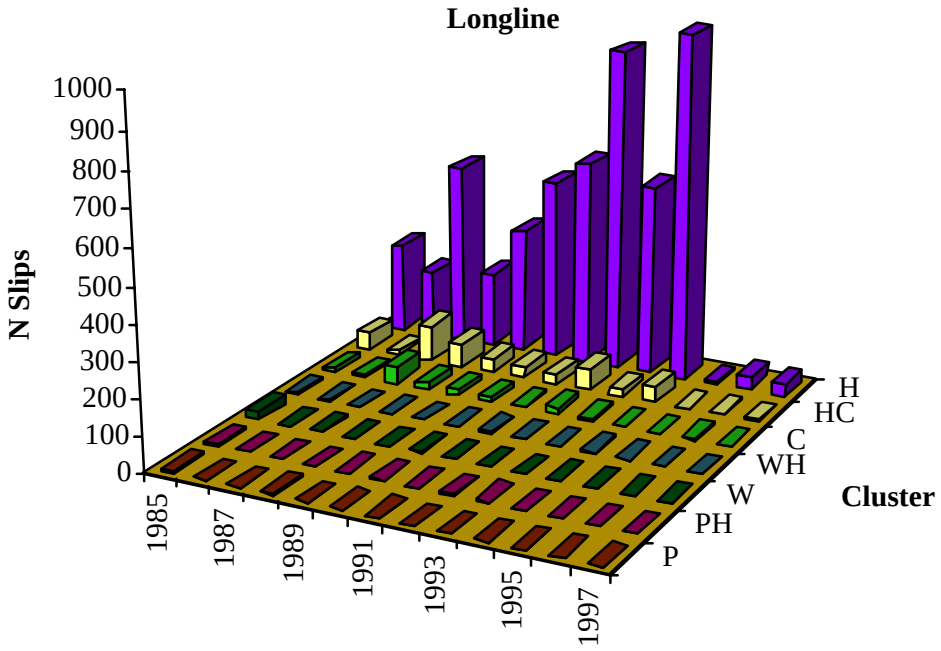

Figure 12: Numbers of purchase slips in each fishery type for longline gear in St. Georges Bay, 1985 - 1997.

Longlines have been used almost exclusively for fishing white hake (Fig. 12). There were only minor numbers of purchase slips from the white hake/cod mixed and the cod fisheries. The number of purchase slips in the white hake fishery type increased from 1985 to 1994, indicating an increase in fishing effort toward this species. However, the white hake fishery was closed in 1995 when it became apparent that the abundance of this species in the southern Gulf of St. Lawrence had declined to a very low level. After the closure, the white hake fishery, and nearly all fishing activity by longlines in St. Georges Bay, stopped. The low number of slips in the white hake fishery in 1996 and 1997 were from vessels participating in the DFO sponsored sentinel survey program, which is designed to measure white hake abundance in years when the fisheries are closed.

6.2. Gillnet

Similar to longlines, gillnets are also used predominantly for white hake (Fig. 13). The highest number of slips came from the white hake fishery, followed by the white hake/cod mixed fishery. These fisheries stopped with the closure of the white hake directed fishery in the southern Gulf of St. Lawrence in 1995. There were also a large number of slips from the winter flounder fishery type in 1990 and 1994, possibly a tangle net fishery for lobster bait. Accompanying the winter flounder fishery in 1990, there was also a winter flounder/white hake mixed fishery. Fishing effort was low in other fishery types.

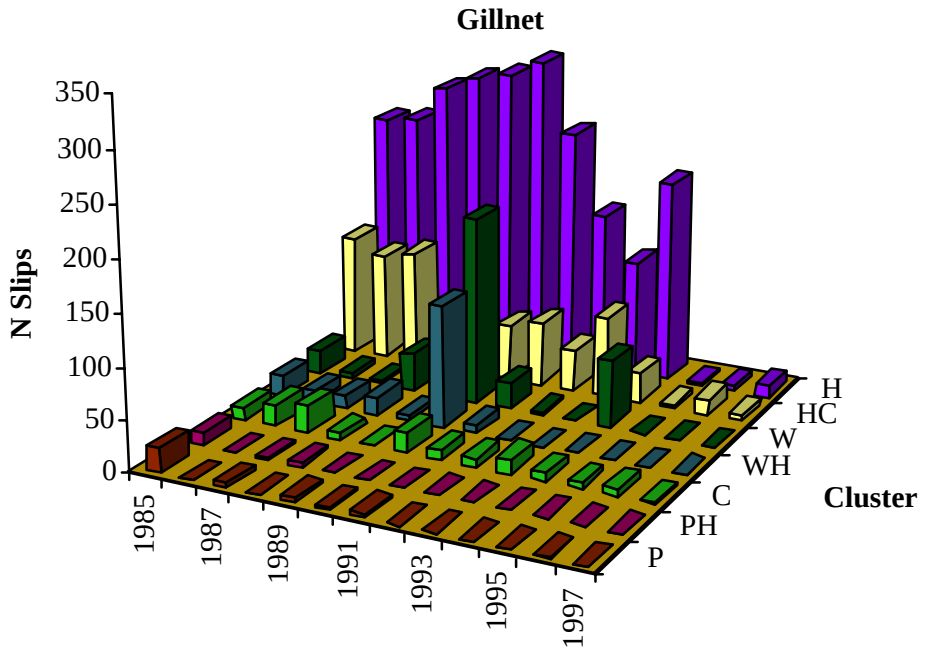

Figure 13: Numbers of purchase slips in each fishery type for gillnet gear in St. Georges Bay, 1985 - 1997.

6.3. Otter Trawl

The main fishery prosecuted by the otter trawl fleet was directed toward winter flounder (Fig. 14). The white hake directed fishery was active until 1992, but the level of fishing effort was greatly reduced in 1993, and almost non existent in 1994. The winter flounder/white hake mixed fishery was active up to 1993, but almost ceased thereafter. The mixed fishery for plaice and white hake was an important component of otter trawl fishing effort until 1991, after which it was a very small fishery. Fishing effort in the plaice and the winter flounder directed fisheries increased in 1994, and it is possible that fishing effort was displaced away from white hake towards these other species at that time. This shift of effort preceded the closure of the white hake fishery by 2 to 3 years.

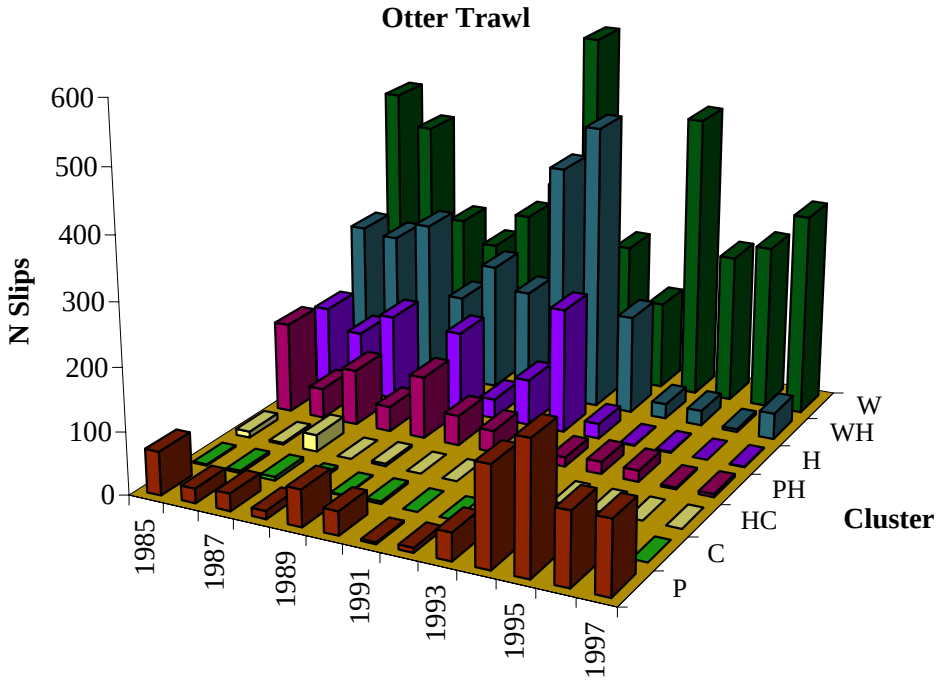

Figure 14: Numbers of purchase slips in each fishery type for otter trawl gear in St. Georges Bay, 1985 - 1997.

It was possible to examine fishing locations and reported catches to see if the change in fishing strategy was accompanied by a shift in the area fished. Otter trawl vessels fishing from St. Georges Bay ports have supplied logbook information on fishing locations since 1991. Fishing locations are recorded on a grid system of 10' of latitude and longitude. Each grid covers approximately 70 square miles of sea bottom. This information was summarized for three time periods: 1991-92 included fishing before the cod fishery was closed and before the minimum mesh size was increased; 1993-94 included the period after the mesh size increase but before the hake fishery was closed; and 1995-97 included the period after the hake fishery was closed.

A visual examination of the distribution of fishing effort indicated very little change in fishing grounds, at least on the scale at which the information was recorded (Fig. 15). The fishing grounds included the Bay proper and the area west of Cape George. There was a slight movement of effort to the east between time periods, but this was minor in comparison with changes in reported catches. The hake landings declined considerably between the 1991-92 and 1993-94 time periods, while there was an increase in plaice landings. Winter flounder landings were similar in the three time periods. Cod landings by this fleet were very low in all time periods.

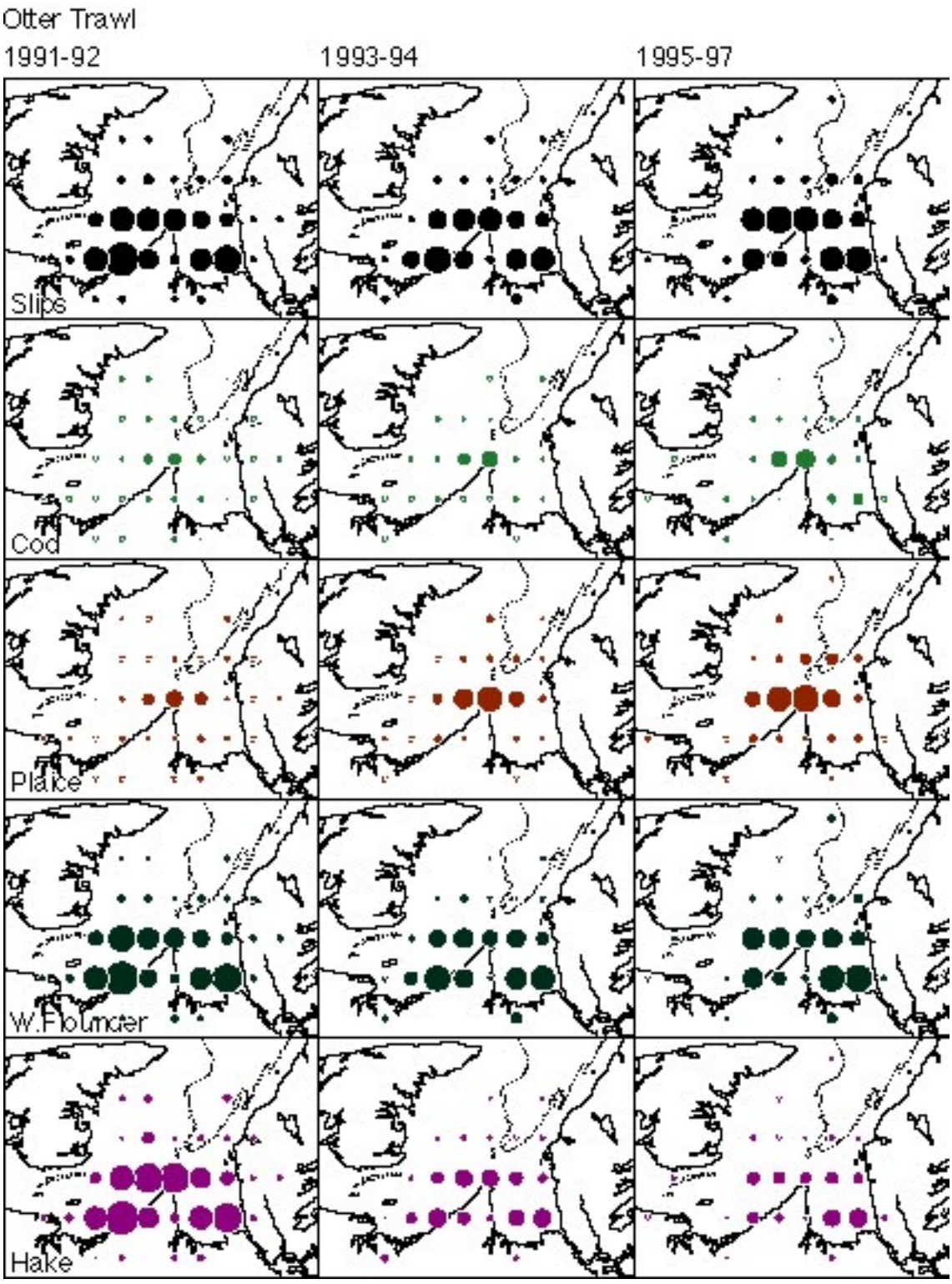

Figure 15: Maps of fishing effort (numbers of slips) and reported catches of cod, plaice, winter flounder, and hake by otter trawlers in St. Georges Bay, 1991-92, 1993-94, and 1995-97.

6.4. Seine

Fishing effort by seines has been directed mainly at plaice (Fig. 16). There was a higher diversity of species in the seine landings prior to 1993, however. There were mixed fisheries for plaice/white hake, white hake/cod, and winter flounder/white hake as well as directed fisheries for white hake and cod. This changed dramatically in 1991 with an increase in plaice directed effort and a cessation of cod directed fishing. Further changes occurred over the next 2 years with the plaice/hake mixed fishery and the white hake directed fishery stopping. In recent years, the only seine fishery was that directed toward plaice.

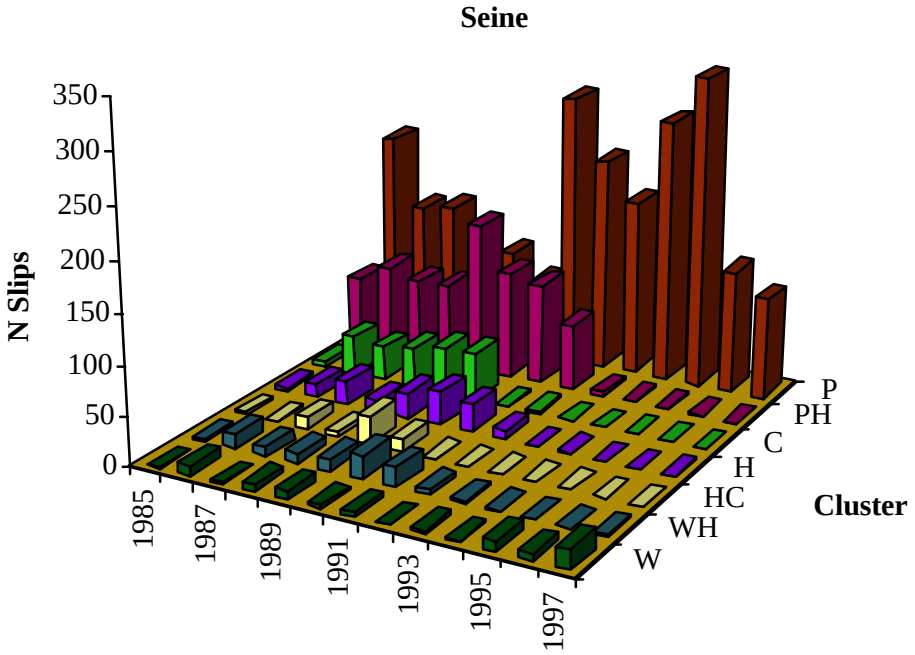

Figure 16: Numbers of purchase slips in each fishery type for seine gear in St. Georges Bay, 1985 - 1997.

As was the case for otter trawls, the distribution of fishing effort and reported catches were also examined for seines. Three time periods were examined: 1991-92 included fishing before the cod fishery was closed and before the minimum mesh size was increased; 1993-94 included the period after the mesh size increase but before the hake fishery was closed; and 1995-97 included the period after the hake fishery was closed.

There was hardly any change in the reported fishing locations among these time periods (Fig. 17). The fishing grounds were further north and east of those occupied by otter trawlers, and were concentrated between Port Hood and Ballantyne's Cove. Landings of cod and hake were greatest in the 1991-92 time period. and negligible thereafter. Landings of plaice were similar in all three periods while those of winter flounder were very low in all periods.

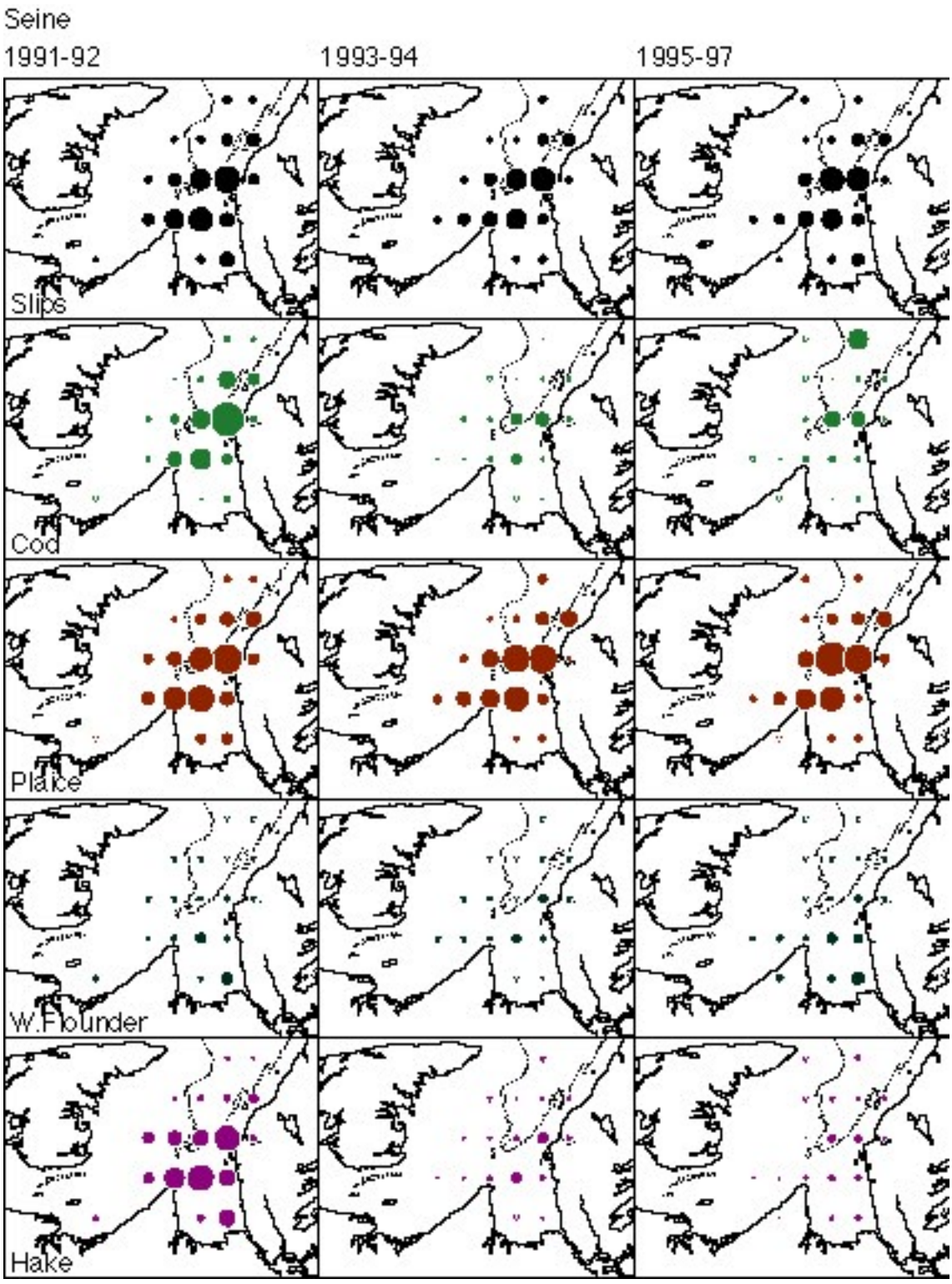

Figure 17: Maps of fishing effort (numbers of slips) and reported catches of cod, plaice, winter flounder, and hake by seines in St. Georges Bay, 1991-92, 1993-94, and 1995-97.

6.5. Summary of Changes in Fishing Strategies

There have been major changes in the fishing strategies of the groundfish fleets in St. Georges Bay over the past 13 years. White hake was an important species for all gear types for most of the time period. However, its abundance declined throughout the southern Gulf of St. Lawrence during the early 1990s, and this culminated in a closure of the directed fishery. This had a dramatic effect on the longline and gillnet fleets which were highly dependent on white hake. Having no alternative groundfish species to fish, many of these vessels apparently stopped fishing groundfish completely. At this time, we do not know if they switched effort to alternative species groups such as the pelagics (herring, mackerel, tuna), invertebrates other than lobster (rock crab, scallops), the developing dogfish fishery, or changed to mobile gear and fished plaice and winter flounder. Further study of the purchase slip data may provide some insight.

The situation was somewhat different for the otter trawl and seine fleets. White hake was an important component of their landings, but these vessels were capable of fishing other species and it appears they succeeded in switching away from white hake while either maintaining (seine) or increasing (otter trawl) catches of plaice. The timing of events suggests that something other than the closure of the white hake fishery prompted the switch. White hake landings declined considerably before the white hake closure came into effect. It was suggested that the change in species composition of landings by mobile gear was the result of the increase in regulated mesh size in the Northumberland Strait in 1993. Many fishers protested this change, feeling that the larger mesh size would prevent an effective white hake fishery. This could explain why the hake landings declined while there was very little change in the spatial distribution of the fisheries. It is possible that the hake simply were not retained by the larger meshed nets. This does not necessarily mean, however, that those fish escaping the net all survived. Very little is known about how well hake survive the effects of passing through the meshes of seines or otter trawls. It is also possible that some fishers elected to fish white hake using longlines rather than mobile gear. This might explain the increase in longline fishing effort that occurred in the early 1990s.

7. Catch Rates

Fishing success, measured in terms of catch per unit effort, is commonly used as an index of the abundance of fish stocks. The basic idea is that the more fish that are caught with a fixed amount of fishing effort, the larger the population of fish is. While a higher catch per slip may indicate a more abundant population, several other factors may influence catch rates. For example, the area fished, the season fished, the type of fishing gear used, the amount of gear used, the experience of the fishers, and technological improvements. We have attempted to take as many of these factors as possible into account in our analysis of catch rates. We have restricted analysis to the four fishery types where one species is by far the dominant part of the landing, and we have omitted mixed fishery types. A statistical model was used that allowed for the inclusion of effects such as gear, month of fishing, and the fishing vessel. Nonetheless, it is quite possible that some important factors have not been included, and we would appreciate receiving suggestions

of other things to try. In this report, we have used the number of purchase slips as a measure of the amount of fishing effort, and catch per slip as a measure of catch per unit effort.

The following table summarizes the number of purchase slips available for the catch rate analyses, by species and gear. There was considerable variation in the numbers of purchase slips available for analysis among these groupings. In order to avoid undue influence from relatively small numbers of observations, we used the criterion that there had to be at least 10 observations per species, gear, year group for inclusion in the analysis.

Species	Gillnet	Longline	Otter Trawl	Seine
White Hake	2320	5173	846	135
Plaice			2221	871
Winter Flounder			4005	
Cod				207

7.1. White Hake Catch Rates

White hake were fished by all four gear types. Longline and gillnets were the dominant gears, but there were enough purchase slips for analysis of the otter trawl and seine catch rates too. However, data were not available from all gears in each year. There were no data at all in 1995 presumably because this was the first year of the moratorium. Data for 1996 and 1997 came from longline and gillnet vessels involved in the sentinel surveys. Otter trawl data were available for the period 1985 - 1993, and for seines from 1986 - 1991.

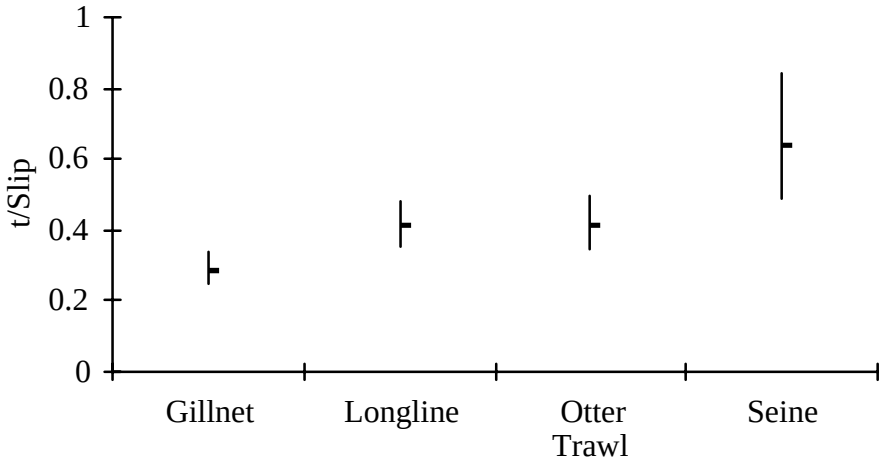

Figure 18: Comparison of overall mean catch rates by fishing gear for white hake in St. Georges Bay, 1985 - 1997. The vertical bars give the approximate 95% confidence interval of the average.

The analysis method used allows for comparisons between fishing gears and seasons. The highest white hake catch rates were recorded by seines. Gillnets had the lowest catch rates, about half the seine catch rates, while longline and otter trawl catch rates were intermediate (Fig. 18). There was little variation in white hake catch rates by month. There were a low number of observations from May and June, and these two months had the lowest catch rates. But from July to October, catch rates remained relatively high with little variation.

Annual average white hake catch rates declined from 1985 - 1994, from 0.5 t/slip to 0.25 t/slip (Fig. 19). There was a substantial increase in catch rates in 1996 and 1997 in the sentinel surveys. These values were about twice as high as the average annual catch rate in the 1985 - 1994 period. This is very perplexing given the low estimate of stock size from the DFO research vessel survey in this same area in the same years.

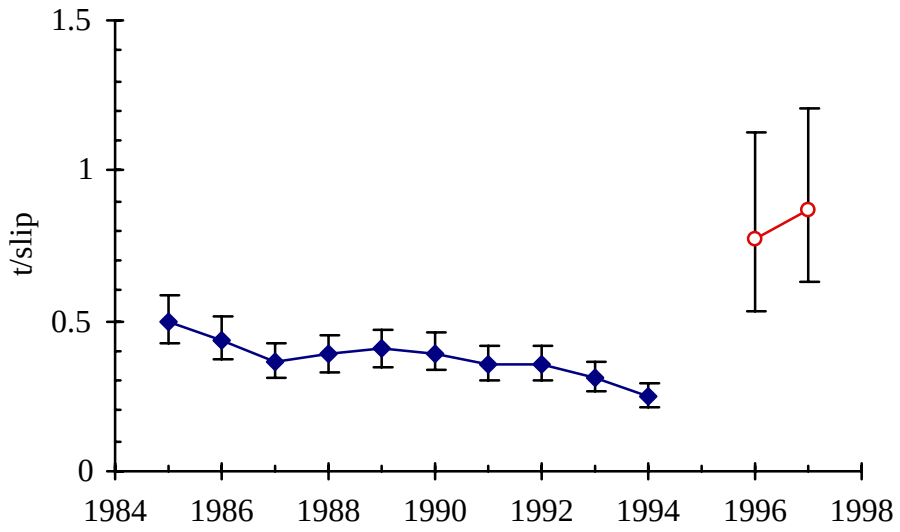

Figure 19: Average annual catch rates for white hake in St. Georges Bay. The estimates are from an analysis of purchase slip data from longlines, gillnets, otter trawls, and seines. The high catch rates in 1996 and 1997 were observed in the sentinel survey. The error bars indicate the approximate 95% confidence intervals of the averages

It is possible that the catch rates from 1996 and 1997 were so much higher than the other years because of difference in the level of fishing. The catch rates calculated for 1985 - 1994 were taken from commercial fishing trips when the total fishing effort was very high, with over 500 fishing trips being made annually. The 1996 and 1997 points came from the sentinel surveys when only 4 vessels were fishing and the total number of fishing trips per year was less than 50 (Fig. 20). It is possible that when a commercial fishery is occurring there is competition for the best fishing grounds and disturbance of the fish, and this in turn may reduce the average catch rate. In the case of the sentinel

survey, there was rarely more than 4 vessels fishing white hake at any one time, and their fishing locations were dispersed around the Bay. Fishermen could also choose the best fishing locations for their trips, at least within a 2.5 km radius.

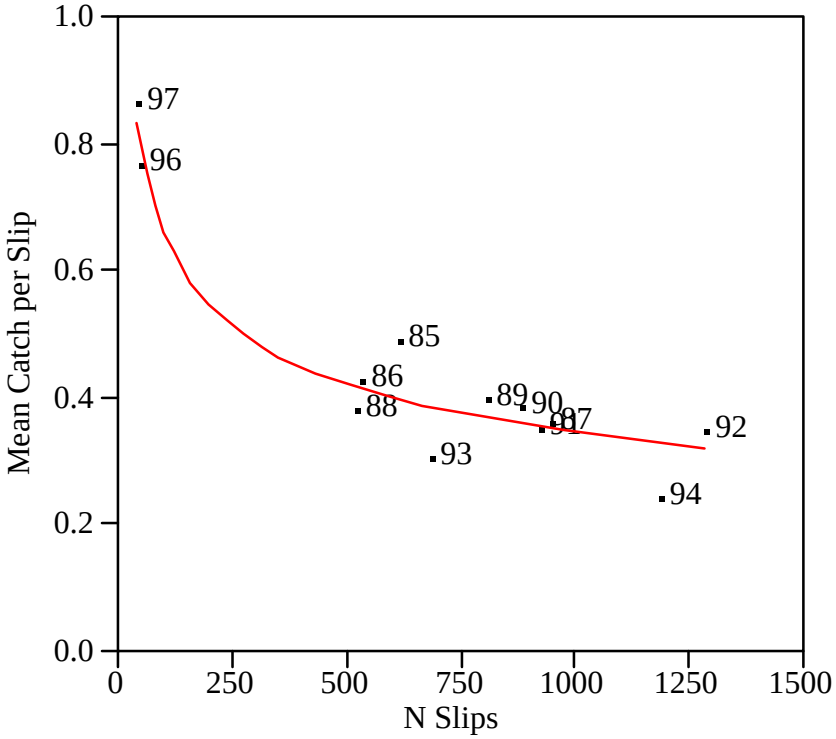

Figure 20: Comparison of the average annual catch rate for white hake in St. Georges Bay with the annual total fishing effort directed at white hake, as indicated by the number of purchase slips.

We examined the available data to try and determine if competition among vessels and disturbance of the fish may have an effect on catch rates. The approach was to examine the weekly catch and effort data for individual years to see if catch rates were lower in weeks with high fishing effort. An example for 1992 is shown in Fig. 21. In this year, catch rates increased in the initial weeks of the fishery, then remained relatively high but variable throughout the rest of the year. Fishing effort increased from low initial values in week 27 to a peak of about 225 slips in week 34. There was a drop of more than 50% in effort in week 35 to about 100 slips, and thereafter effort declined for the rest of the year. If interference was an important factor in catch rates, then one would have expected a decline in catch rate during the initial weeks when effort increased, followed by an increase in week 35 and thereafter when effort declined. Instead, catch rates remained relatively constant. Another possibly complicating factor is the effect of stock depletion. One would expect catch rates to decline as the cumulative catch from the population increases and the local abundance of fish becomes depleted. It is possible that the depletion effect offset the interference effect.

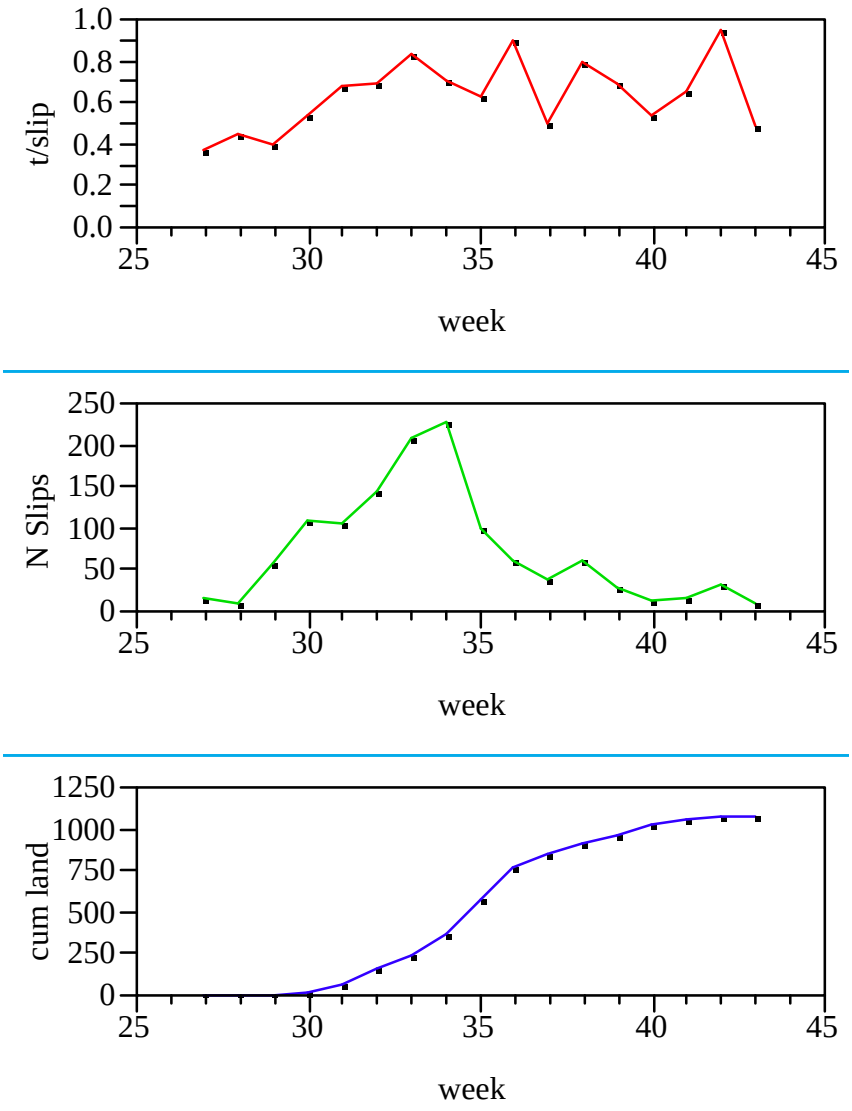

Figure 21: Weekly average catch rate (top panel), fishing effort (number of purchase slips), and cumulative landings of white hake in the 1992 longline fishery in St. Georges Bay.

Unfortunately, the annual pattern of fishing effort in other years was similar to that in 1992. In order to test whether the depletion or interference effects are occurring, it might be necessary to conduct an experiment. This could consist of conducting a sentinel survey and recording catch rates throughout the fishing season, as is currently being done. Then, there could be intense open fishing for a period long enough to allow approximately 100 - 150 vessel-fishing days. The test would be whether or not the sentinel survey catch rates decline during the period of open fishing, and recover in the ensuing period. More than one open period could be used. However, the amount of fishing allowed would have to account for the status of the resource. An experiment should only be conducted if the resource is assessed to be on the road to recovery.

Another possible explanation for the high catch rates in the sentinel survey is that the fishermen who participated were also among the best in the area. There were 284 different fishing vessels identified as having directed for white hake during the study period. Of the four vessels in the sentinel surveys, one had catch rates close to the average while the other 3 were in the top 80% of the entire fleet. We attempted to account for this factor by adjusting the annual estimates for the overall average performance of the vessels. At this point it is not clear whether this was enough.

7.2. Plaice Catch Rates

Plaice were fished mainly by seine and otter trawl with seines being the dominant gear. The fishery has operated each year since 1985 allowing the calculation of an annual catch rate index. The main fishing months were July-October and there was little variation in catch rate among months.

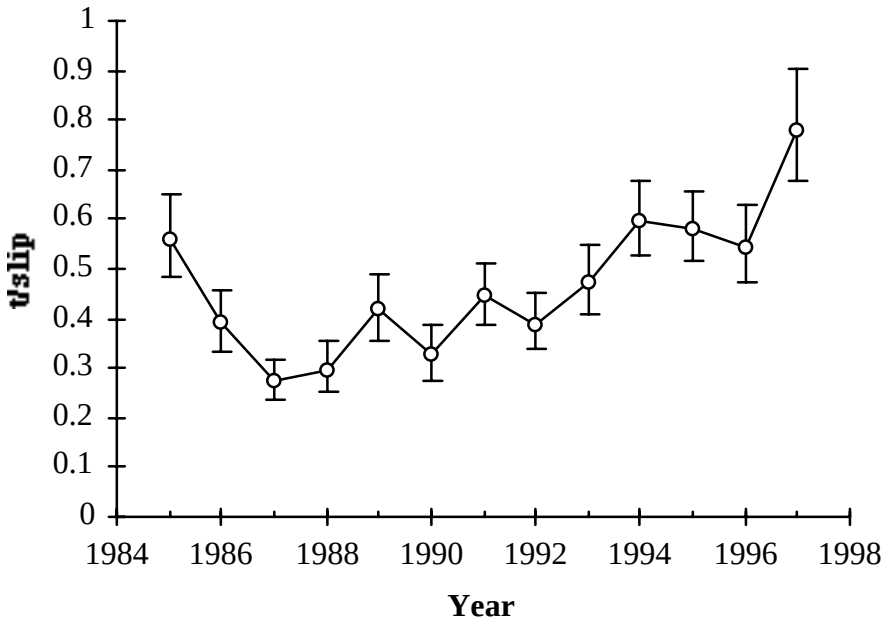

Figure 22: Average annual catch rates for plaice in St. Georges Bay. The estimates are from an analysis of purchase slip data from otter trawls and seines. The error bars indicate the approximate 95% confidence intervals of the averages

Plaice catch rates initially declined between 1985-87 from about 550 kg per slip to a low of less than 300 kg per slip (Fig. 22). This was followed by an increasing trend from 1987 to 1997 when catch rates reached 750 kg per slip.

7.3. Winter Flounder Catch Rates

Winter flounder were fished almost exclusively by otter trawlers in the St. Georges Bay area. The commercial fishery operated in each year and it was possible to calculate an annual catch rate index for the entire time period. The fishery was concentrated in the months of July to October and there was little variation in catch rate among months.

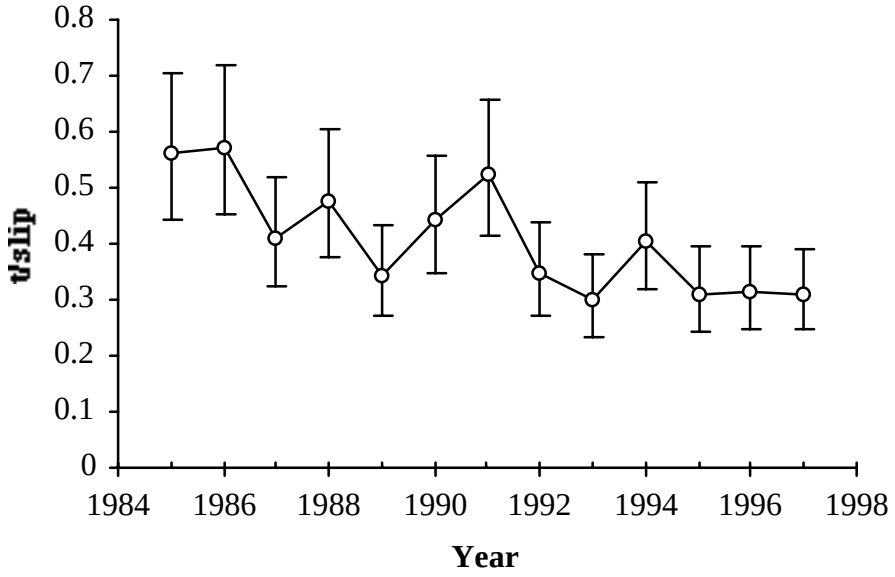

Figure 23: Average annual catch rates for winter flounder in St. Georges Bay. The estimates are from an analysis of purchase slip data from otter trawls. The error bars indicate the approximate 95% confidence intervals of the averages

There was a downward trend in winter flounder catch rates in the St. Georges Bay area (Fig. 23). The average catch per purchase slip was around 550 kg in 1985-86 and this declined to about 300 kg per slip in 1995-97.

There were a total of 88 different vessels that participated in the winter flounder fishery in the period 1984-97. The catch rate trends of vessels with a relatively long history in the fishery (5 years and more) were compared with those with a shorter history. There were 29 vessels that submitted purchase slips for the winter flounder fishery for 5 or more years, and the remainder had landings in 4 years or less. The catch rate trend for the vessels with a longer history was very similar to the overall average (Fig. 24). The trend for vessels with the shorter history was comparable to the overall average in the first 4 years of the study, but then increased to over 900 kg per trip in 1989. The catch rates then declined to about 300 kg per trip in 1997, a level again comparable to that of the remainder of the fleet.

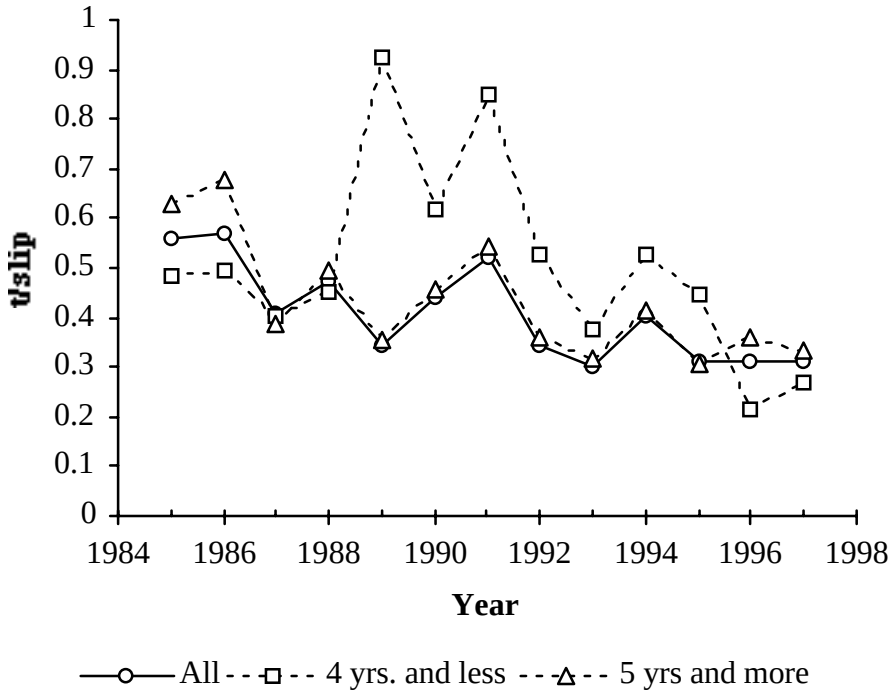

Figure 24: Comparison of annual winter flounder catch rates in St. Georges Bay estimated for vessels with 4 or less years participation in the fishery with those with 5 or more years in the fishery.

7.4. Cod Catch Rates

The cod directed fishery in the St. Georges Bay area was prosecuted mainly by seine vessels landing their fish in Murphy's Pond. The bulk of these landings were made between 1986-1990 during which time the annual landings declined from 160 t to 50 t in 1990. Most of the landings were made in April and May indicating the fishery was targeting the spring migration of cod. While logbook data are not available for these years, it is likely that the cod were caught somewhat to the north of St. Georges Bay, probably between East Point, P.E.I. and Cape Breton. Cod directed landings by longlines and gillnets never exceeded 10 t per year and consequently these were not used to calculate catch rates.

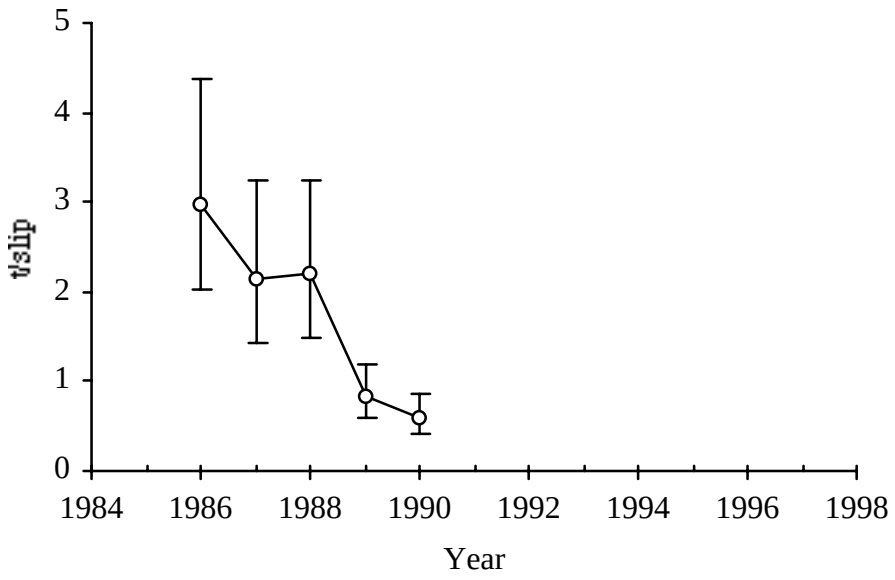

Figure 25: Average annual catch rates for cod in St. Georges Bay. The estimates are from an analysis of purchase slip data from seines and is restricted to years where more than 10 purchase slips for cod directed fishing were available for this gear. The error bars indicate the approximate 95% confidence intervals of the averages.

The cod catch rate index declined from 3 t per slip in 1986 to about 700 kg per slip in 1990 (Fig. 25). A total of 18 vessels reported landings from this fishery during the 1986-90 period, and 7 had landings in at least the last 3 years. This large decline was reflected in data from all 7 of these vessels. Only 1 vessel participated in cod directed fishing in later years. It would be interesting to investigate why this fishery stopped in 1990, 3 years before the cod directed fishery was closed in the southern Gulf of St. Lawrence.

8. Discussion

Groundfish fisheries in St. Georges Bay produce 4 main species, white hake, plaice, winter flounder and cod. These fisheries are prosecuted with four types of fishing gear, longline, gillnet, otter trawl and seine. The fixed gears (longline and gillnet) were used mainly for white hake and cod and yielded very low catches of the flatfish species. Seines were used to fish white hake, cod, and plaice, but not for winter flounder. Otter trawls produced the most varied catch composition with landings of all four species. Seven fishery types were defined based on the species composition of individual trip catches. Four were directed, respectively, at the four species, and the remaining three were mixed fisheries for white hake and cod, white hake and plaice, and the last for white hake and winter flounder. These fishery types reflect the species distribution in the area. White hake was the most widespread species in the St. Georges Bay study area. Winter flounder were found mainly in shallow, warm water, close to shore. Plaice were found in

deeper and colder water while cod were rarely found within St. Georges Bay but more toward the northern edge of the banks fished by area fishers.

The use of the different fishing gears varied throughout the study area. Gillnet and otter trawl were the main gears used at the western part of the study area (i.e. Lismore and Arisaig). Within St. Georges Bay the fisheries were prosecuted mainly with longline, otter trawl and gillnet. There was little otter trawling from Cape Breton ports but seines, longline and gillnets were common.

There were a number of striking changes in operations of these different fisheries. Closure of the white hake fisheries resulted in a large decline in fixed gear fishing effort. These gears had not been used for the flatfish species in the past, and there was no opportunity to fish cod because this fishery was closed throughout the southern Gulf of St. Lawrence. Mobile gear effort declined to a lesser extent as the fishers had latitude to switch to alternative species such as plaice and winter flounder. There was a change in the species composition of the mobile gear fisheries in the early 1990s Between 1992 and 1993, their landings of white hake declined considerably, well in advance of the moratorium on this species in 1995. Otter trawlers increased their fishing for plaice and winter flounder while seines increased effort on plaice. It was suggested that the main reason for this change was an increase in the regulated mesh size for mobile gear. There was very little change in the spatial distribution of fishing effort by either otter trawls of seines, suggesting that perhaps the hake were not retained by the larger meshes. It may be worthwhile considering whether or not the process of passing through the meshes affects hake survival, especially given the very low abundance of hake in the southern Gulf of St. Lawrence.

The catch rate analysis highlighted several interesting questions. Commercial catch rate indices have been used to describe trends in local abundance of fish stocks. However, many other factors may also influence catch rates and it may be possible to study these in St. Georges Bay. The fixed gear catch rates experienced by participants in the sentinel fishery for white hake were well above the average commercial catch rates experienced before the white hake fishery was closed. It would be interesting to investigate the possible influence that competition for fishing grounds, disturbance of fish schools, and local depletion may have had on these results. Catch rates for plaice have increased considerably in recent years while those for winter flounder have declined. How do these trends compare to local knowledge about trends in abundance of these 2 species in the study area? Finally, the seine fishery for cod, that was based in Murphy's Pond in the late 1980s, came to an end 3 years before the commercial cod fishery in the southern Gulf was closed. Was this a reflection of local markets for cod or an early indication that the stock was in trouble?

9. Acknowledgement

This project benefited greatly from Erin Breen's involvement through the summer of 1998. Tom Hurlbut and Rod Morin provided many helpful comments on the analysis and manuscript.