Final Report

ANALYSIS OF TAGGING DATA TO QUANTIFY LAKE TROUT MIGRATION IN LAKE HURON

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Summary

This study advances our understanding on movement patterns of hatchery lake trout in Lake Huron, from analysis of coded wire tag recoveries in the sport non-charter and charter fisheries. In this study, we estimated coefficients to standardize recoveries of tagged fish from these fisheries by different sources using generalized linear models. Overall, tag recovery rates from creel clerks interviewing non-charter boat fisherman were double those self-reported by captains operating charter boats, while recoveries from headhunters sampling the catch of non-charter boat fishing trips were three times as large, and when sampling charter boat catch are nine times as high. These coefficients vary by year. We developed a matrix of proportions that represent the distribution of tagged lake trout by statistical area. The matrix cells are the proportions of the fish recovered during the fishing season and in the fishing grounds of statistical districts MH1 to MH6 that had been released in stocking sites from MH1 to MH4. These estimates are based on GLM predictions of adjusted tag recoveries by trips, and can be used to interpret movement. Overall, about 40% of the fish were found in the area of release. Further, proportions recovered in the neighboring area to the south of MH1, the north of MH2 and MH3 and the east of MH4 were not significantly different to those in the release area. These estimated proportions differ from proportions calculated from the original CWT recoveries even when these recoveries were adjusted for the number of fishing trips. We found not only that fish move from the release area to other statistical districts, but also that seasonal movement occurs between statistical districts. This result can have consequences for stock assessment where a fixed proportion of fish is assumed to move from the release areas within the first year and stay. Results from our analysis can be incorporated in an analysis along the lines of Hilborn (1990) to estimate natural mortality of lake trout in Lake Huron and a multidirectional movement matrix.

Analysis of lake trout catch rates in the charter and non-charter fisheries complement the results obtained from modelling of data from recoveries of CWT fish. Both CWT and catch rate analyses suggest that seasonal movement occurs among areas during the fishing season. Interpretation of other results from the catch rate analysis was constrained by the unknown origin of release of the fish caught.

Recommendations are presented to address some of the several shortcomings revealed in the analysis that were generated by the characteristics of the fisheries and the protocols to recover tagged fish

1. Introduction

The collapse and rehabilitation of stocks of lake trout *Salvelinus namaycush* in Lake Huron has been well documented (i.e. Hile 1949, Eschmeyer 1957, Coble *et al.* 1990, Eshenroder *et al.* 1995). After being the dominant predator in the fish community of Lake Huron, lake trout stocks collapsed in the 1940s because of commercial fishing and sea lamprey-imposed mortality. In the early 1970s, only two stocks remained in the Great Lakes and were located in Ontario waters (Lawrie 1970). Stocking of hatchery-raised lake trout began in 1973 and lake trout populations began to recover via restocking programs (Eshenroder *et al.* 1995). Since the early 1980's spawning populations have been re-established but their contribution to the total population is insignificant. Rehabilitation efforts are now in place through stocking targets and keeping mortality low (Eshenroder *et al.* 1995). Stocking experiments employing coded-wire-tagged lake trout were launched in fall of 1985. There have been multiple objectives for marking efforts, ranging from strain evaluations to movement studies, evaluations of offshore reef stocking, evaluations of survival of differing "quality" hatchery fish, and estimates of site-specific and strain-specific sea lamprey induced mortality rates. Initially the objective was to evaluate performance of paired releases of Seneca Lake, Marquette Superior, and Jenny lake strains of lake trout. Beginning in 1992, additional tagged fish were stocked to quantify post-stocking movements and survival at strategic locations along the western shore of Lake Huron. Tag recovery efforts through assessment and creel census are carried out through collaborative efforts of the Great Lakes Science Center (GLSC), Michigan Department of Natural Resources (MDNR), Chippewa-Ottawa Resource Authority (CORA), Ontario Ministry of Natural Resources (OMNR), the USFWS Alpena Fishery Resources Office (FRO), three National Fish Hatcheries (NFH), and various fishing groups. This study uses tagging data from sport fisheries to investigate lake trout movement.

Previous studies on lake trout migration suggest that movement is localized (Buettner

1961, Pycha *et al.* 1965, Schmalz et al. 2002), but the extent of movement may increase with fish age, size or density with consequences for management (Schmalz et al. 2002). In western Lake Michigan, Smith and Van Oosten (1939) reported that 77% of tagged trout were caught within 80 km of a tagging location. Further, Rybicki (1990) found that although almost all yearlings stocked in Lake Michigan Northern Refuge were captured in the vicinity were they were stocked. By age 2 they had dispersed as far as 120 km, and had traveled to southern Lake Michigan by ages 3 and 4. Schmalz *et al.* (2002) found that 90% of lake trout tagged in Clay Banks, remained within 68 km from the tagging locations regardless of tagging or recapture season, and the movements of fish tagged and released in spring (but not fall) increased with population density. Overall, nearly 40% of lake trout released in no-harvest refuges were recaptured outside of the refuge.

In Lake Huron, approximately 6 million lake trout have been stocked and marked with coded-wire tags (Table 1). Releases since 1985 have been mostly in statistical districts MH1 and MH3. Release sites are in near shore areas: Adams Point (statistical area MH1), Middle Island (MH2), Sturgeon Point (MH3), and Point aux Barques (MH4). The release offshore areas are Six Fathom Bank (MH2 and MH3 depending on the year), and Drummond Island Refuge (MH1). Systematic recoveries of coded-wire tags have been obtained through agency assessment surveys and standardized for effort deployed. Results from the 2002 recoveries are presented in the Lake Trout Rehabilitation in Lake Huron—2002 Progress Report on Coded-Wire Tag Returns (Madenjian *et al*. 2003). Results from releases near-shore indicate a north-south gradient in the percentage of fish remaining in the release area with 64% of the fish stocked in Adams Point, 40% of those stocked in Middle Island, 35% of those stocked in Sturgeon Point, and about 26% of those stocked in Point aux Barques recovered in same statistical district where they were released. Fish from the two later areas were reported to show a tendency for southeasterly movement pattern. From release sites in offshore areas, 42% of tags recovered in Six Fathom Bank were from fish stocked in the same refuge, and about half of the tags recovered in the Northern Refuge have been released at the site. The study does not take into account large percentages of coded-wire tag returns from recreational fishers that come from different sources of recovery and for which it is hard to identify the tag

recovery effort. Lacking standardization for effort and competing sources of mortality, returns of coded-wire tagged lake trout can give biased estimates of movement between management units and biased site-specific population parameters.

Table 1. Number of CWT marked lake trout stocked in Lake Huron from 1985 to 2001

	MH1	MH2	MH3	MH4	Total
1985	104,094	-	271,268	-	375,362
1986	-	--	-	-	-
1987	187,566	-	230,800	-	418,366
1988	-	-	221,300	-	221,300
1989	147,000	-	202,100	-	349,100
1990	138,700	-	194,300	-	333,000
1991	127,000	-	184,900	-	311,900
1992	191,800	60,000	253,000	58,500	563,300
1993	130,200	190,800	-	-	321,000
1994	59,400	182,200	60,000	62,100	363,700
1995	128,680	184,900	-	-	313,580
1996	190,900	229,850	56,100	59,900	536,750
1997	135,300	177,100	-	-	312,400
1998	181,200	231,900	54,200	56,200	523,500
1999	118,700	-	-	-	118,700
2000	117,396	-	192,280	-	309,676
2001	123,386	-	216,895	-	340,281
Total	**2,081,322**	**1,256,750**	**2,137,143**	**236,700**	**5,711,915**

Lake trout fishery managers use age-structured population models (Sitar *et al*. 1999) to establish catch quotas for statistical districts in Lake Huron. These models cannot, without the inclusion of immigration parameters, reasonably reconcile yield, mortality imposed by sea lampreys and stocking levels (Johnson *et al*. 1995).

This study was conducted to complement studies of movement patterns based on the survey and commercial catch data of hatchery-produced lake trout in Lake Huron, using analysis of coded-wire tag data from sport (charter and non-charter) fisheries. The movement patterns interpreted from these tag returns are compared with movement

patterns interpreted from spatial-temporal variability of catch rate data in sport fisheries. The study also attempted to evaluate the tag recovery program to investigate fish migration and makes recommendations on survey design where appropriate.

2. MATERIAL AND METHODS:

Tagging data are potentially useful to investigate movement patterns of lake trout in Lake Huron because most fish are from hatchery origin, large numbers of the released fish have been tagged, and several tag recovery plans are in place to collect tag information. To use tag data in making inferences about fish distribution of abundance and migration patterns, it is necessary to consider the effort spent catching the fish and recovering the tags (Hilborn 1990, Schmalz *et al*. 2002). Otherwise tag counts might merely reflect distribution of the fishery or allocation of effort of the tag recovery programs. Thus, analysis of fish movement can be performed only with data from those sources of tag recovery for which the effort data for recovering tags are available and the units of effort are similar. Accordingly, for the analysis we selected tag data from sport fisheries (charter and non-charter boats) from the Coded-Wire-Tag (CWT) database. The database contains records of tags collected mostly from sport fisheries (charter boats, non-charter boats) in Michigan waters of Lake Huron, and also from assessment surveys, and tribal fisheries, and recovered by several methods such as self-report forms from charter boat fishers, creel clerk and headhunter interviews, volunteers and tournaments. A total of 4,240 coded-wire tags records have been entered in the CWT database of fish recovered in waters of Lake Huron from 1989 to 2000. For this study we selected records containing data from tags recovered by creel clerks and headhunters from charter and non-charter boat trips and from self-reported tags by charterboat captains. Numerous records from tags were recovered by volunteers and were excluded since the effort to recover those tags is unknown.

Given the diverse origin of the tag recoveries, tag rates need to be adjusted for efficiency in catching the fish and for the effort in collecting the tagged fish. Sport fisheries are conducted by charter boat and non-charter boat fishermen, and higher catch rates are experienced in charter boat trips. This is because the number of anglers in charter boats is, on average, double that in non-charter boats, trips tend to be longer, the number of rods by angler is higher (although not reported) and the charterboat captains have greater experience in catching fish. Thus, the chances of catching (tagged) fish are higher in charter than in non-charter boat trips. In terms of recovering the tags, these are self reported by charter boat captains or are recovered by headhunters and creel clerks. Tags from charterboat trips are generally under-reported by captains and headhunters should be more efficient than creel clerks since they specifically sample fish heads while clerks do not collect heads in every interview. These differences were quantified in this analysis.

Data on non-charter and charter fisheries from 4 databases described in the following sections were considered in the analysis. Tagging data are from the CWT database, and effort data are from the creel, charterboat and headhunter databases. From these data, we estimated the number of tags recovered and the number of trips from where these originated by gear type/tag recovery program. This was not a trivial exercise because no relational link exists between these files. The databases do not contain information on tags recovered and sport fishery effort in Canadian waters. Data from Canadian sport fishery are not available at the level of detail required for this study, and thus the analysis was for Michigan waters of Lake Huron.

2.a. Data Sources

***Tagging data*:**

We analyzed tag recovery data collected from 1986 to 2000 from sport fisheries. This Coded-Wire-Tag database is housed by the Michigan Department of Natural Resources

in Charlevoix and contains records from tags recovered in Michigan State waters. This is the most complete database available for tag data from sport fisheries for several fish species. Unfortunately data from tags recovered in waters outside of the State of Michigan are not included in the database. A less detailed subset of these data is also part of the **STANDARDIZED CWT DATABASE** for lake trout maintained by the Great Lakes Science Center and used by the Modeling Subcommittee of the Technical Fisheries Committee for stock assessment. We could not combine data from the two databases because they were created for different end-users, and the overlap between the two is unclear. This question needs to be clarified by the lake trout stock assessment group.

We processed lake trout data from the CWT database to check for data integrity and we made necessary corrections. Numerous errors also were reported to personnel of the Charlevoix Research Station so the CWT database could be updated. The CWT database contains records of tags collected from sport fisheries, assessment and tribal fisheries, weirs, and by several tag recoveries methods including creel clerk and headhunter interviews. The full listing of these recovery sources in the CWT database and their corresponding CWT codes ("gear types" in the CWT database) are: bottom gill net (BGN), bottom trawl (BTL), self-reporting charter boat (CBT), creel clerks collecting from charter boats (CCB), creel clerks collected from non-charter fishers (CCK), found dead (DEA), electrofishing (ELE), fish ladder (FLD), headhunter collected from charter boats (HHB), headhunter collected from non charter fishers (HHR), mid water trawls (MWT), other (OTH), pens (PEN), surface gillnet (SGN), seine (SNE), tournament collected (TRN), unknown gillnet (UGN), unknown (UNK), volunteers (VOL), and weir (WER). We selected data from sport fisheries and gear types CCB, CBT, CCK, HHB and HHR for our analysis.

***Effort data (fishing and recovering tags)*:**

Creel survey data. The number of trips performed by non-charter fishers, and from which creel clerks performed interviews, was calculated from creel interview files. Creel clerks do not collect tag information from every interview. Unfortunately, the number of trips for which tags are collected is not reported (although it would be trivial for creel clerks to include this information). The creel files contain information recorded during creel interviews such as the interview date, interview site and fishing site, mode and method of fishing (1=boat, 2=shore, 4=open ice, 5=pier, 6=ice shanty, and 9 =pleasure boat), starting and ending date of the time of operation, target species, number of anglers by trip as well as catch information by species and the targeted species. We selected records from fishing boat trips, which constituted more than 99% of trips from where lake trout were caught in Lake Huron. The method of fishing information in the database indicate if fishing corresponded to fly fishing, casting, troll, etc. We did not subset the data based upon the mode of fishing.

Several data handling procedures were necessary. First, it was necessary to standardize the formats of the creel interview files, which were compiled annually with differences in their layouts. Also data were in different processing stages depending on the year data were collected. Further, for some years it was also necessary to process the data to associate catch information with the trip information kept in separate files. Finally, for the analysis it was required to assign the statistical district for each trip. This was done using the location information of the fishing sites. These sites in Lake Huron in the creel database from 1993 to 2000 and were assigned to the corresponding statistical districts as follows: **MH1**= 207, 208, 209, 210, 211, 214, 218, 219, 223, 224; **MH2**= 225, 227; **MH3**= 232, 234, 316; **MH4**= 250, 255, 260, 261, 278, 288, 355 356, **MH5**=236, 241, and **MH6**= 245, 246.

Charterboat data. The number of trips performed by charterboat fishers, and from which they could have reported tags were calculated from charterboat files. Charterboat files contain information from forms sent by charterboat captains themselves. Information in these files is similar to those in creel interview files with the exception that instead of

containing information about the fishing site, the geographic location corresponds to the port. A desirable feature of these files, and not available in creel files, is that the actual grid where fishing took place is reported. We used the fishing grid information to assign the statistical district for each trip. We did not select charterboat data based on any particular criteria and used all records from these files.

Headhunter data. The number of trips from which headhunters obtained their tags was calculated from headhunter files. Information in these files is similar to those in creel interview files with the exception that the location reference corresponds to the port instead of a site. We used the port information to assign the statistical district for each trip. For all assignments of trips from location to statistical districts we used the creel and charter site codes and the CWT Capture Sites Master List provided by MDNR personnel from the Charlevoix Research Station. Several errors were detected, corrected and reported.

The headhunter program has changed protocols over the years. The number of non-charter trips from where headhunters collected samples between 1993 and 2001 varied between statistical districts by month. Table 2 presents a summary for all years but differences by year also exist. Overall, headhunters did not take samples during May in MH1 and during September in MH4 to MH6, while most of the effort was spent in MH6 in May. The uneven distribution of the sampling effort by headhunters poses problems when incorporating these data in some analysis. Also, in early years headhunters did not consistently sample lake trout heads.

Table 2. Number of trips sampled by headhunters by statistical district and month for 1993 to 2000.

Statistical District	May	June	July	August	September
MH1	-	21	577	2679	385
MH2	45	457	2116	1060	38
MH3	256	1029	1571	1413	623
MH4	377	1320	1489	975	-
MH5	752	673	828	588	-
MH6	2516	423	103	25	-

2.b. Statistical Analysis of temporal and spatial variation of tag recovered by trips

The analysis consisted in modelling the number of tagged lake trout recovered per number of trips performed in time and space by source of recovery. In essence, we used tags per trips from charter and non-charter fisheries as indices of abundance. Modelling addressed several factors affecting tag recoveries rates such as the source of tag recoveries (gear type), location of hatcheries of origin of the tags, and spatial unit and year the tags were recovered. The age of the fish was not considered in the modelling because most tags were recovered from fish ages 4 and 5 depending on the year, and the number of tagged fish of other ages was very low. The number of lamprey wounds in tagged fish recovered was not available for us from the CWT database, and this information was not incorporated in the analysis. Consistency of patterns was investigated among years

The statistical analysis was done using Generalized Linear Models (GLMs) techniques (McCullagh and Nelder, 1989). We used the following regression:

$$g(\mu_{ymdg}) = \alpha + \delta_y + \phi_m + \lambda_d + \tau_g + \varepsilon_{ymdg} \qquad (1)$$

where μ, the response variable, is the number of tags recovered by number of trips and is modeled as a function of a linear predictor incorporating as variables: δ the year, Ø the month, λ the statistical district (as the spatial unit), and τ the source of tag recovery (so called "gear type" in the CWT database). In these models, all variables were introduced as factors. The month and the statistical district where tagged fish were recovered were the finest spatial/temporal resolution for which data were available for analysis. The analysis was also done by year since the number of released tagged fish varies annually. Input data (in Appendix I) correspond to the numbers of tags recovered from the selected gear types, and the number of trips from which the tags were generated, aggregated by year, month and statistical district. We used a binomial probability distribution to describe the chance of obtaining a number of tags given a number of trips with binomial variance function:

$$\left(\frac{\mu(1-\mu)}{n}\right) \qquad (2)$$

We used the logit link function to relate the response variable to the linear predictor:

$$g(\mu) = \log(\frac{\mu}{1-\mu}) \qquad (3)$$

Analysis of deviance was performed to test significance of the variables in the models, and model coefficients were estimated to quantify the effect of the covariates on catch rates (McCullagh and Nelder, 1989). Analysis of deviance was performed by comparing full models with models excluding the tested variable. GLMs were run with routines contained in the S-Plus programming environment (Becker *et al.* 1988) and developed by Venables and Ripley (2000).

First, a comparison in the return rates was performed between "gear types", i.e. a combination between fishing and recovery sources. This analysis was done to investigate the relative efficiency in rates between recovery sources and estimate conversion factors. Results from this comparison were also used to guide subsequent modelling. Next, to investigate movement from recovery rates we performed analysis considering the origin of release since fish were released from several stocking sites. We aggregated the recoveries by statistical area (MH1 to MH4) of release. Models incorporating interaction terms between gear types, and spatial and temporal units were run, and the significance of the interaction was tested. Further, we evaluated model performance for validity of variance and link functions through examination of model residuals.

Results

CWT data handling and selection criteria

Only a fraction of the 4,243 lake trout records from the CWT database for years 1990 to 2000 was suitable for the analysis. The following sections describe the information available in the databases used for the study and criteria for data selection necessary for the analysis.

Tag identification: Tags are identified by unique six-digit tag numbers (CWTTAG). There are 112 unique tag numbers for lake trout in the CWT database and most are 43-xx-xx. Almost half of the records (1620) correspond to fish with no tag information: CWTTAG= NO TAG, BAD TAG, NOTAG LP, NOTAG RP, SHORT, and LOST. Records with no tag information are from fish that were thought to have CWT tags but turned out not to have them, and were excluded from further analysis. These records should be excluded from the CWT database since they are not from coded-wire tagged fish.

Location of recovery: The information on location where each tag was recovered was recorded in the CWT database by the grid (GRID, CALC.GRID), the port (PORT.OR.CI), the site name and number (SITE.NAME, SITE), and the statistical district (STAT.DIST). 42 records did not contain information on the location of recovery despite having tag information. These records were excluded from further analysis. The grid (or calculated grid) by definition should correspond to the location where a fish was caught while the other location information should refer to where the interview took place. The criteria to assign the statistical district were nevertheless not always consistent and assignment was based on the fishing grid information or on the port or site where the interview took place (John Clevenger, MDNR, personal communication). This caused, for example, that tags that were recovered while fishing in one particular grid could be assign to different statistical districts. Thus, to capture the actual recovery area, the original definition in the database was not used and statistical district were reassigned from the grid where fishing was declared or from the calculated grid. For the 108 selected

records without grid information the original assignment in the database was used. Ports of the interviews in the CWT database (30) and corresponding statistical districts are presented in Table 3.

Date of recovery: From the selected records with information on the recapture site there are 31 with no information on the corresponding recovery date. Those records were excluded from further analysis.

Gear type for recovery: The recovery source and corresponding number of tags recovered from the remaining records from the sport fishery are: CBT (159), CCK (688), HHB (75), HHR (642) TRN (20), UNK (6), VOL (947). Thus only 1514 records (from CBT, CCK, HHB, HHR) could be used to investigate the number of tags recovered by number of trips. The spatial distribution of these selected tag recoveries is shown in Figure 1. The number of tagged fish that were recovered by the selected source of recovery and aggregated by year, statistical district and month are presented in Appendix I.

Origin of release of tagged fish: Information on the release location is stored separately from the tag and fish information in the CWT database. Nevertheless, records include a tag number (CWTTAG) that can be linked to the CWT codes for release sites (PLANT.SITE). The assignments to plant site and to statistical districts based on the CWTTAG tag numbers are presented in Table 4.

Only 2580 records in the CWT database had CWTTAG information. Most tagged fish recovered had been released in Six Fathom Bank (Table 5). This is not surprising because this is planting site from where the highest number of fish (CWT tagged and overall) have been released. Numbers of fish stocked in Table 5 are from the stocking database in the Great Lakes Fisheries Commission Web site.

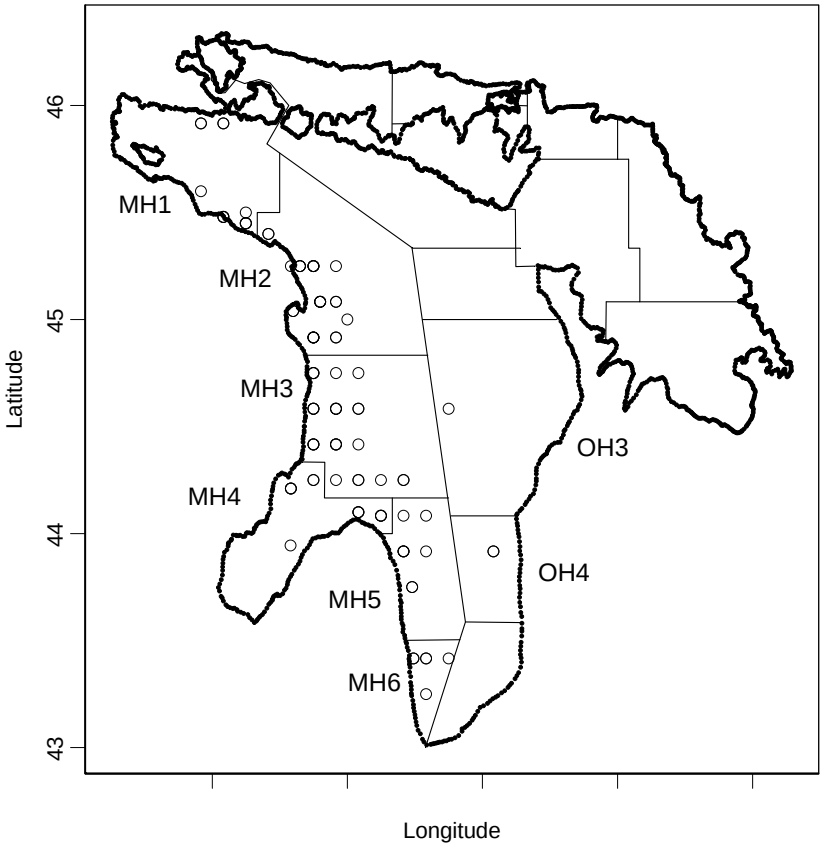

Fig. 1. Reported grids where tags recovered in CWT database for records with date of recovery information and for gear types CCK, CBT, HHR or HHB.

Table 3. Ports of the creel interviews in the CWT database and the corresponding statistical districts. In parentheses the port codes from creel and charter site code

District	Ports
MH1	CHEBOYGAN (218), DE-TOUR-VILLAGE, ROGERS-CITY (223), SAULT-STE-MARIE, HAMMOND BAY (219)
MH2	PRESQUE-ISLE (224), ALPENA (227), THUNDERBAY (227), STONEPORT, ROCKPORT (225)
MH3	BLACK-RIVER-VILLAGE (230), AU-SABLE (234), BLACK RIVER (230) BLACK-RIVER-HARBOR, HARRISVILLE (232), OSCODA (234), GREENBUSH (234)
MH4	AU-GRES (255), PORT-AUSTIN (236), TAWAS-CITY (250), PORT-HOPE (240), SAGANING CK TO SAGINAW RV (260), QUANICASSEE TO WISCOGGIN DRAIN (278), BAY SHORE MARINA (288), ESSEXVILLE TO FINN RD (356)
MH5	GRINDSTONE-CITY (238), HARBOR-BEACH (241), HURON-CITY, WHITE-ROCK (242)
MH6	LAKEPORT (247), LEXINGTON (246), PORT-HURON (248), PORT-SANILAC (245)
ONT	PORT-FRANKS, MIDLAND

Table 4. Assignment of CWT tag numbers to site and statistical district of release

Lake Huron MH1

"CHEBOYGAN REEF": 43-16-13, 43-16-14, 43-19-12

"DRUMMOND ISLAND": 43-20-47, 43-20-46, 43-16-18, 43-19-46,43-20-32, 43-20-40

"DRUMMOND ISLAND SCAMMON COVE": 43-17-55, 43-17-38, 43-17-40, 43-19-08, 43-1
09

"NORTHEAST REEF SHEBOYGAN REEF": 43-18-11

"DETOUR REEF DRUMMOND ISLAND": 43-18-34, 43-18-35

"SCAMMON COVE": 43-16-26, 43-19-61

"N REFUGE HOLDRIDGE BIG SHOALS": 43-18-09

"HOLDRIDGE SHOAL": 43-18-10

"ADAMS POINT": 43-01-42, 43-01-44, 43-20-54, 43-20-58, 43-20-13, 43-19-20

Lake Huron MH2

*"SIX FATHOM BANK": 43-19-55, 43-19-59, 43-19-57, 43-20-36, 43-20-15, 60-47-50, 43-2
04, 43-20-03, 43-19-60, 43-20-35, 43-19-56, 43-20-33.

"ROCKPORT": 43-20-14, 43-01-43

Lake Huron MH3

*"SIX FATHOM BANK": 43-17-03, 43-17-53, 43-19-18, 43-18-19, 43-18-39, 43-19-07, 43-1
19, 43-17-04, 43-18-41, 43-17-39, 43-16-16, 43-18-06, 43-18-38, 43-18-05, 43-20-50, 43-20-4
43-16-15, 43-18-03, 43-17-01, 43-18-36, 43-17-05, 43-17-02, 43-16-17, 43-17-06, 43-18-02, 4
18-04, 43-18-40, 43-17-36, 43-18-37, 43-17-37, 43-18-07, 43-18-18, 43-18-20.

"STURGEON POINT": 43-01-45, 43-19-21, 43-20-11, 43-20-52, 43-20-56

Lake Huron MH4

"POINT AUX BARQUES: 43-19-23, 43-20-12, 43-20-51, 43-20-55

***Lake Michigan* MM3**

"PENN DIXIE CEMENT": 43-16-55

"NORTHERN REFUGE": 43-17-31

"BOULDER REEF": 43-20-08, 43-17-45

"GULL ISLAND REEF": 43-17-30, 43-18-43, 43-20-09

"EAST REEF RICHARDS REEF": 43-19-24

"RICHARDS REEF": 43-17-32, 43-18-46, 43-19-26, 43-19-27, 43-20-38, 43-19-28

***Lake Michigan* WM5**

"NORTHEAST REEF ": 43-18-15

"EAST REEF": 43-19-31

*location of the release site changed from MH2 and MH3

Table 5. Number of CW tagged lake trout released and recovered by planting sites in Lake Huron from 1985 to 2000. Numbers recovered in Lake Huron and planted in Lake Michigan are included.

Western planting sites	**#recovered**	**#stocked**
"ADAMS POINT"	370	240,100
"ROCKPORT"	104	180,900
"MIDDLE ISLAND"	249	60,000
"STURGEON POINT"	541	234,800
"POINT AUX BARQUES"	360	226,700

Offshore and northern areas	**# recovered**	**#stocked**
"SIX FATHOM BANK"	815	2,361,718
"SIX FATHOM REEF"		147,300
"DRUMMOND ISLAND"	17	500,076
"N REFUGE HOLDRIDGE BIG SHOALS"	16	50,800
"HOLDRIDGE SHOAL"	7	76,200
"DETOUR REEF DRUMMOND ISLAND"	24	147,000
"SCAMMON COVE"	8	943,760
"DRUMMOND ISLAND SCAMMON COVE"	4	
"YANKEE REEF"		192,280

Lake Michigan from where tags were recovered in Michigan district waters:

"NORTHERN REFUGE"	1
"BOULDER REEF"	3
"RICHARDS REEF"	7
"GULL ISLAND REEF"	3
"PENN DIXIE CEMENT"	1
"EAST REEF"	1
"EAST REEF RICHARDS REEF"	1
"MID LAKE REFUGE"	1

Stocking origin of tagged fish and areas where tags were recovered

Most fish were recovered within the statistical district where they had been stocked (Table 6). Nevertheless a high percentage was also recovered in other areas.

Table 6. Number of tags recovered by statistical districts and corresponding stocking areas. * indicates that the areas of stocking and release are the same.

	Statistical district of recovery						
Stocking areas	MH1	MH2	MH3	MH4	MH5	MH6	tot
Near-shore areas							
ADAMS-POINT	181*	129	42	11	6	1	370
ROCKPORT	8	40*	43	9	3	1	104
MIDDLE-ISLAND	81	112*	46	4	5	1	249
STURGEON-POINT	22	141	292*	50	33	3	541
POINT-AUX-BARQUES	4	11	66	162*	94	23	360
Offshore-northern areas							
SIX-FATHOM-BANK	53	288*	213*	150	97	14	810
DRUMMOND-ISLAND	9	4	0	2	1	1	17
N-REFUGE-HOLDRIDGE-BIG-SHOAL	8*	7	1	0	0	0	16
HOLDRIDGE-SHOAL	3*	3	1	0	0	0	7
DETOUR-REEF-DRUMMOND-ISLAND	16*	4	2	0	2	0	24
DRUMMOND-ISLAND-SCAMMON-COVE	17*	18	5	0	1	0	41
SCAMMON-COVE	5*	1	1	0	1	0	8
Michigan areas							
NORTHERN-REFUGE	1	0	0	0	0	0	
BOULDER-REEF	1	0	0	2	0	0	3
RICHARDS-REEF	0	4	0	2	1	0	
GULL-ISLAND-REEF	1	1	1	0	0	0	
PENN-DIXIE-CEMENT	0	1	0	0	0	0	
EAST-REEF	0	0	1	0	0	0	
EAST-REEF-RICHARDS-REEF	0	0	0	0	1	0	
MID-LAKE-REFUGE	1	0	0	0	0	0	

* Release sites in Six Fathom bank was in MH3 up to 1992 and in MH2 in later years

Age of tagged fish at recovery: Age of the fish is only available for those specimens with CWT tags. The age of tagged fish ranged from 2 to 15 with most fish recovered at ages 4 and 5 (Table 7).

Table 7. Number of tagged lake trout recovered by age in the CWT database 1986-2000. Only 2 age 2 fish and 3 age 14 and 15 fish were recovered.

Year	#released	3	4	5	6	7	8	9	10	11	12	13
1990	333,000	2	2	0	2	0	0	0	0	0	0	0
1991	311,000	2	7	26	13	0	0	0	0	0	0	0
1992	**563,300**	1	15	9	36	10	0	0	0	0	0	0
1993	321,000	0	15	30	4	7	4	1	0	0	0	0
1994	**363,700**	4	16	37	39	12	12	5	1	0	0	0
1995	313,580	0	**228**	49	31	22	3	11	2	0	0	0
1996	**536,750**	5	8	**435**	29	16	4	2	3	0	0	0
1997	312,400	1	**114**	32	**177**	13	3	3	2	8	1	0
1998	523,500	6	11	**225**	25	79	2	4	2	1	7	4
1999	118,700	1	**170**	29	**190**	13	25	4	4	7	1	10
2000	309,676	17	4	**143**	22	39	2	8	0	0	0	0
Total		39	**590**	**1015**	**568**	211	55	38	14	16	9	14

Estimation of fishing effort

The first step in estimating effort for this analysis involved investigating which trips from the charter and non-charter fishery should be incorporated as effort for catching lake trout. This task differs when analyzing data from charter and non-charter boat trips because the information available from these fisheries is not the same. Creel clerks record information on declared target species for each trip from non-charter operations, but charterboat captains are not required to submit that information. Since targeting on a particular species can affect the probability of catching others, the declared target information is particularly relevant to identify trips with probability of catching lake trout where no catch of lake trout occurred. Also, trips targeting a species that translated in no chances of catching lake trout should be excluded from

the analysis. Otherwise the trip should be counted as effort with the corresponding 0 catch. Within lake trout assessment procedures, this issue has been dealt with by including all trips from ports considered as “salmonids ports”.

Effort in non-charterboat fishery

To select which trips to consider as fishing effort for lake trout we examined the presence of lake trout in catches given the declared target species. The criterion adopted was that only the trips for the declared targets that resulted in positive catch of lake trout were considered as effort. There were 25 target species contained in the database: ANY, BLG (blue gill), BNT (brown trout), CAR (carp), CCF (cat fish), CHS (chinook salmon), CWS (common white sucker) DRU (drum), LAT (lake trout), LMB (large mouth bass). NOP (northern pike), PAW (), RBT (rainbow trout), RKB (rock bass), RWF (round white fish), SAL (salmonids), SAT (salmon and trout), SMB (small mouth bass), SMT (), TRT (trout), WAE (walleye), WHB (white bass), WHP (white perch), YEP (yellow perch), and YLB (yellow bull head). It was noted that the definition of targets in the database changed in 1997, where in earlier years a high percentage of trips corresponded to target CHS, while from 1997, these trips are classified as SAT. This change should not affect our results. Trips for only 9 out of the 25 declared targets (ANY, BNT, CHS, LAT, RBT, SAL, SAT, TRT, WAE) resulted in lake trout catch (Table 8). Thus, for further analysis we selected trip records from these 9 targets, and assumed that chances of catching a lake trout when targeting the other 16 species was 0. Also, since the number of lake trout caught in the walleye fishery was only 12 in more than 11,000 trips, thus a very small probability, trips targeting walleye were not considered as effort. Most lake trout catches relative to the number of trips (on average around 1 fish every other trip) were among trips that declared lake trout as target, followed by trips for which salmon and trout targets were declared (around 20% of the trips) (Table 8).

Table 8. Number of lake trout caught by targeted species for which catches **have been positive for lake trout (Lake trout +)** and number of trips (Total).

Year		Targets									
		ANY	BNT	CHS	LAT	RBT	SAL	SAT	TRT	WAE	Total
94	**Lake trout #**	**6**	**0**	**5**	**59**	**0**	**100**	**389**	**8**	**2**	**569**
	Total trips	802	0	12	94	0	2865	3654	140	2339	
95	**Lake trout #**	**15**	**0**	**0**	**7**	**0**	**77**	**1010**	**94**	**0**	**1203**
	Total trips	676	126	15	8	0	1473	6202	283	1307	
96	**Lake trout #**	**83**	**0**	**0**	**0**	**0**	**53**	**1390**	**121**	**1**	**1648**
	Total trips	813	148	5	2	0	1560	6385	281	1452	
97	**Lake trout #**	**5**	**4**	**611**	**139**	**2**	**79**	**1115**	**2**	**6**	**1963**
	Total trips	516	175	1767	247	192	1696	4672	36	1386	
98	**Lake trout #**	**10**	**2**	**490**	**97**	**3**	**89**	**1140**	**0**	**3**	**1834**
	Total trips	756	173	2397	207	133	1161	3663	41	1640	
99	**Lake trout #**	**58**	**0**	**218**	**60**	**5**	**258**	**653**	**1**	**0**	**1253**
	Total trips	955	107	1229	132	254	3248	1973	340	2103	

Effort in charterboat fishery

Since targets are not declared in the charterboat fishery, we used the species composition of the catch as a guide to select which trips to include. The problem is when no fish are caught during a fishing trip because there is no information to differentiate between a 0 catches for lake trout or for other species. From the 24,550 trips in the charter boat database, less than 5% reported absolutely no catch. Thus, the problem of identification of effort for 0 catches should be of little importance. These proportions are different to those in the non-charter boat fishery where about 40% of the fishing trips resulted in no catch. About 12,062 trips reported lake trout catch.

Main species in the charter boat catch are yellow perch, walleye, coho and chinook salmon, and rainbow and brown trout. When the numbers of lake trout are plotted against the numbers of other main species caught by trip, it is clear that lake trout were practically absent in trips where yellow perch were caught. Thus, based on these results the trips with yellow perch catches were not considered part of the effort to catch lake trout and were excluded from the analysis. Also, although the numbers of lake trout caught during a trip were, in general, negatively correlated with the catch of

every species (Figure 2) the chance of catching a fish was still greater than 0. Thus, all other trips were included. Numbers of trips selected from the described criteria are presented in Table 2.

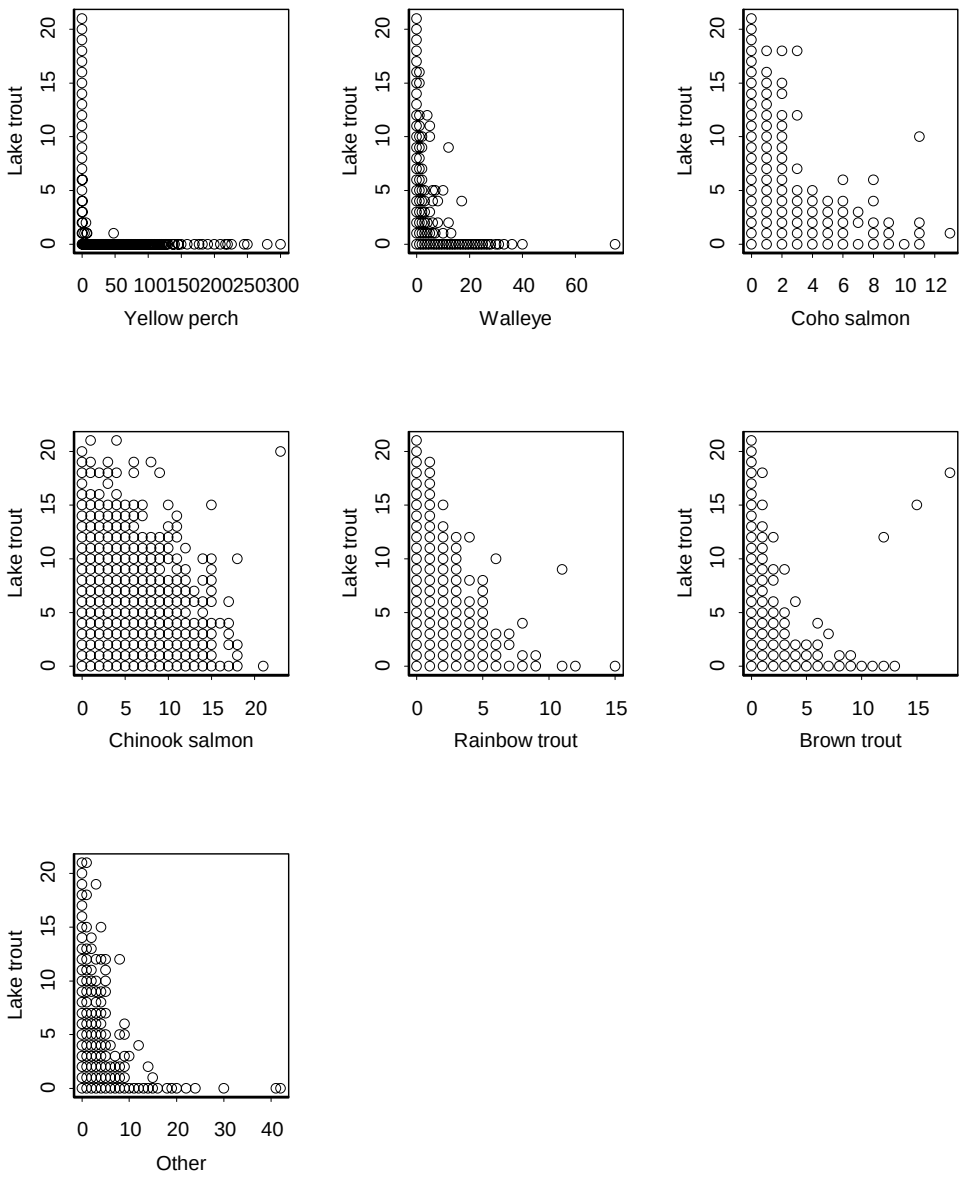

Figure 2. Number of Lake trout and other species caught by trip in the Lake Huron charter boat fisheries based on self-reported catches. Years 1991 to 2001 combined.

Comparison of tag recoveries from different sources.

Results from main effects GLM indicate that rates varied significantly between sources of recovery (charter and non-charter boat trips sampled by creel clerks and headhunters) (Table 9). Model fitted effects represented in Fig. 3 show that overall recoveries by trip were significantly highest among headhunters reporting on charter boat catch, followed by headhunters sampling non-charter boat, while tag recoveries from creel clerk interviews and self-reported recoveries from charter boats were lower than those from headhunters.

Table 9. Analysis of deviance table for main effects GLM for tags recovered by trips in sport fisheries. Df=degrees of freedom, Dev=deviance and coefficients for recovery source in reference to CBT (treatment contrast of coefficient matrix).

Terms	Residual Df	Residual Dev	Df	Dev	Pr(Chi)
Null model	739	4223.6			
Gear	723	2438.3	3	477.4	0
Month	724	2855.9	4	894.1	0
Year	727	2245.6	7	284.6	0
Statistical district	725	2612.0	5	651.0	0
Full model	720	1960.6			

Coefficients	Value	Standard error	t- value
CBT (intercept)	-5.975	0.109	-54.879
CCK	0.611	0.092	6.6619
HHB	2.60	0.150	17.3265
HHR	1.42	0.09	15.6856

The model coefficients for each recovery source in Table 3 indicate that differences between levels were significant. Coefficients indicate that the chance of recovering tags from creel interviews of non-charter trips is about double than from a charter boat that self reports, that of headhunters collecting tags from non-charter boat trips is about three times larger, and headhunters collecting tags from charter boat trips is about nine times larger. Thus, to interpret tag recoveries it is necessary to standardize the numbers by these coefficients.

Recovery levels varied with source of recovery, but this was not the most important cause of variation (not the GLM explanatory variable with highest deviance contribution in Table 9). Recovery levels also varied between years, months and statistical districts. The difference between months was the largest, followed by the variation between districts. The model explains about 50% of the variation in the data. Return rates were lowest in 1993 when few years of CWT fish stocking had taken place and were highest in 1999 probably because of the highest numbers released in 1996. Recoveries by trip were overall highest in statistical districts MH2 and MH3, despite the fact that more tagged fish have been released in MH1 than in MH2. Several causes, including differential mortality by area, catchability by area and movement between areas can account for this result. In terms of seasonal variation, levels strongly decreased from May to September indicating that lake trout become less available to the sport fisheries in the fishing grounds. These aspects were further investigated by running GLMs by release areas.

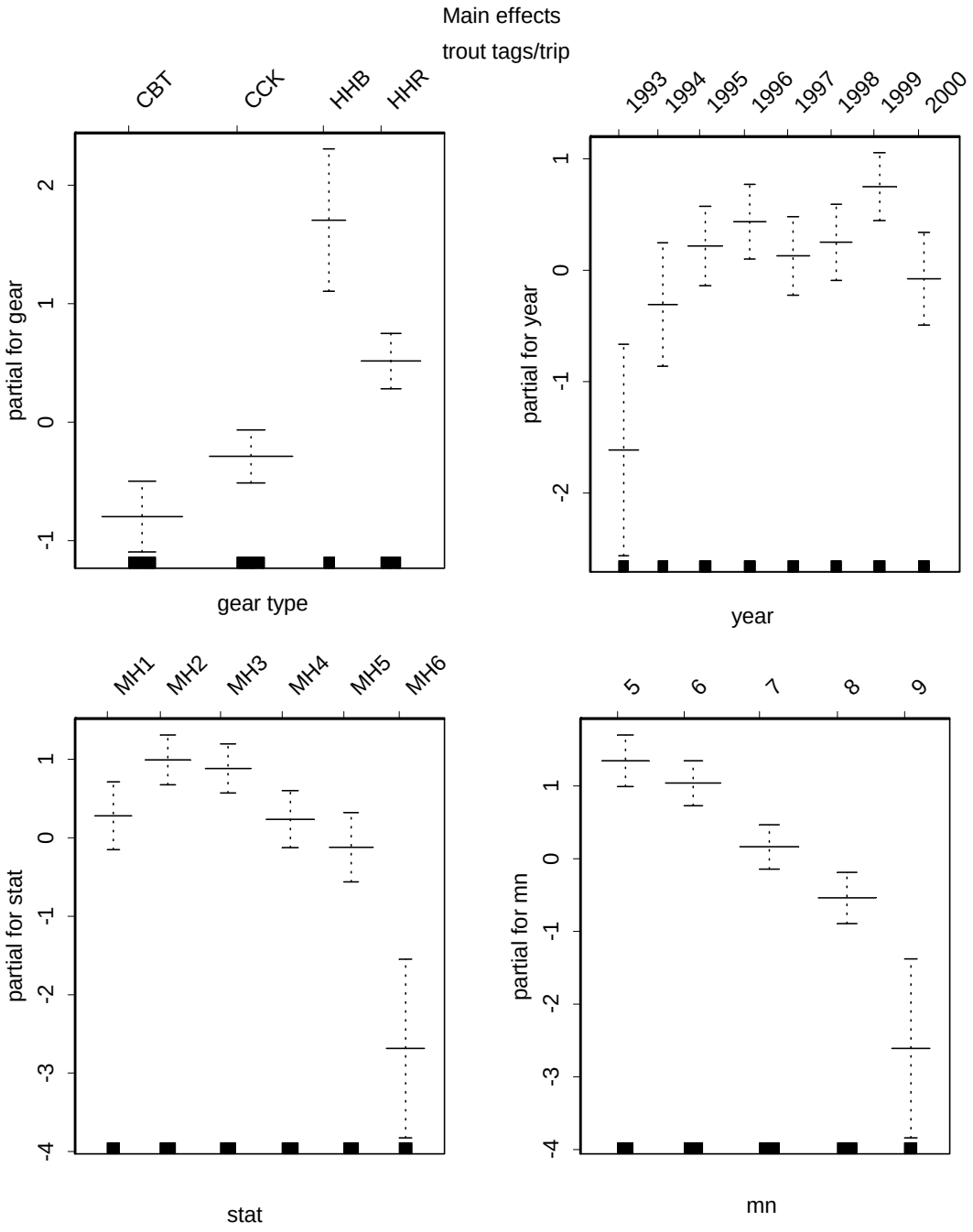

Figure 3. Fitted effects from main effects binomial GLM where recoveries by trip are modeled as a function of source of recovery (gear type), year, statistical district (stat), and month (mn). Brackets represent 95% confidence intervals, ticks in the x-axis represent available data and the y-axes are standardized so that 0 represents the mean.

Analysis of recoveries considering the origin of release of tagged fish:

Independent of the recovery source, more tagged fish were recovered in the same area where fish were stocked than in other areas (49 to 36% of the tags) (Table 10). Variable relative proportions were found in areas other than the stocking area. With the exception of recoveries in MH3, the highest levels were in areas towards the south of the area where fish were released. The release area with highest proportion of fish recovered in the same area was MH1 (Table 10).

Recoveries were generated by variable number of trips since the number of fishing trips varied between statistical areas. The fishing effort ranged from a high level in MH3, to a low level in MH6 (Table 10). We adjusted the recovery numbers by number of trips by area (Adj.prop. in Table 10). The pattern of recoveries by area remained the same when numbers of recovered CWT fish were adjusted by total numbers of trips. This is because most tagged fish were recovered in areas MH1 to MH3 where fishing effort was similar. Nevertheless, these figures include tags recovered from all sources of recovery in the sport fisheries from May to October and from 1993-2000. Given that previous results indicated that the numbers of fish recovered by trip varied between source of recovery, year, month and statistical district, these results can be affected by temporal movement between areas, and variation in the number of fish tagged between years, and by the source of fish recovery. The following analysis addresses this question by modelling the recoveries by trip from each release site (statistical district) and adjusting the proportions according to the results.

Table 10. CWT fish recovered by statistical district given the release areas, proportions of CWT fish in the statistical district of recovery and proportions adjusted by number of trips.

	Statistical district where fish were recovered						
Released in	**MH1**	**MH2**	**MH3**	**MH4**	**MH5**	**MH6**	**total**
Trips	19,778	18,149	22,182	12,811	9,021	8,191	91,032
Effort factor	1.1	1.2	1	1.7	2.45	2.7	
MH1							
Tag #	240	167	55	13	11	2	488
Proportion	49%	34%	11%	3%	2%	0.4%	
Adj.prop.	46%	35%	10%	4%	5%	1%	
MH2							
Tag #	102	209	177	50	34	11	868
Proportion	18%	36%	30%	8%	6%	2%	
Adj.prop.	15%	34%	24%	11%	11%	4%	
MH3							
Tag #	62	371	417	177	91	7	881
Proportion	5%	32%	37%	16%	8%	1%	
Adj.prop.	5%	31%	28%	20%	15%	1%	
MH4							
Tag #	4	11	66	164	92	23	360
Proportion	1%	3%	18%	45%	25%	6%	
Adj.prop.	1%	4%	10%	43%	33%	9%	
MM3	3	6	1	3	3	0	16
WM5	0	0	1	0	0	0	1

Recoveries from fish released in MH1**.**

To understand the distribution of tagged fish in time and space we used generalized linear models where the numbers of tagged fish recovered by trip are modeled as a function of the statistical district where they were recovered, and the month, the year and the source

of recovery. The numbers in Appendix II constitute the input data for those models. These data consist of the aggregated number of tags recovered by source of recovery, statistical district, month and year from 1995 to 2000 that were released in MH1, and the corresponding numbers of trips from where the CWT fish could have been recovered.

Results from main effects GLM models for recoveries by trips of CWT fish released in MH1 in Figure 4 show that on average, significantly highest and similar rates of recovery occurred in MH1 (release area), and in the neighboring area MH2. These results account for the source of recovery, and for annual and monthly variation. Return rates decreased towards the south, with practically no tagged fish recovered in MH6 (not included in the analysis). This trend indicates that fish do move out from the release area and that the numbers of the fish found out of the release areas decrease with the distance from stocking. The annual variation of recovery rates is statistically significant but the differences were minor. Highest return rates occurred in 1996 and 1999. Most fish recovered in those two years were age 4, which is consistent with higher CWT releases in 1992 and 1996 than in other years (over 190,000 fish, Table 1). GLM results indicate that recovery rates of CWT fish decreased from May to September to the point that CWT fish were not recovered during September (excluded from the analysis). This is consistent with the results from the previous analysis with data from all release areas. Also, the differences between recovery rates by creel clerks and headhunters, and charter and non-charter boats were consistent with previous results, where highest levels correspond to headhunters sampling CWT fish from charter boat trips.

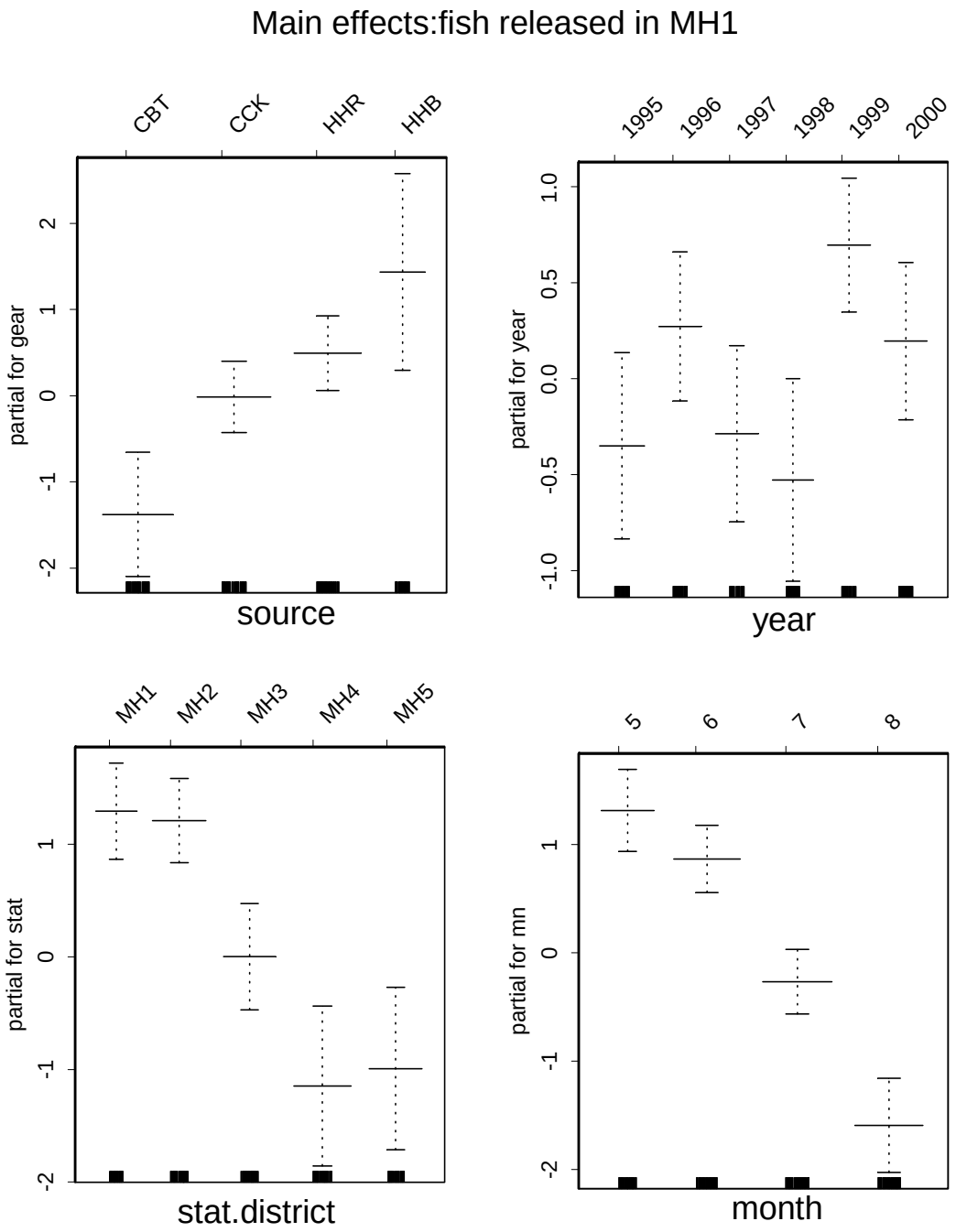

Figure 4. Fitted effects from a GLM of tag recovery rates from fish released in MH1 as a function of recovery source year, month and statistical district of recovery.

Next, we analyzed interactions between source of recovery and month, to eliminate the possibility that monthly variations were not an artifact of changes in the way the tags were recovered. The results of the GLM by source of tag recovery represented in Figure 5 indicate that similar monthly patterns occurred among recoveries from creel clerks and headhunters. The analysis was restricted to non-charter recoveries (CCK and HHR) since the data of CWT fish recovered by others sources were not amenable for modelling. From the results we conclude that observed monthly differences were not spurious results due to some change in the mode of sampling the tags, but reflected actual monthly variations.

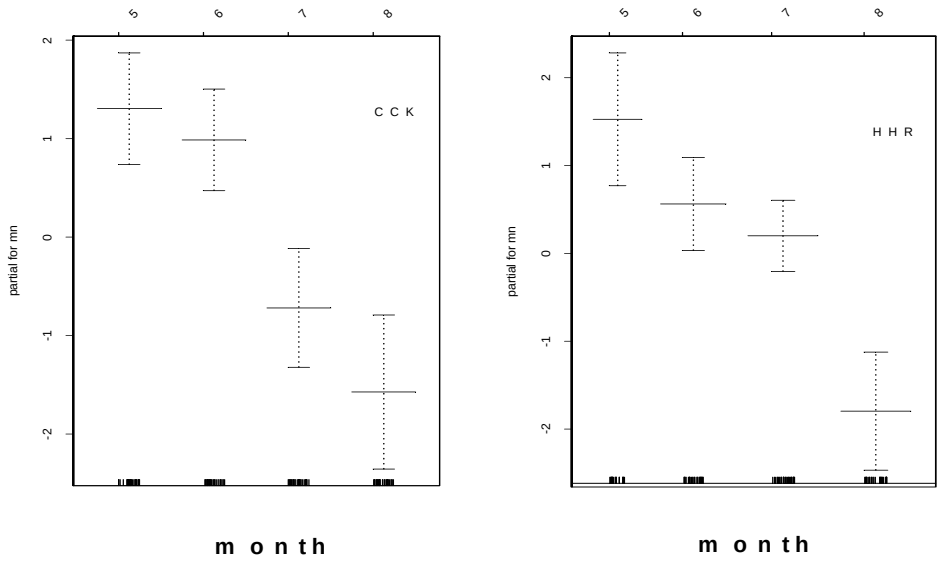

Figure 5. Fitted effects for monthly variation of rates for recoveries made from CWT fish released in MH1 from 1995 to 2000 by creel clerks and headhunters from the non-charter fishery (CCK and HHR) accounting for year, month and statistical area of recovery.

Further, we investigated if seasonal variation in recovery rates from the main effect GLM was the same for each area (first order area-month interaction). We ran GLMs for each

statistical district and for each month. Results of the analysis of monthly recovery rate variation by areas are presented in Figure 6. The figure represents the fitted effects for monthly variations in recoveries by trip of CWT fish stocked in MH1. Fitted effects are from main effects GLMs for areas MH1, MH2, MH3 and MH4, accounting for annual variation and source of recovery. Recoveries were very low in MH5 and MH6 and those areas were not included in the analysis. Rates of recovery decreased from May to August in areas MH1 to MH3, while in MH4 there were no significant differences.

Decreases in monthly rates in MH1 to MH3 can be caused movement of fish to areas that are not accessible to the fishery, such as the lake trout refuge of Drummond Island or to Canadian waters. In MH4 there are no refuge areas. There is also the possibility that fish are less susceptible to the fishing gear in later months as water temperature rises and the spawning season approaches. From our analysis, we cannot differentiate between these hypotheses because we do not have tagging/fishing effort data for Canadian waters or data from statistical grids within refuge areas closed to fishing. Because the monthly variation was similar by area, despite the overall difference in levels, we can infer that there was no significant seasonal movement of fish released in MH1 between MH1 and MH3 between May and September. Otherwise, we should have observed a relative decrease in return rates in a particular month in one area, followed by a relative increase in the following month in another area. Thus, since all fish in the analysis were released in MH1 the movement to other areas must take place in months for which data are not available or occur before fish reach the size of recruitment to the fishery.

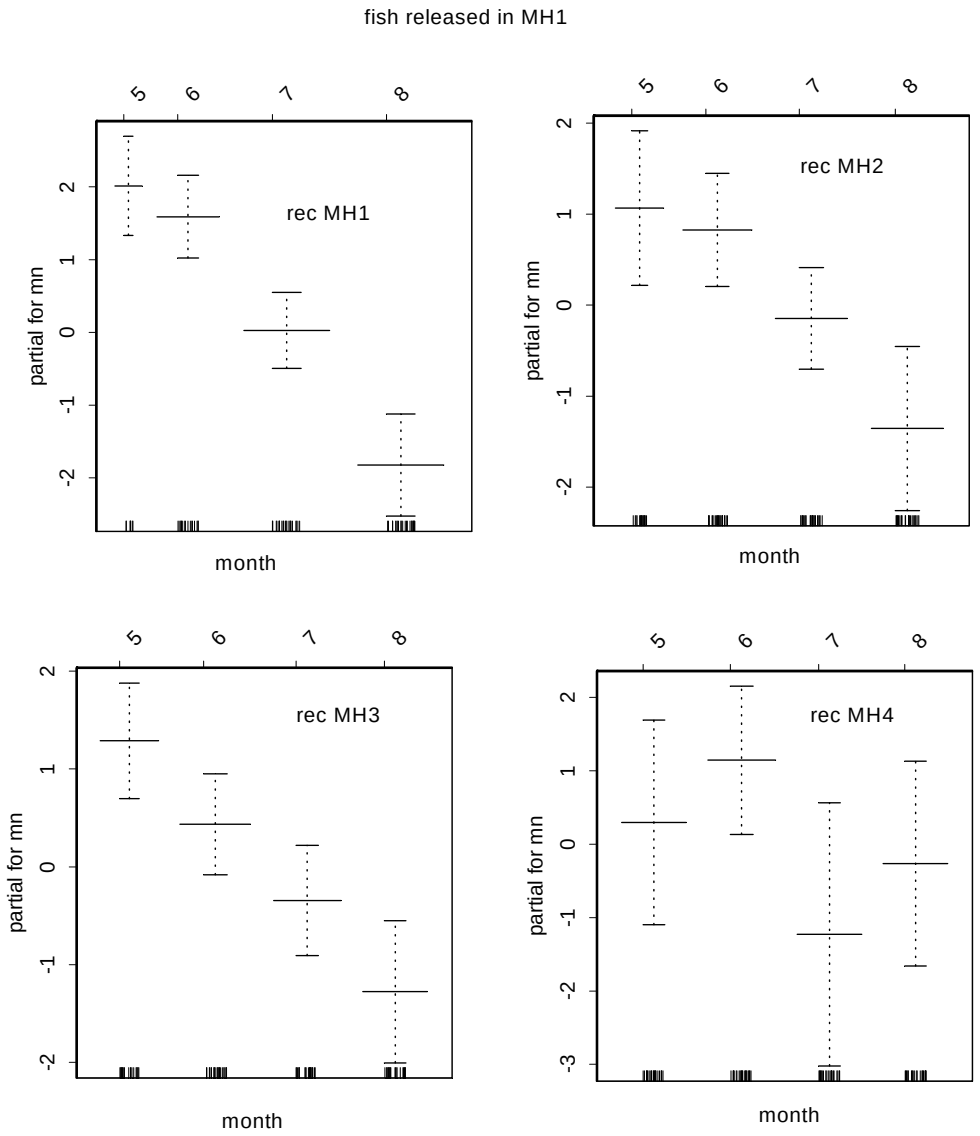

Figure 6. Fitted effects from GLMs for monthly variation of recovery rates for areas MH1, MH2, MH3 and MH4 from 1995 to 2000 by creel clerks and headhunters from the non-charter fishery accounting for year and source of recovery.

Another way to look at month-area interactions is to compare spatial trends in recovery rates by month and areas. Results from such GLMs are presented in Figure 7 and show that significant differences in recovery rates occurred in May and June, but became similar during July and August. We interpret these results as before. The consistent seasonal decrease in tag return rates within areas MH1 to MH3 (from around 30 tags per 1000 trips to 1) and no increases in MH4 to MH6 (around 1 tag per 1000 trips) indicates that changes in recovery rates are not caused by seasonal latitudinal movement between areas MH1 and MH6.

Change in the tag recovery rates during the fishing season imply that it is necessary to consider seasonality when investigating fish movement between areas. Seasonality should be considered when analyzing data to estimate a movement matrix for assessment. For example, if an analysis of fish distribution uses data from CWT recoveries in sport fishery and these data were collected mostly during August, results would show a uniform distribution indicating equal proportion by area, which will be incorrect. In this analysis, we selected data from May to model the recovery rate variation between areas and calculate a distribution matrix. We selected only data from creel clerks sampling non-charter boats because headhunters did not sample MH1 in May making the distribution of the data non-orthogonal, and self-reported tagged fish from charter boat captains were very low. We included data from all years, and did not introduce a factor for year in the models because annual differences were minor and insignificant. The model coefficients, estimated such that they represent the difference between rates in MH1 and in each of the other statistical districts (contrast treatment), indicate no significant differences (at the 95% confidence level) between rates in MH1 and MH2 and significant differences with other areas. Based on these coefficients, the matrix of proportions of CWT fish recovered by statistical district to infer lake trout distribution is such that it indicates that 43% of the fish were found in MH1 where tagged fish were released (Table 11), a lower percentage than was calculated if we do not standardize by gear and month (49% in Table 10) or if we just adjust the number of tagged fish by the number of trips (46%).

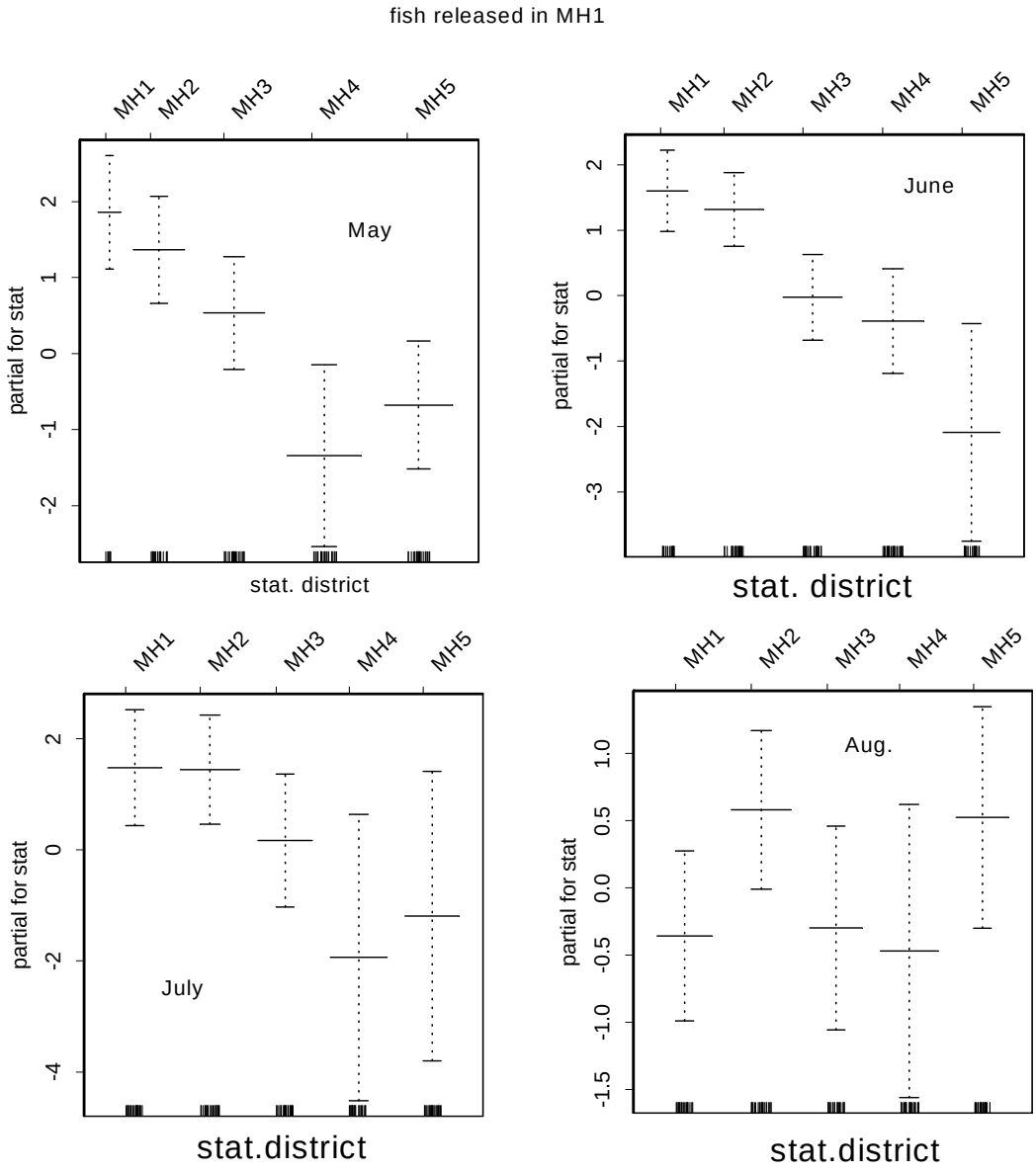

Figure 7. Fitted effects from GLMs for statistical districts of recovery rates by month for areas MH1, MH2, MH3 and MH4 from 1995 to 2000 by creel clerks and headhunters from the non-charter fishery accounting for year and source of recovery.

Table 11. GLM coefficients from a model of tags per trip as a function of statistical district as for May 1995-2000 recovered by creel clerks sampling non-charter boat trips. The coefficients are all in reference to MH1 (contrast=treatment). MH6 was not included because no recoveries were made.

Coefficients	Value	Std. Error	t value	Rate Prediction	Predicted Proportions
MH1(Intercept)*	-2.95	0.209	-14.107	0.049	*MH1 43%
MH2	-0.612	0.335	-1.820	0.049	MH2 43%
MH3	-1.491	0.459	-3.247	0.011	MH3 10%
MH4	-3.251	1.014	-3.205	0.002	MH4 2%
MH5	-2.921	0.733	-3.983	0.002	MH5 2%

Recoveries from fish released in MH2***.***

The number of tags recovered by source of recovery, statistical district, month and year from 1995 to 2000 are presented in Appendix III together with the corresponding number of trips from where the tags were recovered. These constitute the input data for the GLM analysis of recovery rates of tagged fish released in MH2. Results from main effects GLM models in Figure 8 show that recovery rates in MH2 (the release area) were similar to those in neighboring area MH3, and significantly higher than in other areas. These results account for source of recovery, and inter-annual and monthly variation. The recovery rates in MH1, MH4 and MH5 were similar and no latitudinal gradient was observed. Highest recovery rates were in 1999. During this year most fish recovered were age 4, which is consistent with higher releases in MH2 during 1996 (Table 1). As in the case of analysis from fish released in MH1, GLM results indicate that recovery levels decreased from May to September. Also, the results of variation between rates by source of recovery were consistent with previous results, with significant differences between sources, and highest return rates for headhunters sampling charter boat trips.

Results of the analysis of monthly variation of tag recovery rates by areas (month:area interaction) are presented in Figure 9. The figure represents the fitted effects for monthly variations for fish stocked in MH2, and recovered in areas MH1 to MH4 accounting for annual variation and source of recovery. Monthly decreases in tag recovery rates tended to be similar in areas MH1 and MH2 with significantly higher levels in May and June, while patterns were different in MH3 and MH4 with less variation in the decline between months.

Results from GLMs to compare spatial distribution by month, presented in Fig. 10, show that relative tag recovery rates changed seasonally. The picture obtained from main effect GLM, showing high and similar recovery rate levels in MH2 and MH3, holds only during July. During May and June rates in MH2 and MH1 were highest, then decreased in MH1 while those in MH3 and MH4 increased. The actual levels slightly decreased from May to June and plunged in all areas during July and August. Thus, these results suggest that some movement occurred between MH1 and MH3 before fish became less vulnerable/available to the fishery in July-August.

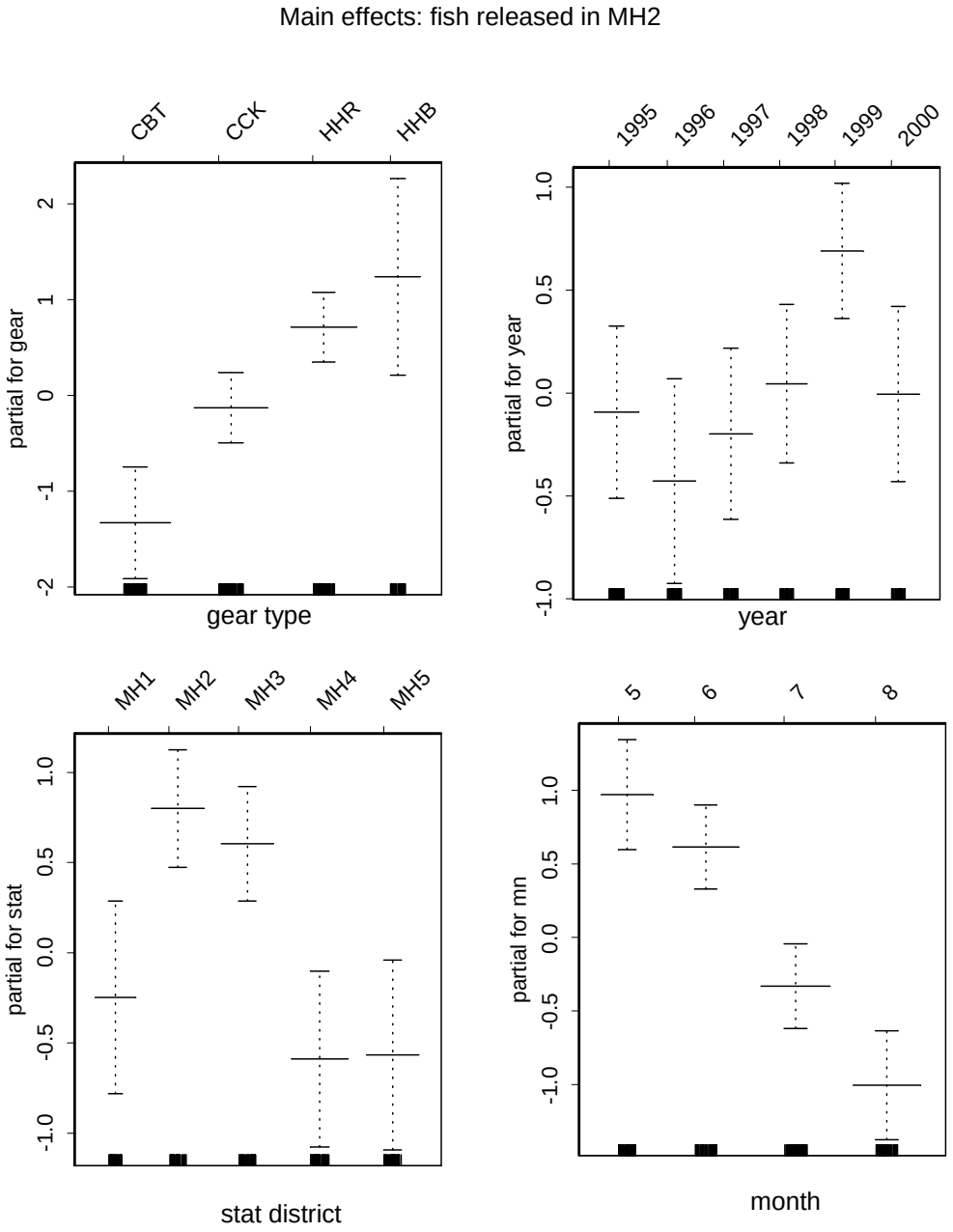

Figure 8. Main effects from GLM for tagged fish recovered by trip for releases in MH2.

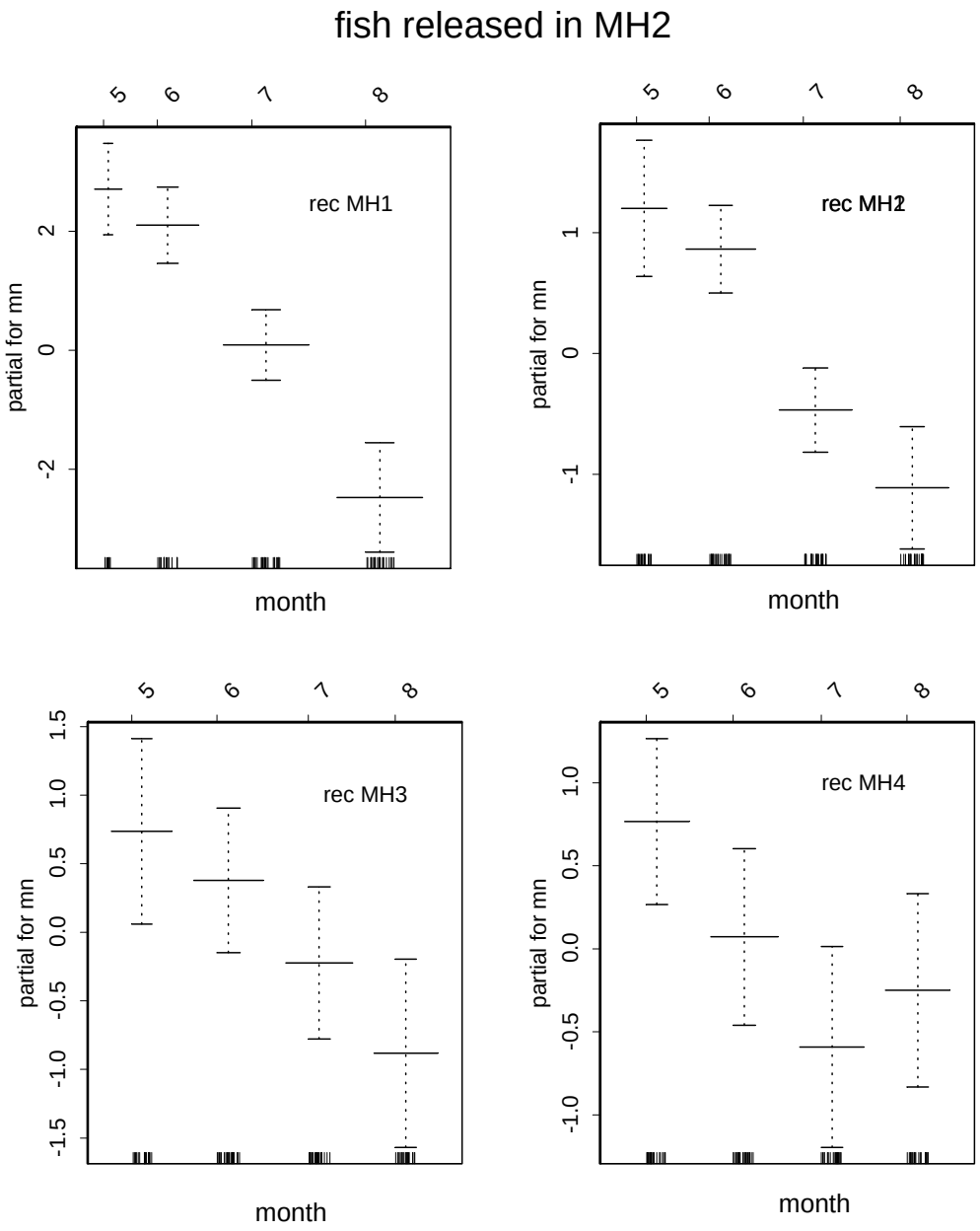

Figure 9. Fitted effects from GLMs for monthly variation of recovery rates for fish released in MH2 and recovered in areas MH1, MH2, MH3 and MH4 accounting for year and source of recovery. Data for recoveries in MH5 are not amenable to analysis.

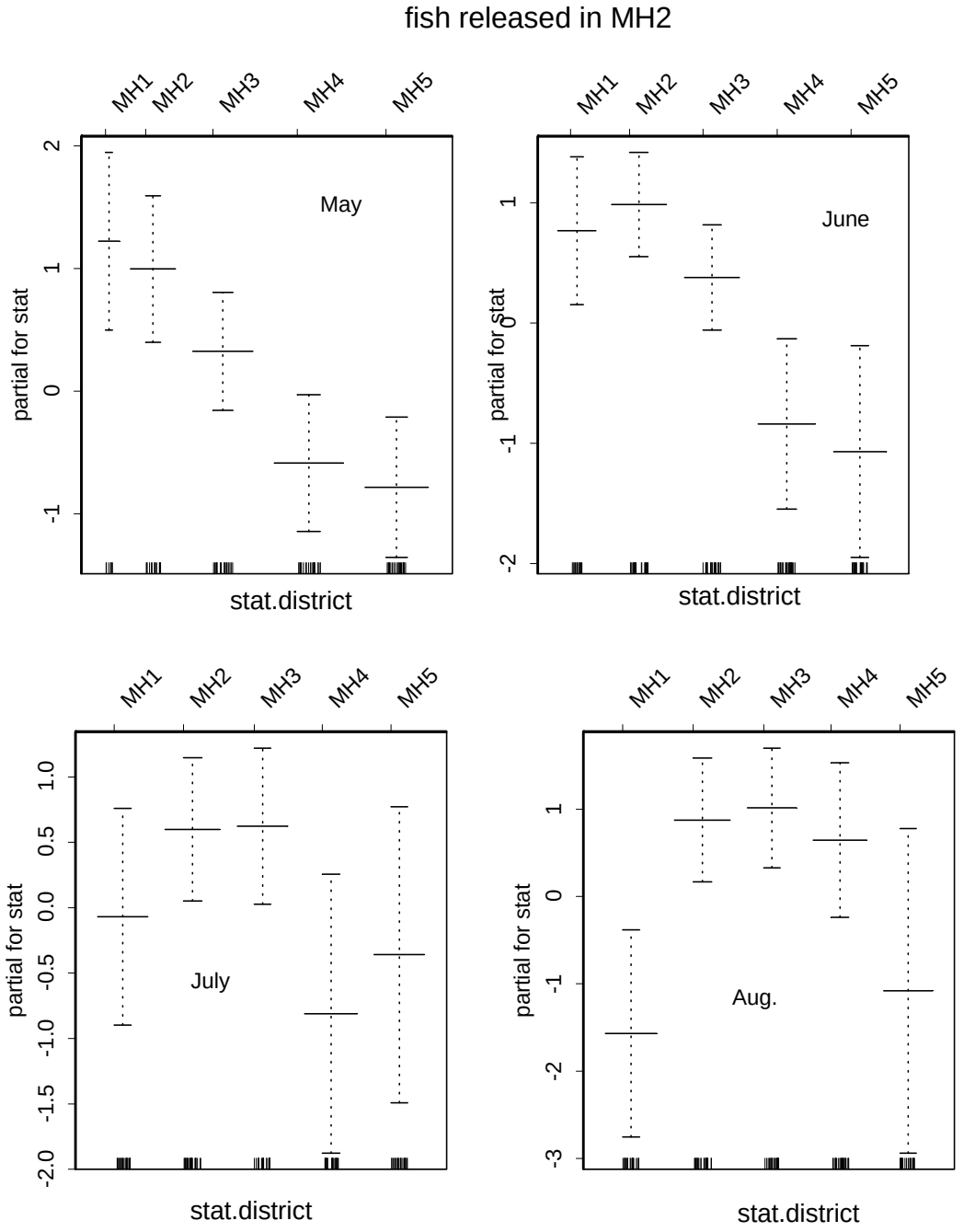

Figure 10. Fitted effects from GLMs for spatial variation of recovery rates of fish released in MH2 from May to August accounting for year and source of recovery.

To calculate a distribution matrix of fish stocked in MH2 we modeled the recovery rate variation during May. We selected only data from creel clerks sampling non-charter boats. The model coefficients and corresponding standard errors indicate significant differences between rates in MH2 and the other areas (Table 12). Coefficients presented in table 12 were estimated such that they represent the difference between MH2 rates and rates at each of the other statistical districts (contrast treatment of GLM matrix coefficients). Results indicate that rates were similar in MH2 and MH1 rather than in MH2 and MH3 as indicated by results of main effects GLM for all months. Based on these coefficients the matrix of proportion of CWT fish recovered by statistical district is such that only 38% of the fish remained in the release area MH2 (Table 12). The standardized percentages differ from those in Table 10 and reverse the interpretation on the direction of movement towards the north.

Table 12. GLM coefficients from a model of tags recovered per trip as a function of statistical district of recovery for fish released in MH2 and recovered by creel clerks sampling non-charter boat trips during 1995 to 2000 in May. The coefficients are all in reference to MH2 (contrast=treatment). MH6 was not included because of low recoveries.

Coefficients	Value	Std.-Error	t-value	Prediction	Predicted Proportion
MH2	-3.27	0.227	-14.38	0.0356	38%
MH1	-0.02	0.335	-0.063	0.0363	38%
MH3	-1.01	0.443	-2.287	0.0135	14%
MH4	-1.54	0.549	-2.808	0.008	8%
MH5	-2.59	0.733	-3.516	0.002	2%

Recoveries from fish released in MH3***.***

The number of tagged fish stocked in MH3 and recovered by statistical district, month, year and source of recovery are presented in Appendix IV together with numbers of trips from where the tags were recovered. These numbers constitute the input data for models in this analysis. Results from main effects GLM model, presented in Figure 11, show that recovery levels in MH3 (release area) were similar to neighboring area MH2, and significantly higher than in other areas. These results account for source of recovery and inter-annual and monthly variation. Lowest recovery rates were found in MH1 suggesting that fish move preferentially to the south, although this distribution can also be affected by higher mortalities in MH1. Highest recovery rates occurred in 1996. During that year recoveries were mostly of age 5 fish, which is consistent with higher releases in MH3 during 1992 (Table 1). Similarly, lowest rates occurring in 2000 are consistent with low releases starting in 1993. As in the case of the previous analysis, with data from all release areas and from fish released in MH1, MH2, and MH3, GLM results suggest that fish availability to the fishing gear decreases from May to September and that there were significant differences in rates between sources of recovery, with highest levels for headhunters sampling charter boat trips.

Results of the analysis of monthly variation of tag recovery rates by areas (month:area interaction) are presented in Figure 12. The figure represents the GLMs fitted effects for monthly variations in recovery rates of CWT fish stocked in MH3 and recovered in areas MH1 to MH5, accounting for annual variation and source of recovery. Monthly decreases in rates of recovery by trip tended to be different by area. In MH1 and MH3, return rates only decreased in August, in MH2 there was a steady decrease in return rates from May to August, and in MH4, May and June return rate levels were similar and decreased in July.

Results from GLMs to compare spatial trends by month areas show different trends by month (Figure 13). Lowest and variable tag return levels occurred in MH1 during all months. Interestingly, there is a progression in highest return levels in MH2 to MH3 from May to June, suggesting a latitudinal movement between areas. Also, an overall decrease

in return rates to similar levels in all areas during August indicated that fish became less vulnerable or available to the fishery as they moved to protected areas or are not susceptible to the fishing gear.

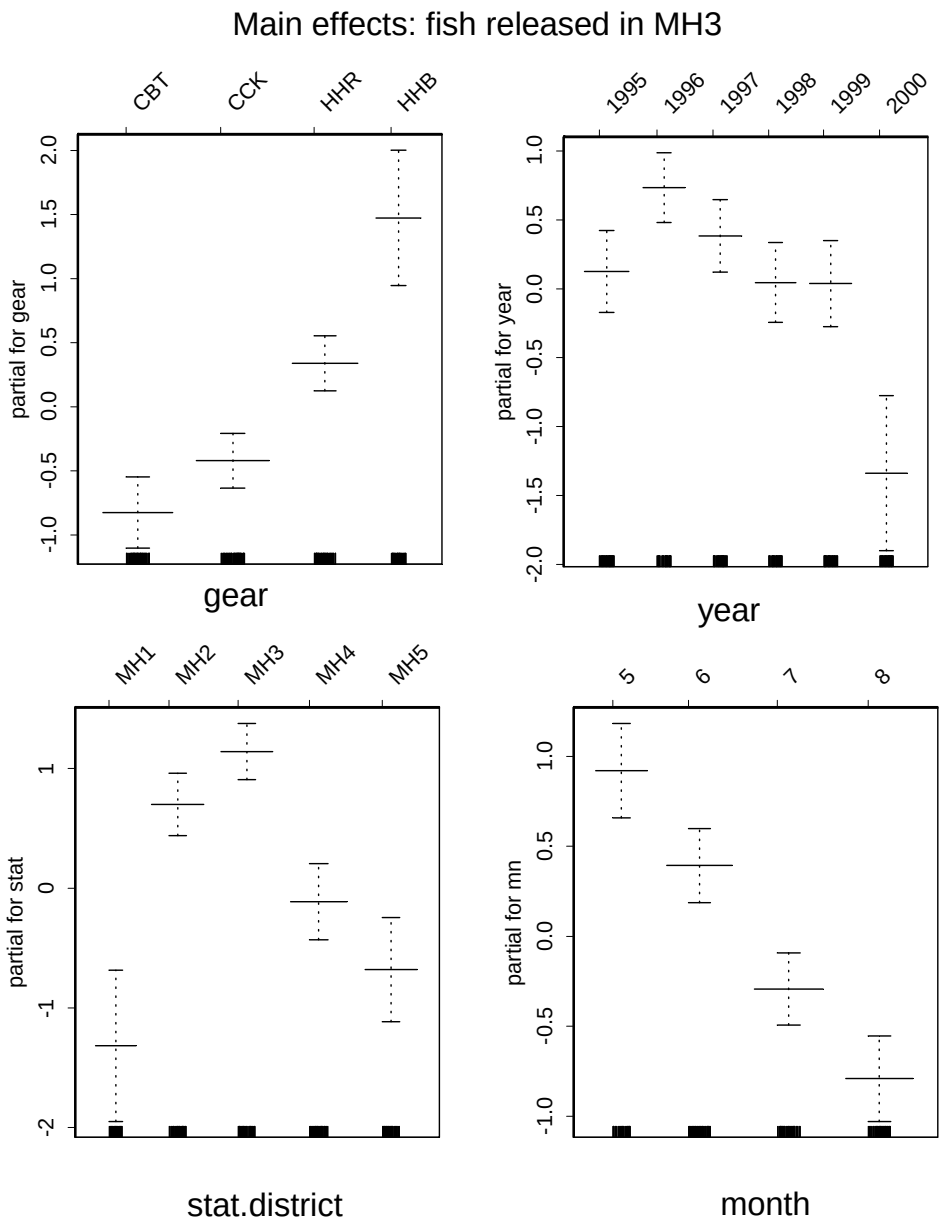

Figure 11. Main effect GLM for tagged fish recovered by trip for fish released in MH3.

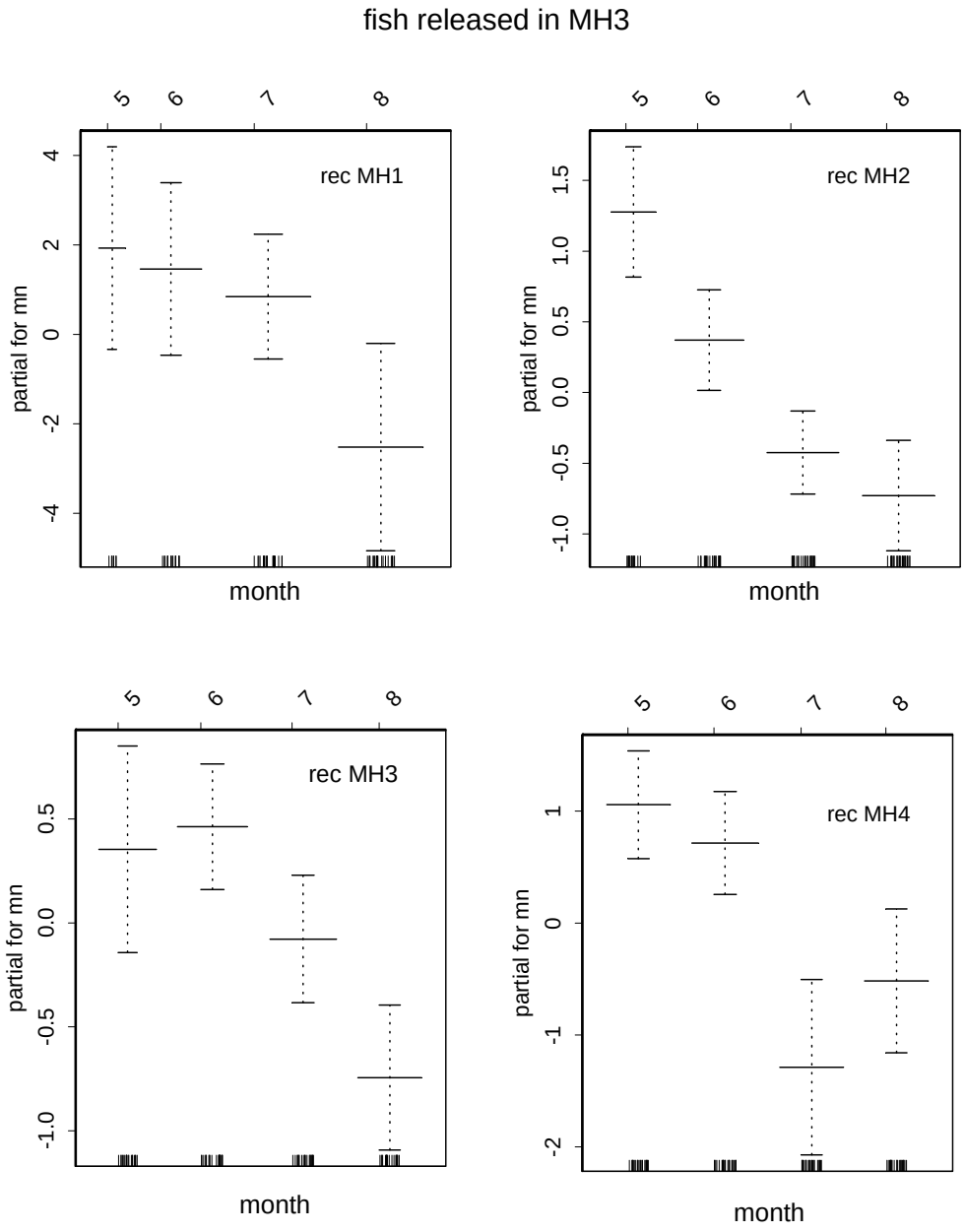

Figure 12. Fitted effects from GLMs for monthly variation of recovery rates for fish released in MH3 and recovered in areas MH1, MH2, MH3 and MH4 accounting for year and source of recovery. Data for recoveries in MH5 are not amenable to analysis.

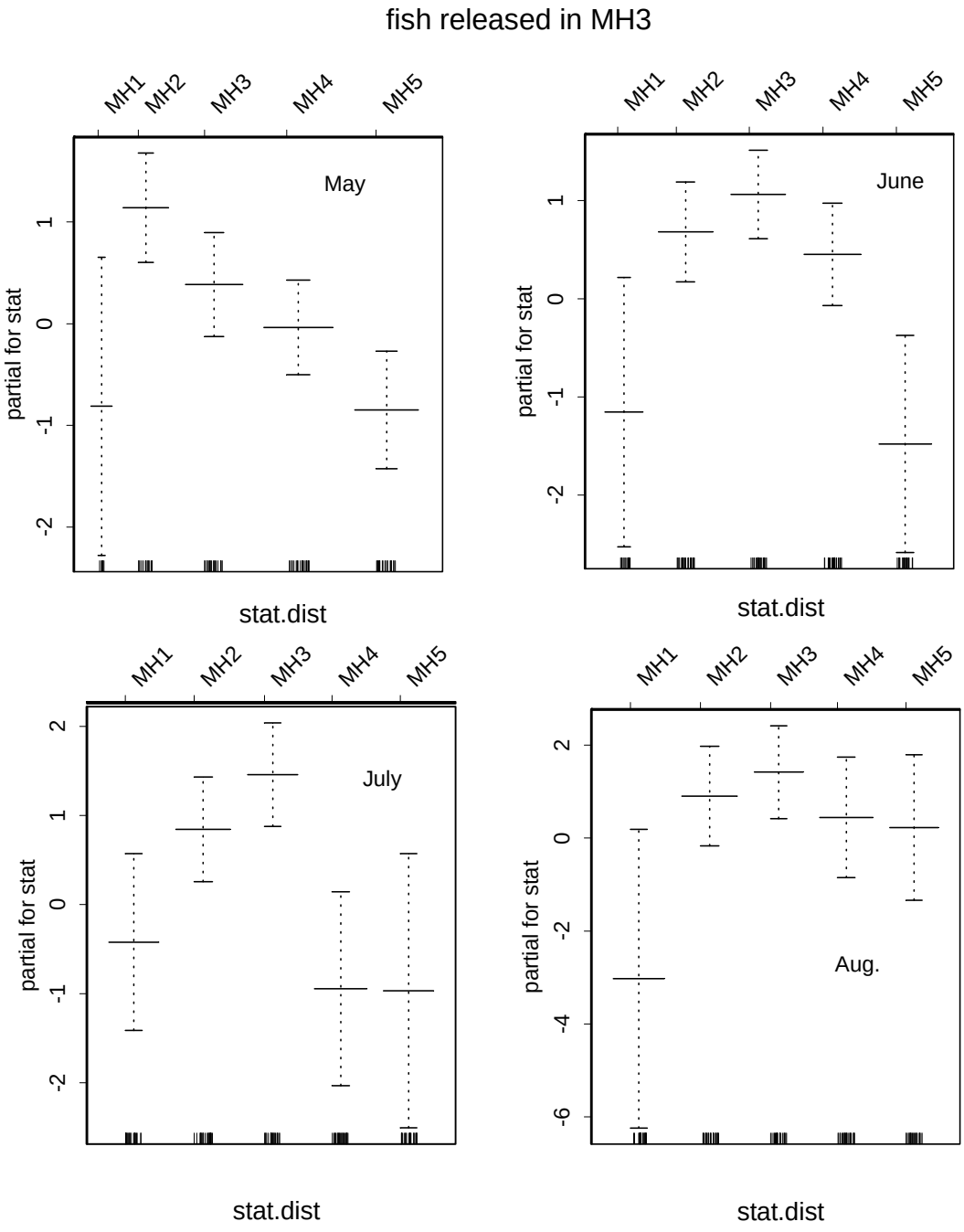

Figure 13. Fitted effects from GLMs for spatial variation of recovery rates of fish released in MH3 from May to August accounting for year and source of recovery.

To calculate a distribution matrix of tagged fish released in MH3 we modeled the recovery rate variation for selected months. We ran the models for May and June because patterns were different. We selected data from creel clerks sampling non-charter boats and self- reported recoveries from charter boat trips. The model coefficients and corresponding standard errors, estimated such that they represent the difference between MH3 rates and rates at each of the other statistical districts (contrast treatment), indicate significant differences between rates in MH3 and other areas in both months (Table 13). Based on the May coefficients, the matrix is such that higher return rates were found in MH2 than in the release area MH3, while June predictions were highest for MH3. The standardized percentages in June are more similar to those in Table 10 than in May.

Table 13. GLM coefficients from models of tags per trip as a function of statistical district for fish stocked in MH3 by creel clerks sampling non-charter boat and self reported charter boat trips during 1995 to 2000 in May and in June. The coefficients are all in reference to MH3 (contrast=treatment). MH6 was not included because no recoveries were made.

May					
Coefficients	Value	Std.-Error	t-value	Prediction	Predicted Proportion
MH3(intercept)*	-3.91	0.269	-14.506	MH1- 0.0064	7%
MH1	-1.12	0.637	-1.762	MH2- 0.0396	44%
MH2	-0.73	0.338	2.149	*MH3- 0.0195	22%
MH4	-0.21	0.354	-0.585	MH4- 0.0156	22%
MH5	-1.41	0.521	-2.726	MH5- 0.0047	5%

June					
Coefficients	Value	Std.-Error	t-value	Prediction	Predicted Proportion
MH3(intercept)*	-3.45	0.110	-31.212	MH1- 0.0035	4%
MH1	-2.18	0.570	-3.832	MH2- 0.0238	36%
MH2	-0.25	0.194	-1.320	*MH3- 0.0291	36%
MH4	-0.64	0.200	-3.156	MH4- 0.0164	20%
MH5	-2.35	0.507	-4.654	MH5- 0.0029	4%

Recoveries from fish released in MH4***.***

The numbers of tagged fish stocked in MH4 and recovered by statistical district, month, and source of recovery are presented in Appendix V with the corresponding numbers of trips from where the tags could be recovered. These numbers constitute the input data for models in this analysis. Results from main effects GLM models in Figure 14 show that recovery rates in MH4 (the release area) were similar to those in neighboring area MH5, and significantly higher than in other in areas accounting for source of recovery, and inter-annual and monthly variation. Lowest rates were found in MH1 and MH2. These results suggest that fish released in MH4 move preferentially to the south. In terms of annual variation of recovery rates, highest levels were in 1998 and 1999. During those years recovered fish were mostly 5 and 6 year, which is consistent with higher releases in MH4 during 1994. As in the case of previous analysis with data from all release areas and from fish released in MH1, MH2, and MH3, GLM results indicate there were significant differences in rates between sources of recovery, with highest levels for headhunters sampling charter boat trips. On the other hand, the monthly variation of recovery rates is different than rate variation from tagged fish released in others areas. Rather than showing a steady decline from May to August, rates were higher, and similar, during May and June than levels during July and August (also similar). One difference between fish released in MH4 than in other statistical districts is that the release area does not constitute a lake trout refuge. Thus, it is plausible that the steady decline in other areas is from fish moving to refuges while the decline in MH4 occurring a month later is from fish becoming less vulnerable to the fishing gear as they approach spawning that occurs in the fall.

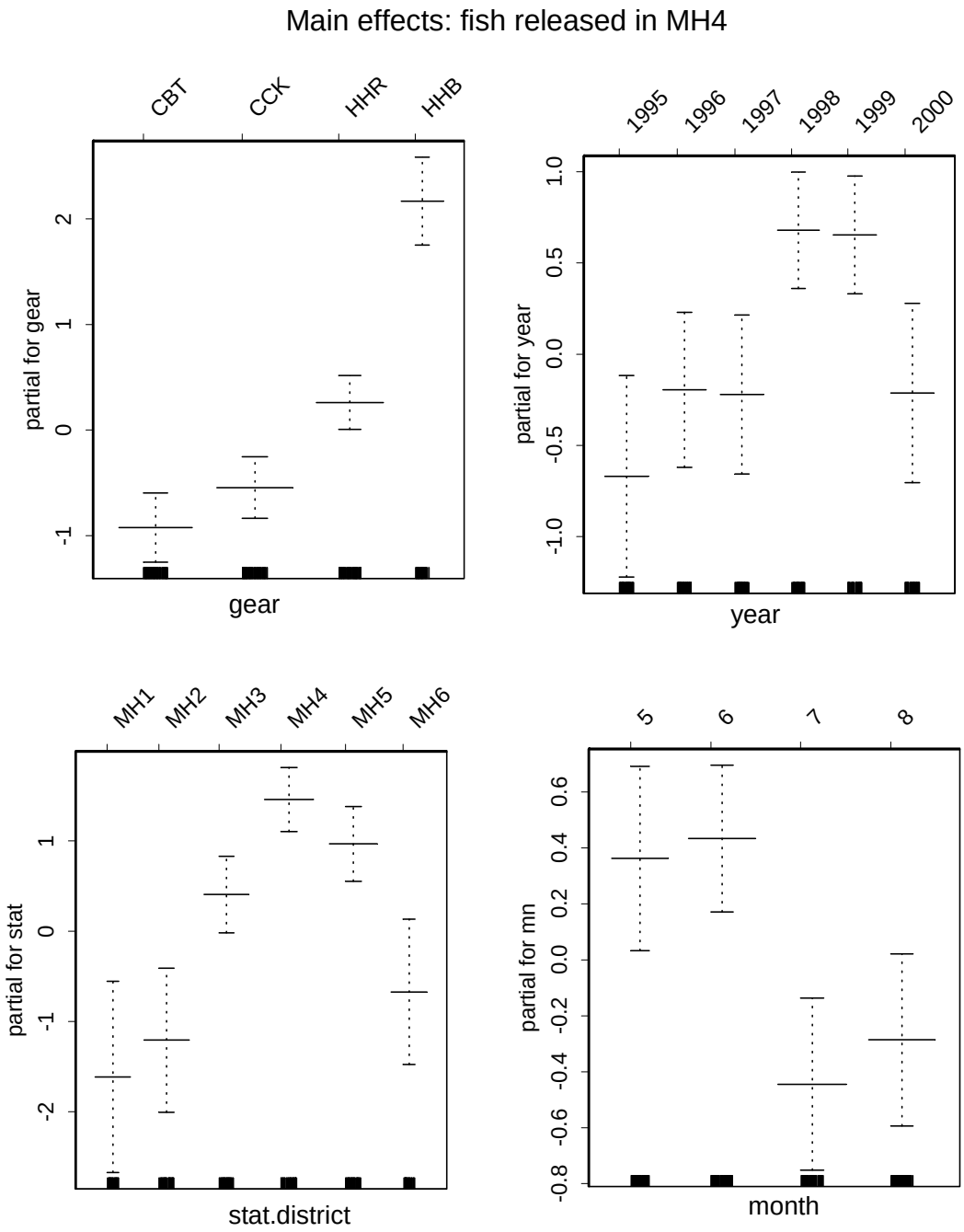

Figure 14. Fitted effects from main effect GLMs of recovery rates for fish released in MH4 and recovered in areas MH1 to MH6 accounting for year and source of recovery.

Results from the analysis of monthly tag recovery rate variation by areas (month:area interaction) are presented in Figure 15. The figure represents the GLMs fitted effects for monthly variations in recovery rates of CWT fish stocked in MH4 from for areas MH1 to MH5 (data from fish recovered in MH6 are not amenable to analysis), accounting for annual variation and source of recovery. Monthly decreases in rates of recovery are similar by area but minor from MH3 to MH5, with higher levels in May-June than in July-August. Results of the spatial variation of recovery rates by month in Figure 16 show that highest levels were found in MH4 and that the rates were similar to those in MH3 and MH5 every month except for June when the difference with MH3 levels is significant.

To calculate standardized recovery rates we modeled the variation between districts during June. We selected data from creel clerks sampling non-charter boats. The model coefficients and corresponding standard errors (Table 14), estimated such that they represent the difference between MH4 rates and those of other statistical districts (contrast treatment), indicate similar rates in MH4 and MH5 and significant differences with rates in other areas. Based on predictions using the GLM coefficients, the matrix of proportions across areas is such that highest recovery rates were found in MH4 and MH5 with 38% of the tagged fish recovered by area. These figures are fairly similar to those in Table 10.

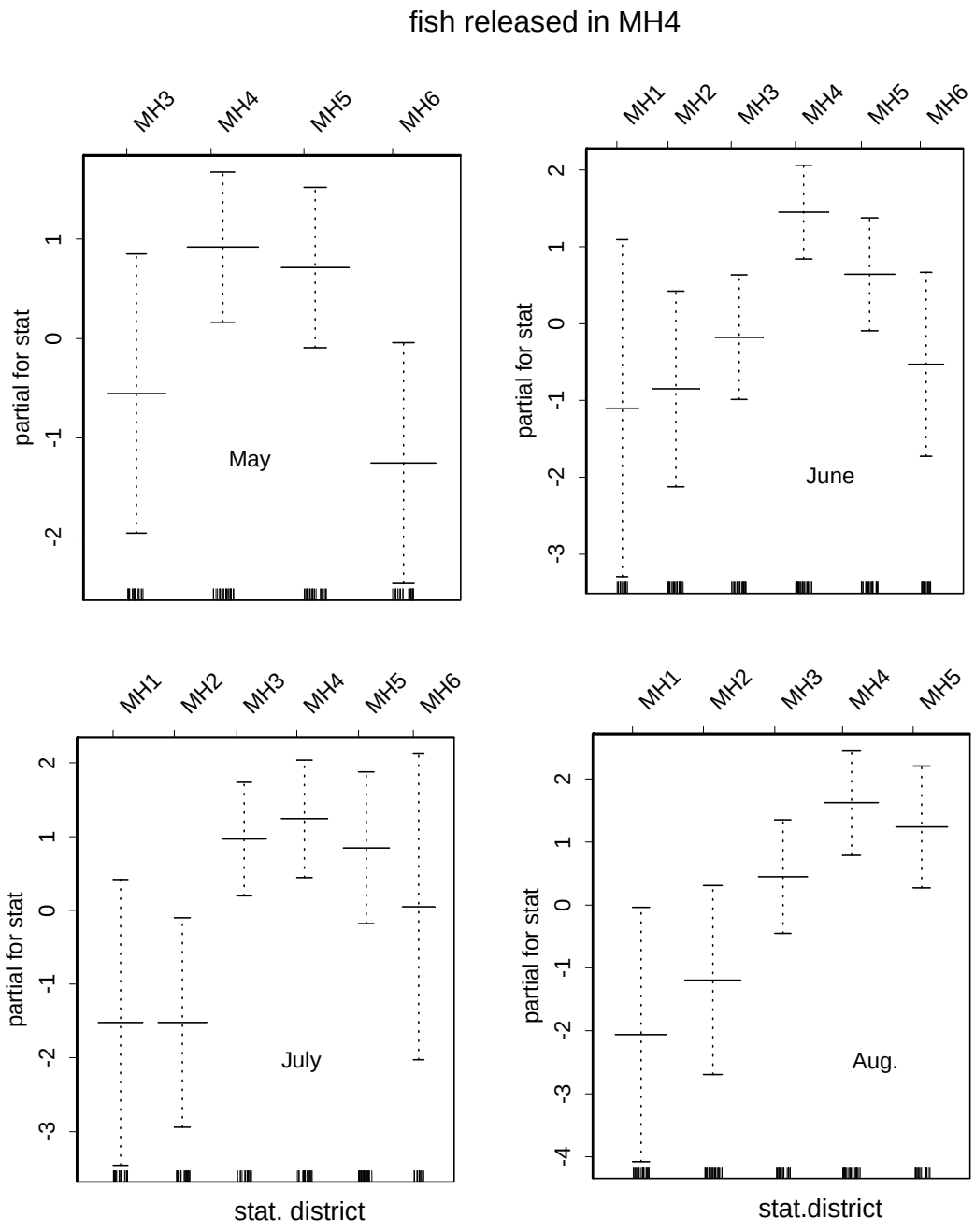

Figure 15. Fitted effects from GLMs for spatial variation by moth of recovery rates for fish released in MH4 and recovered in areas MH1 to MH6 accounting for year and source of recovery.

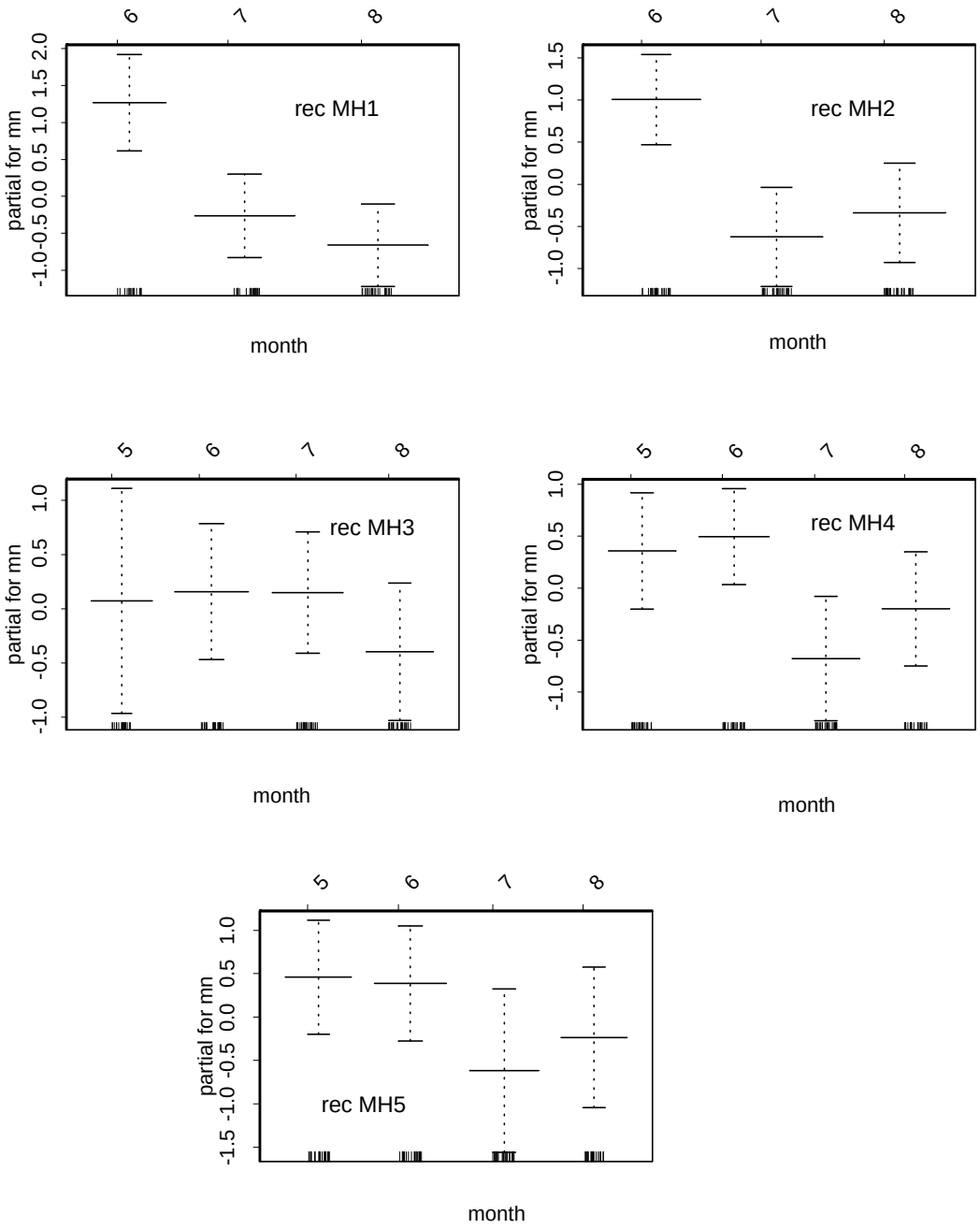

Figure 16. Fitted effects from GLMs for monthly variation by area of recovery rates for fish released in MH4 and recovered in areas MH1 to MH5 accounting for year and source of recovery.

Table 14. GLM coefficients from a GLM model of recovered tagged fish per trip of MH4 releases a function of statistical district where fish were recovered by creel clerks sampling non-charter boat trips during 1995 to 2000 in June. The coefficients are all in reference to MH2 (contrast=treatment).

Coefficients	Value	Std.-Error	t-value	Prediction	Predicted Proportion
MH4(Intercept)*	-4.397	0.3788	-11.609	MH1-	4%
MH1	-2.249	1.0609	-2.120	MH2-	6%
MH2	-1.901	0.8004	-2.376	MH3-	10%
MH3	-1.337	0.6266	-2.134	*MH4-	38%
MH5	-0.407	0.5874	-0.694	MH5-	38%
MH6	-2.464	1.0551	-2.334	MH6-	4%

Overall analysis considering recoveries from fish released in statistical districts MH1 to MH4.

To compare recovery rates from tagged fish released in MH1, M2, MH3 and MH4 we ran a GLM (similar to equations 1 to 3) with data from all release areas and including release area as a factor. Results are represented in Figure 17 and show that MH3 was the release area with highest recovery rates between 1995 and 2000, independently of the year, the month, the source of recovery or the area where tagged fish were recovered. This is not surprising because more CWT tags were released in MH3 than in other areas (Table 1). Also, the low recovery rate from fish released in MH4 is consistent with the low number of tagged fish released in that area. Nevertheless the levels from MH1 are much lower than those in MH2 while the numbers released had been much higher. This is probably the result of high mortalities reported for fish released in that area, although movement out the area could also explain the low recovery. The age distribution of the recovered fish in MH1 relative to MH3 supports the hypothesis that higher mortalities occur in

MH1, since the proportions of age 4 fish are much higher and proportions of age 6 are smaller (Table 15).

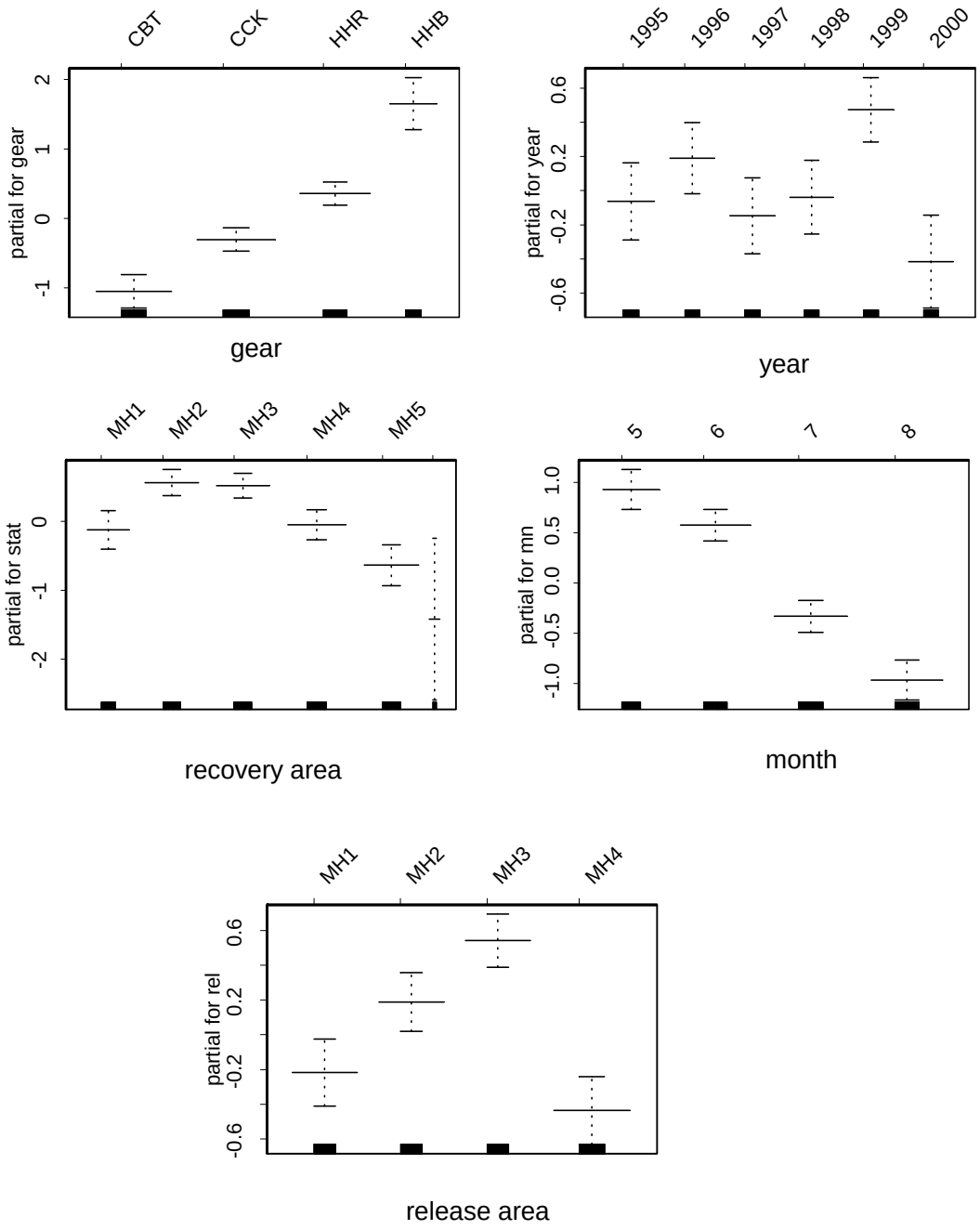

Figure 17. Fitted effects from a main effect GLM for tagged fish recoveries from all areas of release.

Table 15. Proportions at age of recovered fish by area of release.

Area	3	4	**5**	6	7	8	9	10	11
MH1	3%	32%	40%	18%	5%	1%	1%	0.2%	-
MH2	2%	30%	40%	20%	7%	0.5%			
MH3	1%	17%	37%	24%	11%	3%	3%	1%	1%
MH4	1%	19%	45%	26%	8%	2%			

Complementary analysis: Catch rates in sport fisheries

We interpreted movement patterns from spatial-temporal fluctuation in catch rates in angler fisheries. Commercial (tribal, non-tribal fishery harvest data), thought to be a useful complement to this study, occurs at reduced spatial distribution and does not provide information for movement studies and, therefore was not included in this study. The concept behind the analysis of catch rates is that changes in relative distribution of the fish in time and space should indicate movement. Thus, such an analysis relies on the assumption that catch per unit effort CPUE is indicative of fish abundance. It is not clear nevertheless if an index of abundance estimated for lake trout based on numbers caught in the sport fishery is reliable. One difficulty of using CPUE as index of abundance is the catch is influenced by management regulations, namely the maximum number of fish that can be caught corresponds to a daily possession limit of 5 salmonids but no more than 3 lake trout. Thus, we propose that an alternative index of abundance for lake trout is the probability of catching a fish during a trip (presence and absence) instead of how many fish are caught. Another general problem with the use of lake trout catch data from sport fisheries, is the existence of lake trout refuges in some areas where an unknown fraction of the fish can stay during the months that the fisheries take place. This problem has

unpredictable consequences both for the analysis of abundance indices from sport fisheries as well as for the analysis of CWT data.

Analysis from the sport fishery data cannot incorporate information on the origin of release of the lake trout in the catch, as was the case for the analysis of CWT data. The lack of origin information obscures the analysis of movement and the interpretation of the results. Nevertheless, in principle if fish would remain in the areas were they were released, and mortality by area were similar, catch rates by area should be proportional to the numbers released and deviation of this pattern could give indication of movement. Also, seasonal differences in the distribution of the catch rates by area can give information on seasonal movement between areas during the fishing season.

We performed statistical analysis of the spatial and temporal distribution of lake trout using catch data from the creel surveys and qualitative analysis using data from charter boat self-reported catch. These data are from the creel and charter boat databases. The charter boat fishery data provide limited spatial coverage (no fishing in MH1 and MH6 during some months) and declared catch is less reliable than non-charter data collected by creel clerks. Nevertheless, the information on the fishing location is available and can be used to map the distribution of catch rates at a better spatial resolution than data from creel interviews.

Analysis of non-charter boat fishery data

The statistical analysis of data collected during creel interviews was done using Generalized Additive Models GAMs techniques (Hastie and Tibshirani 1999). We used the following regression:

$$g(\mu_{ymdg}) = \alpha + \delta_y + \phi_m + \lambda_d + s(X1) + s(X2) + \varepsilon_{ymdg} \qquad (4)$$

where μ, the response variable, is a matrix of the presence/absence of lake trout per trip modeled as a function of a linear predictor where δ is the year, Ø is the month, λ the statistical district (as the spatial unit), $X1$ is the number of anglers per trip and $X2$ is the number of hours fishing. $X1$ and $X2$ are introduced as smooth continuous functions described in Hastie and Tibshirani (1996). The binomial probability distribution and probit link functions are as in equations 2 and 3 were used.

Similarly to the previous analysis of recoveries of tagged fish we selected data from trips that can be considered to have a chance to catch lake trout, i.e. trips for which any salmonine target or any target was declared. The analysis was conducted by year since the number of stocked fish (yearlings) varies annually (Table 16).

Table 16. Numbers of lake trout stocked (yearling) in Lake Huron in MH1 to MH5 (from Great Lakes Fishery Commission stocking database).

	MH1	MH2	MH3	MH4	MH5	MH6
1980	460,700	150,000	355,000	265,000	100,000	50,000
1981	393,100	160,500	378,900	262,000	95,000	50,000
1982	404,530	139,900	340,700	307,300	76,000	72,000
1983	140,100	140,200	308,200	297,000	100,000	75,000
1984	54,000	135,800	199,700	230,000	120,000	49,716
1985	389,461	219,265	650,421	524,200	147,930	40,000
1986	245,000	360,000	335,000	471,900	232,000	-
1987	297,866	230,000	407,600	-	-	-
1988	278,200	188,800	642,300	364,700	139,800	-
1989	378,800	279,400	454,700	400,000	397,550	-
1990	265,200	192,650	253,850	-	-	-
1991	462,745	481,200	309,900	182,000	180,000	-
1992	479,500	474,200	802,860	180,300	185,000	-
1993	352,500	549,800	108,000	163,000	166,500	-
1994	59,400	549,100	635,550	252,900	236,600	-
1995	128,680	422,250	134,375	171,775	126,200	-
1996	190,900	403,940	102,100	195,400	127,800	-
1997	135,300	548,600	550,600	259,800	157,500	-
1998	498,400	1593,900	96,190	151,900	140,600	-
1999	503,200	214,490	408,335	92,400	101,400	-
2000	265,576	319,837	426,758	116,495	116,135	-

Results from the analysis of 1993 to 2000 non-charter fishery show that in general the probability of catching a lake trout, relates to the numbers of fish released by area in previous years so that they would be around 4 and 5 years old (Figures 18 to 32). The exceptions are levels in MH4 and MH5. Levels in MH4 are proportionally too low compared to the numbers released. Since the release area is on the border of MH5 and MH3 it is possible that fish released in this area move to neighboring areas and are consistently harvested there. It is also possible that our selection of trips to account as effort has not successfully excluded trips targeting other species. Levels in MH5 are proportionally too high compared to numbers released. MH5 is the area with highest successful trips for lake trout but from where relatively few fish were released (Table 16). The relatively high level of catch success in that area can be due to high abundance given fish movement from area MH4, but also because of the absence of lake trout refuges in this statistical district. These results can be due also to the poor spatial resolution in the creel data. It is symptomatic that the declared fishing site is mostly identical to interview site, which does not reflect the actual fishing location. This problem may be exacerbated for the analysis of lake trout catch rates in areas MH4 and MH5 since most probably high catches will be recorded from statistical grids 1412 and 1413, where fish are released and these trips will be most probably interviewed in MH5 ports. Thus the results for MH4 and MH5 should be treated with caution.

Further, results indicated the catch levels varied by month, and in general highest levels occurred in June and May. Analysis of the seasonal distribution of lake trout (interactions) showed that index changed by month, where initial higher levels in the north decreased and levels proportionally increased in MH5. These results indicating that the abundance index varied seasonally suggest that fish move during the fishing season, but can also mean that there were artifacts due to changes in the gear selectivity during the fishery period or in the availability of alternative target species such as chinook salmon. Other results from the analysis are that the chances of catching a fish generally increased linearly with the number of anglers and non-linearly with hours fishing. Catching success increased linearly up to around 7 fishing hours and then the rate

decreased, slightly decreased, leveled off or significantly declined depending on the year. In the next sections the results by year are presented.

Table 17. Cumulative number of lake trout stocked in Lake Huron from previous 4 and 5 years.

	MH1	MH2	MH3	MH4	MH5
1993	644,000	472,050	**708,550**	400,000	397,550
1994	**727,945**	673,850	563,750	182,000	180,000
1995	942,245	955,400	**1112,760**	362,300	365,000
1996	832,000	**1024,000**	910,860	343,300	351,000
1997	411,900	**1098,900**	743,550	415,900	403,100
1998	188,080	**971,350**	769,925	424,675	362,800
1999	319,580	**826,190**	236,475	367,175	254,000
2000	326,200	**952,546**	652,700	455,200	285,300

Results from the main effect GAM analysis of 1993 non-charter data are presented in Figure 18. Results show that higher success levels occurred in trips conducted in June and July than in other months. Levels increased from MH-1 to MH5 (about 30% of the trips caught lake trout in June), except for a low in MH4. The levels across districts were not proportional to the number of fish released by area; most noticeable levels in MH5 were proportionately too high. The numbers of fish released in years 1989 and 1990, which should dominate the 1993 catch, were highest in MH3 and MH1 and similar in MH2, MH4 and MH5 (Table 17). Results from the analysis of spatial variation by month (month-area interactions) in Figure 19 indicated that the relative levels of catching success across areas varied seasonally with levels during June mostly proportional (except for MH5) to the numbers released. During May catch levels were similar but the fit was poor due to low number of trips in most areas and levels after June showed a latitudinal gradient. Catch levels were highest in MH5 in every month and especially during August and September. These results suggest that fish move during the fishing season, and that the existence of refuge areas is partly responsible for the patterns observed from the analysis of CWT recoveries. Also, other factors must affect these rates because even in MH5, where no refuge areas exist, only 2% of the trips during September caught lake trout compared to 10 to 30% in other months.

Analysis of 1994 data in Figure 20 shows highest abundance indices from May to July, and fairly similar from MH-1 to MH-5 (except for MH4). This spatial distribution corresponds to the proportions of numbers of fish released by area, except for MH5. The results from the analysis of the spatial variation of abundance by month in figure 21 shows highest levels in MH1 in May and June (about 50 and 30% of the trips caught lake trout respectively), and decreasing levels towards MH4 indicating that there are more fish where more fish are released. During following months, levels in MH1 become relatively lower while levels in MH2 and MH3 become higher suggesting some movement to the south during May, June and July.

Analysis of 1995 data in Figure 22 shows higher levels for June and in area MH3, where most fish were released 4 and 5 years earlier, and in MH5. The trend in spatial distribution of abundance by month shown in Figure 23 indicates that highest levels in May and June occurred not in MH3 but in MH1 (about 50% of the trips with Lake trout catch) but that in later months relative levels changed and levels in MH3 became highest. These results suggest movement between areas during the fishing season.

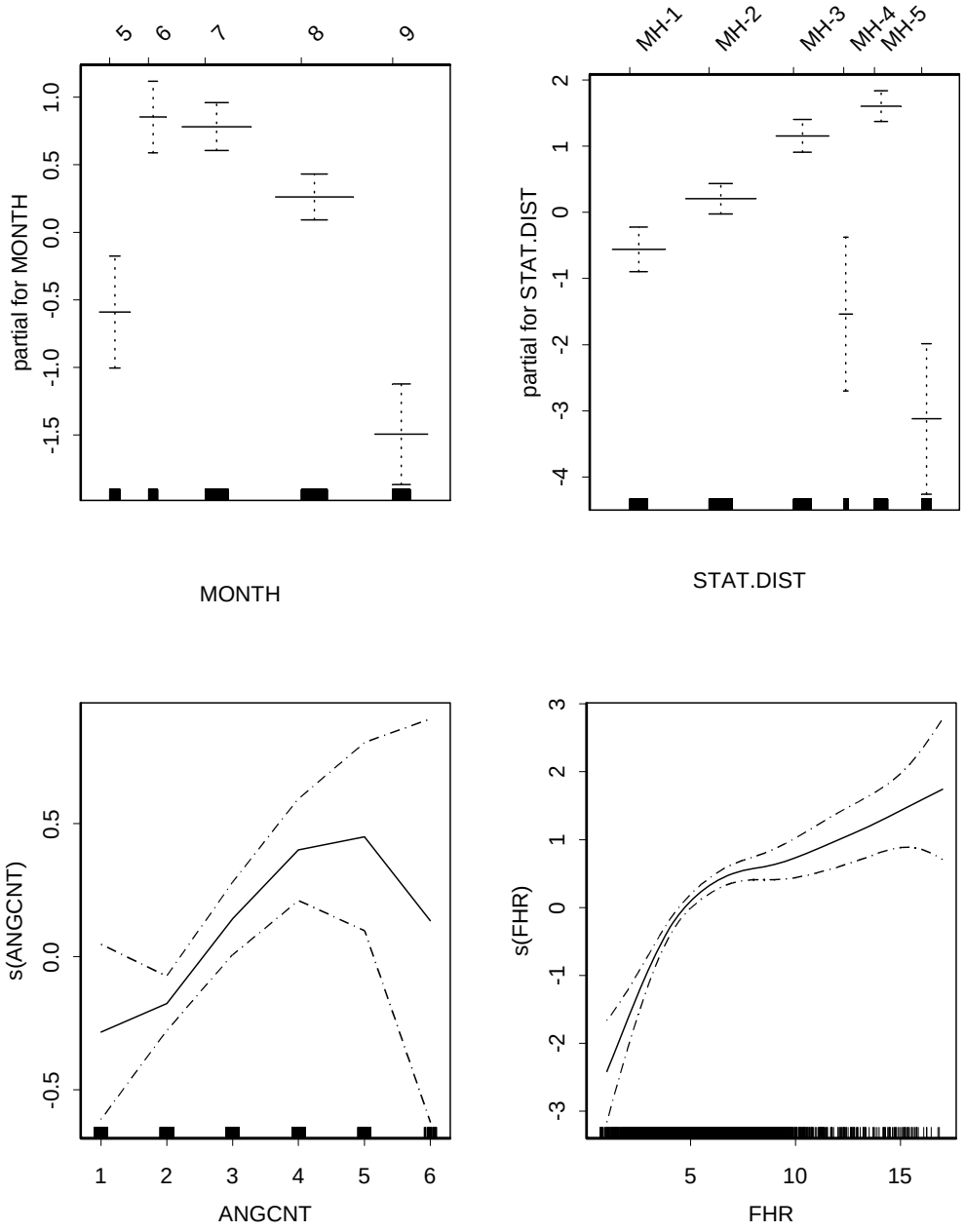

Figure 18. Results from main effect binomial GAM for number of trips with lake trout catch during 1993 non-charter boat fishery. ANGCNT=number of anglers, FHR=fishing time in hours.

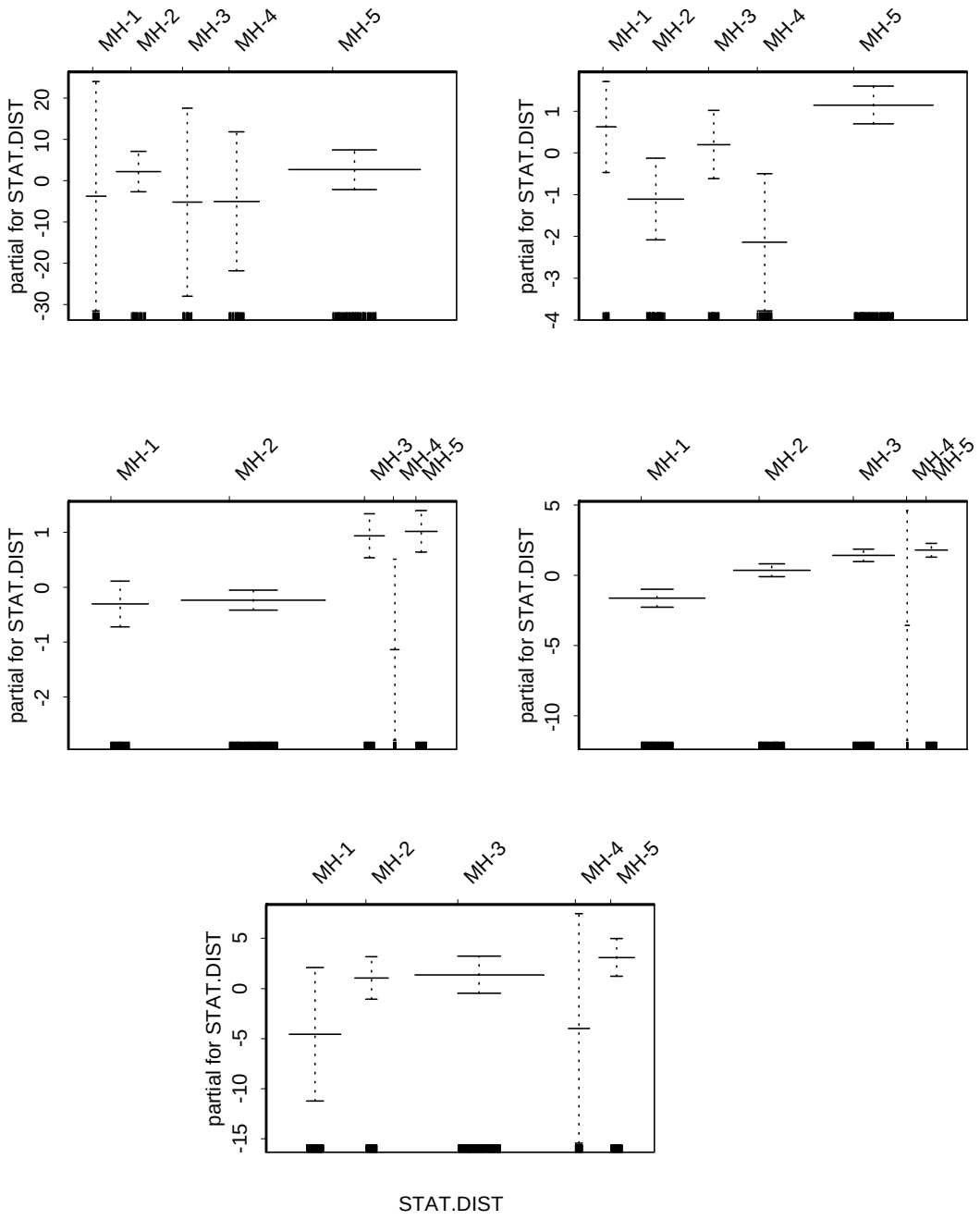

Figure 19. Results from binomial GAMs for spatial variation in the number of trips with lake trout catch by month from May to September 1993 in the non-charter boat fishery.

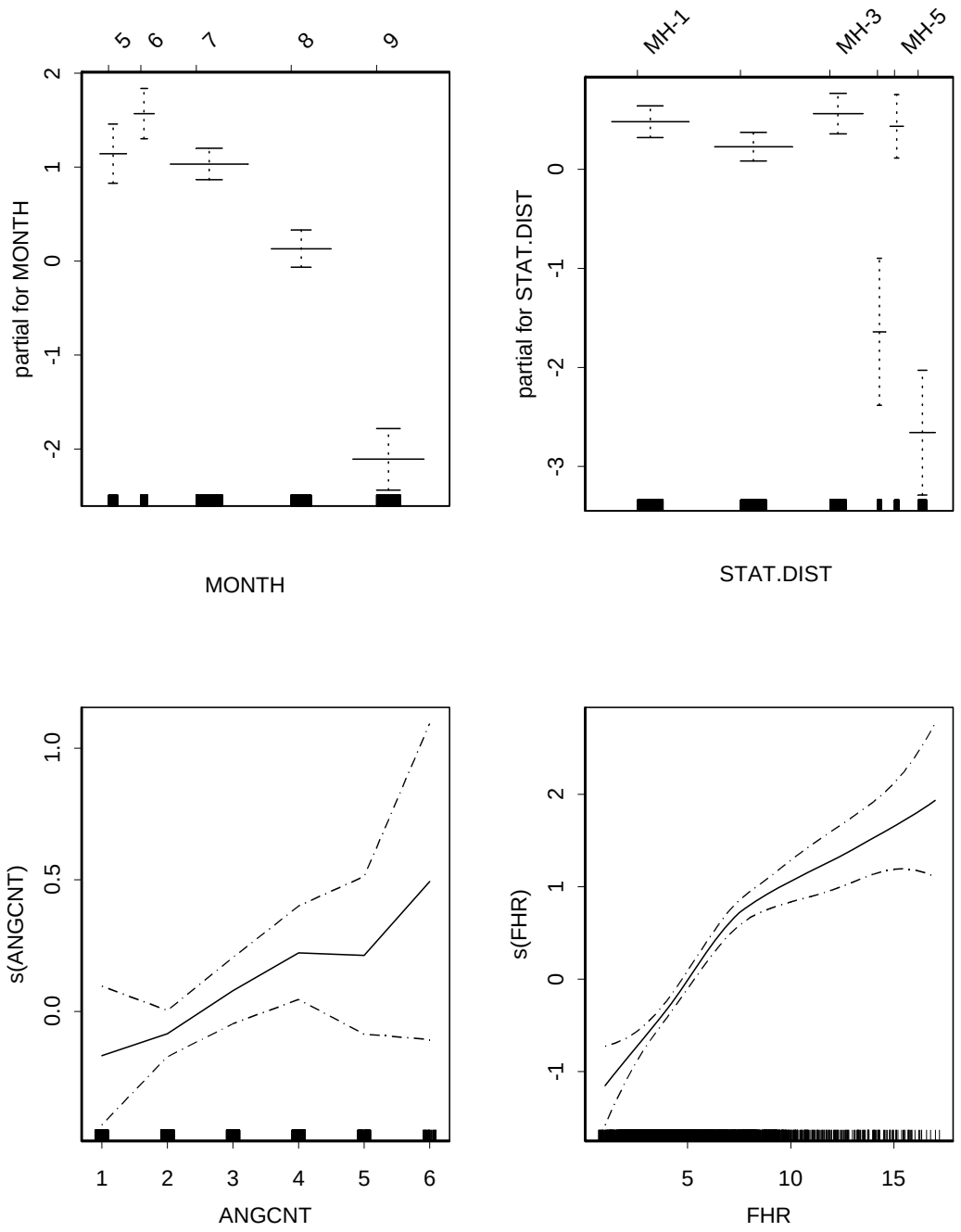

Figure 20. Results from main effect binomial GAM for number of trips with lake trout catch during 1994 non-charter boat fishery. ANGCNT=number of anglers, FHR=fishing time in hours.

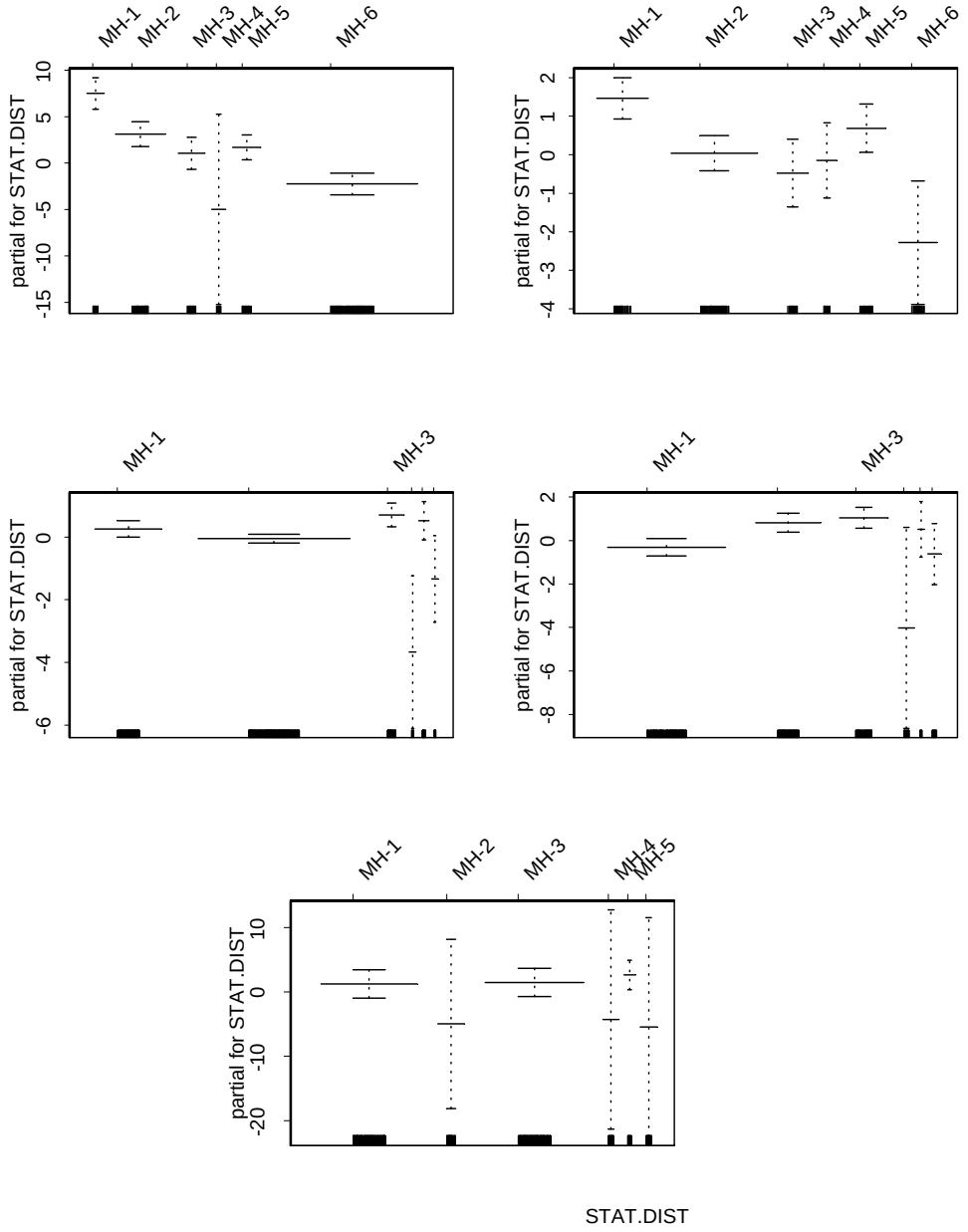

Figure 21. Results from binomial GAMs for spatial variation in the number of trips with lake trout catch by month from May to September 1994 in the non-charter boat fishery

Analysis of 1996 data in figure 24 shows highest levels from May to July and increasing levels from MH1 to MH5 (except for low levels in MH4). A fairly similar number of fish had been released from MH1 to MH3 four and five years earlier. The analysis of spatial variation by month in figure 25 shows the same patterns as from previous years with high

levels in MH1 for May and June (about 40% of the trips with Lake trout catch), and a reverse south-north gradient in later months. MH4 continues to be lowest and in particular much lower than MH5 where the same number of fish had been released.

Analysis of 1997 data in Figure 26 also shows highest catch levels occurred from May to July, but monthly variation was not as important as in other years. Levels increased to the south except for MH4 and MH6. Analysis of spatial variation by month in figure 27 show higher catch levels in MH1 in May and June (about 40%), becoming similar and later relatively lower than in southern areas. The cumulative numbers of fish released in MH1 in the previous 4 and 5 years were much reduced, and this seem not to have changed the pattern observed in previous years.

Results from main effect GAM analysis of 1998 data in figure 28 show higher catch levels in June and May, and increasing levels from MH1 to MH3 (with low levels in MH4). This pattern does not reflect the fact that highest cumulative numbers had been released in MH2 in the previous 4 and 5 years, but numbers released in MH3 had been second in importance. The difference between levels by districts in 1997 becomes more important than in other years and reflects the much lower lake trout numbers released in MH1. The GAM analysis of spatial distribution by months in figure 29 shows that highest levels in MH3 occurred in most months and that high levels observed for MH1 in other years did not occur, a consequence of the low numbers of fish released in that area.

Analysis of 1999 data in Figure 30 shows highest levels for June and in MH3 and MH5. The pattern in abundance by areas does not reflect the numbers of fish released since the year before significantly higher numbers had been stocked in MH2. Analysis of spatial distribution by month in figure 31 indicates that levels were higher in MH3 than in MH2 in every month. Results from 1999 and 1998 suggest that reducing release levels in MH1 resulted in reducing catching success in MH2; thus that movement from MH1 to MH2 or from MH2 to MH3 occurs. Results from 2000 data in figures 32 and 33 are similar to those from 1999.

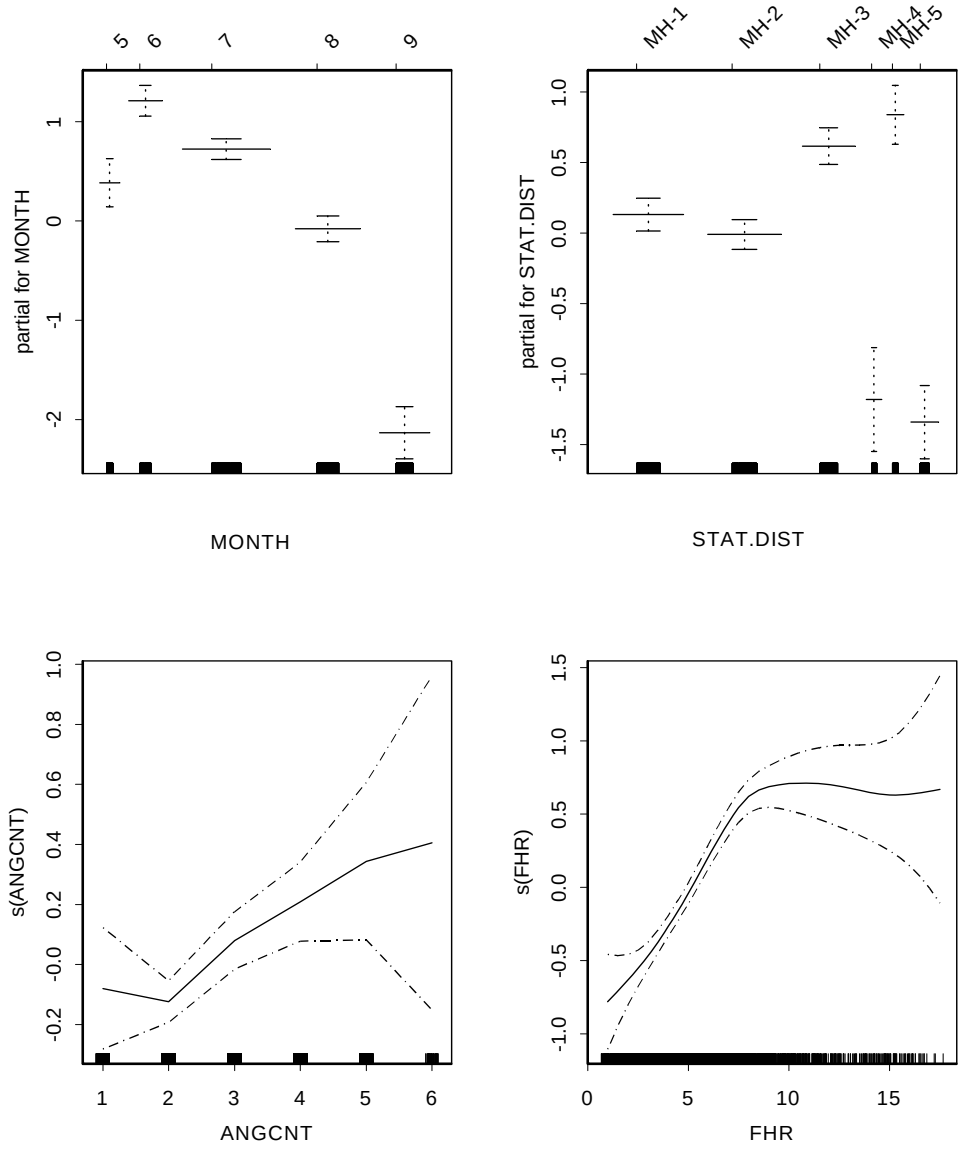

Figure 22. Results from main effect binomial GAM for number of trips with lake trout catch during 1995 non-charter boat fishery. ANGCNT=number of anglers, FHR=fishing time in hours.

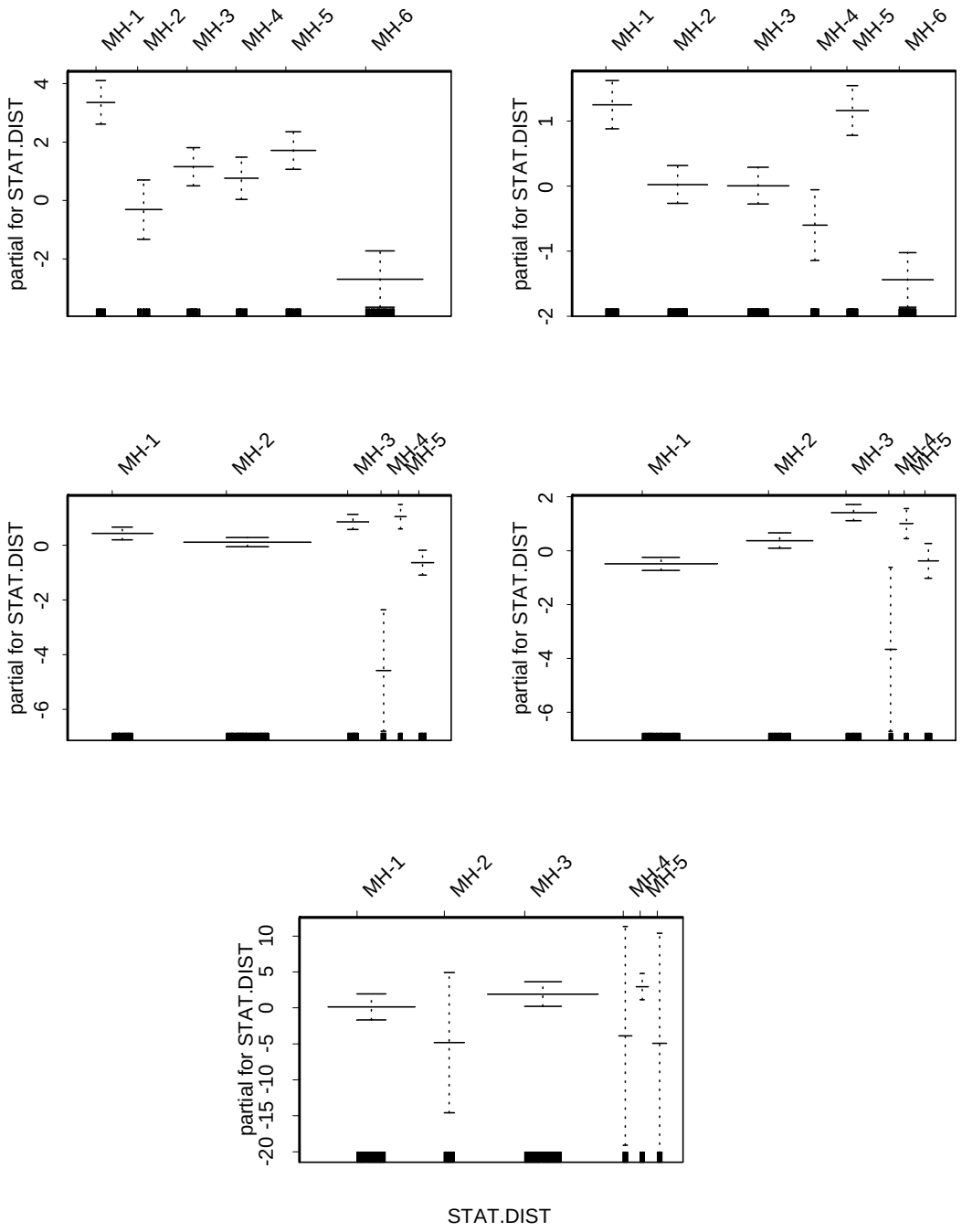

Figure 23. Results from binomial GAMs for spatial variation in the number of trips with lake trout catch by month from May to September 1995 in the non-charter boat fishery

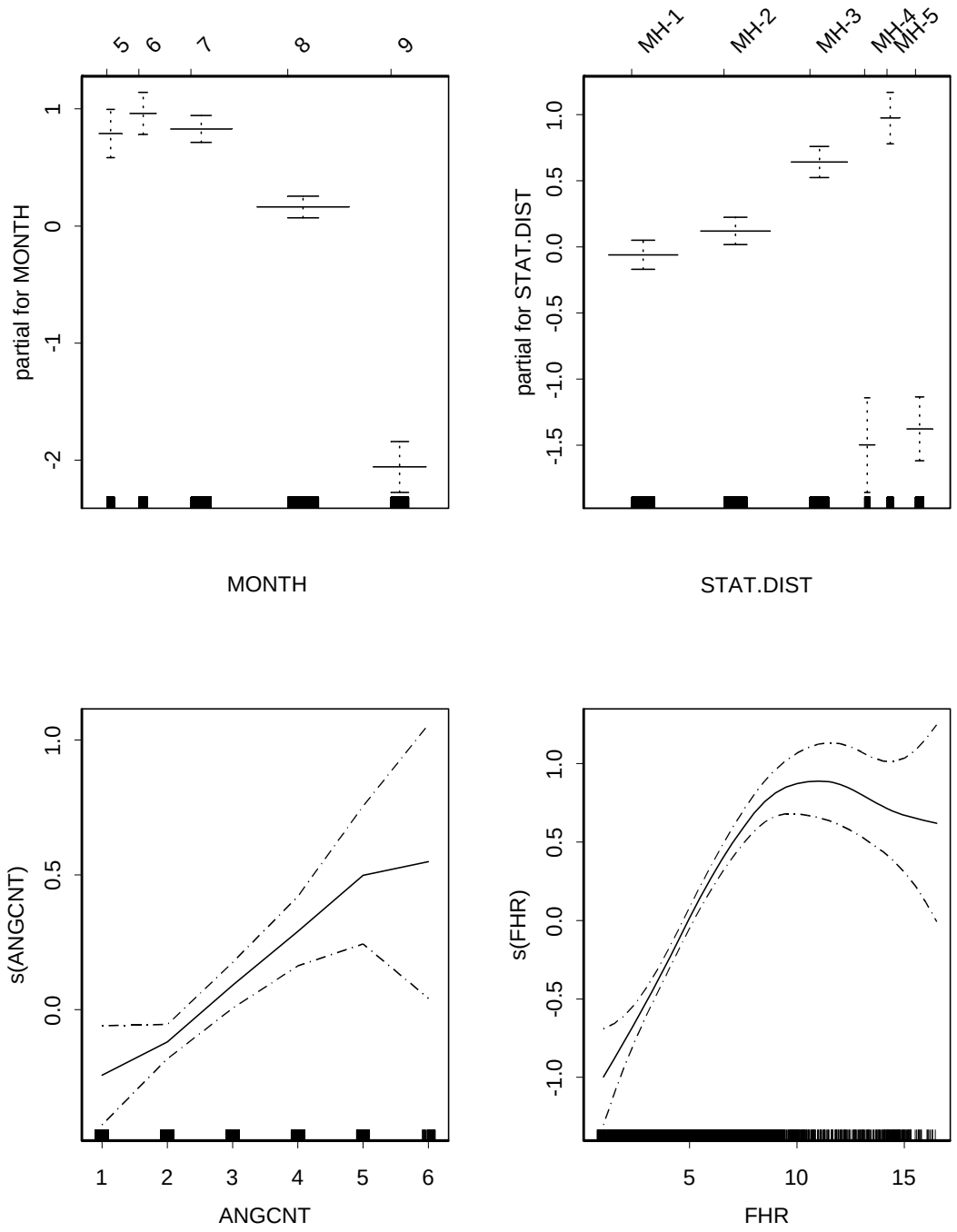

Figure 24. Results from main effect binomial GAM for number of trips with lake trout catch during 1996 non-charter boat fishery. ANGCNT=number of anglers, FHR=fishing time in hours.

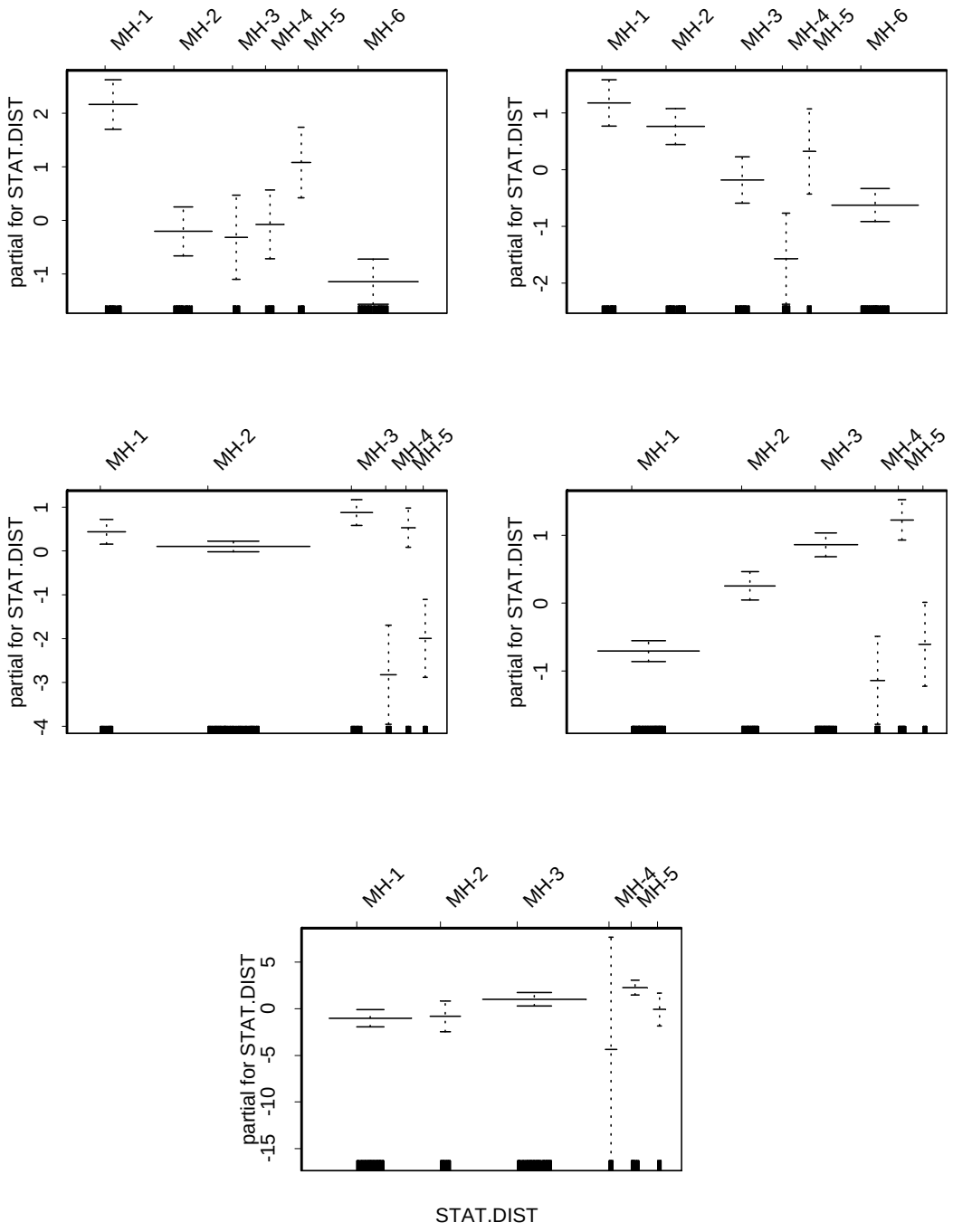

Figure 25. Results from binomial GAMs for spatial variation in the number of trips with lake trout catch by month from May to September 1996 in the non-charter boat fishery

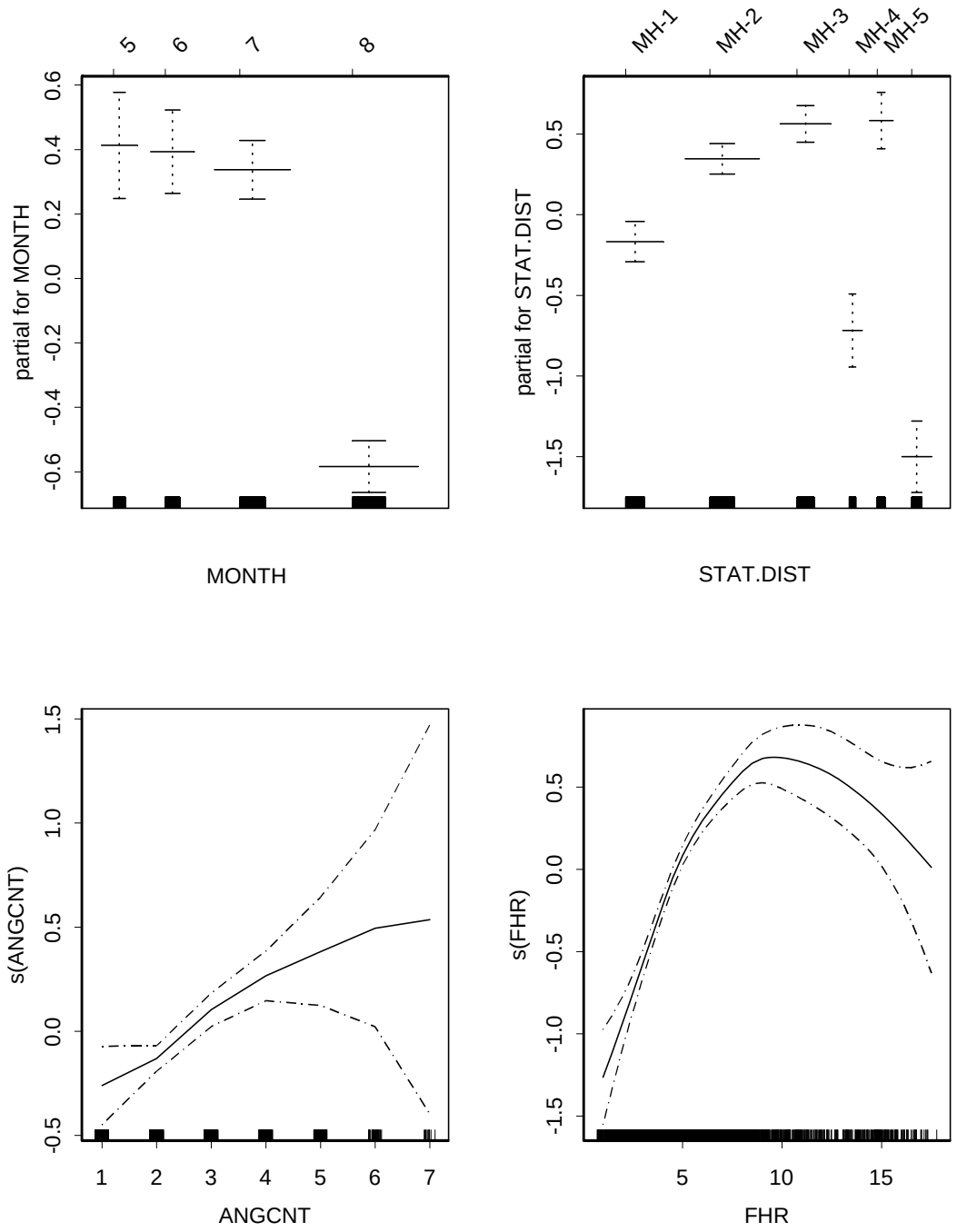

Figure 26. Results from main effect binomial GAM for number of trips with lake trout catch during 1997 non-charter boat fishery. ANGCNT=number of anglers, FHR=fishing time in hours.

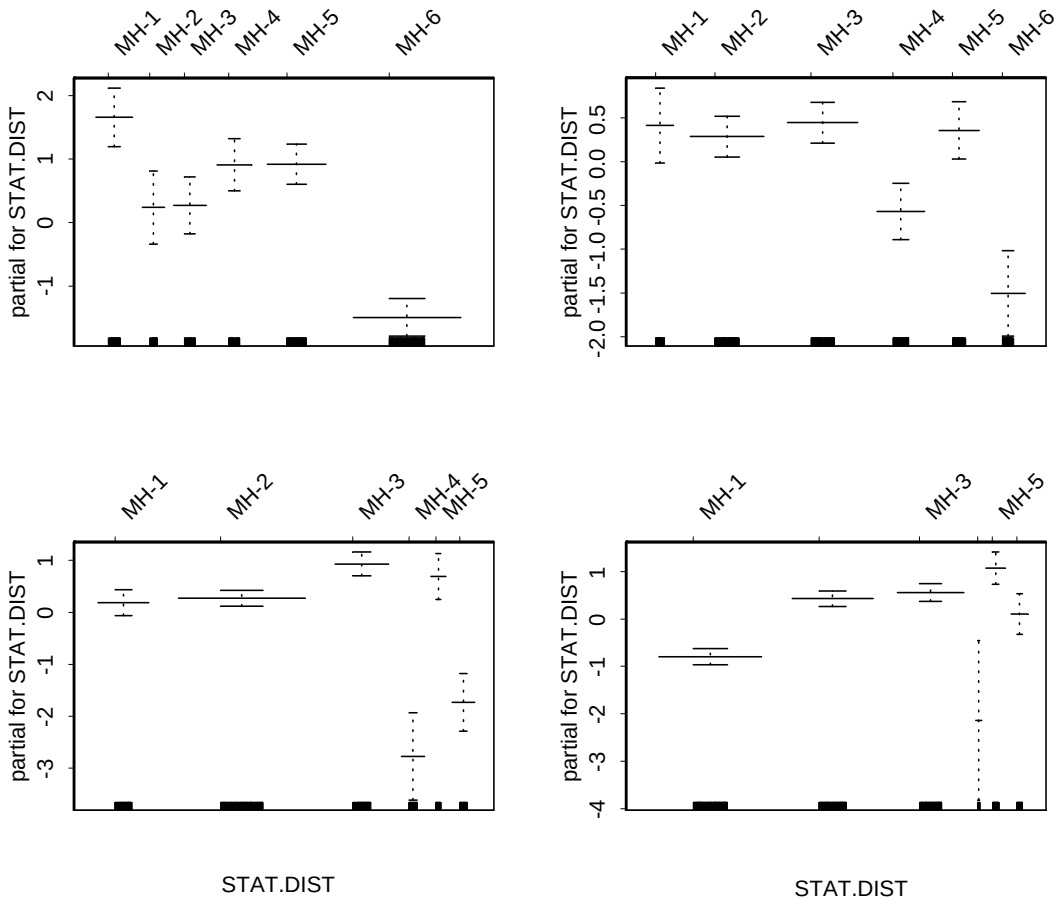

Figure 27. Results from binomial GAMs for spatial variation in the number of trips with lake trout catch by month from May to September 1997 in the non-charter boat fishery

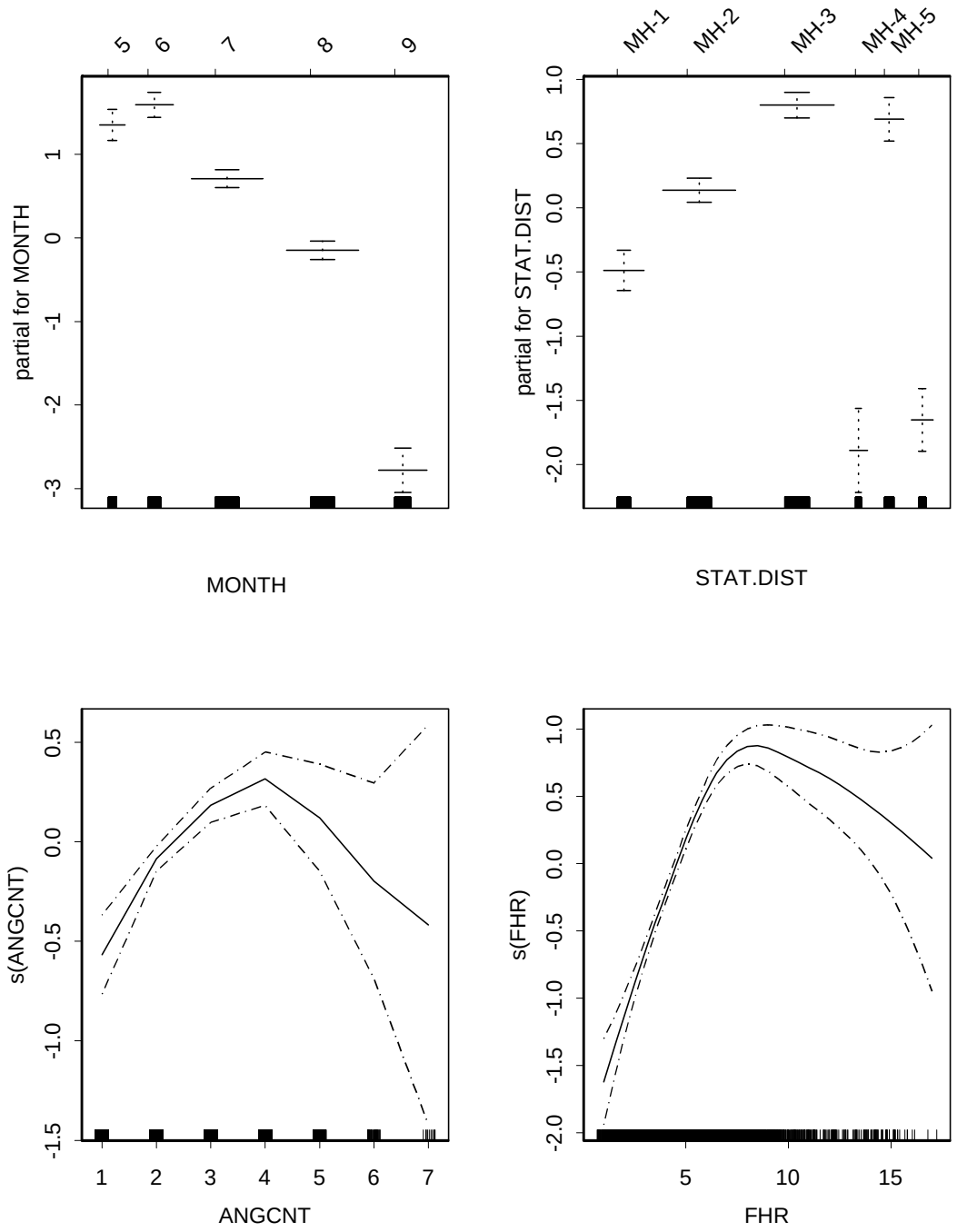

Figure 28. Results from main effect binomial GAM for number of trips with lake trout catch during 1998 non-charter boat fishery. ANGCNT=number of anglers, FHR=fishing time in hours.

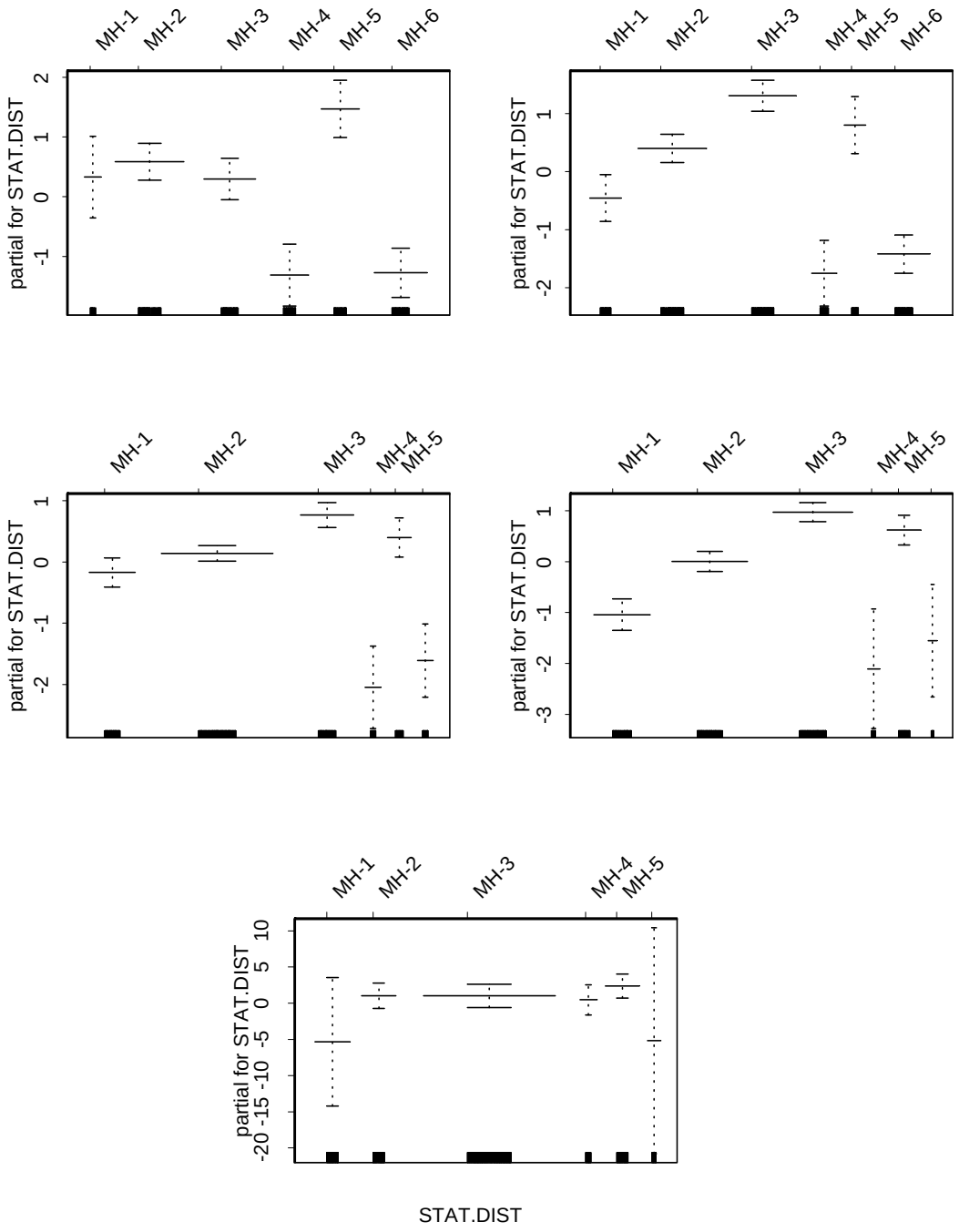

Figure 29. Results from binomial GAMs for spatial variation in the number of trips with lake trout catch by month from May to September 1998 in the non-charter boat fishery

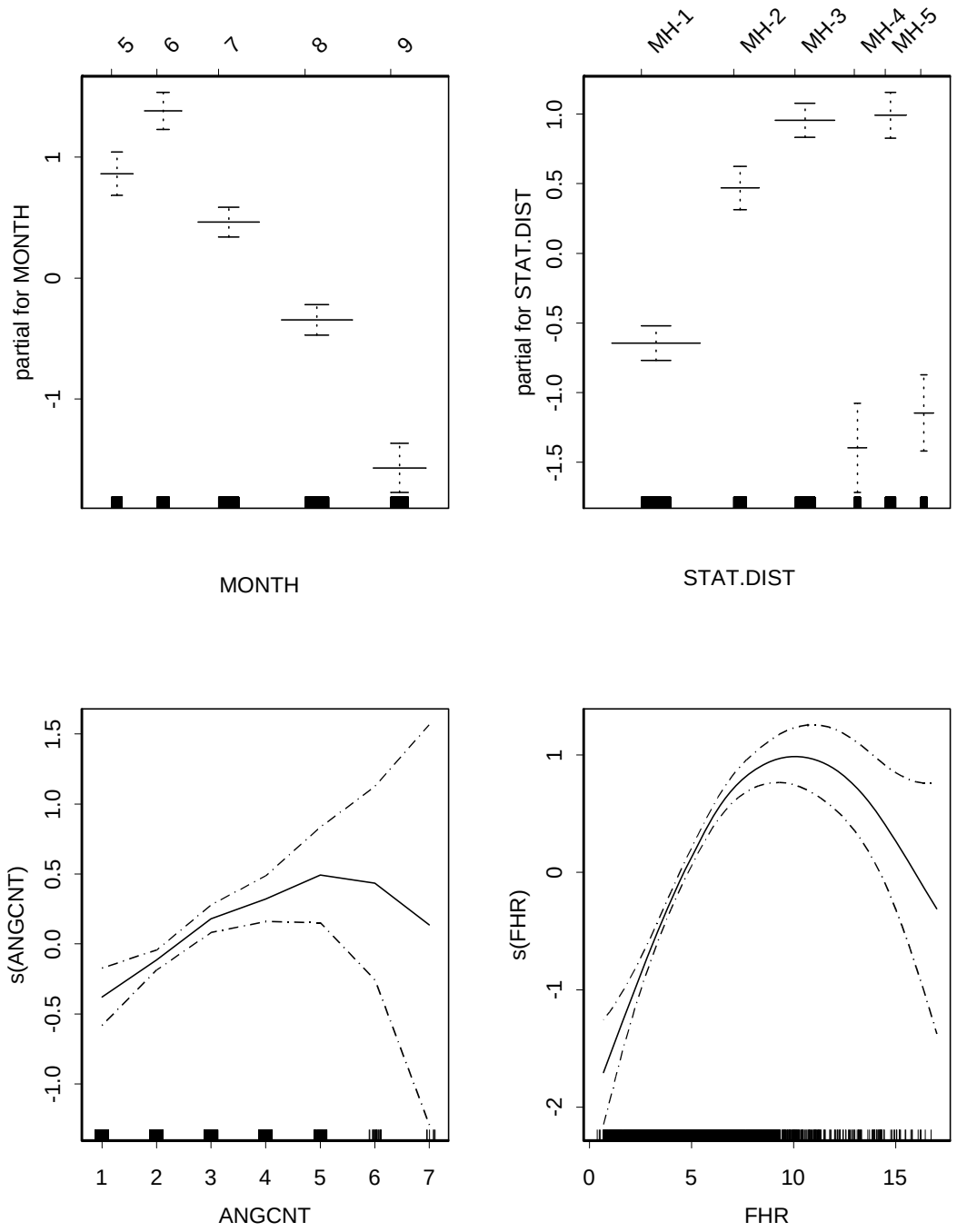

Figure 30. Results from main effect binomial GAM for number of trips with lake trout catch during 1999 non-charter boat fishery. ANGCNT=number of anglers, FHR=fishing time in hours.

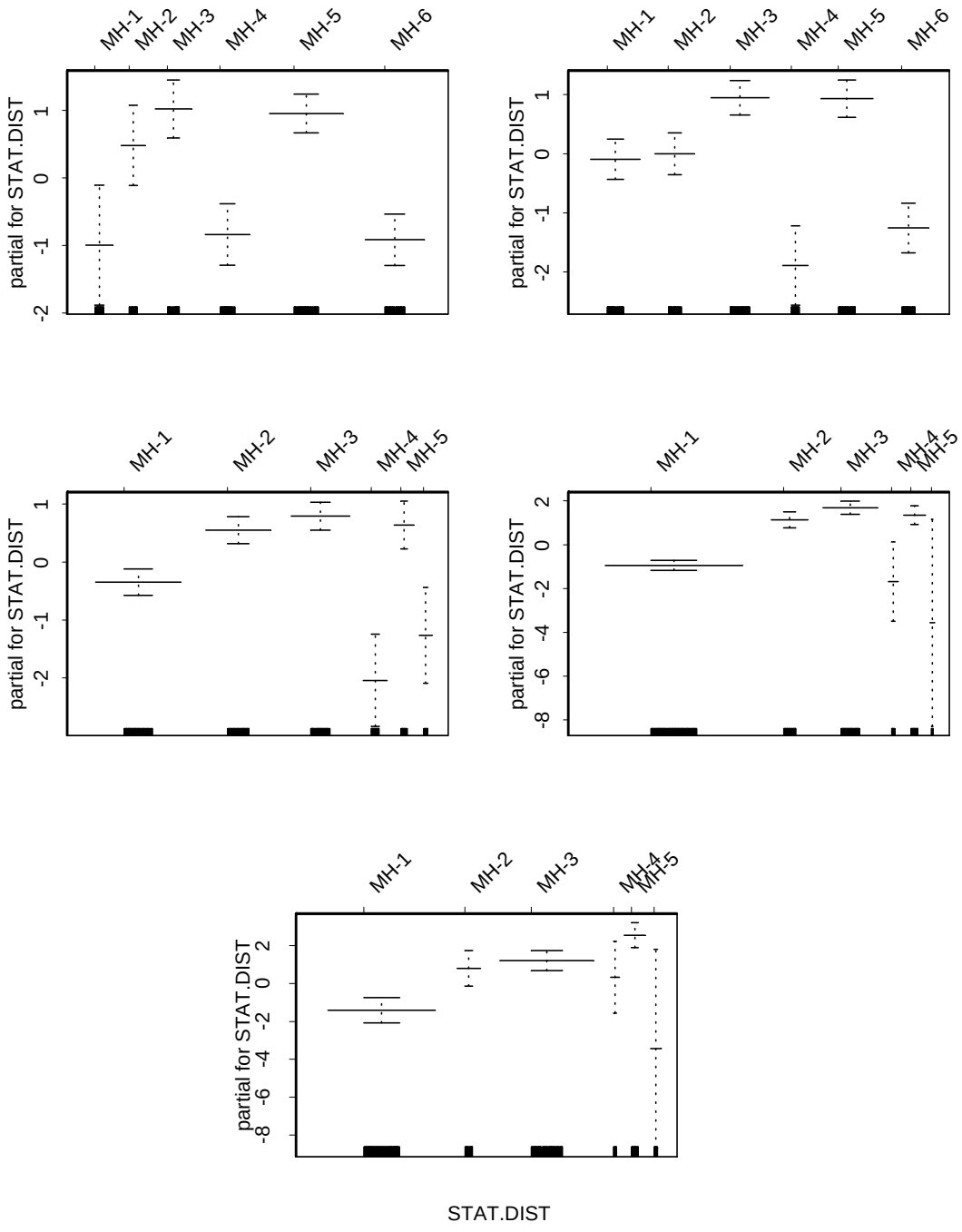

Figure 31. Results from binomial GAMs for spatial variation in the number of trips with lake trout catch by month from May to September 1999 in the non-charter boat fishery.

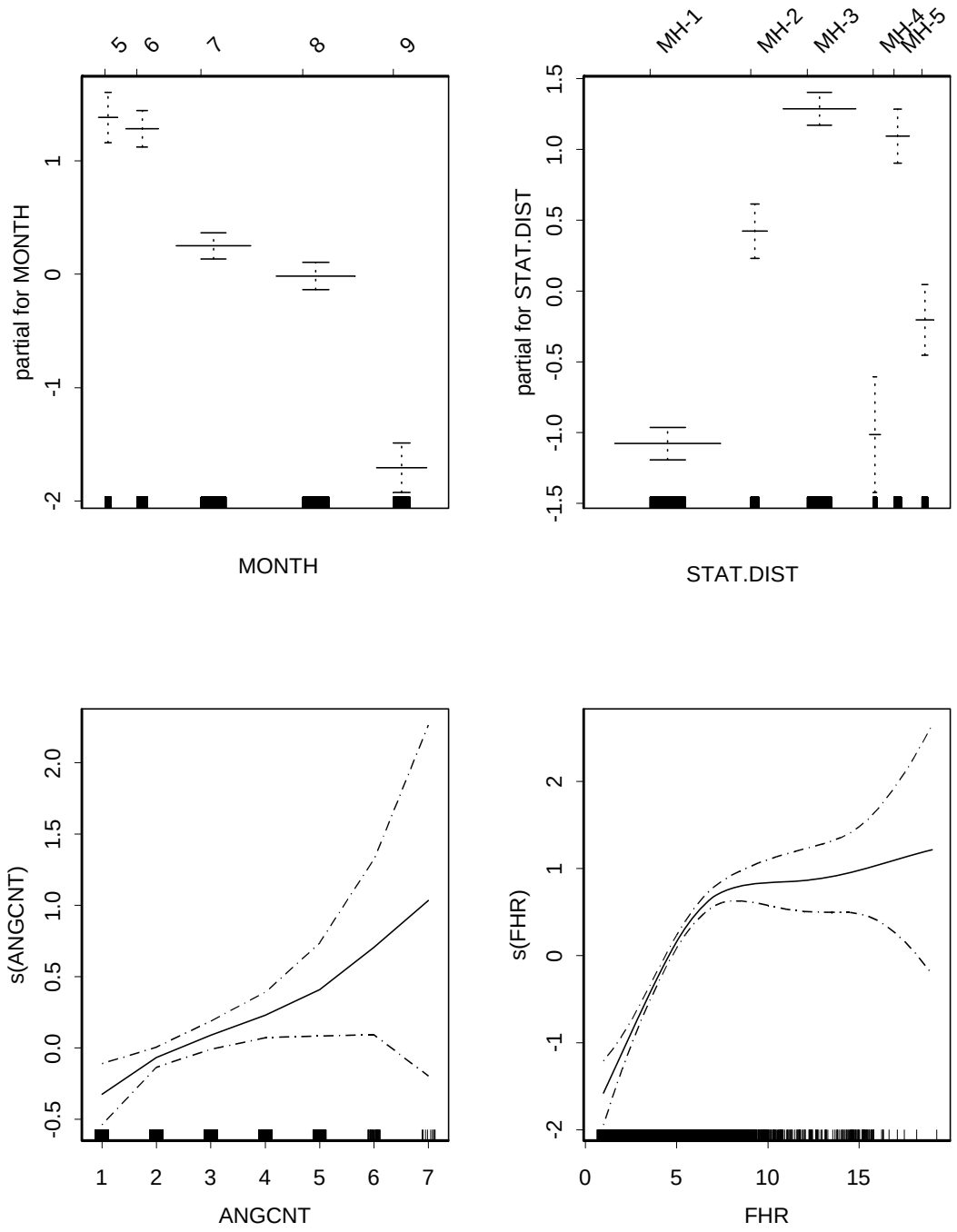

Figure 32. Results from main effect binomial GAM for number of trips with lake trout catch during 2000 non-charter boat fishery. ANGCNT=number of anglers, FHR=fishing time in hours.

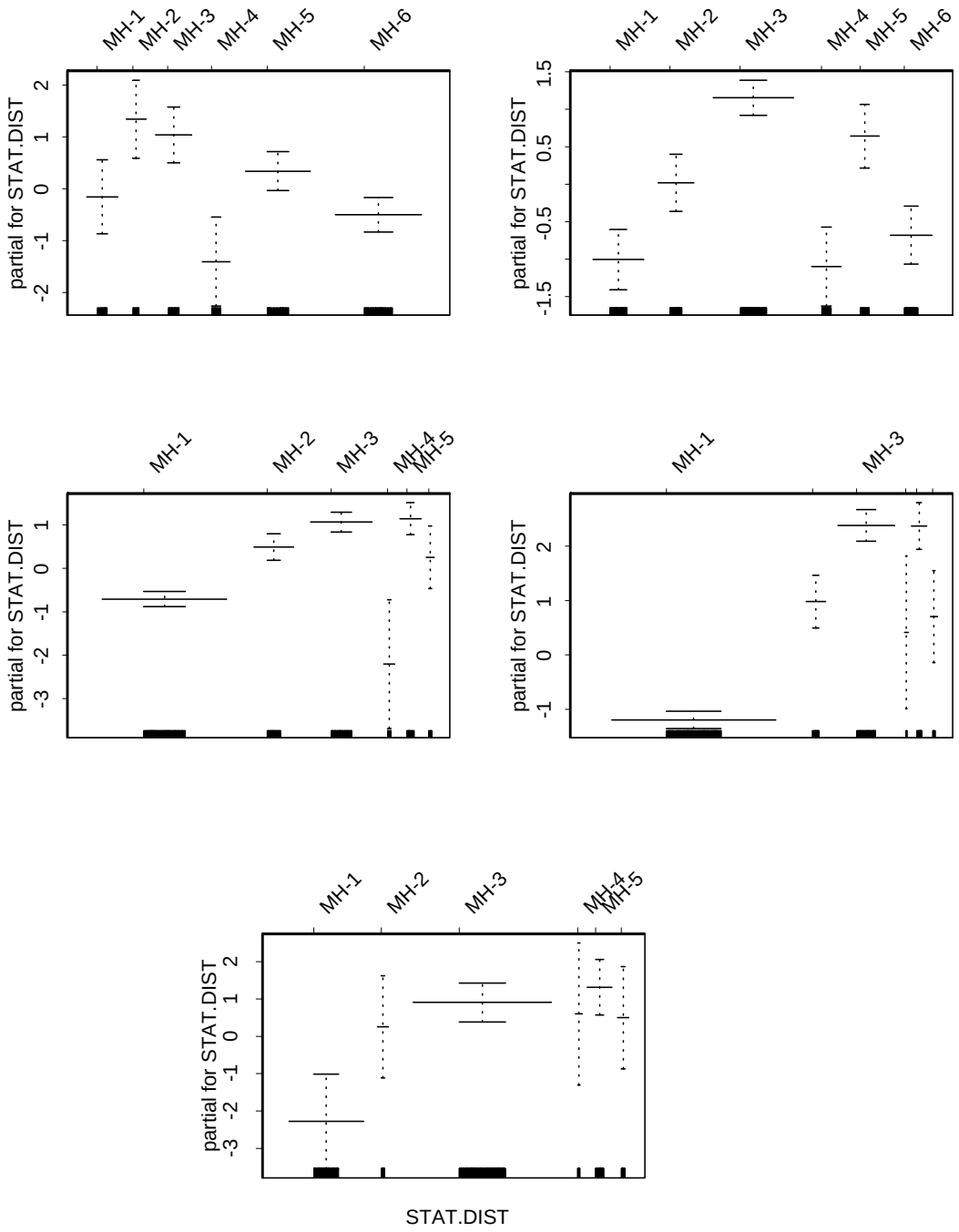

Figure 33. Results from binomial GAMs for spatial variation in the number of trips with lake trout catch by month from May to September 2000 in the non-charter boat fishery

Analysis of charter boat data

To investigate the relative abundance of lake trout in Lake Huron and complement the previous analysis, we examined the mapped distribution of catch rates in the charter boat fishery by month and year. We excluded trips with yellow perch catches. Catch rates by hour angler by trip were calculated for each grid for which information was available.

Fairly similar patterns were observed for each year. Figure 34 presents the distribution obtained with data from the 1998 fishery, which is representative of other years (except for low rates in MH1 in May and June). Rates were highest in May to July and in grids from areas MH3, MH4 and MH5. Levels tended to be higher in the north at the beginning of the season and in the south later in the year; although the spatial coverage in northern areas was limited during May and in southern areas during September. During 1993 rates were highest in July and in MH4 and MH5, and patterns by month were also similar to those found in the analysis of creel data. During 1994 rates were high in June, and in MH1 and MH5. Although few data were available for MH1, it can be observed that high rates in the north decrease towards September as was found for the creel data analysis. The same patterns were observed from 1995 to 1997. In later years, rates in MH1 were comparatively low from May to July.

The patterns observed in the charter boat catch rates are consistent with the results from the analysis in previous sections and suggest seasonal movement during the fishing season. Nevertheless, unlike the results from the analysis of creel data, catch rates in grids in MH4 were among the highest for every year (Figure 34). This result deepens our concerns about influence in our previous result of the spatial information contained in the creel database. It implies that the low catch levels for MH4 from the previous analysis occurred because of reported fishing in ports outside of this district (for example Harbor Beach, Port Austin and Grindstone City in MH5) where fish were caught (statistical grids 1412 and 1413 in MH4) and do not reflect the distribution of fish abundance. This is a real shortcoming of the creel database for studies that require a finer spatial resolution, such as analysis of fish movement of species that do not perform large displacements.

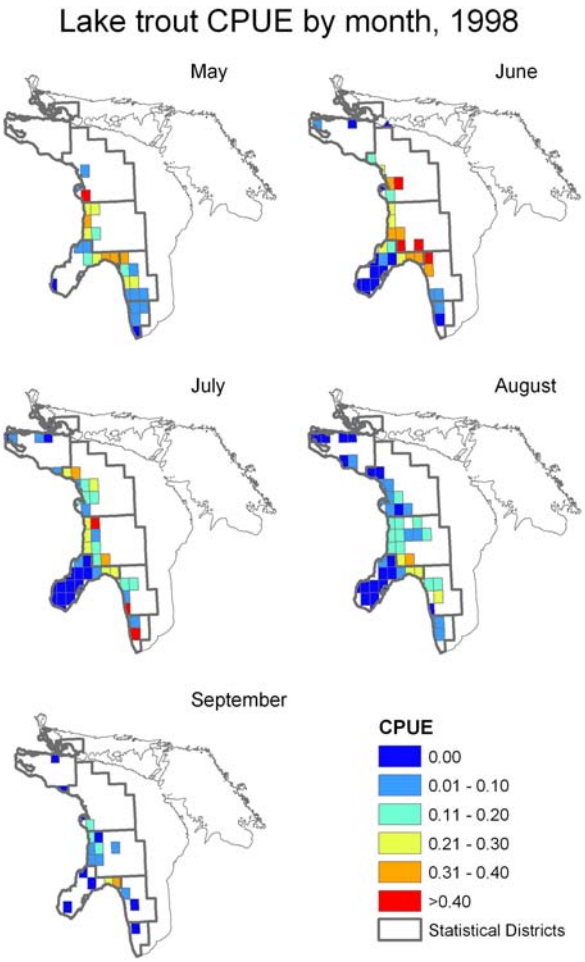

Figure 34. Seasonal distribution of lake trout catch rates (numbers caught by angler hours by trip) in Michigan waters of Lake Huron in the 1998 charter boat fisheries. Data are from the MDNR Charterboat database. Trips with yellow perch catch are excluded.

DISCUSSION

This analysis estimated coefficients to standardize coded wire tag recoveries of lake trout from several recovery sources in the sport fisheries in Lake Huron. The coefficients can be used to analyze CWT data, and study distribution and movement of tagged fish recovered by creel clerks and headhunters or self-reported by captains. Overall, although estimated coefficients varied annually, if we take the tag recoveries by trip reported by charter boat captains as reference, tag recoveries by creel interviews from non-charter boats were double, and those of the headhunters from non-charter boat trips were triple and headhunters from charter boat were nine times higher. This means that forms submitted by captains severely under-report tag recoveries.

Based on the results of the analysis of CWT data we constructed a matrix of proportions of tagged lake trout recoveries by statistical district (Figure 35 and Table 16 for a summary). This matrix represents the distribution of tagged fish during the fishing season and in the fishing grounds. Overall about 40% of the fish were found in the area of release, and proportions of tags recovered in the neighboring areas to the south of MH1, the north of MH2 and MH3 and the east of MH4 were not significantly different to those in the release area. These recoveries reflect the number of fish released, affected from the year of release to the year of capture by area, age and year specific and age mortality (natural and fishing mortality), and also by movement between areas. Since the highest proportion of recoveries was of age 4 to 6 fish, several years of natural mortality and fishing mortality generally have taken place before fish are recovered. Further, since the data are from the sport fishery these numbers represent the distribution outside refuge areas and are the net balance of emigration and immigration from refuges. Further modelling, along the lines of Hilborn (1990) can now be used to complement this analysis of tag recovery data and estimate a multidirectional movement matrix and natural mortality by release area. This analysis needs to be done within the framework of assessment models and requires for example a revision of current estimates of effort in sport fisheries.

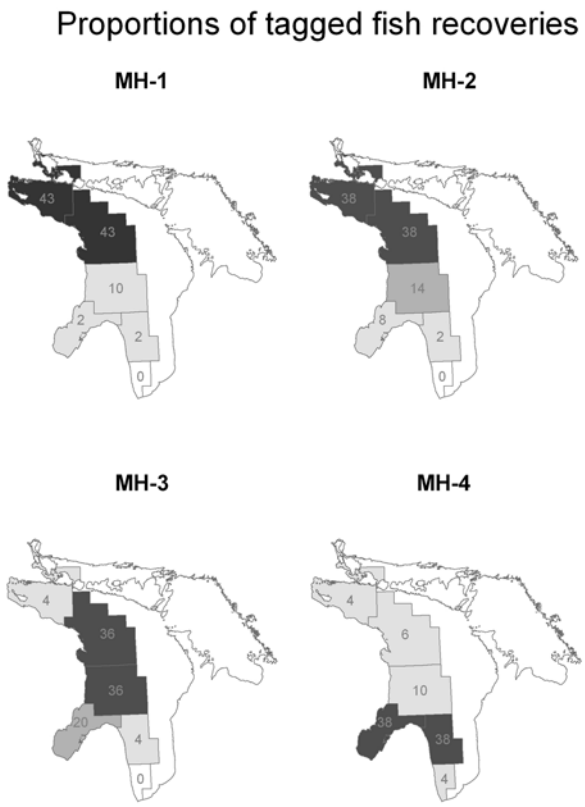

Figure 35. CWT lake trout overall distribution, expressed as proportions, of fish recovered in the 1993 to 2000 sport fisheries released in statistical districts. Proportions are predicted from GLM analysis and account for the source of recovery.

Results from this study suggest that seasonal movement of fish between statistical districts occurs with consequences for stock assessment. First, the question arises about the timing to sample the fish distribution for calculating a movement matrix. Our adjusted proportions in the distribution matrix are from selected months and represent the distribution of tagged fish released by statistical area and caught in the sport fisheries during one month in the summer when recoveries rates were the highest. Data for assessment combines data collected in different months. Further, assessment assumes that movement between areas occurs only during the first year according to a distribution matrix. For lake trout stock assessment, a catch at age model is used. In this model,

recruitment of stocked lake trout is modeled as a number of yearling equivalents actually stocked and calculated to move into an area. These yearling equivalents are calculated using movement matrices multiplied by a year-specific "survival adjustment" factor. The numbers stocked at various locations are adjusted for movement soon after stocking (before substantial spatially varying mortality comes into play) by apportioning fixed proportions of the numbers of yearling equivalents stocked at each location as being effectively stocked into each of the management areas on the lake. These translations of numbers from stocking location to recruitment location are in the form of a "movement matrix." The numbers effectively stocked to a management unit (recruitment location) are then summed over the stocking locations. These effective numbers stocked are the yearling equivalent input, which are then adjusted upward or downward to account for year specific variations. This procedure assumes that fish move from the release area and stay in that area through out the life span. Since our results suggest that fish recruited to the fishery move between areas during the fishing season this can have several implications for example on the estimate of number of fish decreasing due to area specific fishing and natural mortality.

Significant differences were found in the proportions for a lake trout distribution matrix in Lake Huron calculated from the original numbers of CWT fish recovered in the sport fisheries and from numbers adjusted using GLM (Table 16). The major difference was for recoveries from fish released in MH2 where proportions calculated from recovery numbers are highest for MH2 and MH3, indicating movement preferentially to the south, while adjusted proportions were highest for MH2 and MH1 indicating movement to the north.

The lake trout matrix derived from our analysis based on recovery rates of CWT data from the charter and non-charter boat sport fisheries in Michigan waters of Lake Huron is fairly similar to the matrix obtained by Madenjian et al. (2003) (Table 16) obtained from all sources of tagged fish recoveries from fish released in offshore areas. The directional movements indicated from both calculations are similar, with displacement of tagged fish to the south from releases in areas MH1 and MH4, and to the north from MH2 and MH3.

The main differences between Madenjian's et al (2003) study and our results are that we estimated lower proportions of fish released and recovered in MH1 (43% vs. 64%), and higher proportions of fish released and recovered in MH4 (38 vs. 26%). This later result is influenced by the number of fish that move to Canadian waters (estimated at about 18% from assessments and not included in our analysis).

Table 16. Summary of proportions of tagged fish recoveries based on unadjusted numbers of tags and adjusted GLM predictions. Ass.= proportions from Madenjian et al. (2003). # =proportions from recoveries. GLM = proportions from GLM predictions.

	MH1			**MH2**			**MH3**			**MH4**		
Recov, Area	Ass.	#	**GLM**	Ass.	#	**GLM**	Ass.	#	**GLM**	Ass.	#	**GLM**
MH1-	**64%**	**49%**	**43%**	33%	18%	38%	5%9	5%	4%	0.4%	1%	5%
MH2-	24%	34%	43%	**42%**	**36%**	**38%**	26%	32%	36%	3%	3%	6%
MH3-	6%	11%	10%	14%	30%	14%	**35%**	**37%**	**36%**	9%	18%	10%
MH4-	1%	3%	2%	3%	8%	8%	9%	16%	20%	**26%**	**45%**	**38%**
MH5-	1%	2%	2%	1%	6%	2%	7%	8%	4%	21%	25%	38%
MH6-	0.1%	>1%		0.1%	2%		0.5%	1%		2%	6%	4%

Analysis of lake trout catch rates in the charter and non-charter fisheries complemented the results obtained from modelling recoveries of CWT fish. Nevertheless, this analysis was not as useful as found in a previous analysis by Adlerstein et al. (2004) for chinook salmon fishery data, where changes in angler catch rate correlated well with movement patterns interpreted from analysis of coded-wire tagged fish. Some of the differences are that lake trout have been released at more stocking sites than chinook and that these sites are spread through out Lake Huron, and that lake trout exhibit less movement than chinook salmon. Also, there are no refuge areas for chinook salmon, thus the sport fisheries cover more of the area of their distribution than for lake trout, for which several statistical rectangles are closed to the fishery.

There are several shortcomings in the analysis generated by the protocols to recover tagged fish. Data from creel interviews, thought to be the most reliable source of information, do not provide information about on the effort sampling tagged fish. This is because there is no predefined schedule for clerks in the protocols to collect tags. Thus, we know how many trips the clerk interviewed but not in how many trips CWT fish were sampled. The problem arises because the effort of creel clerks in collecting tags varies, depending on the number of trips that the clerk is required to interview. In terms of the headhunter database, the program started to consistently collect lake trout tags only in 1995, and even since then the spatial and temporal coverage of headhunter sampling has been reduced. Since the headhunters' priority is to recovering tags from chinook salmon, the effort in collecting tags from lake trout is variable, making the information imprecise. As for the creel survey, the effort deployed by headhunters is imprecise because it is not known in how many trips lake trout heads were sampled.

Another shortcoming of the data available for this study was that the information for the tag recoveries is reported by grid, but information on fishing effort for non-charter is reported by port of the interviews. This has consequences both for the analysis of the CWT recoveries and for the analysis of catch rates. Major problems occurred for tags recovered in grids 1412 and 1413, which were reported in interviews from MH4 and MH5 ports.

A further problem in using fishery data for analyzing the distribution of lake trout was that fishery data only covers part of their distribution. Several grids in Six Fathom Bank and Drummond Island, main release areas for lake trout, are closed to the lake trout fishery but not for other species. This has two implications for this analysis. First and most importantly, no information can be obtained from the sport fishery for fish that remain within or move into this protected areas. Second, trips conducted in these areas should not be counted as effort for lake trout catch rates, but because creel data does not contain information on location of the trips, we cannot identify the trips occurring in the specific statistical grids to count them out of the analysis. This should not have major consequences because at least in the charter boat fisheries, no trips were reported to take

place in those grids, indicating that fishermen avoid the lake trout refuge areas all altogether.

A further shortcoming of using fishery data to investigate fish distribution was that area specific regulations in terms of size at capture for lake trout can influence the results of the analysis. Size of capture and daily limit regulations varied such that in MH1 there is a minimum size of 15 and a maximum size of 19 inches (around 38 to 48 cm), with one daily possession of 34 inches or greater (86 cm). In MH2, the minimum size is 22 inches (56 cm) and in MH3 to MH6 is 15 inches. Thus, tag recoveries can only be made from fish within these ranges. Also the maximum daily limit by anglers in any statistical district is 3 fish per day. Further, regulations vary from year to year for some areas, and this further confounds analyses.

Finally, CWT recovery data from sport fishery were too scarce to perform analysis by age, or by release site, which would be desirable. Although the CWT database contains more than 4000 records for the years of the study, about half are not from CWT fish, and many of the CWT fish were recovered by volunteers and thus lack necessary information for the analysis.

Recommendations:

Among the sport fisheries, the non-charter boat catch constituted the most valuable source of information for tag recoveries. Nevertheless, there are several shortcomings. Major limitations are that information necessary to account for the fishing and tag recovery effort does not contain the required spatial definition for movement analysis of lake trout and that the time spent by the creel clerk sampling for tags is variable. To overcome these limitations:

- It is necessary to incorporate the information of the grid where the trips are conducted.

- There should be information in the CWT database concerning the proportion of trips sampled for tags by species and by day. Alternatively, the protocol for clerks should specify the proportion of trips to be sampled by day of the week.

Self-reporting of captains of the charter boat fishery results in poor information for movement studies.

- It is recommended that the charter boat fishery would be reincorporated within the creel survey, as it once used to be.

The headhunter program provides incomplete spatial-temporal coverage of the lake trout fishery and effort to sample lake trout is imprecise.

- We believe that a combined effort with the creel survey could give more valuable information from this recovery program.

From data handling of the various databases used in the analysis, several inconsistencies were detected.

- Formats in the creel databases need to be standardized.
- The documentation of the CWT database needs to be improved so that every field in the files is precisely defined.
- The CWT database should incorporate all CWT data available (including those in the database used for assessment and should contain data only of CWT marked fish.
- A link between the CWT database and the charter and non-charter databases needs to be established, so that the information can be verified and be used.

Throughout the years, several studies have been carried involving lake trout CWT tagging. These studies investigated different aspects of the lake trout stocking program. Because of the difference in objectives of these projects, data were not always appropriate to model movement. Further thoughts are needed for an overall study of fish movement that involves release and recovery of the tags.

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APPENDIX I

Number of tags recoveries, and corresponding number of trips from which the tags were recovered aggregated by gear type, month and statistical area.

Year 1993										
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR Trips	VOL
5	MH1	-	-	0	23	-	-	-	-	0
	MH2	0	19	0	52	-	-	-	-	1
	MH3	0	8	0	34	-	-	-	-	0
	MH4	0	36	0	53	-	-	-	-	2
	MH5	0	72	0	155	-	-	1	96	0
	MH6	0	37	0	326	0	3	2	452	0
6	MH1	0	17	0	32	-	-	-	-	0
	MH2	0	33	0	86	-	-	-	-	0
	MH3	0	87	2	50	-	-	-	-	2
	MH4	0	99	0	69	0	14	3	166	1
	MH5	0	30	0	186	-	-	0	81	1
	MH6	0	16	0	134	0	-	-	-	0
7	MH1	3	70	0	293	-	-	0	70	5
	MH2	0	107	1	753	0	11	3	277	19
	MH3	1	160	0	156	0	2	1	80	1
	MH4	0	250	0	44	0	16	0	139	0
	MH5	0	31	0	165	-	-	0	95	0
	MH6	0	6	0	31	-	-	-	-	0
8	MH1	1	166	0	564	-	-	0	248	1
	MH2	0	96	0	450	0	3	0	131	2
	MH3	1	267	2	361	0	1	1	187	2
	MH4	0	253	0	25	0	2	0	21	0
	MH5	0	78	0	189	-	-	0	24	1
	MH6	0	8	0	36	-	-	-	-	-
9	MH1	0	54	0	197	-	-	0	69	0
	MH2	0	16	0	127	0	1	0	15	0
	MH3	0	82	0	491	0	1	0	237	0
	MH4	0	31	0	81	-	-	-	-	1
	MH5	0	45	0	137	-	-	-	-	0
	MH6	0	10	0	71	-	-	-	-	0

APPENDIX I Cont.

Year 1994										
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips	VOL
5	MH1	-	-	0	37	-	-	-	-	0
	MH2	0	11	0	104	-	-	-	-	1
	MH3	0	13	1	55	-	-	-	-	1
	MH4	0	68	1	29	-	-	4	20	1
	MH5	0	63	1	59	0	0	6	59	0
	MH6	0	47	0	270	-	-	0	403	-
6	MH1	0	7	2	79	-	-	-	-	3
	MH2	0	21	0	133	-	-	-	-	1
	MH3	0	68	0	48	-	-	-	-	0
	MH4	0	100	0	31	-	18	1	103	0
	MH5	0	15	0	60	0	0	0	24	2
	MH6	0	12	0	59	-	-	0	2	-
7	MH1	0	88	2	410	-	-	-	-	2
	MH2	0	115	2	916	0	4	36	133	22
	MH3	1	172	3	150	1	9	2	110	2
	MH4	0	225	0	40	-	16	0	84	0
	MH5	0	17	0	62	0	0	1	103	0
	MH6	0	6	0	38	-	-	-	-	-
8	MH1	2	138	0	555	-	-	0	13	2
	MH2	0	103	0	302	0	4	5	56	7
	MH3	0	223	2	225	0	8	1	123	4
	MH4	0	235	0	73	0	14	0	7	-
	MH5	0	40	0	30	-	-	0	13	-
	MH6	0	4	0	63	-	-	-	-	-
9	MH1	0	66	0	533	0	1	0	30	0
	MH2	0	28	0	147	0	4	-	-	-
	MH3	0	77	0	543	-	-	1	94	1
	MH4	0	45	0	91	-	-	-	-	-
	MH5	0	33	0	64	-	-	-	-	-
	MH6	0	2	0	94	-	-	-	-	-

APPENDIX I Cont.

Year 1995										
Month		CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips	VOL
5	MH1	-	-	9	57	-	-	-	-	9
	MH2	0	13	12	69	-	-	0	4	-
	MH3	0	28	1	74	0	2	1	12	0
	MH4	0	71	6	64	-	3	-	7	4
	MH5	0	52	0	85	0	0	6	149	-
	MH6	0	52	0	164	0	8	0	235	1
6	MH1	0	12	19	126	-	-	1	5	17
	MH2	0	38	24	192	0	3	1	57	1
	MH3	9	102	7	198	0	7	7	121	6
	MH4	1	138	1	77	0	19	3	106	9
	MH5	0	32	1	104	0	2	0	108	5
	MH6	0	21	0	164	-	-	0	40	-
7	MH1	0	93	1	512	0	1	2	81	19
	MH2	0	133	13	1064	0	3	39	193	22
	MH3	2	239	8	264	0	3	7	216	6
	MH4	0	236	0	121	-	22	0	136	2
	MH5	0	29	0	94	0	1	0	123	3
	MH6	0	14	0	183	-	-	0	2	-
8	MH1	0	140	0	696	0	1	0	491	2
	MH2	0	122	5	410	0	3	0	34	1
	MH3	2	294	6	279	5	2	12	279	6
	MH4	0	194	0	66	0	12	0	67	1
	MH5	0	51	0	81	0	1	0	110	4
	MH6	0	6	0	123	-	-	-	1	-
9	MH1	0	53	0	461	-	-	0	7	-
	MH2	0	20	1	144	-	-	1	21	-
	MH3	0	133	0	530	-	-		0	-
	MH4	0	22	0	63	-	-	0	0	0
	MH5	0	58	0	60	-	-	-	0	2
	MH6	0	2	0	66	-	-	-	0	-

APPENDIX I Cont.

Year 1996										
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips	VOL
5	MH1	-	-	10	117	-	-	-	-	28
	MH2	0	16	26	130	-	-	4	22	15
	MH3	1	39	8	51	-	-	0	3	4
	MH4	1	77	0	64	0	6	1	72	5
	MH5	3	55	0	42	0	2	2	160	4
	MH6	0	57	1	204	0	7	1	335	2
6	MH1	0	8	3	113	-	-	-	-	4
	MH2	2	28	16	151	2	2	11	75	2
	MH3	6	112	4	112	0	1	4	49	4
	MH4	1	134	1	60	1	24	1	185	2
	MH5	0	39	0	32	0	4	0	100	6
	MH6	0	21	0	227	-	-	0	41	2
7	MH1	1	83	0	232	-	-	8	125	2
	MH2	0	101	12	934	1	3	28	152	45
	MH3	10	208	9	195	0	5	14	118	19
	MH4	2	222	2	97	1	33	0	234	4
	MH5	3	28	1	86	0	0	0	60	11
	MH6	0	13	0	71	-	-	0	21	0
8	MH1	2	144	0	942	-	-	1	415	20
	MH2	0	168	19	467	3	9	7	137	5
	MH3	10	347	15	585	0	3	3	129	29
	MH4	1	237	2	131	1	11	1	161	5
	MH5	2	71	3	208	0	0	0	80	7
	MH6	-	4	0	109	-	-	-	19	0
9	MH1	0	65	0	437	-	-	-	-	0
	MH2	0	21	0	161	-	-	-	-	0
	MH3	0	116	0	547	-	-	-	-	2
	MH4	0	23	0	62	-	-	-	-	0
	MH5	0	46	0	130	-	-	-	-	1
	MH6	-	-	0	64	-	-	-	-	0

APPENDIX I Cont.

Year 1997										
Month		CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips	VOL
5	MH1	-	-	2	113	-	-	-	-	-
	MH2	3	19	9	64	-	-	-	-	-
	MH3	0	21	3	95	-	-	-	-	2
	MH4	0	108	2	102	-	8	0	20	3
	MH5	0	58	1	172	6	4	3	93	3
	MH6	0	59	0	315	0	9	0	336	1
6	MH1	0	3	1	98	-	-	-	-	-
	MH2	1	23	17	264	0	1	18	98	4
	MH3	1	116	14	251	0	1	14	156	10
	MH4	1	154	5	170	2	16	5	127	-
	MH5	1	34	0	144	1	5	6	81	5
	MH6	0	28	0	121	-	-	0	30	0
7	MH1	3	96	4	317	0	2	2	48	5
	MH2	1	121	4	790	1	17	25	430	23
	MH3	9	201	12	339	0	1	12	162	18
	MH4	2	231	1	145	0	14	1	100	13
	MH5	1	21	0	93	0	3	0	108	6
	MH6	0	19	0	142	-	-	0	31	1
8	MH1	0	134	1	836	-	1	0	400	0
	MH2	0	201	6	653	0	7	1	135	3
	MH3	1	341	8	537	0	1	2	185	9
	MH4	1	195	1	48	0	11	3	94	5
	MH5	3	58	1	157	0	0	4	92	6
	MH6	0	10	0	134	-	-	-	-	2
9	MH1	0	45	0	499	-	-	-	-	-
	MH2	0	25	0	111	-	-	-	-	-
	MH3	0	141	0	581	-	-	1	93	1
	MH4	4	17	0	59	-	-	-	-	-
	MH5	0	33	0	148	-	-	-	-	-
	MH6	0	2	0	55	-	-	-	-	-

APPENDIX I Cont.

Year 1998										
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips	VOL
5	MH1	-	-	0	40	-	-	-	-	0
	MH2	0	15	2	164	-	-	-	-	2
	MH3	0	45	8	124	1	2	14	59	5
	MH4	0	157	0	91	0	8	6	61	5
	MH5	3	90	0	91	-	-	15	46	5
	MH6	0	51	0	126	-	-	2	183	1
6	MH1	0	16	2	113	-	-	0	2	2
	MH2	0	25	8	243	-	-	1	76	1
	MH3	2	133	38	238	0	3	13	137	8
	MH4	2	208	1	89	7	17	17	112	6
	MH5	0	43	0	77	-	-	4	78	10
	MH6	0	32	0	185	0	1	3	84	0
7	MH1	0	90	1	312	-	-	2	60	7
	MH2	0	131	4	752	0	13	0	262	3
	MH3	0	228	26	358	0	4	0	256	9
	MH4	5	340	0	107	6	15	6	181	6
	MH5	0	42	0	158	-	-	2	76	10
	MH6	0	38	0	105	-	-	0	8	0
8	MH1	0	158	0	386	-	-	1	251	2
	MH2	0	208	0	511	0	8	3	126	1
	MH3	3	346	19	536	-	-	0	118	8
	MH4	16	265	0	82	4	8	4	195	5
	MH5	2	93	0	228	0	3	0	39	2
	MH6	0	18	0	62	-	-	-	-	0
9	MH1	0	43	0	161	-	-	-	-	0
	MH2	0	12	0	155	-	-	-	-	0
	MH3	0	162	0	608	-	-	-	-	2
	MH4	0	41	0	77	-	-	-	-	0
	MH5	0	28	0	157	-	-	-	-	2
	MH6	0	2	0	61	-	-	-	-	0

APPENDIX I Cont.

Year 1999										
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips	VOL
5	MH1	-	-	13	75	-	-	-	-	8
	MH2	0	8	2	66	-	-	0	2	-
	MH3	0	24	8	100	-	-	12	52	1
	MH4	14	154	5	123	16	2	15	96	1
	MH5	0	27	0	202	-	-	8	48	2
	MH6	0	98	1	163	-	-	1	116	2
6	MH1	1	17	21	159	-	-	3	9	26
	MH2	0	19	17	126	0	1	5	35	26
	MH3	0	109	13	184	-	-	17	137	3
	MH4	5	157	5	80	5	11	25	96	7
	MH5	0	66	3	165	1	3	3	85	5
	MH6	0	32	1	128	0	3	2	100	0
7	MH1	0	114	8	449	0	2	6	77	10
	MH2	0	121	12	338	0	2	36	257	4
	MH3	1	231	11	305	-	-	12	193	4
	MH4	2	361	0	124	3	15	5	121	1
	MH5	0	41	0	102	1	3	0	96	2
	MH6	0	6	0	67	-	-	1	21	0
8	MH1	0	154	2	833	0	1	2	332	5
	MH2	0	200	1	221	0	6	6	146	1
	MH3	0	356	3	332	-	-	1	183	1
	MH4	1	257	0	60	8	20	3	101	2
	MH5	0	42	0	133	0	3	1	85	0
	MH6	0	1	0	28	-	-	0	3	-
9	MH1	0	59	0	485	-	-	0	130	-
	MH2	0	28	0	105	-	-	-	-	-
	MH3	0	141	0	424	-	-	0	57	0
	MH4	1	61	0	39	-	-	-	-	0
	MH5	0	30	0	95	-	-	-	-	0
	MH6	0	1	0	48	-	-	-	-	-

APPENDIX I Cont.

Year 2000										
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips	VOL
5	MH1	0	3	10	58	-	-	-	-	2
	MH2	0	5	8	37	-	-	3	16	-
	MH3	0	34	0	67	-	-	3	44	4
	MH4	0	111	5	51	0	2	1	37	2
	MH5	0	45	5	120	0	2	1	24	3
	MH6	0	70	0	159	0	1	0	102	0
6	MH1	0	10	6	162	-	-	0	2	2
	MH2	0	29	13	113	0	2	3	50	1
	MH3	0	109	0	256	0	1	10	142	19
	MH4	0	169	7	93	0	1	0	118	0
	MH5	0	50	2	89	-		0	21	1
	MH6	0	25	0	131	-		0	38	0
7	MH1	0	104	10	910	0	1	2	92	6
	MH2	0	82	10	292	0	15	11	213	1
	MH3	0	264	0	452	0	0	10	244	13
	MH4	0	349	1	78	-	-	0	154	2
	MH5	0	51	6	156	-	-	0	56	0
	MH6	0	11	0	61	-	-	0	13	1
8	MH1	0	106	0	1269	0	3	4	360	5
	MH2	0	232	2	149	0	7	4	145	1
	MH3	0	289	1	435	-	-	1	121	15
	MH4	0	255	3	30	-	-	0	123	0
	MH5	0	38	1	119	-	-	0	17	1
	MH6	0	2	0	54	-	-	0	2	1
9	MH1	0	24	0	370	-	-	0	2	0
	MH2	0	14	0	54	-	-	0	-	0
	MH3	0	102	0	680	-	-	0	10	1
	MH4	0	23	3	33	-	-	-	-	0
	MH5	0	21	0	120	-	-	-	-	0
	MH6	0	0	0	55	-	-	-	-	-

APPENDIX II

Number of tags recovered by year, statistical district and gear from fish released in MH1.

Recovered 1995									
Month	Stat. Dist.	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	6	57	-	-	3	-
	MH2	0	13	1	69	-	-	0	4
	MH3	0	28	1	74	0	2	0	12
	MH4	0	71	0	64	-	3	-	7
	MH5	0	52	0	85	-	-	0	149
	MH6	0	52	0	164	0	8	0	235
6	MH1	0	12	8	126	-	-	0	5
	MH2	0	38	2	192	0	3	0	57
	MH3	0	102	0	198	0	7	1	121
	MH4	0	138	0	77	0	19	0	106
	MH5	0	32	0	104	0	2	0	108
	MH6	0	21	0	164	-	-	0	40
7	MH1	0	93	1	512	0	1	0	81
	MH2	0	133	1	1064	0	3	7	193
	MH3	0	239	0	264	0	3	0	216
	MH4	0	236	0	121	-	22	0	136
	MH5	0	29	0	94	0	1	0	123
	MH6	0	14	0	183	-	-	0	2
8	MH1	0	140	0	696	0	1	0	491
	MH2	0	122	0	410	0	3	0	34
	MH3	0	294	1	279	0	2	0	279
	MH4	0	194	0	66	0	12	0	67
	MH5	0	51	0	81	0	1	0	110
	MH6	0	6	0	123	-	-	-	1

APPENDIX II Cont.

Recovered 1996									
Month	Stat. Dist.	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	4	117	-	-	-	-
	MH2	0	16	6	130	-	-	0	22
	MH3	0	39	4	51	-	-	0	3
	MH4	0	77	0	64	0	6	0	72
	MH5	0	55	0	42	0	2	0	160
	MH6	0	57	0	204	0	7	0	335
6	MH1	0	8	1	113	-	-	-	-
	MH2	0	28	2	151	1	2	0	75
	MH3	0	112	0	112	0	1	0	49
	MH4	0	134	0	60	0	24	0	185
	MH5	0	39	0	32	0	4	0	100
	MH6	0	21	0	227	-	-	0	41
7	MH1	0	83	0	232	-	-	3	125
	MH2	0	101	2	934	0	3	4	152
	MH3	1	208	0	195	0	5	0	118
	MH4	0	222	0	97	0	33	0	234
	MH5	0	28	0	86	0	0	0	60
	MH6	0	13	0	71	-	-	0	21
8	MH1	1	144	0	942	-	-	0	415
	MH2	0	168	4	467	1	9	1	137
	MH3	1	347	1	585	0	3	0	129
	MH4	0	237	2	131	0	11	0	161
	MH5	0	71	3	208	0	0	0	80
	MH6	-	4	0	109	-	-	-	19

APPENDIX II Cont.

Recovered 1997									
Month	Stat. Dist.	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	1	113	-	-	-	-
	MH2	1	19	2	64	-	-	-	-
	MH3	0	21	0	95	-	-	-	-
	MH4	0	108	0	102	-	8	0	20
	MH5	0	58	0	172	0	4	3	93
	MH6	0	59	0	315	0	9	0	336
6	MH1	0	3	1	98	-	-	-	-
	MH2	0	23	2	264	0	1	0	98
	MH3	0	116	4	251	0	1	0	156
	MH4	0	154	2	170	0	16	0	127
	MH5	0	34	0	144	0	5	1	81
	MH6	0	28	0	121	-	-	0	30
7	MH1	3	96	1	317	0	2	0	48
	MH2	1	121	2	790	0	17	4	430
	MH3	1	201	1	339	0	1	1	162
	MH4	0	231	0	145	0	14	0	100
	MH5	0	21	0	93	0	3	0	108
	MH6	0	19	0	142	-	-	0	31
8	MH1	0	134	1	836	-	1	0	400
	MH2	0	201	1	653	0	7	0	135
	MH3	0	341	1	537	0	1	0	185
	MH4	0	195	0	48	0	11	0	94
	MH5	0	58	0	157	0	0	0	92
	MH6	0	10	0	134	-	-	-	-

APPENDIX II Cont.

Recovered 1998									
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	0	40	-	-	-	-
	MH2	0	15	0	164	-	-	-	-
	MH3	0	45	1	124	0	2	2	59
	MH4	0	157	0	91	0	8	0	61
	MH5	0	90	0	91	-	-	0	46
	MH6	0	51	0	126	-	-	0	183
6	MH1	0	16	1	113	-	-	0	2
	MH2	0	25	5	243	-	-	1	76
	MH3	0	133	4	238	0	3	1	137
	MH4	0	208	0	89	1	17	1	112
	MH5	0	43	0	77	-	-	0	78
	MH6	0	32	0	185	0	1	0	84
7	MH1	0	90	0	312	-	-	0	60
	MH2	0	131	2	752	0	13	0	262
	MH3	0	228	4	358	0	4	0	256
	MH4	0	340	0	107	0	15	0	181
	MH5	0	42	0	158	-	-	0	76
	MH6	0	38	0	105	-	-	0	8
8	MH1	0	158	0	386	-	-	1	251
	MH2	0	208	0	511	0	8	0	126
	MH3	0	346	1	536	-	-	0	118
	MH4	0	265	0	82	0	8	0	195
	MH5	0	93	0	228	0	3	0	39
	MH6	0	18	0	62	-	-	-	-

APPENDIX II Cont.

		1999							
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	5	75	-	-	-	-
	MH2	0	8	1	66	-	-	2	2
	MH3	0	24	0	100	-	-	1	52
	MH4	0	154	1	123	0	2	0	96
	MH5	0	27	0	202	-	-	0	48
	MH6	0	98	0	163	-	-	0	116
6	MH1	0	17	10	159	-	-	3	9
	MH2	0	19	11	126	0	1	1	35
	MH3	0	109	1	184	-	-	2	137
	MH4	0	157	0	80	1	11	1	96
	MH5	0	66	0	165	0	3	0	85
	MH6	0	32	0	128	0	3	0	100
7	MH1	0	114	6	449	0	2	3	77
	MH2	0	121	5	338	0	2	13	257
	MH3	0	231	1	305	-	-	0	193
	MH4	1	361	0	124	0	15	0	121
	MH5	0	41	0	102	1	3	0	96
	MH6	0	6	0	67	-	-	0	21
8	MH1	0	154	1	833	0	1	2	332
	MH2	0	200	0	221	0	6	0	146
	MH3	0	356	0	332	-	-	0	183
	MH4	0	257	0	60	0	20	0	101
	MH5	0	42	0	133	0	3	0	85
	MH6	0	1	0	28	-	-	0	3

APPENDIX II Cont.

		2000							
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	0	3	8	58	-	-	-	-
	MH2	0	5	5	37	-	-	1	16
	MH3	0	34	0	67	-	-	0	44
	MH4	0	111	0	51	0	2	0	37
	MH5	0	45	2	120	0	2	0	24
	MH6	0	70	0	159	0	1	0	102
6	MH1	0	10	6	162	-	-	0	2
	MH2	0	29	5	113	0	2	0	50
	MH3	0	109	0	256	0	1	0	142
	MH4	0	169	1	93	0	1	0	118
	MH5	0	50	0	89	-		0	21
	MH6	0	25	0	131	-		0	38
7	MH1	0	104	6	910	0	1	1	92
	MH2	0	82	4	292	0	15	1	213
	MH3	0	264	0	452	0	0	1	244
	MH4	0	349	0	78	-	-	0	154
	MH5	0	51	0	156	-	-	0	56
	MH6	0	11	0	61	-	-	0	13
8	MH1	0	106	0	1269	0	3	3	360
	MH2	0	232	1	149	0	7	1	145
	MH3	0	289	0	435	-	-	0	121
	MH4	0	255	0	30	-	-	0	123
	MH5	0	38	1	119	-	-	0	17
	MH6	0	2	0	54	-	-	0	2

APPENDIX III

Number of tags recovered by year, statistical district and gear from fish released in MH2.

Recovered 1995									
Month	Stat. Dist.	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	2	57	-	-	1	-
	MH2	0	13	6	69	-	-	0	4
	MH3	0	28	0	74	0	2	1	12
	MH4	0	71	0	64	-	3	0	7
	MH5	0	52	0	85	-	-	3	149
	MH6	0	52	0	164	0	8	0	235
6	MH1	0	12	9	126	-	-	1	5
	MH2	0	38	6	192	0	3	0	57
	MH3	1	102	0	198	0	7	1	121
	MH4	0	138	0	77	0	19	1	106
	MH5	0	32	0	104	0	2	0	108
	MH6	0	21	0	164	-	-	0	40
7	MH1	0	93	0	512	0	1	0	81
	MH2	0	133	3	1064	0	3	11	193
	MH3	0	239	0	264	0	3	0	216
	MH4	0	236	0	121	-	22	0	136
	MH5	0	29	0	94	0	1	0	123
	MH6	0	14	0	183	-	-	0	2
8	MH1	0	140	0	696	0	1	0	491
	MH2	0	122	2	410	0	3	0	34
	MH3	0	294	0	279	0	2	1	279
	MH4	0	194	0	66	0	12	0	67
	MH5	0	51	0	81	0	1	0	110
	MH6	0	6	0	123	-	-	-	1

APPENDIX III Cont.

Recovered 1996									
Month	Stat. Dist.	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB Trips	HHR tags	HHR trips
5	MH1	-	-	4	117	-	-	-	-
	MH2	0	16	6	130	-	-	0	22
	MH3	0	39	0	51	-	-	0	3
	MH4	0	77	0	64	0	6	0	72
	MH5	0	55	0	42	0	2	0	160
	MH6	0	57	0	204	0	7	0	335
6	MH1	0	8	0	113	-	-	-	-
	MH2	2	28	7	151	0	2	0	75
	MH3	0	112	0	112	0	1	0	49
	MH4	0	134	0	60	0	24	0	185
	MH5	0	39	0	32	0	4	0	100
	MH6	0	21	0	227	-	-	0	41
7	MH1	0	83	0	232	-	-	1	125
	MH2	0	101	2	934	0	3	4	152
	MH3	1	208	1	195	0	5	3	118
	MH4	0	222	0	97	0	33	0	234
	MH5	1	28	0	86	0	0	0	60
	MH6	0	13	0	71	-	-	0	21
8	MH1	0	144	0	942	-	-	0	415
	MH2	0	168	1	467	0	9	0	137
	MH3	0	347	2	585	0	3	0	129
	MH4	0	237	0	131	0	11	0	161
	MH5	0	71	0	208	0	0	0	80
	MH6	-	4	0	109	-	-	-	19

APPENDIX III Cont.

Recovered 1997									
Month	Stat. Dist.	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	1	113	-	-	-	-
	MH2	0	19	3	64	-	-	-	-
	MH3	0	21	0	95	-	-	-	-
	MH4	0	108	0	102	1	8	0	20
	MH5	0	58	0	172	0	4	1	93
	MH6	0	59	0	315	0	9	0	336
6	MH1	0	3	0	98	-	-	-	-
	MH2	1	23	8	264	0	1	10	98
	MH3	1	116	5	251	0	1	0	156
	MH4	0	154	0	170	0	16	0	127
	MH5	0	34	0	144	0	5	1	81
	MH6	0	28	0	121	-	-	0	30
7	MH1	0	96	1	317	0	2	2	48
	MH2	0	121	0	790	0	17	8	430
	MH3	2	201	2	339	0	1	5	162
	MH4	0	231	0	145	0	14	0	100
	MH5	0	21	0	93	0	3	0	108
	MH6	0	19	0	142	-	-	0	31
8	MH1	0	134	0	836	-	1	0	400
	MH2	0	201	1	653	0	7	0	135
	MH3	0	341	3	537	0	1	0	185
	MH4	0	195	0	48	0	11	0	94
	MH5	0	58	0	157	0	0	0	92
	MH6	0	10	0	134	-	-	-	-

APPENDIX III Cont.

Recovered 1998									
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	0	40	-	-	-	-
	MH2	0	15	2	164	-	-	-	-
	MH3	0	45	2	124	0	2	8	59
	MH4	0	157	0	91	0	8	2	61
	MH5	0	90	0	91	-	-	4	46
	MH6	0	51	0	126	-	-	1	183
6	MH1	0	16	1	113	-	-	0	2
	MH2	0	25	2	243	-	-	0	76
	MH3	1	133	12	238	0	3	4	137
	MH4	0	208	1	89	1	17	2	112
	MH5	0	43	0	77	-	-	2	78
	MH6	0	32	0	185	0	1	1	84
7	MH1	0	90	1	312	-	-	1	60
	MH2	0	131	1	752	0	13	0	262
	MH3	0	228	10	358	0	4	0	256
	MH4	0	340	0	107	1	15	2	181
	MH5	0	42	0	158	-	-	1	76
	MH6	0	38	0	105	-	-	0	8
8	MH1	0	158	0	386	-	-	0	251
	MH2	0	208	0	511	0	8	2	126
	MH3	1	346	9	536	-	-	0	118
	MH4	1	265	0	82	1	8	0	195
	MH5	1	93	0	228	0	3	0	39
	MH6	0	18	0	62	-	-	-	-

APPENDIX III Cont.

		Recovered 1999							
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	8	75	-	-	-	-
	MH2	0	8	1	66	-	-	0	2
	MH3	0	24	5	100	0	6	8	52
	MH4	2	154	1	123	0	2	3	96
	MH5	0	27	0	202	-	-	3	48
	MH6	0	98	0	163	-	-	1	116
6	MH1	1	17	9	159	-	-	0	9
	MH2	0	19	3	126	0	1	2	35
	MH3	0	109	6	184	-	-	7	137
	MH4	2	157	1	80	0	11	3	96
	MH5	0	66	0	165	0	3	3	85
	MH6	0	32	0	128	0	3	1	100
7	MH1	0	114	2	449	0	2	2	77
	MH2	0	121	5	338	0	2	18	257
	MH3	1	231	5	305	-	-	5	193
	MH4	1	361	0	124	1	15	2	121
	MH5	0	41	0	102	1	3	0	96
	MH6	0	6	0	67	-	-	0	21
8	MH1	0	154	1	833	0	1	0	332
	MH2	0	200	1	221	0	6	5	146
	MH3	0	356	2	332	-	-	1	183
	MH4	1	257	0	60	1	20	2	101
	MH5	0	42	0	133	0	3	1	85
	MH6	0	1	0	28	-	-	0	3

APPENDIX III Cont.

		Recovered 2000							
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	0	3	2	58	-	-	-	-
	MH2	0	5	2	37	-	-	0	16
	MH3	0	34	0	67	-	-	1	44
	MH4	0	111	3	51	0	2	0	37
	MH5	0	45	2	120	0	2	1	24
	MH6	0	70	0	159	0	1	0	102
6	MH1	0	10	0	162	-	-	0	2
	MH2	0	29	7	113	0	2	2	50
	MH3	0	109	0	256	0	1	7	142
	MH4	0	169	1	93	0	1	0	118
	MH5	0	50	0	89	-		0	21
	MH6	0	25	0	131	-		0	38
7	MH1	0	104	3	910	0	1	1	92
	MH2	0	82	4	292	0	15	10	213
	MH3	0	264	0	452	0	0	4	244
	MH4	0	349	1	78	-	-	0	154
	MH5	0	51	3	156	-	-	0	56
	MH6	0	11	0	61	-	-	0	13
8	MH1	0	106	0	1269	0	3	1	360
	MH2	0	232	1	149	0	7	3	145
	MH3	0	289	0	435	-	-	1	121
	MH4	0	255	2	30	-	-	0	123
	MH5	0	38	0	119	-	-	0	17
	MH6	0	2	0	54	-	-	0	2

APPENDIX IV

Number of tags recovered by year, statistical district and gear from fish released in MH3.

Recovered 1995									
Month	Stat. Dist.	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	1	57	-	-	1	-
	MH2	0	13	5	69	-	-	0	4
	MH3	0	28	0	74	0	2	1	12
	MH4	0	71	4	64	-	3	0	7
	MH5	0	52	0	85	-	-	6	149
	MH6	0	52	0	164	0	8	0	235
6	MH1	0	12	0	126	-	-	0	5
	MH2	0	38	15	192	0	3	1	57
	MH3	7	102	7	198	0	7	4	121
	MH4	1	138	0	77	0	19	2	106
	MH5	0	32	0	104	0	2	0	108
	MH6	0	21	0	164	-	-	0	40
7	MH1	0	93	0	512	0	1	2	81
	MH2	0	133	9	1064	0	3	20	193
	MH3	2	239	6	264	0	3	6	216
	MH4	0	236	0	121	-	22	0	136
	MH5	0	29	0	94	0	1	0	123
	MH6	0	14	0	183	-	-	0	2
8	MH1	0	140	0	696	0	1	0	491
	MH2	0	122	3	410	0	3	0	34
	MH3	2	294	3	279	4	2	10	279
	MH4	0	194	0	66	0	12	0	67
	MH5	0	51	0	81	0	1	0	110
	MH6	0	6	0	123	-	-	-	1

APPENDIX IV Cont.

Recovered 1996									
Month	Stat. Dist.	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	1	117	-	-	-	-
	MH2	0	16	13	130	-	-	4	22
	MH3	1	39	3	51	-	-	0	3
	MH4	1	77	0	64	0	6	1	72
	MH5	2	55	0	42	0	2	1	160
	MH6	0	57	1	204	0	7	0	335
6	MH1	0	8	2	113	-	-	-	-
	MH2	1	28	6	151	1	2	7	75
	MH3	6	112	3	112	0	1	3	49
	MH4	0	134	0	60	0	24	0	185
	MH5	0	39	0	32	0	4	0	100
	MH6	0	21	0	227	-	-	0	41
7	MH1	1	83	0	232	-	-	2	125
	MH2	0	101	8	934	1	3	15	152
	MH3	8	208	7	195	0	5	11	118
	MH4	0	222	0	97	0	33	0	234
	MH5	1	28	0	86	0	0	0	60
	MH6	0	13	0	71	-	-	0	21
8	MH1	0	144	0	942	-	-	1	415
	MH2	0	168	13	467	1	9	5	137
	MH3	7	347	11	585	0	3	3	129
	MH4	1	237	1	131	0	11	0	161
	MH5	1	71	1	208	0	0	0	80
	MH6	-	4	0	109	-	-	-	19

APPENDIX IV Cont.

Recovered 1997									
Month	Stat. Dist.	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	0	113	-	-	-	-
	MH2	2	19	4	64	-	-	-	-
	MH3	0	21	2	95	-	-	-	-
	MH4	0	108	1	102	3	8	0	20
	MH5	0	58	1	172	0	4	1	93
	MH6	0	59	0	315	0	9	0	336
6	MH1	0	3	0	98	-	-	-	-
	MH2	0	23	7	264	0	1	0	98
	MH3	0	116	5	251	0	1	8	156
	MH4	1	154	3	170	1	16	11	127
	MH5	1	34	0	144	0	5	2	81
	MH6	0	28	0	121	-	-	2	30
7	MH1	0	96	2	317	0	2	0	48
	MH2	0	121	1	790	1	17	13	430
	MH3	6	201	7	339	0	1	4	162
	MH4	0	231	1	145	0	14	1	100
	MH5	0	21	0	93	0	3	0	108
	MH6	0	19	0	142	-	-	0	31
8	MH1	0	134	0	836	-	1	0	400
	MH2	0	201	4	653	0	7	1	135
	MH3	1	341	3	537	0	1	2	185
	MH4	0	195	0	48	0	11	2	94
	MH5	0	58	1	157	0	0	2	92
	MH6	0	10	0	134	-	-	-	-

APPENDIX IV Cont.

Recovered 1998									
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	0	40	-	-	-	-
	MH2	0	15	0	164	-	-	-	-
	MH3	0	45	5	124	1	2	3	59
	MH4	0	157	0	91	0	8	2	61
	MH5	2	90	0	91	-	-	4	46
	MH6	0	51	0	126	-	-	0	183
6	MH1	0	16	0	113	-	-	0	2
	MH2	0	25	1	243	-	-	0	76
	MH3	1	133	19	238	0	3	7	137
	MH4	1	208	0	89	1	17	3	112
	MH5	0	43	0	77	-	-	0	78
	MH6	0	32	0	185	0	1	0	84
7	MH1	0	90	0	312	-	-	1	60
	MH2	0	131	1	752	0	13	0	262
	MH3	0	228	8	358	0	4	0	256
	MH4	1	340	0	107	1	15	2	181
	MH5	0	42	0	158	-	-	0	76
	MH6	0	38	0	105	-	-	0	8
8	MH1	0	158	0	386	-	-	0	251
	MH2	0	208	0	511	0	8	1	126
	MH3	2	346	7	536	-	-	0	118
	MH4	4	265	0	82	0	8	2	195
	MH5	1	93	0	228	0	3	0	39
	MH6	0	18	0	62	-	-	-	-

APPENDIX IV Cont.

		Recovered 1999							
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	1	75	-	-	-	-
	MH2	0	8	0	66	-	-	0	2
	MH3	0	24	3	100	-	-	3	52
	MH4	10	154	3	123	6	2	5	96
	MH5	0	27	0	202	-	-	2	48
	MH6	0	98	0	163	-	-	0	116
6	MH1	0	17	1	159	-	-	0	9
	MH2	0	19	1	126	0	1	2	35
	MH3	0	109	5	184	-	-	6	137
	MH4	1	157	4	80	2	11	9	96
	MH5	0	66	1	165	0	3	0	85
	MH6	0	32	0	128	0	3	0	100
7	MH1	0	114	0	449	0	2	0	77
	MH2	0	121	1	338	0	2	3	257
	MH3	0	231	4	305	-	-	7	193
	MH4	0	361	0	124	0	15	1	121
	MH5	0	41	0	102	0	3	0	96
	MH6	0	6	0	67	-	-	0	21
8	MH1	0	154	0	833	0	1	0	332
	MH2	0	200	0	221	0	6	0	146
	MH3	0	356	1	332	-	-	0	183
	MH4	0	257	0	60	2	20	0	101
	MH5	0	42	0	133	0	3	1	85
	MH6	0	1	0	28	-	-	0	3

APPENDIX IV Cont.

		Recovered 2000							
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	0	3	0	58	-	-	-	-
	MH2	0	5	1	37	-	-	2	16
	MH3	0	34	0	67	-	-	2	44
	MH4	0	111	0	51	0	2	0	37
	MH5	0	45	0	120	0	2	0	24
	MH6	0	70	0	159	0	1	0	102
6	MH1	0	10	0	162	-	-	0	2
	MH2	0	29	1	113	0	2	0	50
	MH3	0	109	0	256	0	1	3	142
	MH4	0	169	1	93	0	1	0	118
	MH5	0	50	0	89	-		0	21
	MH6	0	25	0	131	-		0	38
7	MH1	0	104	0	910	0	1	0	92
	MH2	0	82	2	292	0	15	0	213
	MH3	0	264	0	452	0	0	5	244
	MH4	0	349	0	78	-	-	0	154
	MH5	0	51	2	156	-	-	0	56
	MH6	0	11	0	61	-	-	0	13
8	MH1	0	106	0	1269	0	3	0	360
	MH2	0	232	0	149	0	7	0	145
	MH3	0	289	0	435	-	-	0	121
	MH4	0	255	0	30	-	-	0	123
	MH5	0	38	0	119	-	-	0	17
	MH6	0	2	0	54	-	-	0	2

APPENDIX V

Number of tags recovered by year, statistical district and gear from fish released in MH4.

Recovered 1995									
Month	Stat. Dist.	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	0	57	-	-	0	-
	MH2	0	13	0	69	-	-	0	4
	MH3	0	28	0	74	0	2	0	12
	MH4	0	71	2	64	-	3	0	7
	MH5	0	52	0	85	-	-	0	149
	MH6	0	52	0	164	0	8	0	235
6	MH1	0	12	0	126	-	-	0	5
	MH2	0	38	1	192	0	3	0	57
	MH3	1	102	0	198	0	7	1	121
	MH4	0	138	1	77	0	19	1	106
	MH5	0	32	1	104	0	2	0	108
	MH6	0	21	0	164	-	-	0	40
7	MH1	0	93	0	512	0	1	0	81
	MH2	0	133	0	1064	0	3	1	193
	MH3	0	239	1	264	0	3	1	216
	MH4	0	236	0	121	-	22	0	136
	MH5	0	29	0	94	0	1	0	123
	MH6	0	14	0	183	-	-	0	2
8	MH1	0	140	0	696	0	1	0	491
	MH2	0	122	0	410	0	3	0	34
	MH3	0	294	2	279	1	2	1	279
	MH4	0	194	0	66	0	12	0	67
	MH5	0	51	0	81	0	1	0	110
	MH6	0	6	0	123	-	-	-	1

APPENDIX V Cont.

Recovered 1996									
Month	Stat. Dist.	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	0	117	-	-	-	-
	MH2	0	16	0	130	-	-	0	22
	MH3	0	39	1	51	-	-	0	3
	MH4	0	77	0	64	0	6	0	72
	MH5	1	55	0	42	0	2	0	160
	MH6	0	57	0	204	0	7	1	335
6	MH1	0	8	0	113	-	-	-	-
	MH2	0	28	0	151	0	2	0	75
	MH3	0	112	1	112	0	1	1	49
	MH4	1	134	1	60	1	24	1	185
	MH5	0	39	0	32	0	4	0	100
	MH6	0	21	0	227	-	-	0	41
7	MH1	0	83	0	232	-	-	0	125
	MH2	0	101	0	934	0	3	0	152
	MH3	0	208	1	195	0	5	0	118
	MH4	2	222	2	97	1	33	0	234
	MH5	1	28	1	86	0	0	0	60
	MH6	0	13	0	71	-	-	0	21
8	MH1	0	144	0	942	-	-	0	415
	MH2	0	168	1	467	1	9	0	137
	MH3	2	347	1	585	0	3	0	129
	MH4	0	237	1	131	1	11	1	161
	MH5	1	71	2	208	0	0	0	80
	MH6	-	4	0	109	-	-	-	19

APPENDIX V Cont.

Recovered 1997									
Month	Stat. Dist.	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	0	113	-	-	-	-
	MH2	0	19	0	64	-	-	-	-
	MH3	0	21	0	95	-	-	-	-
	MH4	0	108	1	102	2	8	0	20
	MH5	0	58	0	172	0	4	1	93
	MH6	0	59	0	315	0	9	0	336
6	MH1	0	3	0	98	-	-	-	-
	MH2	0	23	0	264	0	1	0	98
	MH3	0	116	0	251	0	1	0	156
	MH4	0	154	0	170	1	16	3	127
	MH5	0	34	0	144	1	5	0	81
	MH6	0	28	0	121	-	-	0	30
7	MH1	0	96	0	317	0	2	0	48
	MH2	0	121	0	790	0	17	0	430
	MH3	0	201	2	339	0	1	2	162
	MH4	2	231	0	145	0	14	0	100
	MH5	1	21	0	93	0	3	0	108
	MH6	0	19	0	142	-	-	0	31
8	MH1	0	134	0	836	-	1	0	400
	MH2	0	201	0	653	0	7	0	135
	MH3	0	341	1	537	0	1	0	185
	MH4	1	195	1	48	0	11	2	94
	MH5	2	58	0	157	0	0	2	92
	MH6	0	10	0	134	-	-	-	-

APPENDIX V Cont.

Recovered 1998									
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	0	40	-	-	-	-
	MH2	0	15	0	164	-	-	-	-
	MH3	0	45	0	124	0	2	1	59
	MH4	0	157	0	91	0	8	2	61
	MH5	2	90	0	91	-	-	7	46
	MH6	0	51	0	126	-	-	1	183
6	MH1	0	16	0	113	-	-	0	2
	MH2	0	25	0	243	-	-	0	76
	MH3	0	133	3	238	0	3	1	137
	MH4	1	208	0	89	5	17	11	112
	MH5	0	43	0	77	-	-	2	78
	MH6	0	32	0	185	0	1	2	84
7	MH1	0	90	0	312	-	-	0	60
	MH2	0	131	0	752	0	13	0	262
	MH3	0	228	3	358	0	4	0	256
	MH4	4	340	0	107	2	15	2	181
	MH5	0	42	0	158	-	-	1	76
	MH6	0	38	0	105	-	-	0	8
8	MH1	0	158	0	386	-	-	0	251
	MH2	0	208	0	511	0	8	0	126
	MH3	0	346	2	536	-	-	0	118
	MH4	9	265	0	82	3	8	2	195
	MH5	1	93	0	228	0	3	0	39
	MH6	0	18	0	62	-	-	-	-

APPENDIX V Cont.

		Recovered 1999							
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	-	-	1	75	-	-	-	-
	MH2	0	8	0	66	-	-	0	2
	MH3	0	24	0	100	-	-	1	52
	MH4	2	154	1	123	6	2	7	96
	MH5	0	27	0	202	-	-	4	48
	MH6	0	98	1	163	-	-	0	116
6	MH1	0	17	1	159	-	-	0	9
	MH2	0	19	1	126	0	1	0	35
	MH3	0	109	0	184	-	-	2	137
	MH4	2	157	0	80	2	11	12	96
	MH5	0	66	2	165	1	3	2	85
	MH6	0	32	1	128	0	3	1	100
7	MH1	0	114	0	449	0	2	0	77
	MH2	0	121	0	338	0	2	1	257
	MH3	0	231	1	305	-	-	0	193
	MH4	0	361	0	124	3	15	2	121
	MH5	0	41	0	102	0	3	0	96
	MH6	0	6	0	67	-	-	1	21
8	MH1	0	154	0	833	0	1	0	332
	MH2	0	200	0	221	0	6	0	146
	MH3	0	356	0	332	-	-	0	183
	MH4	0	257	0	60	5	20	0	101
	MH5	0	42	0	133	0	3	0	85
	MH6	0	1	0	28	-	-	0	3

APPENDIX V Cont.

		Recovered 2000							
Month	Statdist	CBT tags	CBT trips	CCK tags	CCK trips	HHB tags	HHB trips	HHR tags	HHR trips
5	MH1	0	3	0	58	-	-	-	-
	MH2	0	5	0	37	-	-	0	16
	MH3	0	34	0	67	-	-	0	44
	MH4	0	111	2	51	0	2	1	37
	MH5	0	45	1	120	0	2	0	24
	MH6	0	70	0	159	0	1	0	102
6	MH1	0	10	0	162	-	-	0	2
	MH2	0	29	0	113	0	2	0	50
	MH3	0	109	0	256	0	1	0	142
	MH4	0	169	5	93	0	1	0	118
	MH5	0	50	2	89	-		0	21
	MH6	0	25	0	131	-		0	38
7	MH1	0	104	1	910	0	1	0	92
	MH2	0	82	0	292	0	15	0	213
	MH3	0	264	0	452	0	0	5	244
	MH4	0	349	0	78	-	-	0	154
	MH5	0	51	1	156	-	-	0	56
	MH6	0	11	0	61	-	-	0	13
8	MH1	0	106	0	1269	0	3	0	360
	MH2	0	232	0	149	0	7	0	145
	MH3	0	289	1	435	-	-	0	121
	MH4	0	255	1	30	-	-	0	123
	MH5	0	38	0	119	-	-	0	17
	MH6	0	2	0	54	-	-	0	2