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EVALUATION OF MODIFICATIONS TO TRAP NETS FOR REDUCING GILLING IN A COMMERCIAL WHITEFISH FISHERY[1]

Kelley D. Smith

[1]Contribution from Anadromous Fish Conservation Project 15, Michigan

ABSTRACT

Large-mesh trap nets, which are used in Lake Michigan for harvesting lake whitefish *Coregonus clupeaformis* commercially, were modified to determine if gilling mortality of non-target species in the pot could be decreased significantly. Modifications were made by reducing the mesh size in the rear corners of the pot and over the tunnel using shoaling twine panels. One-half of each fisherman's nets were modified for each pot size he owned. Control nets were not changed in any way. Two fishermen from the port of Muskegon on Lake Michigan were both monitored a minimum of twice weekly from May to October during 1985 and 1986. Results indicated that changes made to the nets were effective in reducing incidental gilling mortality of non-target species in the modified areas. This decrease was especially significant in the area over the tunnel of the net. However, mortalities were not significantly different for any of the non-target species studied when comparing total performance of control and modified nets. The effects of water temperature at the pot, water depth at the pot, and soak time was not correlated with either whitefish harvest or gilling rates observed for non-target species. Modifications had no detrimental effects on whitefish harvest and, in fact, modified nets harvested significantly higher numbers of whitefish than did control nets in many of the months sampled. Lake trout *Salvelinus namaycush* was the most abundant non-target species in the nets with 72 caught per lift (18,389 ± 4,545 fish) in 1985 and 88 per lift (46,960 ± 6,406 fish) in 1986. Approximately 1,500 of the lake trout caught each year died as a result of gilling. The remaining non-target species studied occurred in the nets in relatively small numbers when compared to lake trout. Yellow perch *Perca flavescens* had the highest abundance of these species, totalling 2,397 (± 404) fish caught in both years combined. They were followed by salmon *Oncorhynchus* spp. (947 ± 168 fish), walleye *Stizostedion vitreum* (769 ± 215 fish), brown trout *Salmo trutta* (202 ± 63 fish), and steelhead *Salmo gairdneri* (47 ± 41 fish), in that order. On the average, 60% to 80% of all yellow perch, salmon, and steelhead caught each year died from gilling, compared to only 20% for brown trout and 13% for walleye. Gilling of lake trout in the pots of these nets (4.5-inch stretched mesh) was very selective. Average age of lake trout gilled ranged from 5.5 to 5.8 years with an average size of 23.6 to 24.3 inches. Recommendations are discussed that have potential for reducing the non-target mortalities observed in this fishery. These include season closures, gear restrictions, and other types of net modifications. At a minimum, a shoaling twine panel in the top of the pot over the tunnel area should be enforced in all large-mesh trap-net fisheries.

INTRODUCTION

Both gill nets and large-mesh trap nets have been used in Lake Michigan to commercially harvest lake whitefish *Coregonus clupeaformis* and lake trout *Salvelinus namaycush* since the mid to late 1800s (Koelz 1926; Van Oosten et al. 1946; Buettner 1965; Wells and McLain 1973). The total demise of lake trout stocks in Lake Michigan during the mid-1950s (see e.g., Eschmeyer 1957; Buettner 1965; Smith 1968; Wells and McLain 1972) caused the Michigan Department of Natural Resources (MDNR) to ban all commercial fishing for lake trout in the 1960s. Later, in the mid-1970s, the MDNR outlawed the use of gill nets for harvesting whitefish commercially because this type of gear precluded restoration of the lost lake trout stocks. It was believed that passive impoundment type gear, such as trap nets, could be fished selectively because they hold fish alive until harvest thus allowing non-target species to be released unharmed. For this reason, all current Michigan-licensed commercial fishermen who utilize impoundment gear to harvest whitefish do so exclusively with large-mesh trap nets. However, gilling mortality of non-target species in these nets has recently gained wide notoriety in light of both the above mentioned rehabilitation efforts for lake trout and the rapidly expanding sport fishery.

The aggressive salmonid stocking program of the MDNR and other agencies has created a high quality sport fishery throughout Lake Michigan (Rakoczy and Rogers 1987a and 1987b). This, in turn, has given anglers greater motivation to voice their concerns about the management of the Great Lakes fish stocks, and they are now demanding further regulation of commercial fisheries to the point of prohibition. It is becoming increasingly evident that the future of commercial fishing depends on whether or not incidental gilling mortality of sport fishes can be reduced to levels which are satisfactory to anglers in a given area. Therefore, fishery managers must determine which factors might be manipulated in the commercial operation to diminish this mortality for all species which are of great sport value.

Sources of mortality in trap nets can be attributed to uncontrollable environmental conditions (e.g., currents and water temperature) or to controllable man-made causes. The latter group includes soak time, speed of lifting, mesh size, and specific net modifications, all of which can be manipulated to try and reduce the number of non-target species killed (Eshenroder 1980; Schneeberger et al. 1982). Actual gilling, wedging, or entanglement in the pot, heart, and leads can often be attributed to the way in which fishermen operate their nets (Schneeberger et al. 1982; Hubert 1983; Rutecki et al. 1983). Although mortality from such causes is known to exist, only a few projects have been undertaken to determine the extent of mortality, the operational mechanisms affecting the level of mortality, or changes in net design that might decrease gilling problems (Eshenroder 1980; Schneeberger et al. 1982; Rutecki et al. 1983; Schorfhaar 1987).

Modifications to trap nets were first used by Eshenroder (1980) to successfully reduce gilling mortality of lake trout in a Lake Huron commercial whitefish fishery. However, Eshenroder's Lake Huron results may not be applicable to commercial operations on Lake Michigan because the habitat types, currents, prevailing winds, and abundance of non-target species can all differ dramatically between the two lakes. Consequently, it was believed necessary to repeat the Lake Huron experiment in Lake Michigan prior to implementing full-scale modifications to the Lake Michigan trap-net operations. This study deals with assessing the effect of these modifications to large-mesh trap nets on incidental mortality of non-target species in a Lake Michigan commercial whitefish fishery.

METHODS

Two commercial fishermen from the port of Muskegon on Lake Michigan (southeastern Lake Michigan) were chosen as cooperators for this study. The pots used by these fishermen to harvest whitefish were constructed of nylon (15 thread size) with a 4.5-inch stretched-mesh measure. Pot sizes used were 12, 20, or 30 feet in depth depending on fishing location. The hearts and tunnel areas were constructed of nylon (15 thread size) with a 5-inch stretched-mesh measure. Leads were also constructed of nylon (15 to 18 thread size) with a 13- to 14-inch stretched-mesh measure. Leads ranged from 800 to 1,200 feet in length, again depending on fishing location and net size. Nets were fished from 20 to 90 foot depths as mandated by season, water temperatures, and thus fish movements; a maximum fishing depth of 90 feet is allowed by State law.

Each fisherman modified one-half of his nets for each pot size he owned and planned to fish during the season (hereafter designated as 12-, 20-, or 30-foot pot nets, modified or control). The pots were modified using shoaling twine panels (2.5-inch stretched-mesh measure) in the rear corners and over the tunnel as described by Eshenroder (1980). All corner panels were 4 feet by 4 feet in size and the tunnel panel was 4 feet wide. The upper rear corners were covered on the top and each side (three panels) while the lower rear corners were covered only on the two sides (Figure 1). The control nets were not modified in any way.

Both operations were monitored during 1985 and 1986. The nets were fished in matched pairs (modified and control) by pot size during both fishing seasons. This resulted in sets of 12- and 20-foot nets only in 1985 as neither fisherman had more than one 30-foot net. However, both fishermen acquired additional 30-foot nets in 1986 and these were then fished in matching pairs during the second season of data collection. The net pairs were fished in close proximity to each other so that habitat type, water temperature at the pot, and water depth at the pot were the same for each net of a matched set.

Two rides with each fisherman per week was the sampling goal. The sampling period during both years ran from May through October. The MDNR prohibits commercial harvest of whitefish during November to protect spawning stocks, and poor weather conditions permit very little, if any, trap-net fishing during the period of December through March or April.

Data were recorded for lake trout, steelhead *Salmo gairdneri*, brown trout *Salmo trutta*, salmon *Oncorhynchus* spp., yellow perch *Perca flavescens*, and walleye *Stizostedion vitreum*. The information taken for these species included total number gilled, area of the net where each fish was gilled (Figure 1), number of gilled fish that were alive when released, number of gilled fish that were dead, and the numbers that were bailed from the pot. Additional data recorded for each net consisted of the number of sublegal whitefish released and legal whitefish harvested, surface and bottom water temperatures, and water depth at the pot. Because so few observations were made on gilling in the hearts and leads, no analysis or discussion of the data collected from these areas of the nets is included in this paper. Lengths and scale samples of lake trout that died from gilling were taken during September and October in 1985 and the entire fishing season in 1986. These data were not collected for the other non-target species because so few were observed gilled in the pots.

Data were analyzed through a variety of means using the Michigan Interactive Data Analysis System (MIDAS) described by Fox and Guire (1973). Analysis of variance (ANOVA) and the Kruskal-Wallis test (Conover 1971) were used to determine differences in harvest of whitefish, catch of other species, and gilling mortality of non-target species between fishermen and years for each pot size. Analysis of covariance (ANCOVA; Snedecor and Cochran 1967) using water temperature at the pot, water depth at the pot, and soak time as covariates was done according to the method of Hamley and Howley (1985). Abundance in the net of all fish, of whitefish, of lake trout, or of dead (gilled) lake trout were analyzed to study differences between months, years, pot sizes, and net types (modified or control). These relationships were tested using each covariate individually and using combinations of temperature with soak time and depth with soak time. Data were pooled for both fishermen within each year before use in the ANCOVA model.

RESULTS

A combined total of 255 lifts in 1985 and 529 in 1986 were reported by both fishermen. Of these, 76 (29.8%) and 136 (25.7%) were monitored in 1985 and 1986, respectively (Table 1). No data were collected in May of 1985 due to poor weather, vessel repairs, and monitoring problems. About 25% of the lifts each month were observed by the monitor in both years.

Average water temperatures at the pot ranged from a low of 54.3 °F in June to a high of 62.7 °F in September during 1985 and from 46.3 °F in May to 62.9 °F in September during 1986 (Figure 2). Monthly water temperatures were extremely variable in this portion of Lake Michigan due to frequent changes in wind and current directions. For example, it was not unusual to find temperatures in the high 50's one day and in the low to mid-40's the next.

However, average water temperatures did follow a very similar monthly pattern in both years with 1986 being slightly cooler on the average than 1985.

Soak time, or the time between lifts of a given net, was fairly consistent, ranging on the average between 4 and 6 days in most months (Figure 3). The variability associated with the monthly mean soak times depended mainly on the weather in both years as, after May, 1985, neither fisherman had gear or vessel problems. Blow days are fairly common for these fishermen and it is not unusual to see soak times in the range of 10 to 12 days during some months. Also, both fishermen had commercial chub *Coregonus hoyi* operations. Thus, they tended to be somewhat opportunistic in utilizing their effort depending on which fishery was producing at the time (i.e., chubs or whitefish). Both of these factors were instrumental in determining the actual soak times observed in these trap-net operations.

No significant differences could be found between fishermen for the number of lifts by month, water temperature at the pot, soak times, depths fished, the number of whitefish harvested, the number of non-target species in the nets, or the number of non-target species gilled in the nets using the Kruskal-Wallis test and ANOVA ($P > 0.10$). This is not unexpected as these two fishermen have very similar operating strategies. They not only dock side by side, but they tend to fish in close proximity to each other and utilize shared information to enhance their harvest. There was also no correlation between water temperature and depth at the pot ($P > 0.10$). This seems reasonable as the surface and bottom temperatures were often the same over the range of depths at which these fishermen were setting their nets. These results allowed the data for both fishermen to be pooled in all remaining analyses.

The effects of the three covariates (water temperature, depth at the pot, and soak time) alone or in combination were not significant in explaining the observed abundance or gilling mortality for any species within a year ($P > 0.10$). Differences associated with months, pot sizes, or net types within each year were most likely masked because of either the small sample sizes created by the stratification of the data or the extreme and unexplainable variability of these data. The abundance of whitefish and lake trout in the nets was different between 1985 and 1986 ($P < 0.01$), but gilling rates were not ($P > 0.10$). The mechanisms affecting abundance while gilling levels remained constant could not be statistically related to any of the factors studied. For example, the number per net lift (CPE) of whitefish, lake trout, or dead lake trout shows essentially no trends with water temperature or soak time (Figures 4 and 5).

Modifications to these nets did not result in less gilling mortality for any of the non-target species regardless of pot size. However, the explanation for this phenomenon was different for lake trout than it was for the other non-target species. When a net is lifted lake trout tend to move towards the corners of the nets in their attempts to escape. In contrast, the other species do not demonstrate this behavior and gilling occurs more often in the sides or top of the net. Thus, the fact that lake trout gilling was not reduced is due to a failure of the net modifications, whereas, for the other non-target species, the changes in net design were ineffective because of the innate behavior of these species once they are impounded.

The corners and tunnel area in modified nets did have significantly fewer numbers of lake trout gilled per lift (the most abundant of the non-target species) than in the same areas of control nets. However, the reverse was true in all other areas resulting in about the same gilling rate for both types of nets (Figure 6). The most significant difference occurred in the area over the tunnel (area C in Figure 6) where the number of lake trout gilled per lift was 18.4 times greater in the control nets than in the modified nets. The spatial distribution of gilling for the remaining non-target species was very consistent for both control and modified nets. Gilling in the corner areas of both net types was almost non-existent while both control and modified nets contained similar numbers of gilled fish in the sides and top.

Whitefish

The two commercial operations at Muskegon have a combined average harvest of 150,000 to 200,000 pounds of whitefish annually. The estimated number of whitefish harvested was 13,138 (±2,430) fish and 46,675 (±6,361) fish in 1985 and 1986, respectively. This harvest was not affected by the modifications made to the nets for any of the three pot sizes tested. Control nets actually caught fewer whitefish per lift on the average than did the modified nets (Figure 7). Control nets had higher CPE's only in June and July during 1985 and August and September during 1986.

Few juvenile whitefish were observed during either fishing season and very few whitefish of any size were found gilled in the nets. The whitefish stocks in the Muskegon area have exhibited fast growth and good recruitment for the last decade (R. Rybicki, personal communication, MDNR, Charlevoix). Thus, either the small juvenile whitefish are not in the areas of operation, or they tend to slip through the large-mesh pots as they are lifted.

Lake trout

Lake trout was the most abundant of all species captured in both years and usually exceeded even the number of whitefish harvested. The number of lake trout in the nets ranged from 18,389 (±4,545) fish in 1985 to 46,960 (±6,406) fish in 1986. Caution must be exercised in interpreting the magnitude of the estimated lake trout catches. Whereas whitefish are removed from the lake and are therefore only counted once, many individuals of each non-target species were returned to the water alive. No method (e.g., tagging released fish) was implemented to determine the level of recapture. Thus, the estimated catch of each non-target species is most likely too high, especially in the case of lake trout. Although this bias affects point estimates of fish abundance, it persisted throughout the entire study for all species. This allowed the assumption that any observed trends in the data were real.

There was no statistical difference in the number of lake trout caught per net lift between control and modified nets except in July of 1985 (Figure 8). Either type of net could have more lake trout than the other in any month with no discernible pattern or mechanism accounting for the abundance.

Whereas total lake trout density in the nets was estimated high because of repeat captures, the predicted number of dead (gilled) lake trout was very accurate as these fish, like whitefish, were removed from the fishable population. The estimated number of dead lake trout in all nets was 1,327 (±431) fish and 1,220 (±270) fish in 1985 and 1986, respectively, even though the number of lifts in 1986 was twice that of 1985. Gilling mortalities were highly variable between months in 1985 with large numbers of dead trout observed in July and August (Figure 9). The 1985 seasonal average of 5.2 (±1.7) dead trout per lift was more than twice that observed in 1986 (2.3 ± 0.5). Monthly average mortalities in the second year were generally lower than in 1985 and showed little variation throughout the fishing season.

Neither the number of lake trout nor the number of dead (gilled) lake trout were affected by whitefish abundance in either net type. Lake trout CPE's were generally higher than those for whitefish in all months except October during both years (Figure 10). The number of dead lake trout per lift was low compared to whitefish CPE's, regardless of whitefish abundance (Figure 11).

Modified nets were as likely to cause mortality from gilling as control nets in any month for any pot size. In fact, modified nets had the highest estimated mortality (17 trout per lift) in August of 1985 and the lowest (less than 1 trout per lift) in October of 1986. As stated above, water temperature, depth at the pot, soak time, and whitefish abundance in the nets showed no relationship with the number of dead trout observed per lift (Figures 4, 5, and 11). The density of lake trout in the nets also showed no direct relation to the number of trout killed (Figure 12). This was demonstrated by the fact that the percent of the total lake trout catch which died from gilling was very consistent from month to month within years, averaging about 6% in 1985 and 3% in 1986.

Scale samples and length data taken from the dead lake trout showed that the 4.5-inch mesh used in these nets was very selective in the age and size of trout killed (Tables 2 and 3). Mean age and length differences between years, months, pot sizes, and net types were insignificant. Trout that were lost to gilling in the fall of 1985 averaged about 5.5 (±0.2) years of age with an average length of 24.3 (±0.4) inches. In 1986 which included samples for the entire fishing season, the average age was 5.5 (±0.1) years and length was 23.6 (±0.2) inches.

Other non-target species

The remaining species for which data were collected include steelhead, brown trout, salmon, yellow perch, and walleye. The occurrence of these species in the nets, in contrast to lake trout, was very low. Yellow perch was the most abundant (810 ± 253 and 1,587 ± 315 fish in 1985 and 1986, respectively) with salmon, walleye, and brown trout following in that order. Only 47 steelhead were estimated caught during both years combined.

CPE's for steelhead were equal in both fishing seasons as was true for yellow perch (Tables 4 and 5). The number of fish per lift for brown trout, salmon, and walleye was much higher for each in 1985 than in 1986. Again, as was the case for lake trout, gilling mortalities of these species could not be related to any of the factors studied. Steelhead mortality per lift in 1985 was only half that observed in 1986 even though the CPE's for the 2 years were essentially equal (Tables 6 and 7). The opposite was true for yellow perch with 1986 showing a considerably lower number of dead fish per lift than in 1985. Although the number of walleye gilled per lift that died was 4.5 times greater in 1985 than in 1986, the percent of all walleye caught that were killed was equal in both years and averaged about 13% (Figure 13). Both steelhead and brown trout showed a pronounced increase in the percentage of fish that died from gilling during 1986 as compared to 1985, whereas salmon and yellow perch showed a decrease. These results corresponded quite well with observed trends in the estimated number killed per lift.

DISCUSSION

The statistical analyses showed no significant effects of water temperature, depth fished, soak time, or net modifications on abundance of fish or levels of gilling mortality in any size net. This could be due to not collecting data often enough in comparison with the rapid changes taking place in, for example, temperatures at the various depths fished, or perhaps these factors were not the main forces regulating the observed catches or mortalities. The former possibility is the more probable explanation. Even monitoring every lift throughout the year may only have slightly decreased the amount of unexplained variation in these measurements. This is because the sampling schedule would still be determined by the long soak times (4 to 6 days) observed which are mainly the result of weather conditions on the lake. Given that water temperature can often be responsible for the spatial distribution of fish in the lake, rapid changes in temperature due to wind would also be expected to cause significant movement of fish onshore and offshore. These changes can take place within 24 hours, and it is easy to discern a number of abrupt changes in a 4 to 6 day period that would be missed utilizing the present sampling design.

Water temperature at the pot had little effect on the density of fish in the nets during both years. Although a slight decreasing trend was observed for both whitefish and lake trout abundance in 1985, there was no indication of any temperature effect on density in 1986 or on gilling mortality for lake trout in either year. Other studies have also concluded that temperature and depth did not seem to affect mortality of fish in trap nets or sport fisheries. Van Oosten et al. (1946) reported that the percent of fish gilled in trap nets of commercial fisheries on both lakes Huron and Michigan could not be explained by the depth, month, or habitat in which the nets were fished. Loftus et al. (1986) found that mortality of hooked-and-released lake trout in a Lake Michigan sport fishery was not affected by the depth at which the fish were caught or the temperature differential from the point of capture to the surface of the lake.

The inability to explain the variation in abundance or gilling mortality as a function of soak time was probably due to the lack of data for short soak periods (1 to 3 days), and the overabundance of measurements for longer times. Approximately 5% of the variability in the gilling data was explained by soak time. Hamley and Howley (1985) attributed 50% to 65% of the variation in trap-net catches to differences in soak time, sampling location, and season. However, they found that catches increased in proportion to soak times of 1 to 3 days, but not beyond. A similar pattern was observed for lake trout abundance in this study but not for numbers of either whitefish or dead (gilled) lake trout. Hamley and Howley believed that the unexplained variation in the trap-net catches was most likely influenced by the effects of wind and water currents on water temperature and thus the movement of fish.

Van Oosten (1935) and Grinstead (1970) both observed that catches increased with soak time of the nets, but not proportionally. A similar trend was observed for whitefish and lake trout abundance in this study during 1986 but not in 1985. The number of both whitefish and lake trout in the nets decreased to zero as soak time approached 6 to 8 days during 1985. It is possible that this result was caused by escapement from the nets during these longer soak periods. Patriarche (1968) found that escapement of warm-water species from trap nets in inland lakes could be fairly substantial with increasing soak times. However, Rutecki et al. (1983) used direct underwater observations to conclude that neither whitefish nor lake trout exhibited escapement behavior in a Lake Huron trap-net fishery. Thus, the explanations for the trends observed in this study are unclear.

The fact that net modifications were not effective in reducing gilling mortality of any non-target species is opposite of the results reported by Eshenroder (1980) for lake trout. He found that the same net modifications as used in this study reduced lake trout gilling mortality by 60% compared to his control net. The differences in these results are most likely related to density of fish in the nets. Eshenroder reported a CPE of 21.7 and 7.7 trout per lift in the control and modified nets, respectively. This is well below the average of 70 to 90 trout per lift in control and modified nets observed in these Lake Michigan operations. Both Schneeberger et al. (1982) and Rutecki et al. (1983) reported that the density of fish in the nets had significant affects on gilling rates, especially when the nets were lifted during the harvest operation.

The failure of the modifications to reduce mortality also appears to be a function of the behavior of the different species once they became impounded. Very little gilling of lake trout or whitefish occurs until lifting commences (Rutecki et al. 1983). Once this operation begins, both species tend to move towards the back of the net. As the fish become more crowded, their attempts to escape increase dramatically which in turn enhances the chances of gilling. Many direct observations were made during both monitoring periods of lake trout bouncing off the shoaling twine panels in the corners of modified nets, only to become gilled in a subsequent escape attempt in the top or sides of the net just outside these smaller-mesh areas. However, the remaining non-target species studied often became gilled quite soon after entering the nets. Although no clear evidence can be given for this fact, it is implied in that many of the gilled lake trout were still alive when released whereas most of the other species gilled were already dead when the net was lifted. The reasons for the differing behavior of these species after becoming impounded is yet unknown.

The results of the current study and those reported by Eshenroder (1980) did show that high levels of gilling in the control nets occur in the mesh directly above the tunnel area. Almost all of this gilling is a function of both the lifting operation and the bailing of fish from the net (Schneeberger et al. 1982; Rutecki et al. 1983).

Whitefish

Whitefish harvest by the two commercial fishermen was not affected by net modifications. In many cases, higher CPE's of legal whitefish were observed in modified as compared to control nets. Eshenroder (1980) reported that the commercial fisherman who cooperated in his study was concerned about shading created in the tunnel area by the smaller-mesh shoaling panel during moonlit nights. This shading effect was deemed responsible for a decrease in harvest during the period of a full moon because it inhibited whitefish entry into the net. However, no conclusive evidence was available that correlated lower harvests with these time periods during the month. No such findings were reported by the fishermen cooperating in this study and, in fact, both realized that the modified nets were harvesting a greater number of whitefish as compared to control nets.

Whitefish abundance was not correlated with gilling mortality of any species in any type of net. An attempt was made to fit the regression model relating whitefish and lake trout abundance to whitefish gilling rates as reported by Schneeberger et al. (1982), but the regression was not statistically significant. In general, very few whitefish were found gilled in these nets which could be the reason for the poor fit of the model.

Sublegal whitefish (less than 19 inches) were rarely observed in the nets even though the whitefish stocks off Muskegon have exhibited very good recruitment for quite some time. Either these fish were able to escape from the net during lifting as observed by Rutecki et al. (1983) in the Lake Huron fishery, or the operations monitored tend not to set nets in habitats frequented by juvenile whitefish.

Lake trout

Lake trout gilling mortality was very consistent during each year and showed no trend with increasing water temperatures, soak times, or density of whitefish or lake trout for all net sizes and types. This implies that some other factor, or combination of factors, not readily perceived is regulating gilling mortality. Because of the high density of trout and whitefish in these nets, a feasible explanation is the area available for gilling itself. Although not analyzed in this report, there does appear to be an increasing trend in mortality as a function of net size.

Gilling mortality rates in trap nets can be compared using a ratio of bailed to gilled fish for each net as an index. The higher the ratio, the more efficient the net is at preventing gilling mortality. Eshenroder (1980) estimated lake trout bailed to gilled ratios on the order of 5.8 for his control net and 18.6 for the modified net. Schorfhaar (1987) had an average ratio of 8.6 during the period 1983–86 in unmodified nets fished in Lake Superior. Similar ratios in the Lake Michigan fishery ranged from 7.3 to 13.2 for control nets and from 7.2 to 15.6 for modified nets during 1985 and 1986, respectively. More than 62% of the trout gilled in Eshenroder's control net were found in the three areas considered for modification (areas A, B, and C in Figure 1), of which 46% were located in the tunnel area itself (area C). This distribution was very different in the current study with 22.5% of the gilling occurring in the three areas combined for control nets, of which 16.8% were observed in the tunnel area. Gilling in the sides of the net was much greater than in the tunnel cover, with 46.7% and 57.4% of all trout mortality occurring here in the control and modified nets, respectively. This was similar to the 68% gilling rate for lake trout observed in the sides of the nets by Schneeberger et al. (1982).

Any reduction in lake trout mortality created by inserting the shoaling twine panels was offset by the greatly increased incidence of gilling in other areas of the modified nets. The opposite was true in control nets, with increased gilling in the corners and over the tunnel but much less in the other areas. Because of this, the two net types were essentially equal in the numbers of trout killed. Eshenroder's (1980) observations paralleled this pattern, but to a lesser degree as he was able to show a significant improvement in the modified nets.

The netting operations off Muskegon have accounted for 15% to 17% of the total withdrawal of all lake trout from this area during 1985–87, the rest being removed by the active sport fishery centered around this port (MDNR, unpublished data; Rakoczy and Rogers 1987a and 1987b). This percentage could become even more significant in the near future because of the lack of lake trout reproduction in the area and the probability of greatly reduced stocking levels south of Arcadia on Lake Michigan, except in the Sheboygan-Milwaukee reef refuge area.

The age and length data collected are extremely important in determining detrimental effects of the commercial operations on lake trout. There have been no other reports in the literature concerning size selective gilling mortality of this species in trap nets. The size of lake trout killed in all nets used in this study was very specific. Although lake trout covering a wide range of lengths were observed in the nets, only those fish of 23 to 25 inches were gilled. The average age was about 5 years which is at least 1 year before a high percentage of lake trout are found to be mature. This selective mortality could have a major effect on rehabilitation efforts in the future if these stocks ever begin to reproduce naturally.

Other non-target species

The number of steelhead, brown trout, salmon, yellow perch, and walleye killed in the nets was extremely low when compared to lake trout. The occurrence of these species in the nets could not be correlated with any of the factors studied. On the average, 60% to 80% of the steelhead, yellow perch, and salmon caught in the nets were found gilled and dead when the nets were lifted. This percentage was much lower for brown trout and walleye, averaging about 20% and 13%, respectively. No other studies have considered the incidental mortality of these species although Schneeberger et al. (1982) reported that captures of species other than whitefish and lake trout were negligible in a Lake Huron trap-net fishery.

Management implications

The incidental mortalities of non-target species, especially lake trout, observed in this study are of great importance to the sportfishing community in and around the port of Muskegon. It was hoped that the shoaling twine panels would reduce the levels of gilling significantly as demonstrated by Eshenroder (1980). However, this was not the case. Thus, other possibilities must be used to eliminate as much mortality as possible.

A season closure for the months of June through August, or July and August only, would reduce lake trout mortalities by 70% and 50%, respectively. Brown trout, salmon, and yellow perch mortalities would be almost eliminated because they are caught primarily during the summer months in this area. Steelhead and walleye losses would remain unchanged as these species are caught during the spring and fall months. However, this would also reduce the whitefish harvest by at least 40%, which would, for all practical purposes, put these commercial operations out of business. There is a surplus of whitefish which can be harvested in the

Muskegon area and sportfishermen have yet to show any interest in pursuing this species. Thus, such a proposal is not realistic given that other methods can be found which would reduce non-target mortalities significantly.

A second technique would be to limit the amount of effort allowed during the summer months when most of the incidental mortality occurs. Although these fishermen were allowed six nets each during the summer months for both 1985 and 1986, they averaged only four nets in the water during this time. Thus, the amount of allowable effort would need to be reduced below this average to obtain any significant reduction in incidental mortality. Again, for economic reasons, this is not a viable option for these commercial operations.

A third option would be to increase the frequency of lifting (i.e., reduce the average soak time). This may not be feasible in many years depending on weather conditions. Also, no significant effects of soak time on mortality could be demonstrated in this study. Thus, it is not certain that such a change in operational strategy would reduce mortalities or be economically feasible, and certainly enforcement of such a regulation would be impossible.

A final possibility would be to consider further modifications to the nets. One example would be to use a larger thread size in the pots and keep the nets heavily tarred. This has been shown to reduce the incidental mortality of walleye in a Lake Huron trap-net fishery (M. Keller, personal communication, MDNR, Charlevoix). Another possibility presented by the cooperating fishermen would be to put shoaling twine panels (2.5-inch stretched-mesh measure) over the entire top and sides of the net while using 5 to 5.5 inch mesh in the front and back of the pot. This increased mesh size would hopefully lighten the nets enough so that the shading effect of the shoaling twine would not inhibit whitefish entry. At the same time, it should allow more of the non-target species and juvenile whitefish impounded to escape through the mesh during lifting without becoming gilled.

Based on the results of this and other studies, a combination of factors must be analyzed to come up with a feasible and successful technique to guarantee a reduction of non-target species mortality in large-mesh trap nets. However, all studies have indicated that the top of the net over the tunnel is a major area of concern. Therefore, all large-mesh trap-net operations should at least include a shoaling twine panel in this area of all nets used to harvest whitefish.

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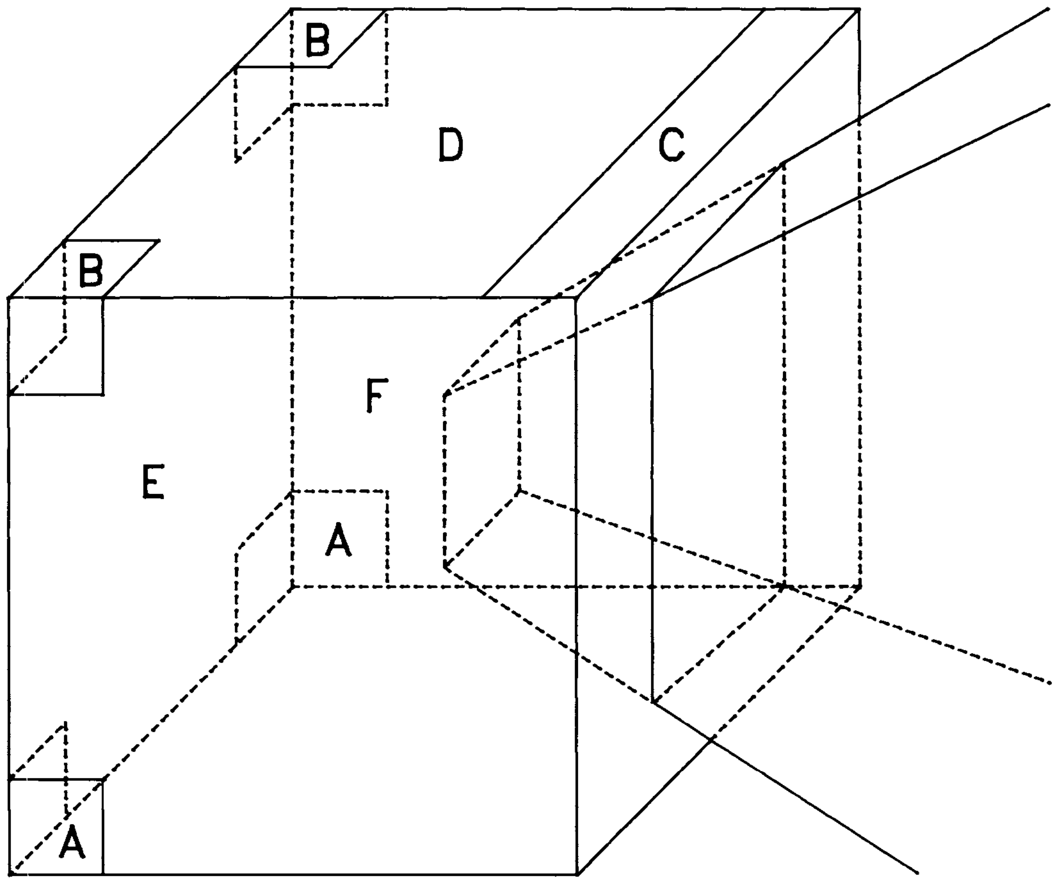

A – lower rear corners (2 panels)
B – upper rear corners (3 panels)
C – tunnel cover
D – top panel

E – rear panel
F – side panels
G – other areas; hearts, leads, etc., when observable

Figure 1. Trap net pot with shoaling twine panel modifications in the rear corners and over the tunnel. Gilling data were collected using the net area designations shown.

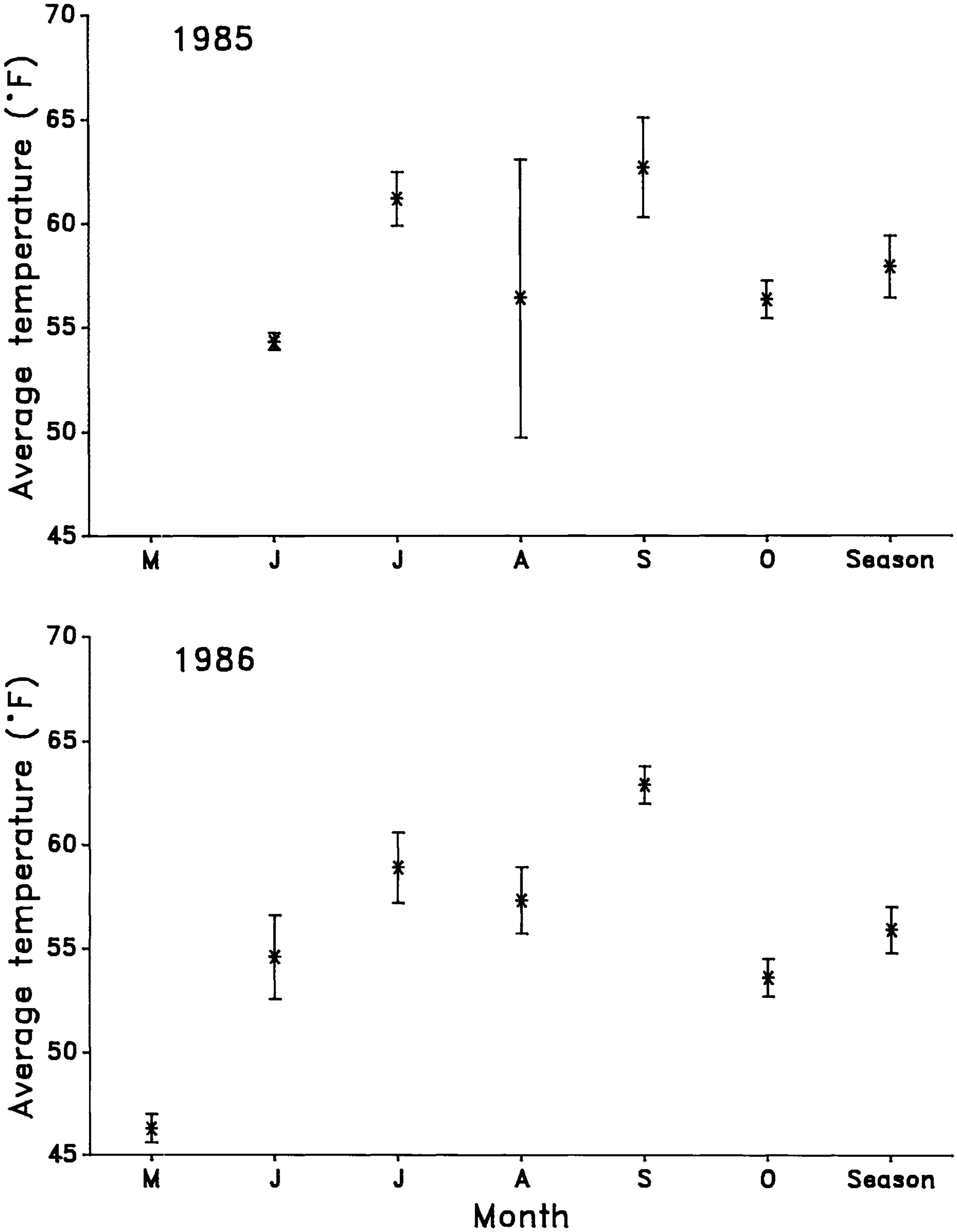

Figure 2. Average monthly temperature (Fahrenheit) at the pot depth for all nets combined during 1985 and 1986. Vertical bars represent two standard errors.

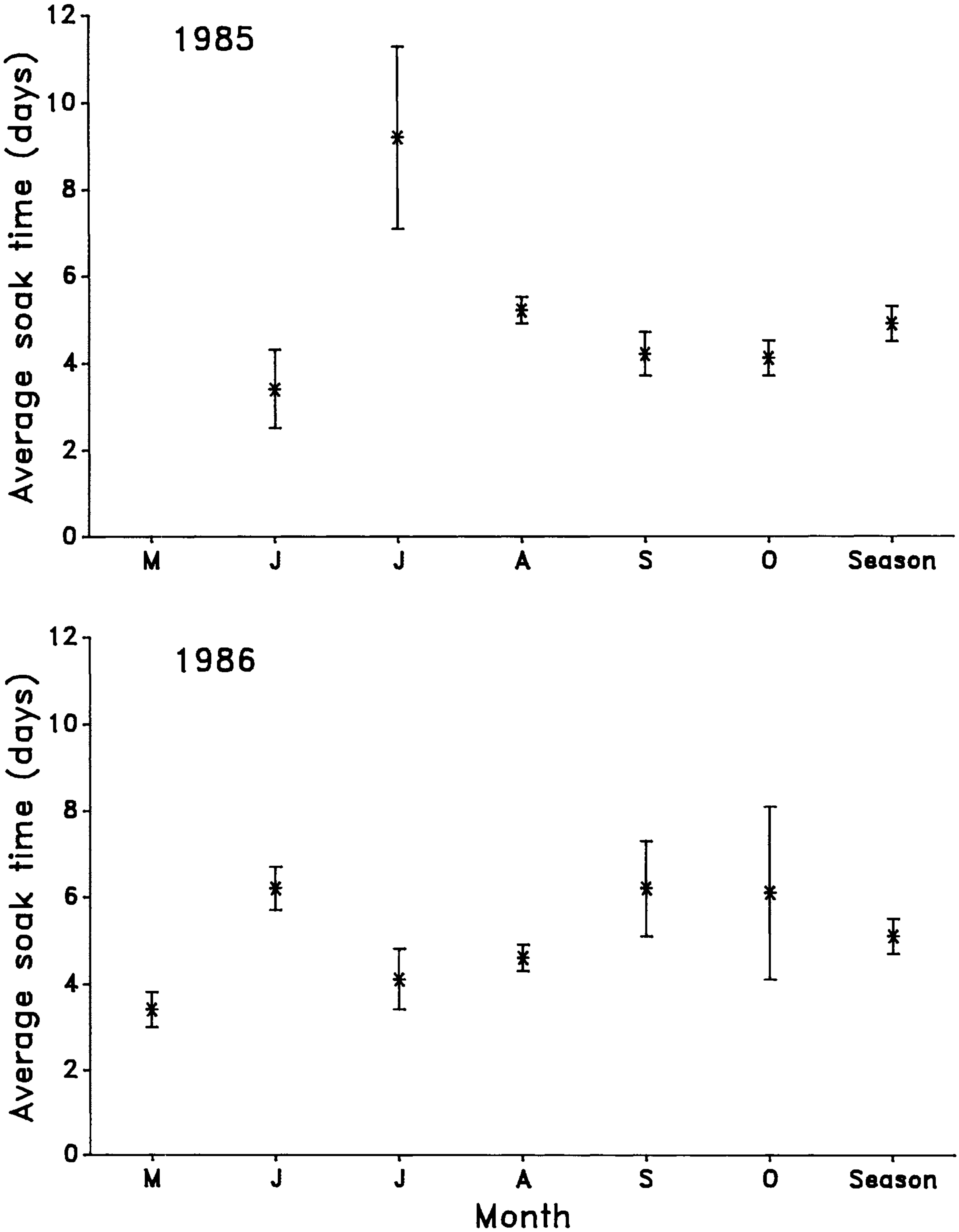

Figure 3. Average number of days between net lifts by month for all nets combined during 1985 and 1986. Vertical bars represent two standard errors.

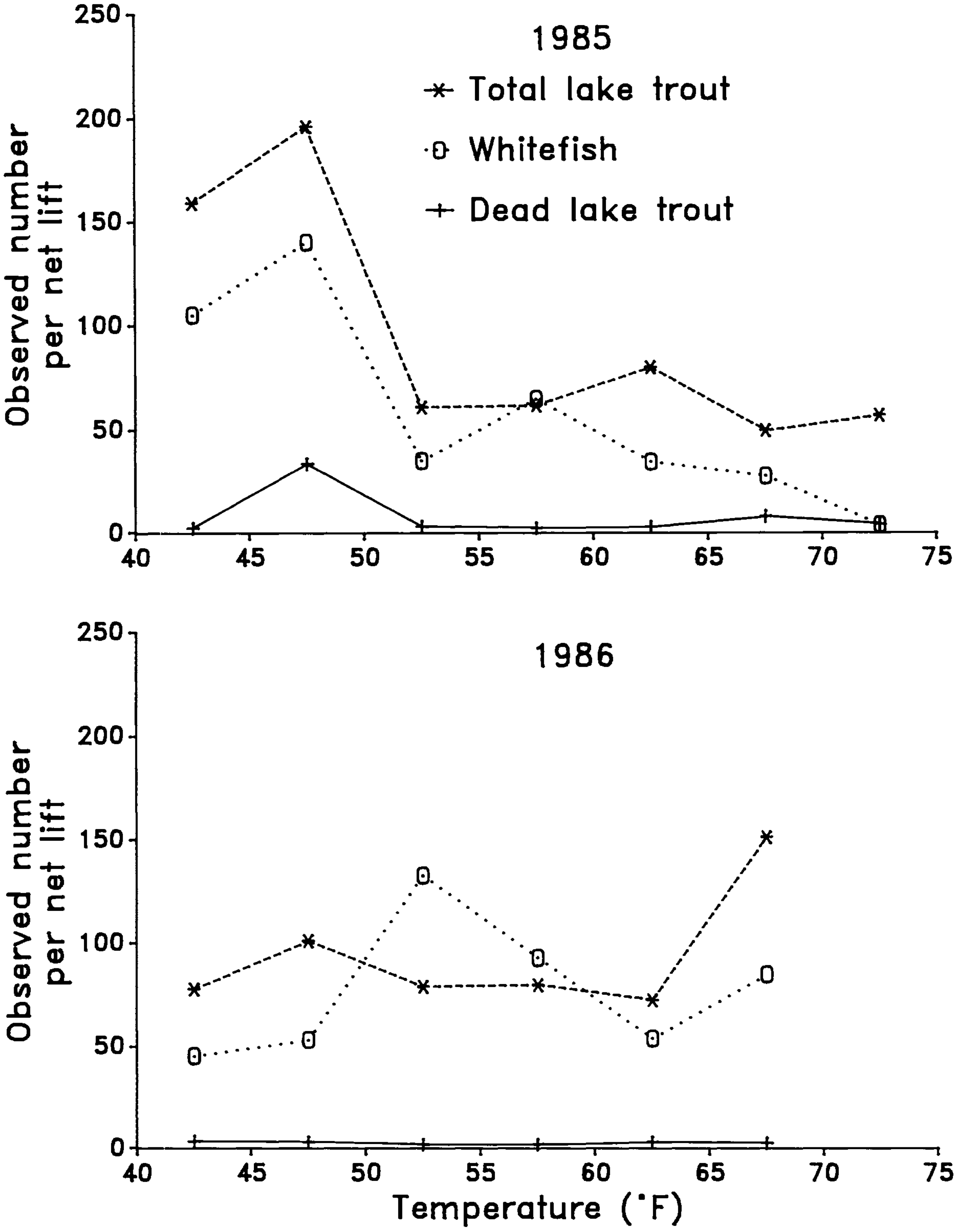

Figure 4. Observed number of lake trout caught, whitefish harvested, and dead (gilled) lake trout per net lift for all nets combined as a function of temperature (Fahrenheit) at the pot during 1985 and 1986.

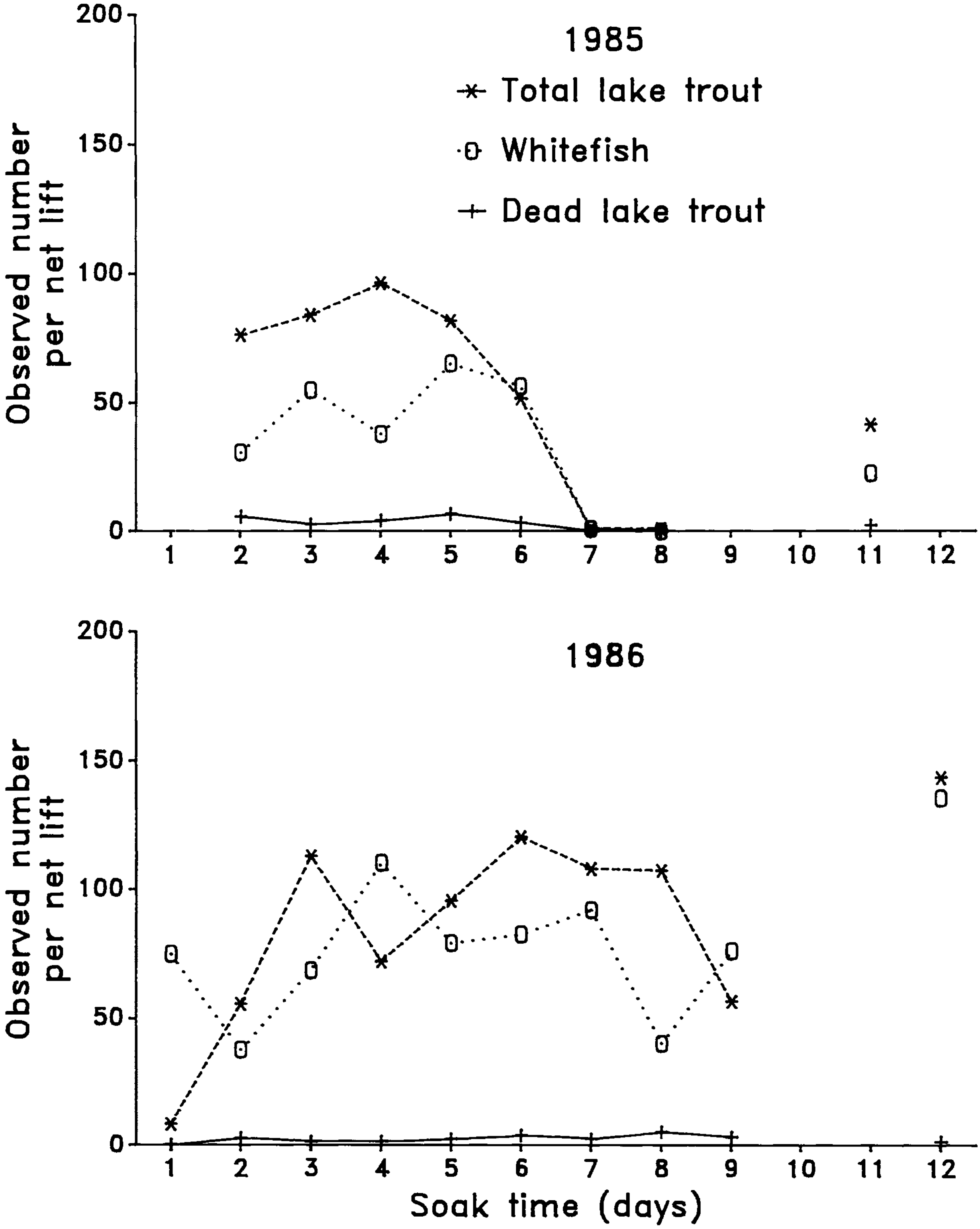

Figure 5. Observed number of lake trout caught, whitefish harvested, and dead (gilled) lake trout per net lift for all nets combined as a function of soak time (days) during 1985 and 1986.

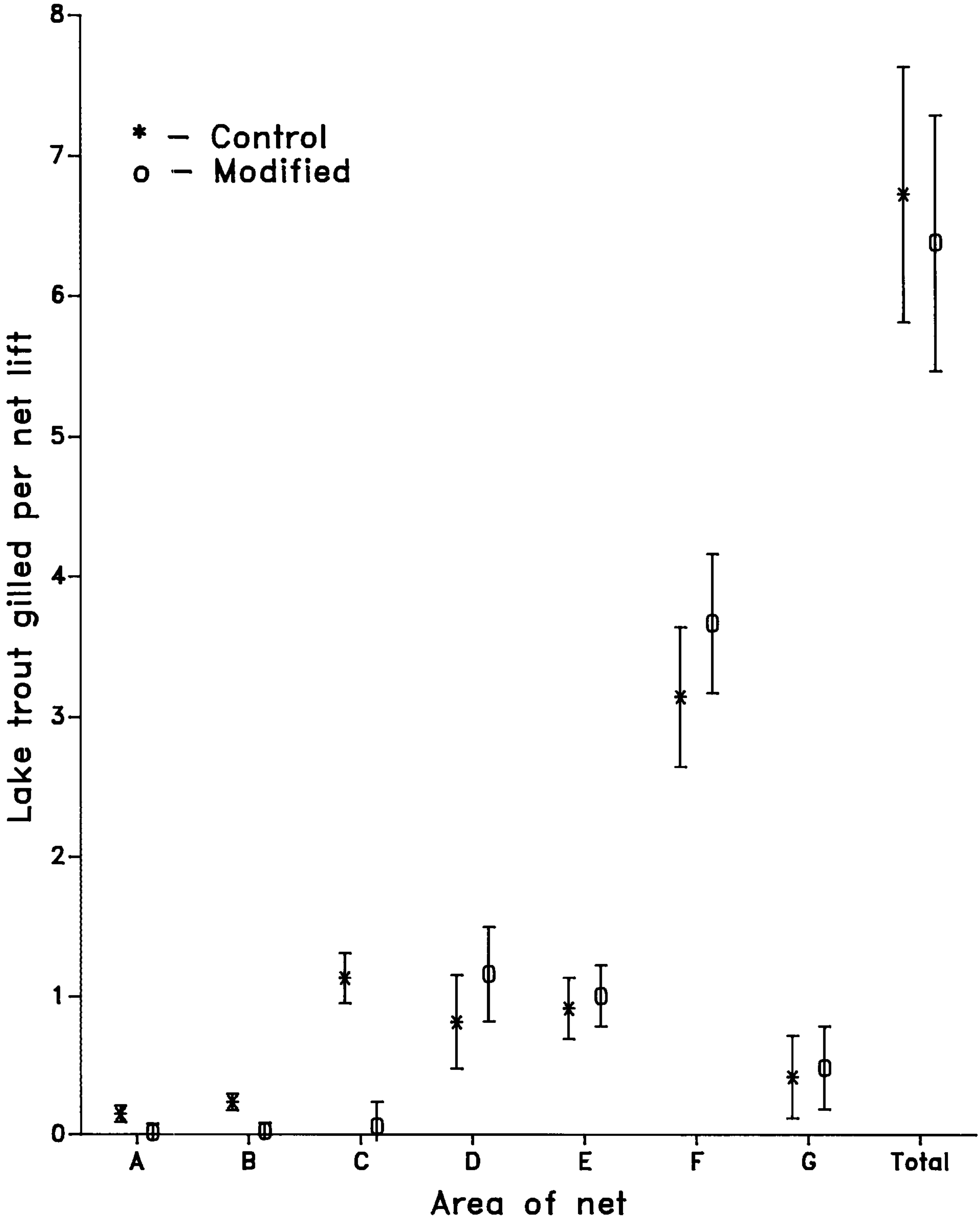

Figure 6. Number of lake trout gilled per net lift in control and modified nets by designated areas for 1985 and 1986 combined. Vertical bars represent two standard errors.

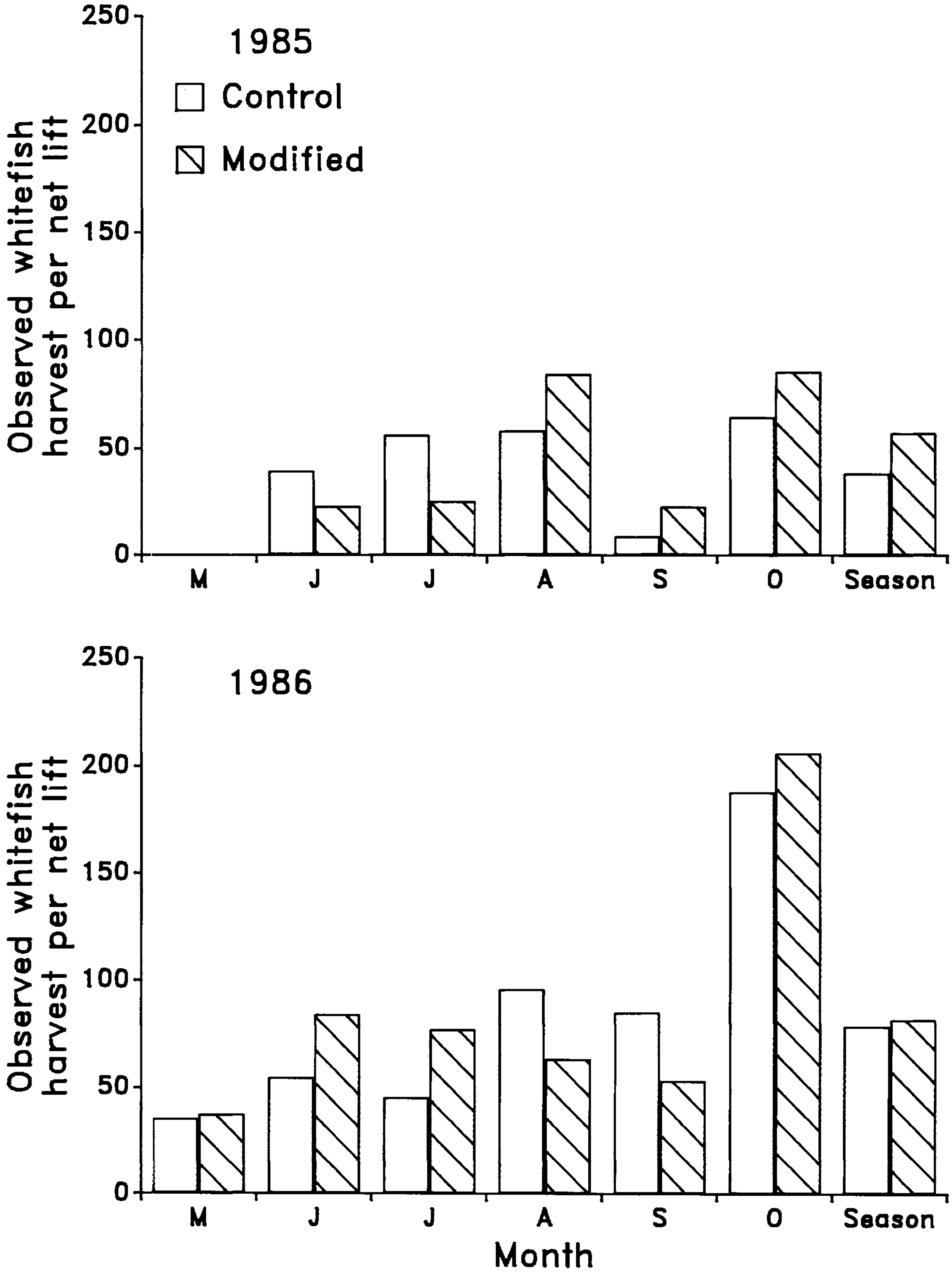

Figure 7. Observed monthly number of whitefish harvested per net lift in control and modified nets during 1985 and 1986.

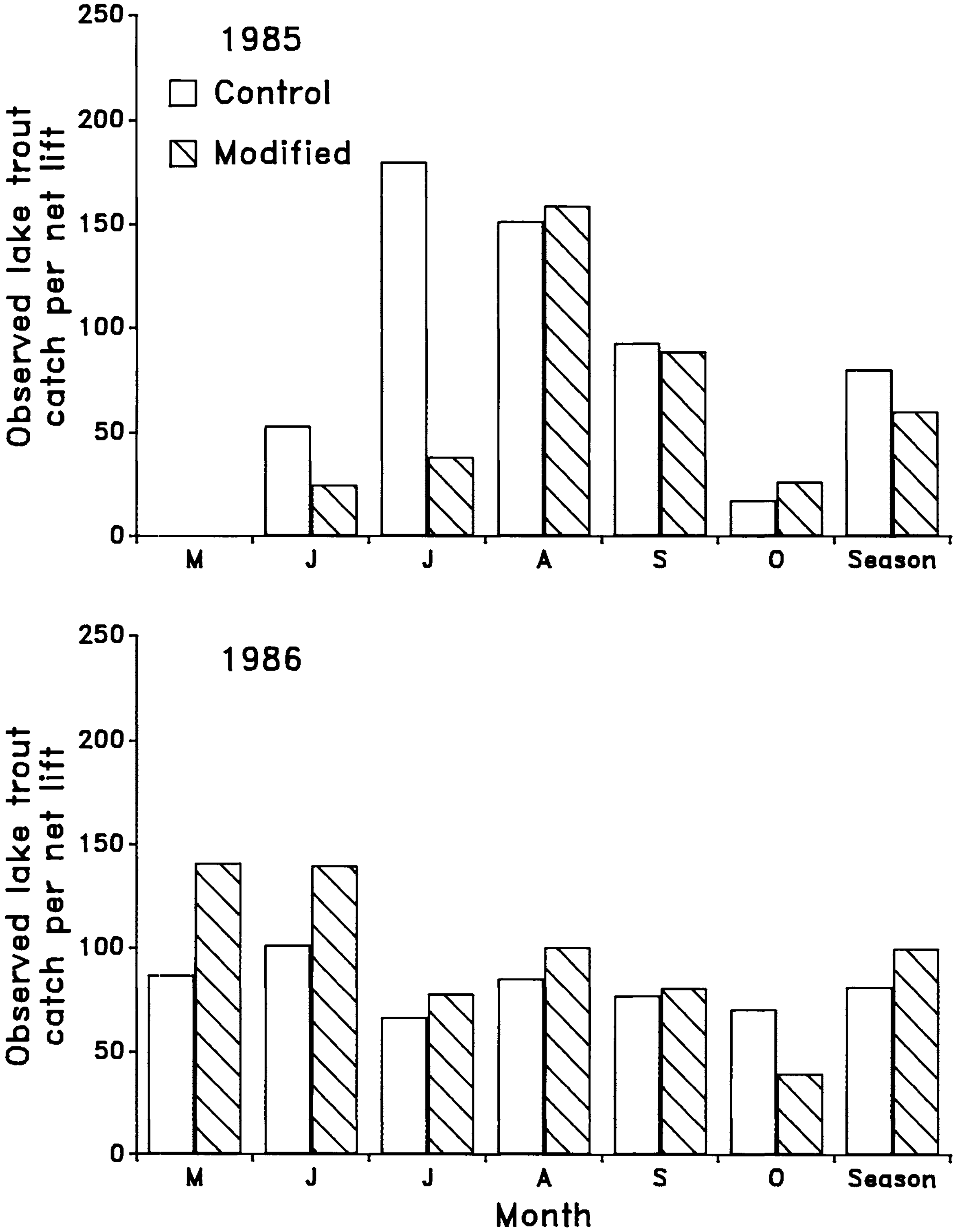

Figure 8. Observed monthly number of lake trout caught per net lift in control and modified nets during 1985 and 1986.

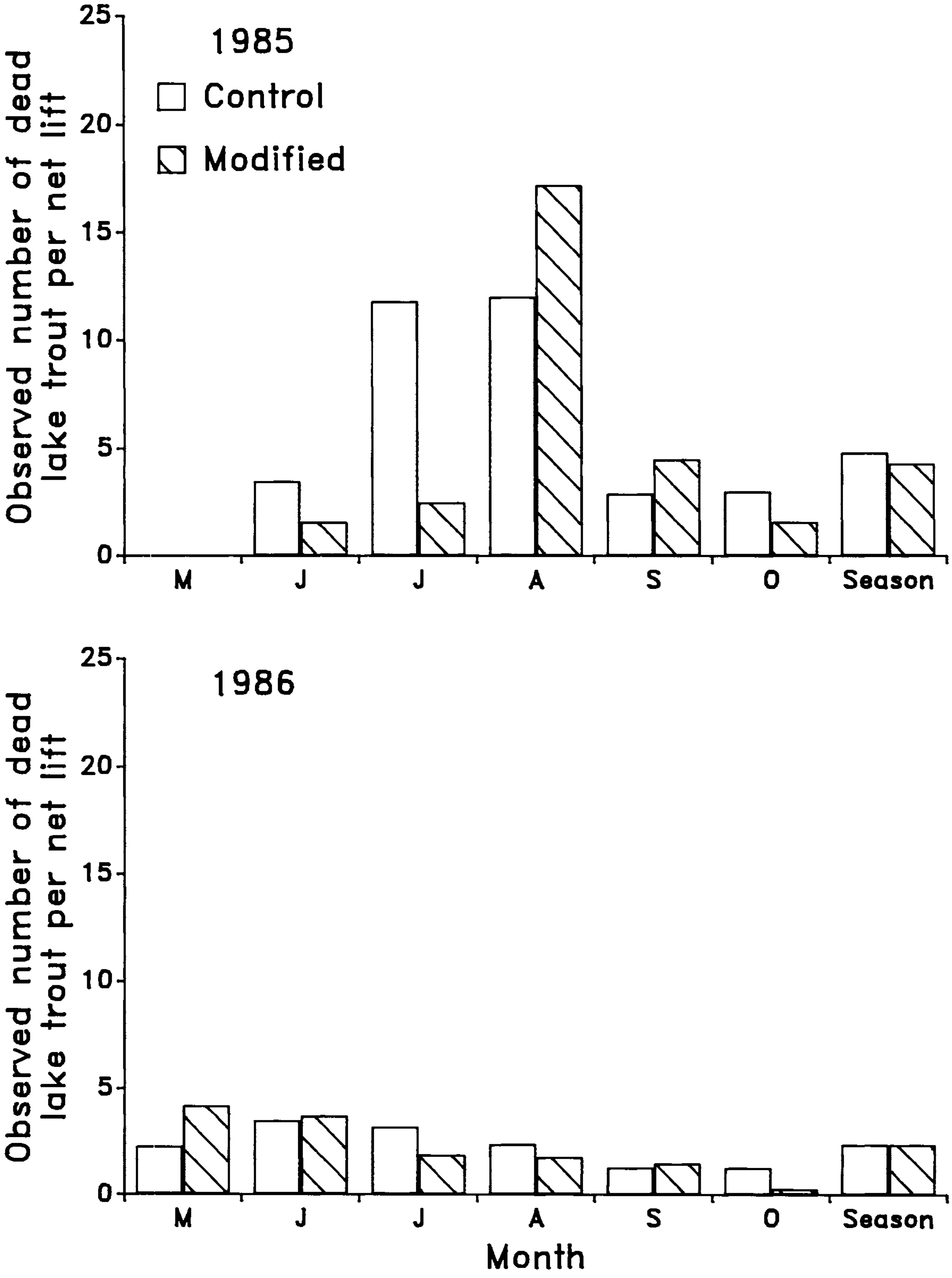

Figure 9. Observed monthly number of dead (gilled) lake trout per net lift in control and modified nets during 1985 and 1986.

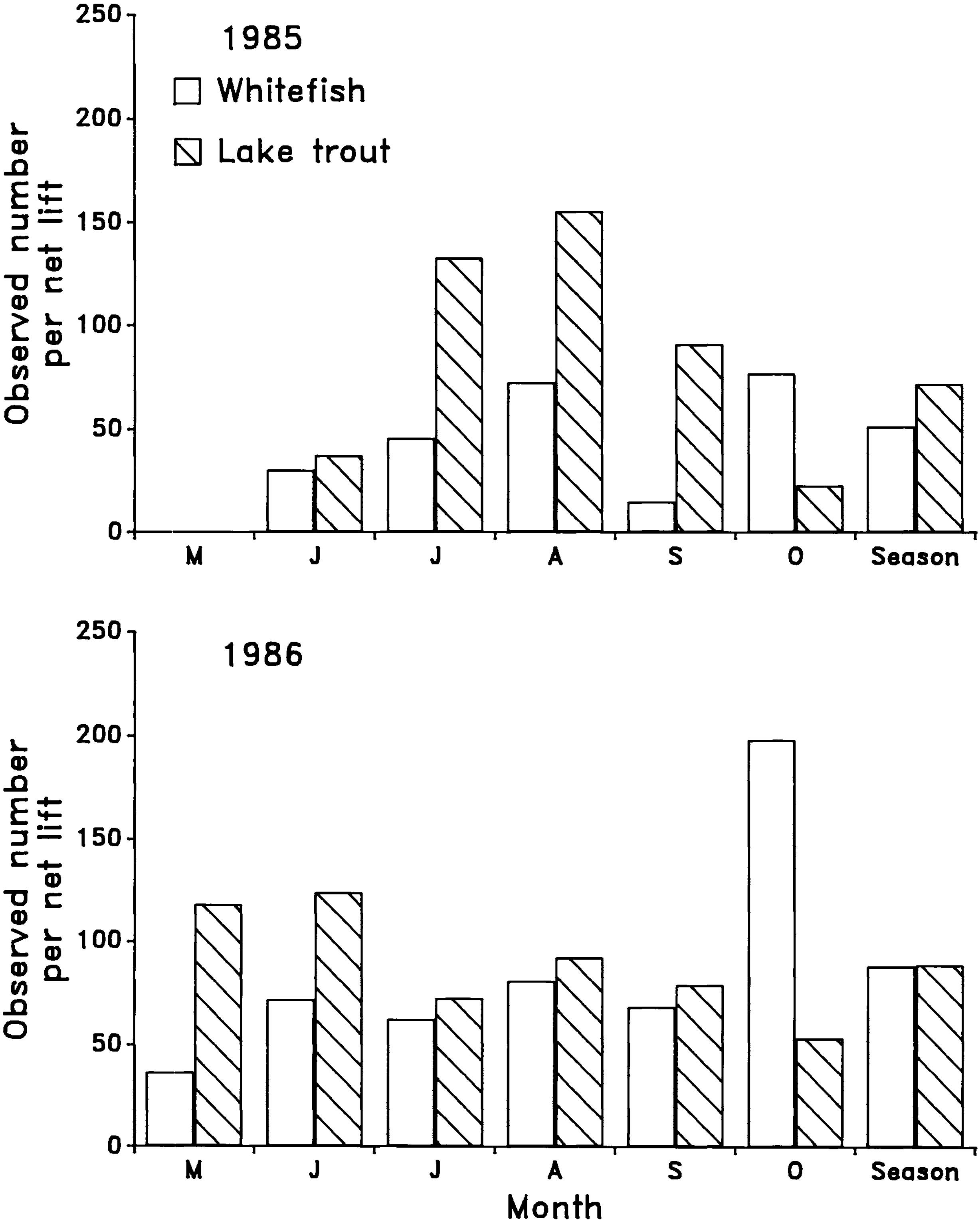

Figure 10. Observed monthly number of whitefish harvested and lake trout caught per net lift for all nets combined during 1985 and 1986.

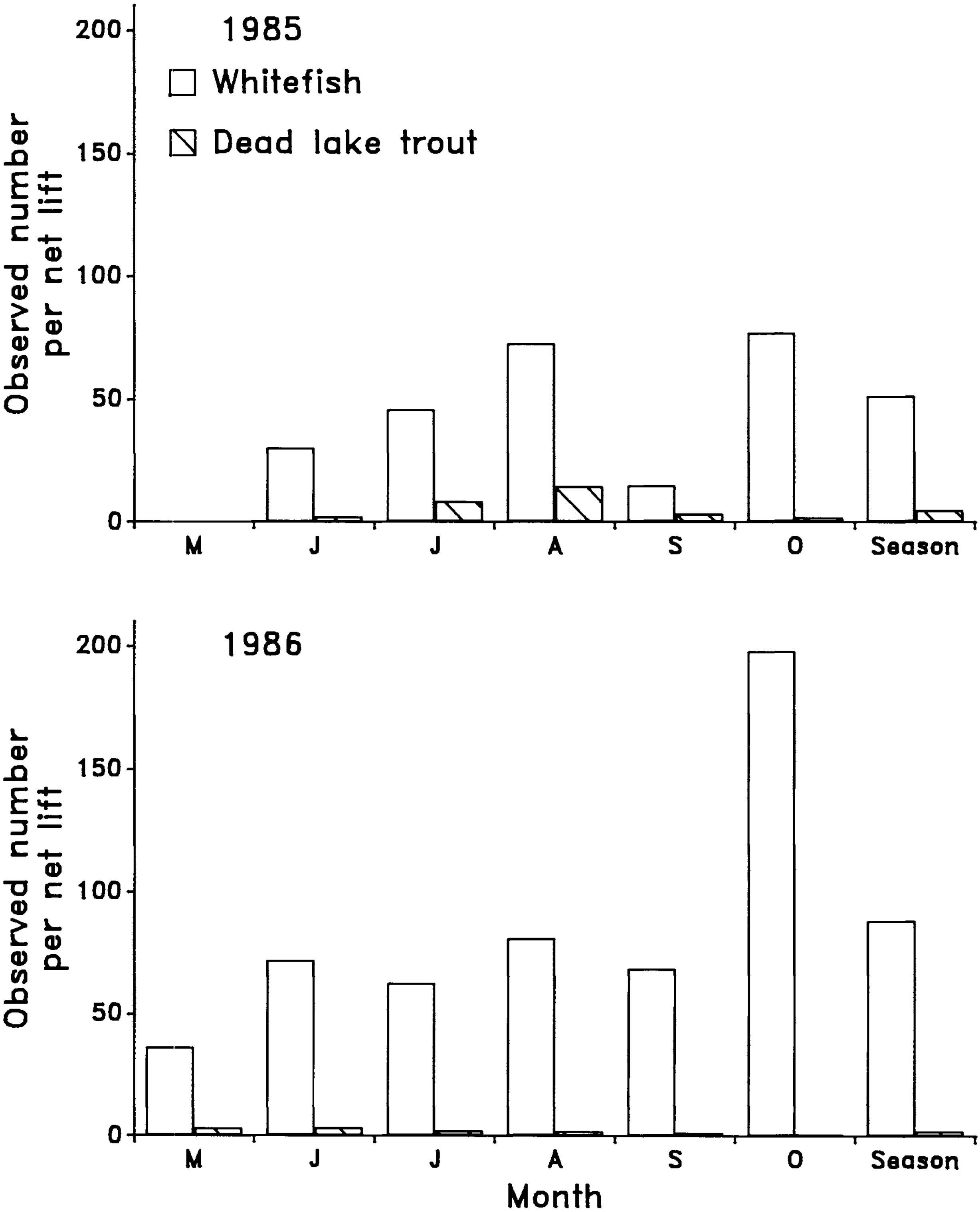

Figure 11. Observed monthly number of whitefish harvested and the number of dead (gilled) lake trout per net lift for all nets combined during 1985 and 1986.

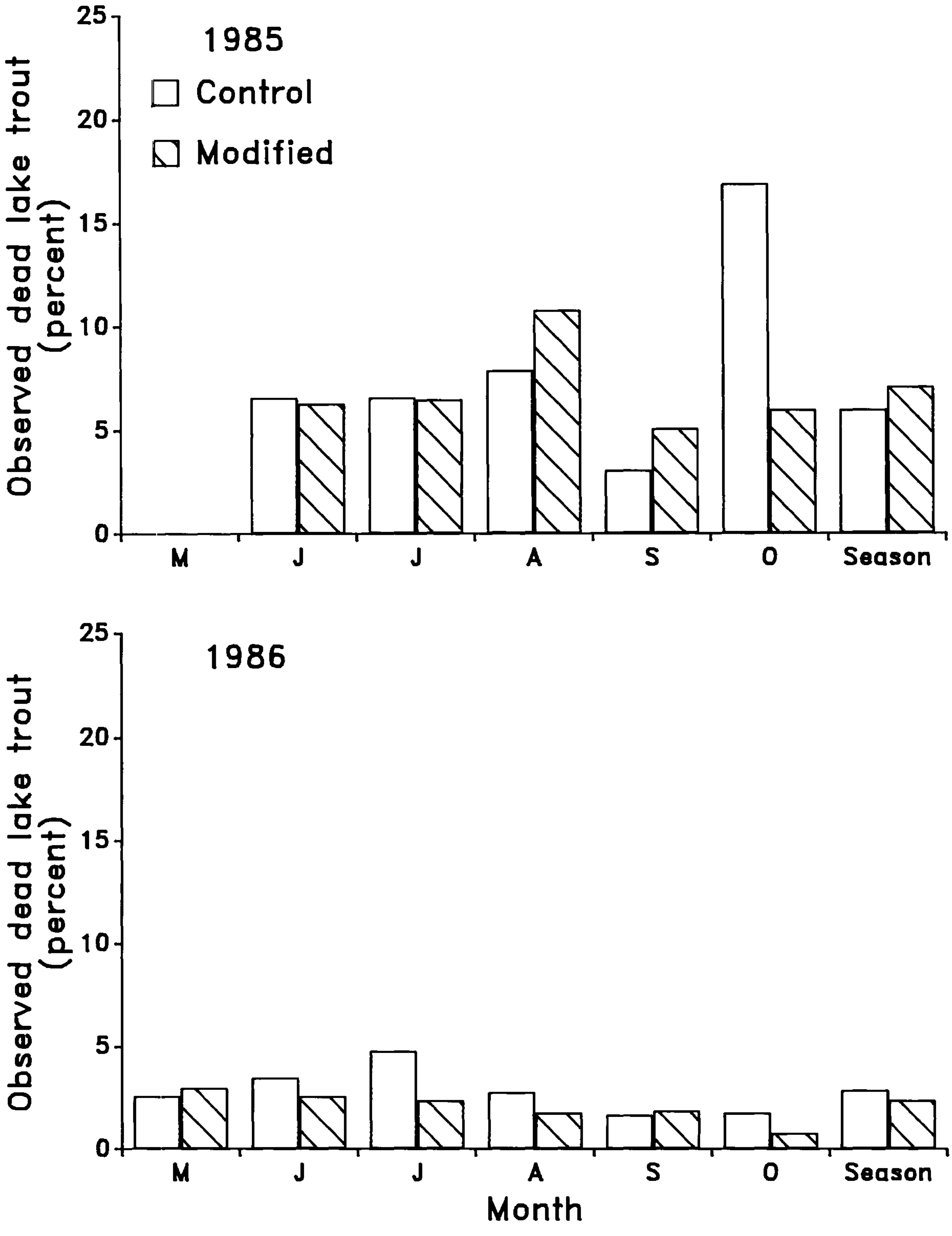

Figure 12. Observed monthly percent of the total lake trout catch that was dead (gilled) in control and modified nets during 1985 and 1986.

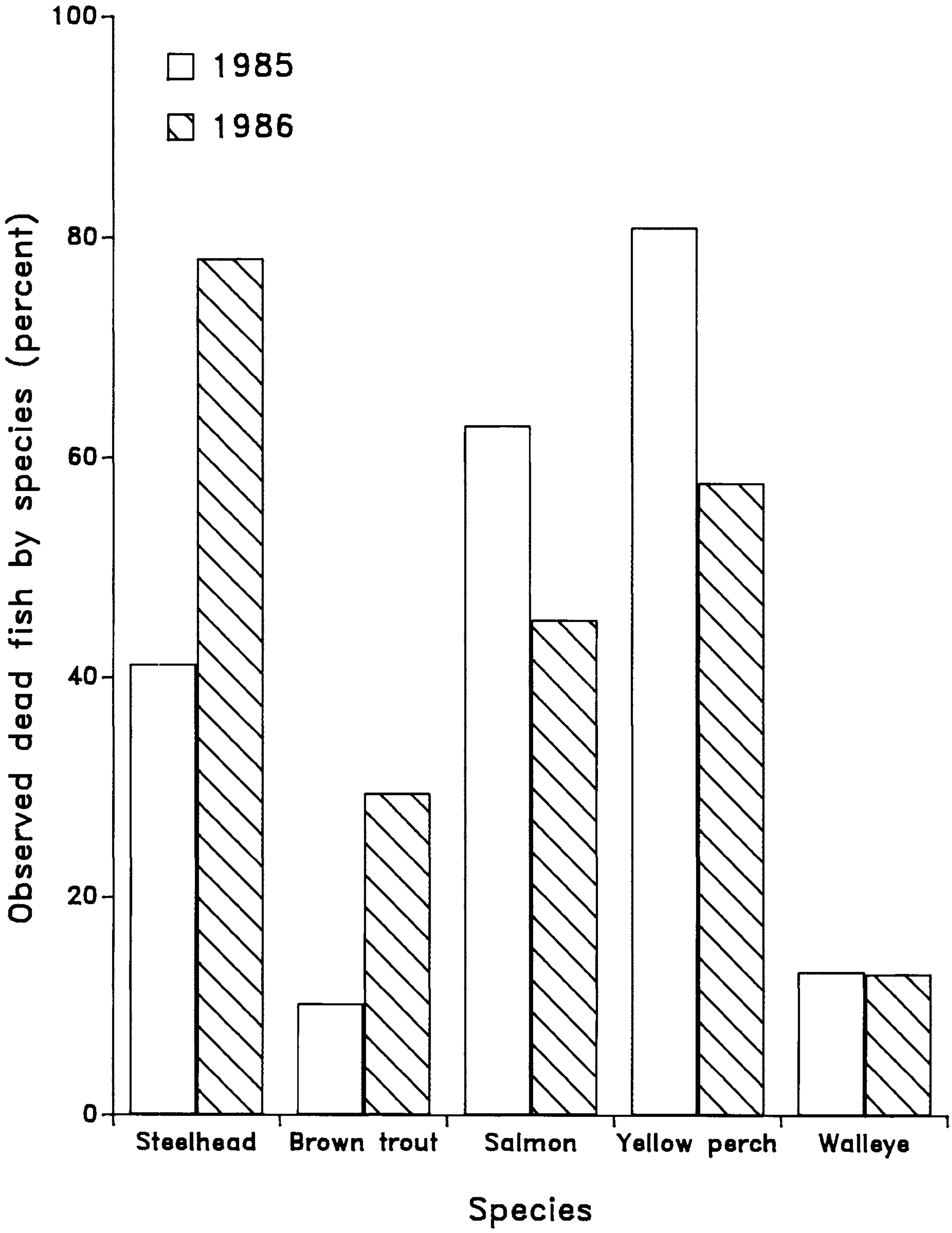

Figure 13. Observed percent of the total catch by species that was dead (gilled) in all nets combined during 1985 and 1986.

Table 1. The number of lifts reported, monitored, and the percent monitored by month for all nets combined during 1985 and 1986.

Month	Reported lifts	Monitored lifts	Percent monitored
1985			
May	—	—	—
Jun	56	9	16.1
Jul	37	6	16.2
Aug	36	9	25.0
Sep	42	25	59.5
Oct	84	27	32.1
Season	255	76	29.8
1986			
May	78	21	26.9
Jun	95	24	25.3
Jul	111	28	25.2
Aug	73	26	35.6
Sep	77	21	27.3
Oct	95	16	16.8
Season	529	136	25.7

Table 2. Average age and total length (inches) of dead (gilled) lake trout by trap net type for summer (before September 1), fall (after September 1), and both periods combined, 1985. Two standard errors in parentheses.

	Summer[1]			Fall			Combined		
Net type[2]	Number	Mean age	Mean length	Number	Mean age	Mean length	Number	Mean age	Mean length
12 C	—	—	—	2	5.5	24.4	2	5.5	24.4
		—	—		(1.0)	(1.5)		(1.0)	(1.5)
12 M	—	—	—	19	5.6	24.6	19	5.6	24.6
		—	—		(0.3)	(0.6)		(0.3)	(0.6)
20 C	—	—	—	6	5.7	25.5	6	5.7	25.5
		—	—		(0.8)	(1.6)		(0.8)	(1.6)
20 M	—	—	—	17	5.4	23.8	17	5.4	23.8
		—	—		(0.3)	(0.7)		(0.3)	(0.7)
30 C	—	—	—	21	5.4	23.9	21	5.4	23.9
		—	—		(0.3)	(0.6)		(0.3)	(0.6)
All nets	—	—	—	65	5.5	24.3	6	5.5	24.3
		—	—		(0.2)	(0.4)		(0.2)	(0.4)

[1]No data were collected in the summer period of 1985.

[2]Pot size in feet where M = modified nets and C = control nets.

Table 3. Average age and total length (inches) of dead (gilled) lake trout by trap net type for summer (before September 1), fall (after September 1), and both periods combined, 1986. Two standard errors in parentheses.

	Summer[1]			Fall			Combined		
Net type[2]	Number	Mean age	Mean length	Number	Mean age	Mean length	Number	Mean age	Mean length
12 C	20	5.7	24.5	2	5.0	25.1	22	5.6	24.6
		(0.3)	(0.7)		(0.0)	(0.6)		(0.3)	(0.7)
12 M	22	5.7	23.6	—	—	—	22	5.7	23.6
		(0.4)	(0.6)		—	—		(0.4)	(0.6)
20 C	58	5.4	23.7	—	—	—	58	5.4	23.7
		(0.2)	(0.4)		—	—		(0.2)	(0.4)
20 M	78	5.6	23.8	8	5.1	23.0	86	5.6	23.8
		(0.2)	(0.5)		(0.3)	(0.9)		(0.2)	(0.4)
30 C	12	5.0	22.7	3	7.0	25.1	15	5.4	23.2
		(0.4)	(0.8)		(1.2)	(1.3)		(0.6)	(0.8)
30 M	32	5.1	22.4	3	7.0	23.8	35	5.2	22.5
		(0.3)	(0.6)		(2.0)	(1.9)		(0.3)	(0.6)
All nets	222	5.5	23.6	16	5.8	23.8	238	5.5	23.6
		(0.1)	(0.3)		(0.6)	(0.8)		(0.1)	(0.2)

[1]Pot size in feet where M = modified nets and C = control nets.

Table 4. Observed monthly number of fish per net lift by species for all nets combined during 1985. Two standard errors in parentheses.

Month	Steelhead	Brown trout	Salmon[1]	Yellow perch	Walleye
May	—	—	—	—	—
	—	—	—	—	—
Jun	0	0.34	2.11	2.00	0
	(0)	(0.43)	(0.98)	(3.66)	(0)
Jul	0	0.51	4.84	0.68	0
	(0)	(0.41)	(2.78)	(0.78)	(0)
Aug	0	1.56	5.44	0	0
	(0)	(0.86)	(2.11)	(0)	(0)
Sep	0.40	0.31	3.36	4.48	4.83
	(0.21)	(0.21)	(1.38)	(1.14)	(2.52)
Oct	0	0	0.23	5.77	3.81
	(0)	(0)	(0.13)	(1.64)	(1.64)
Season	0.07	0.42	2.56	3.18	2.05
	(0.04)	(0.17)	(0.59)	(0.99)	(0.68)

[1]Chinook salmon *Oncorhynchus tshawytscha* and coho salmon *Oncorhynchus kisutch* are combined under Salmon.

Table 5. Observed monthly number of fish per net lift by species for all nets combined during 1986. Two standard errors in parentheses.

Month	Steelhead	Brown trout	Salmon[1]	Yellow perch	Walleye
May	0 (0)	0 (0)	0.09 (0.12)	1.00 (0.58)	0 (0)
Jun	0 (0)	0.38 (0.23)	0.54 (0.29)	3.71 (1.77)	0 (0)
Jul	0.04 (0.06)	0.43 (0.35)	0.82 (0.49)	2.82 (1.40)	0 (0)
Aug	0.08 (0.12)	0.15 (0.15)	1.51 (0.45)	2.73 (0.99)	0.04 (0.07)
Sep	0.29 (0.49)	0 (0)	0.38 (0.25)	3.52 (1.43)	1.00 (0.86)
Oct	0 (0)	0 (0)	0.06 (0.12)	3.94 (1.76)	1.75 (1.14)
Season	0.06 (0.08)	0.18 (0.09)	0.56 (0.14)	3.00 (0.60)	0.47 (0.24)

[1]Chinook and coho salmon are combined under Salmon.

Table 6. Observed monthly number of dead (gilled) fish per net lift by species for all nets combined during 1985. Two standard errors in parentheses.

Month	Steelhead	Brown trout	Salmon[1]	Yellow perch	Walleye
May	— —	— —	— —	— —	— —
Jun	0 (0)	0 (0)	1.89 (0.99)	0.44 (0.81)	0 (0)
Jul	0 (0)	0 (0)	2.50 (2.05)	0.67 (0.77)	0 (0)
Aug	0 (0)	0.22 (0.25)	3.11 (1.24)	0 (0)	0 (0)
Sep	0.16 (0.12)	0.08 (0.07)	2.16 (0.94)	4.20 (1.13)	1.20 (0.69)
Oct	0 (0)	0 (0)	0.11 (0.10)	5.11 (1.62)	0.22 (0.18)
Season	0.03 (0.02)	0.04 (0.04)	1.61 (0.44)	2.57 (0.60)	0.27 (0.13)

[1]Chinook and coho salmon are combined under Salmon.

Table 7. Observed monthly number of dead (gilled) fish per net lift by species for all nets combined during 1986. Two standard errors in parentheses.

Month	Steelhead	Brown trout	Salmon[1]	Yellow perch	Walleye
May	0 (0)	0 (0)	0.10 (0.11)	0.29 (0.29)	0 (0)
Jun	0 (0)	0.13 (0.12)	0.33 (0.25)	1.92 (1.33)	0 (0)
Jul	0 (0)	0.14 (0.15)	0.21 (0.26)	0.96 (0.61)	0 (0)
Aug	0.04 (0.06)	0 (0)	0.73 (0.32)	1.23 (0.55)	0.04 (0.06)
Sep	0.29 (0.49)	0 (0)	0.14 (0.18)	2.43 (1.04)	0.14 (0.18)
Oct	0 (0)	0 (0)	0.06 (0.11)	3.44 (1.68)	0.19 (0.25)
Season	0.05 (0.07)	0.05 (0.04)	0.25 (0.09)	1.73 (0.44)	0.06 (0.05)

[1]Chinook and coho salmon are combined under Salmon.

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