Evaluation of the Effects of North Carolina's 0.08% BAC Law

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November, 1998

Acknowledgement

This research was supported in part by the National Highway Traffic Safety Administration (NHTSA), U.S. Department of Transportation, under Contract No. DTNH22-94-D-07089. The opinions, findings, and recommendations contained herein are those of the authors, and do not necessarily represent those of the NHTSA.

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Executive Summary

Sixteen states have reduced the *per se* illegal blood alcohol concentration (BAC) limit for drivers to 0.08%. There is a substantial amount of evidence from experimental studies to indicate that a variety of individual skills are impaired at BACs well below 0.08%. Epidemiologic studies indicate that the risk of a crash increases sharply for drivers with BACs above 0.08%. To date, however, few studies have been done to determine whether reducing the legal BAC limit translates into reduced numbers of alcohol-related motor vehicle crashes.

Four previous studies of the effects of 0.08% laws on motor vehicle crashes have found equivocal and somewhat conflicting results. In California, a 1991 study reported a 12% decrease in alcohol-related fatalities following implementation of an 0.08% BAC limit. However, California also enacted an Administrative License Revocation (ALR) law six months after lowering the BAC limit, and it was not possible to determine whether the ALR law , the 0.08% law, or the combination of the two was responsible for the decrease. A later study of the California law, looking at longer time periods, found no significant decrease in alcohol-involved crashes as a result of the lower BAC limit.

Two studies examined the first five states to reduce their BAC limit to 0.08%. One study found decreases in at least one indicator of drinking-driving in four of the five states. A second study, using a somewhat different research design, found a decrease in high BACs among fatally injured drivers in three of the five states. Again, however, it was not possible to disentangle effects of ALR laws from those of the lower BAC limit in three of the states studied. Further clouding the issue is the fact that the two states that showed no decrease in the second study were among those in which the earlier study had found an apparent decline in drivers with high BACs.

The present study was conducted in an effort to clarify the effect of reducing the BAC limit to 0.08%. North Carolina enacted an 0.08% BAC limit on October 1, 1993. No other legislation that would significantly affect drinking-driving was enacted in close proximity to the 0.08% law.

Using telephone survey data, we were able to gauge public knowledge and awareness of the 0.08% BAC limit in North Carolina. Interviews with 802 randomly sampled persons in four counties found that about two-thirds believed the BAC limit had changed in the past two years. Just over one-third were able to report the limit correctly as 0.08%. A substantial proportion of the sample did not drink and, as would be expected, drinkers were more aware that the limit had changed (73%) than non-drinkers (56%). They also were twice as likely to know the new limit (50% vs. 26%). Those who reported drinking at least once a week were even more likely to know the new limit (67%). Respondents overwhelmingly (85%) believed that lowering the BAC limit increased the likelihood that individuals would be arrested for drinking-driving.

To determine whether the 0.08% law produced a decrease in alcohol-related crashes, we examined several indicators. Alcohol involvement in all crashes in North Carolina between 1991 and 1995, as well as fatal and serious injury crashes only were examined. In addition, surrogate measures of alcohol-related crashes (nighttime crashes; nighttime fatal and serious injury crashes) were also examined. All these measures have been declining, almost continuously, in North Carolina since the early 1980s. To control for the effects of this general trend, as well as seasonal fluctuations, we carried out structural time series analyses examining monthly crash statistics. In each case we looked for evidence of either an immediate decrease in the rate or a change in the general trend of alcohol-related crashes following implementation of the lower BAC limit. There was no significant change in the rate, nor in the trend, coinciding with introduction of the lower BAC limit, for any of the measures examined.

To determine whether the trend in alcohol-related crashes in North Carolina may have benefitted in comparison with a broader general trend in the U.S. (which had leveled out and appeared to be on the verge of increasing again), we compared North Carolina fatal crash data with those from 11 other states that have high rates of alcohol testing for fatally injured drivers. The data series representing the North Carolina proportion of all fatally injured drivers in the 12 states who had BACs in excess of 0.10% was examined for either a step shift or a change in the trend. Again there was no evidence that the pattern in North Carolina changed following enactment of the lower BAC limit, or that it differed in comparison to the other 11 states.

To see whether the BAC levels of persons had been reduced by the 0.08% law, even if not brought below the 0.10% threshold of the previous limit, we examined the mean monthly BACs of fatally injured drivers whose BAC was above 0.10%. Again there was no evidence of an effect of the new BAC limit. The monthly average BACs remained essentially unchanged from 1990 through 1995, with an overall mean of 0.21%.

Finally, we conducted a series of simple before-after comparisons of various indicators of alcohol involvement in fatal crashes. These analyses examined each the six measures that the National Highway Traffic Safety Administration used in its initial examination of the effect of 0.08% laws: (1) driver BAC $\geq$ 0.01%, (2) driver BAC $\geq$ 0.10%, (3) police-reported alcohol involvement, (4) single vehicle nighttime crash, (5) single vehicle nighttime male driver crash, and (6) estimated alcohol involvement. To examine changes in these measures we used the same analytic approach employed by Hingson et al. (1996) in their widely-cited study of the first five states to enact 0.08% limits – comparing changes in North Carolina rates with those in comparison states. To avoid potential pitfalls of trying to select a single appropriate comparison state, we compared North Carolina data with all 37 states that had retained higher per se limits from 1991 through 1996.

Of the six measures considered, two showed a significantly greater decrease in North Carolina than in the comparison states: police-reported alcohol and estimated alcohol, which is based in part on police report as well. For both these measures, the apparent effect of the 0.08% law is an artifact of grouping several months data before the law took effect, rather than an effect of the law itself. During the pre-0.08% period, noteworthy changes occurred in North Carolina that are obscured when the data are grouped. When analyses to ameliorate this artifact were conducted, none of the six measures showed a significantly greater decrease in North Carolina than in the states that retained a higher BAC limit.

Although North Carolina has a reputation for being progressive and aggressive in its efforts to deal with drinking drivers, it does not appear that the state is so different as to render it non-comparable to other states. Several indicators of alcohol use in fatal crashes during the early 1990s were similar to those for other states. On the salient measures of police-reported alcohol involvement and the proportion of killed drivers with a BAC in excess of 0.10%, the rates in North Carolina were lower by differences of 2.3% and 1.7%, respectively, both of which are statistically significant.

In conclusion, it appears that lowering the BAC limit to 0.08% in North Carolina did not have any clear effect on alcohol-related crashes. The existing downward trend in alcohol-involvement among all crashes and among more serious crashes continued, but does not appear to have changed following enactment of the lower BAC limit. When compared with the 11 other states that measure alcohol use by the large majority of fatally injured drivers, as does North Carolina, the measured BACs of fatally injured drivers did not decline as a result of the 0.08% law in North Carolina. Finally, the North Carolina trend in several other commonly used indicators of alcohol involvement in fatal crashes did not differ in comparison with the 37 states that retained higher BAC limits.

❑ BACKGROUND

Motor vehicle crashes account for approximately half of all fatalities resulting from unintentional injury (Baker et al., 1992). In the U.S., alcohol is involved in about 7% of all traffic crashes, but is much more commonly involved in fatal crashes. During 1997, an estimated 35.6% of traffic fatalities in North Carolina were *alcohol-related* (i.e., involved a driver, pedestrian, or bicyclist with BAC > 0.01%; NHTSA, 1998). This is somewhat less than the 38.6% of fatalities with alcohol-involvement nationally during 1997. Although there has been clear improvement in the proportion of alcohol-related crashes during the past decade, motor vehicle crashes in which alcohol was centrally involved continue to be a major part of the injury problem nationally, as well as in North Carolina.

Following national movement toward establishment of *per se* limits (a blood alcohol concentration [BAC] that is considered to be illegal, regardless of evidence of impaired behavior) and the move to raise the legal drinking age to 21 in all states, traffic safety efforts in many states are now focusing on lowering the *per se* BAC limit from 0.10% to 0.08%. Continuing a trend for North Carolina to be among the leaders in state efforts to combat impaired driving., the illegal *per se* BAC limit was reduced to 0.08% effective October 1, 1993.

Both experimental and epidemiologic evidence suggests that a BAC limit of 0.10% is too high. A variety of behaviors and cognitive functions begin to show evidence of impairment at BACs as low as 0.04% (Moscowitz & Burns, 1990). In addition to this experimental evidence, the best epidemiologic information currently available on BAC and the risk of a driver crashing shows a clear increase in the slope of the risk curve at BACs of about 0.08%. Hence there is a clear and substantial scientific basis for setting the *per se* BAC limit at 0.08% (or lower).

Data on BACs of persons involved in fatal crashes suggests, however, that reducing the legal BAC limit may have little effect. Fatality Analysis Reporting System (FARS; NHTSA, 1991) data indicate that among fatally injured drivers who have been drinking, BACs are well in excess of the current legal limit of 0.10% (in most states). Thus it is argued that drivers killed in alcohol-related crashes are already in substantial violation of the BAC limit and that, therefore, reducing the legal limit will likely have no effect.

A counter argument can be made that, although individuals drive with BACs in excess of the legal limit, reducing that limit can send the message to heavier drinkers that they need to reduce their consumption when they are going to drive. Thus, if drinking drivers believe (though incorrectly) that they are ‘okay,’ to drive after drinking a certain amount, a lowered BAC limit will send the message that their personal “drinking limit” must be lowered as well. Accordingly the predicted effect of a lowered legal BAC limit would be to reduce the general BAC level among drinking drivers, even though it might not bring persons in line specifically with the new, lower limit. This is the classic public health approach, wherein benefits for a population are achieved through policies that alter, even fractionally, the risk of entire groups rather than concentrating on individuals.

Since a number of states have already enacted 0.08% BAC limits, evidence has begun to accumulate on the effect of this lower limit. These results are briefly reviewed below.

Previous Evaluations of 0.08% BAC Laws

There have been four attempts to empirically determine the effects of 0.08% *per se* laws.

- California's 0.08% law was initially examined under the sponsorship of the National Highway Traffic Safety Administration (NHTSA, 1991); more recently the California Department of Motor Vehicles conducted its own assessment (Rogers, 1995).

- In 1994 the NHTSA released the results of a preliminary assessment of the effects of the lowered BAC limit in the first five states to reduce their *per se* limit to 0.08%.

- Most recently Hingson et al. (1996) reported results of another study of the effects seen in the first five states to reduce their BAC limit to 0.08%.

California

Among the 16 states that have reduced the *per se* illegal BAC limit to 0.08%,[1] only the California law has been subjected to a thorough evaluation. Because California has a very large number of crashes, it was possible to conduct a scientifically valid examination of the effects of the lower BAC limit shortly after the new law took effect. A study conducted by Research and Evaluation Associates (NHTSA, 1991) shortly after the lower BAC limit took effect found a 12% decrease in alcohol-related fatalities, but no corresponding decline in non-alcohol crashes. Unfortunately, another law) providing for administrative license revocation (ALR) for persons found driving with illegal BACs) took effect six months after the 0.08% law was implemented. Moreover, a good deal of public discussion about the ALR law occurred prior to its enactment, overlapping the period immediately following enactment of the 0.08% law. As a result, it was not possible to determine whether the decrease in alcohol-related fatalities that occurred was due to the 0.08% law, the ALR law, or some combination of the two.

In 1995 another study examined effects of the California 0.08% law (Rogers, 1995). A large number of crash types[2] were studied using time series analysis techniques to control for a variety of factors such as amount of driving and general economic conditions (indicators of crash exposure). Trends were examined for a five year period prior to implementation of the lower BAC limit and four years following implementation. No decrease in alcohol-involved crashes or alcohol-involved fatal crashes was found to be associated with the 0.08% law. Some decline was found in surrogate measures for alcohol crashes: nighttime serious injury or fatal crashes and fatal or injury crashes occurring between 2 and 3 am.

First Five States to Enact 0.08% BAC Limit

In a preliminary evaluation of the first five states to reduce BAC limits to 0.08%, six measures or indicators of drinking-driving available from FARS were examined for comparable time periods before and after the lower BAC limit was enacted in five states where the lower limit had been in effect for two

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[1] Alabama, California, Florida, Hawaii, Idaho, Illinois, Kansas, Maine, New Hampshire, New Mexico, North Carolina, Oregon, Utah, Vermont, Virginia and Washington.

[2] Alcohol-involved crashes, nighttime crashes, 2-3 am crashes, and single vehicle crashes were all examined. Moreover, each of these types was considered for three different degrees of severity: fatal crashes only, fatal + severe injury, and fatal + injury.

years or more (NHTSA, 1994)[3]. The findings were inconsistent across the five states, with anywhere from zero to four of the six indicators examined showing a statistically significant decline. In three of the five states, the proportion of drivers in fatal crashes found to have a BAC above 0.10% did decline significantly. Despite a somewhat inconsistent pattern of changes on the other measures, it is noteworthy that no significant declines on any of the six measures were found in the rest of the nation. Although this comparison does not control for other possible explanations for this change besides the lower BAC limit, it does help to rule out the possibility that the observed changes merely reflect a general and widespread decline in drinking-driving that has been documented (Transportation Research Board, 1994).

Hingson et al. (1996) reported findings that appear to corroborate the preliminary results reported by NHTSA, using a more controlled research design. Each of the first five states to reduce their per se limit to 0.08% was matched with a similar state from the same general region that did not reduce the limit. Among the 0.08% states, compared with 'matching' states, there was a significant reduction in the proportion of fatal crashes in which a fatally injured driver had a BAC above 0.08%. Similar results were obtained for the proportion of fatally injured drivers with BACs above 0.08%. Unfortunately, as was the case in California, it is difficult to disentangle the effects of the 0.08% laws from administrative license revocation laws that took effect at about the same time as the 0.08% laws in three of the states. Moreover, nearly half (4/9) of the statistically significant effects the NHTSA study found occurred in Vermont and Utah, yet Hingson et al. found no decline in Vermont, and an increase in alcohol-involved crashes subsequent to the 0.08% law in Utah.

Overall then, the available empirical evidence on the effect of 0.08% legislation to date is not strong, but does suggest that there may be a desired effect. The greatest drawback in previous studies has been the inability to attribute apparent effects clearly to 0.08% laws rather than to co-existing ALR laws, which have been demonstrated to reduce drinking-driving (Wagenaar et al., 1995). Another problem is the inherent difficulty in finding appropriate 'matches' to 0.08% states. For example, although Vermont and New Hampshire are both small, largely rural New England states, they are dramatically different politically and in other ways specific to drinking-driving (e.g., sobriety checkpoints are constitutionally prohibited in New Hampshire). Similarly, Utah and Idaho are sparsely populated states in the intermountain west, but there are numerous differences, not the least of which is the presence of a large Mormon population in Utah **S** potentially a critical confounding factor in studies of alcohol use.

Distinctiveness of the North Carolina Study

To shed additional light on the effects of reducing the *per se* BAC limit to 0.08%, we examined data from North Carolina. There is a sufficiently large number of crashes in North Carolina to conduct time series analyses using monthly crash rates, thus allowing use of North Carolina as its own 'control.' An additional benefit of this study is that effects of North Carolina's ALR law, which was enacted in 1983, are not confounded with the 0.08% law. No other major drinking-driving legislation was enacted in close temporal proximity to the October 1, 1993 date on which the 0.08% BAC limit took effect. Thus, the methodological problems that have confounded interpretation of results from others states, rendering conclusions about the effects of 0.08% laws tentative, can be avoided by using North Carolina data.

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[3] Indicators examined were: (1) driver BAC $\geq$0.01%, (2) driver BAC $\geq$0.10%, (3) police-reported alcohol involvement, (4) 'estimated' alcohol involvement (e.g., police reported drinking, positive BAC measurement, or alcohol violations/citations), and two surrogate measures, (5) single-vehicle nighttime crashes, and (6) single-vehicle nighttime male driver crashes.

In the present study, the primary focus of analysis was on crashes prior to and following implementation of the 0.08% law. Time series analyses were employed to examine various possible indicators of the effects of this new law. We considered a variety of outcome or criterion variables: alcohol-related crashes as identified by the investigating officer, alcohol-related fatal crashes, and alcohol-related injury crashes. In addition, because reports of alcohol involvement in all but fatal crashes are somewhat problematic, proxy measures for alcohol-related crashes (nighttime crashes, fatal/serious injury nighttime crashes) were also examined. Although not the primary focus of this research, we were able to obtain information about the general public's knowledge about and perceived effects of the 0.08% law. This information will help to place the effects on crash rates in context. We turn first to the question of public awareness of the new law.

❑ PUBLIC KNOWLEDGE AND PERCEPTIONS OF THE LOWER BAC LIMIT

A critical element in the success of any social policy approach that involves individuals making a choice to alter their behavior is that the public whose behavior is targeted must be aware of the policy. It is often assumed by policy makers that enacting a policy or law is sufficient to achieve its goal. It is axiomatic, however, that without awareness, no effect can be expected. There appear to be essentially three ways in which the public might have learned about the new, lower BAC limit: through the media, through direct experience (being arrested), and subsequently, by word of mouth from individuals who initially learned about the law through one of the two primary channels.

As a proposed law is being deliberated in the legislature, media attention will likely alert some proportion of the public to the issue. Following passage, additional media attention should provide the first information that there is a new BAC limit (albeit not yet in effect). At about the time the new law becomes effective, additional media attention as well as public information/education campaigns should increase awareness. Upon implementation of the law, if it is enforced, awareness should begin to grow slowly. There was relatively little media attention to the 0.08% BAC law as it was being considered, or when it took effect. However, enforcement was vigorous, as is typical in North Carolina.

We were able to obtain one "point-in-time" indicator of awareness of the new 0.08% BAC limit 17 months after the law went into effect. During February, 1995, the Insurance Institute for Highway Safety sponsored a telephone survey in North Carolina to obtain a variety of traffic safety-related information. At our request, a few questions about the 0.08% law were included and the data were provided to HSRC for those items as well as the other questions in the survey. This survey consisted of interviews with 802 randomly selected individuals living in four areas in the state. Consequently, these data are not from a representative sample of the entire state. However, the four areas do provide broad geographic representation. Figure 1 shows the locations where interviews were conducted (Cumberland, Guilford,

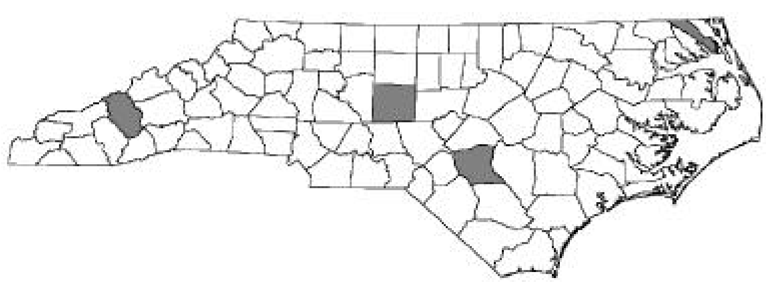

Figure 1 Counties where telephone interviews were conducted

Haywood, and Pasquotank counties)[4]. The demographic characteristics of the composite of these four counties are quite similar to the state as a whole. Table 1 presents 1990 census information on race, sex and age characteristics of the state as a whole, the four counties where interviews were conducted, and the sample of interviewed respondents. This allows for a direct comparison of how well the full interview sample represents the population of the counties interviewed. It is clear that the sample of persons interviewed somewhat over represents females, whites, and persons in the primary age group for drinking-driving.

Table 1. Demographic Characteristics of Survey Respondents and Sampled Geographic Regions

	Population	**% Male**	**% Nonwhite**	**Age 21 - 35**
North Carolina	6,628,637	48.5	24.4	25.6
4-County Population (Mean)		48.4	26.6	25.9
Cumberland County	274,566	51.7	38.1	33.0
Haywood County	46,942	47.7	2.0	19.9
Guilford (High Point)	347,420	47.3	28.2	26.5
Pasquotank (Elizabeth City)	31,298	46.7	38.0	24.1
4-County Survey Respondents (N)	802	40.8	18.4	31.2

Note. Population data are from 1990 census.

In addition to a series of questions pertaining to seat belts and drinking-driving enforcement, respondents were asked the following questions regarding the BAC limit:

- Do you know the legal blood alcohol limit (BAC) for drivers in North Carolina?
  - If respondents said yes, they were asked: "What is it? [The legal blood alcohol limit in North Carolina?]"
- Has the legal blood alcohol content limit for drivers in North Carolina been changed since 1992?
- Do you think that reducing the blood alcohol limit (BAC) has made it more likely that drinking drivers in North Carolina will be arrested for DWI?
- How much publicity have you seen or heard about the new blood alcohol limit (BAC) since it took effect? Would you say this new limit has been publicized. . . *Very well, Pretty well, Not very well, Not at all well*.
- What effect, if any, has the change in the blood alcohol limit had on your own behavior? Would you say you (*Are less likely to drive after drinking since the limit was lowered, Drive more carefully after drinking since the limit was lowered, Drink less since the limit was lowered, Have*

[4] These four counties had been selected as demonstration counties for the 'Booze It and Lose It' campaign which began in November, 1994. Interviews were conducted to learn of residents awareness of that program, and other highway safety issues.

made no change [drink and drive the same as before]. Unread options: *Don't drink*, *Don't drink & drive*).

Knowledge of the BAC Limit

Only half of the respondents (50%) claimed to know the BAC limit (see Figure 2). Of those, nearly three-quarters (74%) correctly reported the limit as 0.08%. Another 17% reported the old limit of 0.10%. Thus, among all respondents, only 37% knew the correct BAC limit.

When asked whether the BAC limit had changed since 1992, sixty-four percent of respondents thought it had; another 27% were not sure and 10% said it had not.

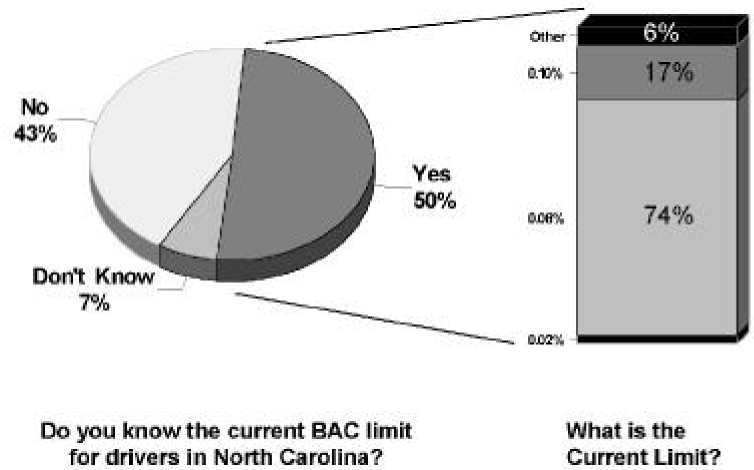

Figure 2 Reported knowledge of new BAC limit.

Knowledge both of the limit and that it had changed was related to education, sex, and race. As is shown in Figure 3, males, those with higher levels of formal education and whites were more likely to know the BAC limit had changed and what the new level was.

It would appear that general knowledge in the population of the new BAC limit was poor. However, this kind of information is not so relevant to non-drinkers as it is for drinkers, and a substantial proportion of North Carolina residents are non-drinkers. Survey data routinely collected on alcohol use indicate that from 45 - 50% of adults in North Carolina report being non-drinkers (Kroutil et al., 1997). In the present sample 70% reported being non-drinkers.

As is shown in Figure 4, those persons who reported that they do drink were far more likely to be aware of the BAC limit and that it had changed recently. Knowledge of the limit was even more closely related to reported frequency of drinking. Whereas 67% of those who drink more than once a week knew the new limit, barely a quarter of non-drinkers could report that 0.08% was the limit (not shown in figure).

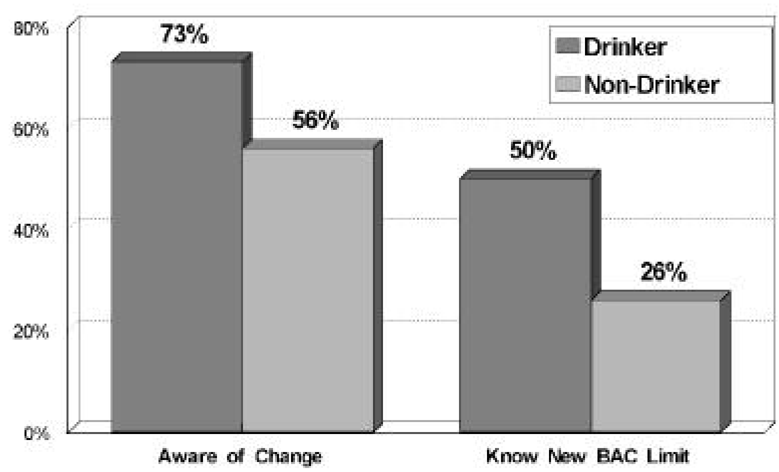

Figure 3 Drinker vs. non-drinker knowledge of 0.08% BAC limit

Drinking status also significantly modified the relationship between knowledge of the BAC limit and demographic characteristics. When drinking status is controlled, neither sex nor race is related to knowledge that the BAC limit had changed (although there is still a weak relationship between race and knowledge among non-drinkers). Among both drinkers and non-drinkers, males are more likely to know the correct BAC limit. Among drinkers, there were no racial differences in knowledge of the limit, but among non-drinkers blacks were less likely to know the current BAC limit.

Not surprisingly, level of formal education was strongly related to knowledge of the BAC limit and that it had changed. Among both drinkers and non-drinkers this relationship remains strong. Moreover, education largely explains the racial differences in knowledge of the limit and that it had changed. Controlling for education had no effect on the relationship between sex and knowledge. Consistently across levels of education, males were more knowledgeable about the new limit than females.

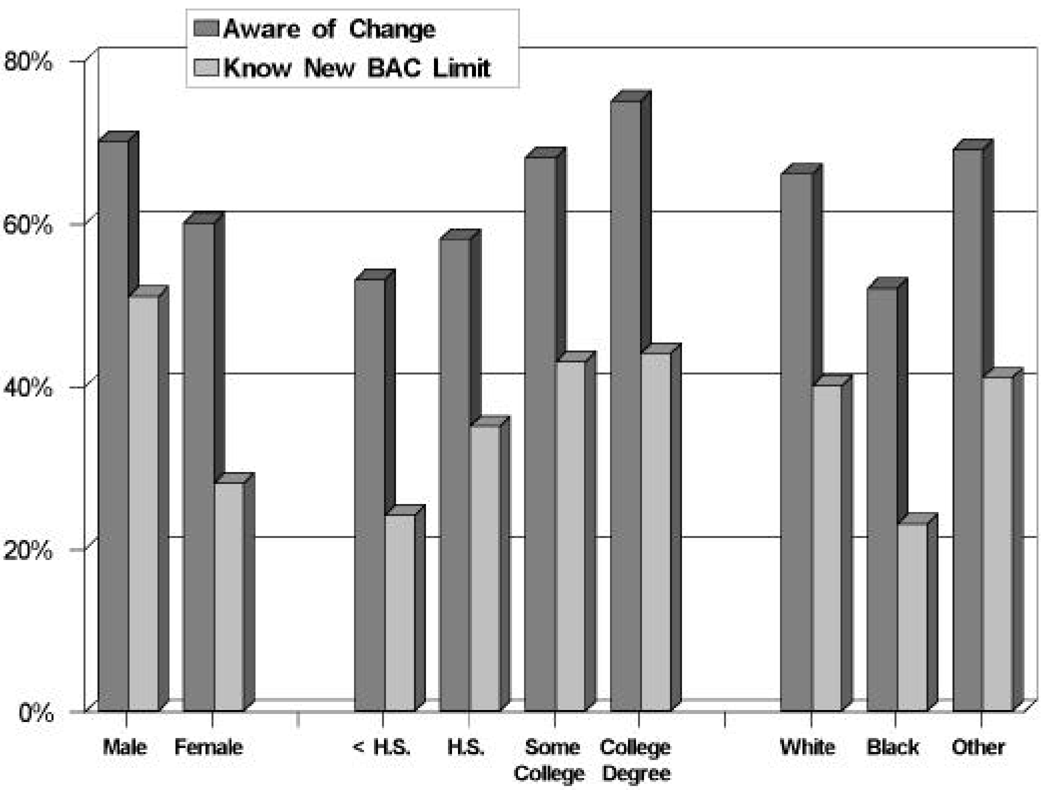

Figure 4 Knowledge of BAC limit by demographic subgroup

Perceived Publicity about the New Law

It is clear that some 17 months after the change formally took place a substantial number of North Carolinians did not know that the BAC limit had been lowered. It is probably not of great importance that non-drinkers were unaware of this change. Nearly three-quarters (73%) of drinkers thought the limit had changed, but only half (50%) could correctly identify the new BAC limit. Even among persons who reported that they drink once a week or more, fully a third could not correctly identify the new limit.

A question arises, then, as to how well the new limit was conveyed to the public. We have no objective way to measure that, but it is possible to address respondents' perceptions of how well the law was publicized. Figure 5 shows the distribution of responses to the question, "How much publicity have you seen or heard about the new blood alcohol limit (BAC) since it took effect? Would you say this new limit has been publicized…" (This question was asked only of those 512 respondents who thought the law had changed.) Despite a substantial lack of knowledge about the new limit, respondents in general appear to believe that the new law was well-publicized. Two-thirds (68%) thought the law was publicized either very well (26%) or pretty well (42%).

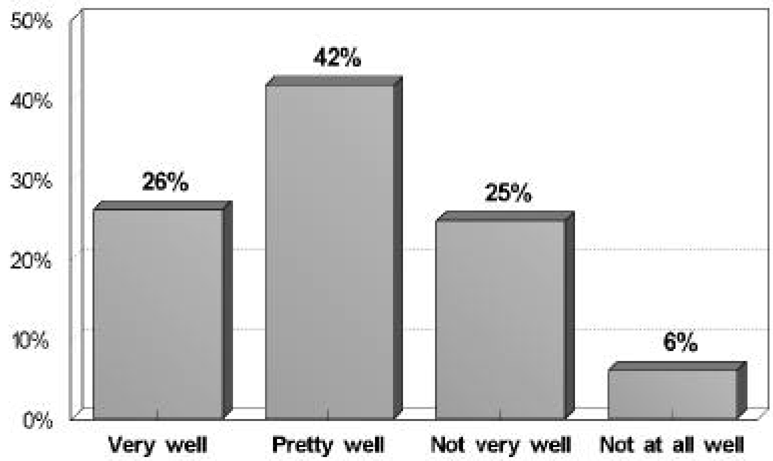

Figure 5 How well has the new BAC limit been publicized? (N = 512)

Perceived publicity of the lower limit was clearly related to age, with older respondents believing the publicity had been more extensive. Education was weakly related to perceived publicity. Less educated respondents were somewhat more likely to believe the change in the law had been well-publicized. Drinking status, race, and sex were unrelated to perceptions about publicity of the law.

Those respondents who correctly identified the new BAC limit were somewhat more likely to believe the law had been well-publicized. This association undoubtedly would have been stronger if the question had been asked of all respondents, including those who did not think there had been a change.

Perceived Effect of the Lower BAC Limit

Respondents overwhelmingly (85%) believed that lowering the BAC limit increased the likelihood that individuals would be arrested for drinking-driving. The vast majority denied that it had any relevance to them, however. Fifty-two percent of those who knew of the change reported either that they don't drink or don't drink and drive. Another 18% said the law had not affected their behavior. (In all likelihood some of these individuals also meant they were unaffected because it didn't apply to them.) Nine percent indicated that they are less likely to drive after drinking and 3% reported that they began drinking less. Of the entire sample, fewer than 6% reported that they had driven after having anything to drink during the past month. Only two admitted that they might have been above the legal limit.

Roadside survey studies of drivers' perceptions of risk of apprehension have demonstrated that those individuals to whom DWI laws are most likely to apply (e.g., persons coming from bars, and those with elevated or illegal BACs) are least likely to believe they will be detected or arrested (Foss & Perrine, 1990). A similar finding emerged in the present survey. In response to the question of whether the new limit would increase the likelihood of individuals being arrested for drinking-driving, persons who drink most frequently (more than once a week) were least likely to believe the likelihood of arrest was increased by the law (see Figure 6).

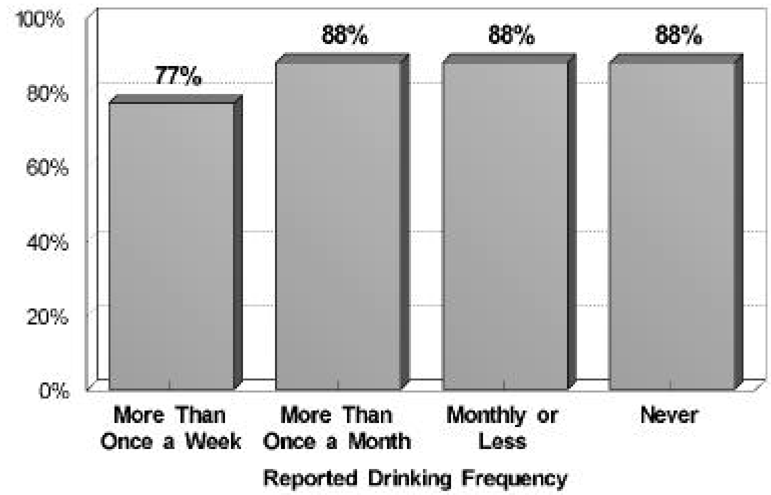

Figure 6 Perceived likelihood that DWI arrests will increase following new law by respondent drinking frequency.

❑ CHANGES IN ALCOHOL-RELATED CRASHES

For the following crash analyses, we used data reported to the North Carolina Division of Motor Vehicles, Collision Reports section (the North Carolina Traffic Crash File). Since January 1991 information obtained from the North Carolina Medical Examiner's Office concerning alcohol use by drivers killed in crashes has been used to update information recorded by investigating officers at the crash scene. As a result, data on alcohol involvement in fatal crashes prior to this date are not directly comparable to the more recent information.

Figure 7 shows the proportion of fatal crashes in North Carolina that involved alcohol from 1991 through 1995 as reported by the NC Division of Motor Vehicles in its annual Crash Facts report. There was a dramatic decline in alcohol-related fatal crashes, from 42% to 27% **S** a 36% relative decrease. The majority of this decline occurred from 1991 to 1993. Although the sharpest drop occurred during the year when the lower BAC limit took effect, the new limit was in effect only for the final three months of 1993.

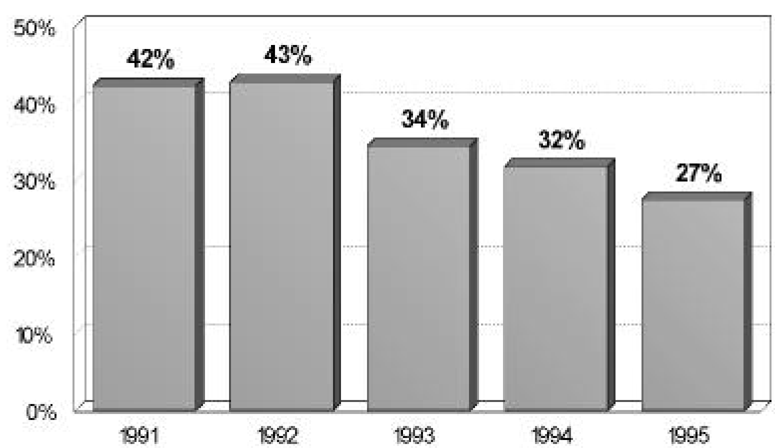

Figure 7 Percent of North Carolina fatal traffic crashes involving alcohol, 1991 - 1995 (source: NC Div. of Motor Vehicles).

Because the 0.08% law applies to operators of vehicles, we examined changes only for those crashes where drivers of motor vehicles had been drinking (either by objective measurement or officer judgment) as the criterion of interest. That is, those crashes that involved alcohol only by virtue of drinking by a pedestrian or bicyclist were not considered alcohol-involved crashes for purposes of this evaluation.

Figure 8 shows the percent of all crashes that involved a drinking driver by month from January 1991 through December, 1995. It is clear that the most dramatic part of the decline in alcohol involvement occurred well in advance of the reduction in the BAC limit. Although 'anticipatory' effects of traffic laws are sometimes seen, that does not appear to have occurred in the present case. Legislation to reduce the BAC limit was introduced in the North Carolina General Assembly in March of 1993 and was passed in July.[5]

Examination of the data series suggests that if there was a time-delineated shift (rather than simply a general continuing decline), it probably occurred somewhere in early- to mid-1992, fully a year before the 0.08% legislation was introduced. We are unable to find any events or policy changes that occurred around that time which might have resulted in such a decline.

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[5] We examined coverage of this issue in the Raleigh *News & Observer*, one of the two major newspapers in the state that give detailed coverage of legislative activity. Given the high level of interest in drinking-driving issues in North Carolina, the low amount of coverage accorded this issue is fairly striking. This may be due, in part, to the fact that the legislation was not the subject of extensive debate. The bill received little attention until the final days of the session, when it was passed.

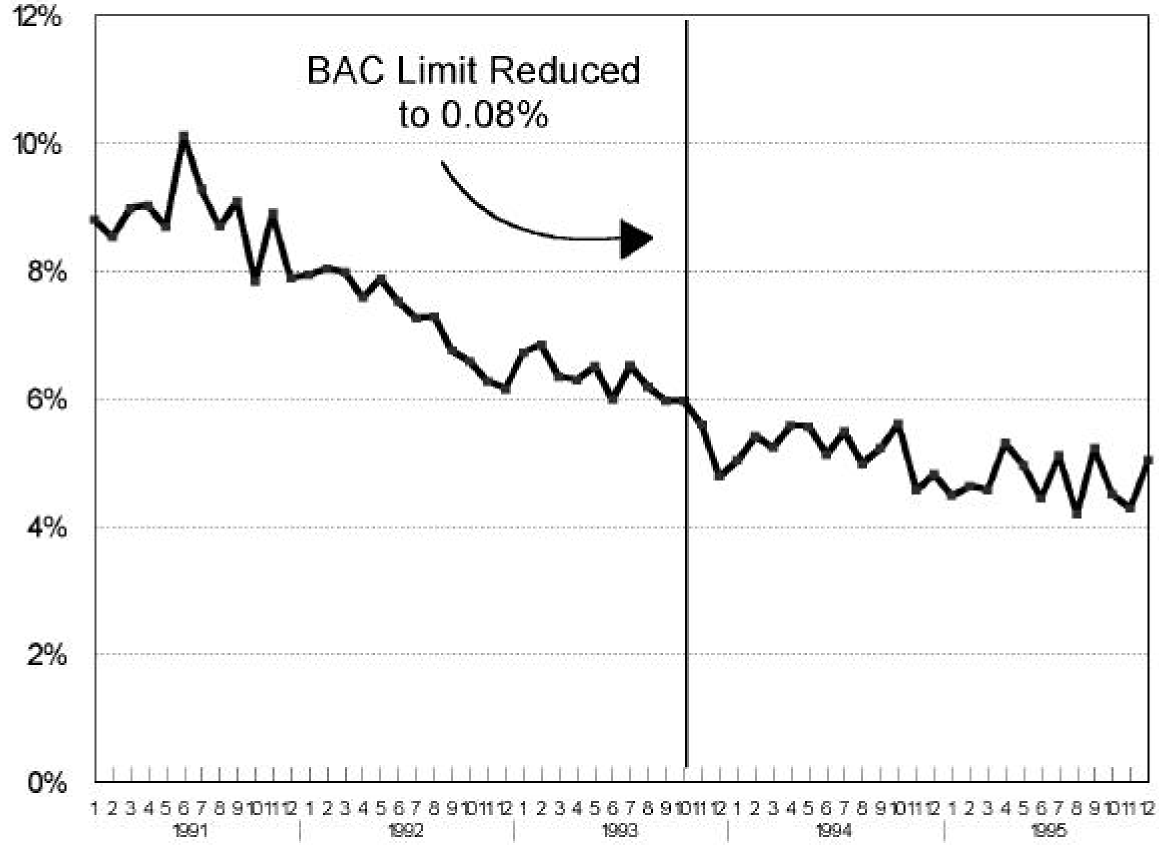

Figure 8 Percent of all North Carolina crashes involving alcohol, 1991 - 1995.

Because of the variety of factors that influence motor vehicle crashes in general, and those involving alcohol in particular, it is necessary to conduct more sophisticated, time-series analyses to determine whether an intervention has had an effect. Accordingly, a number of time series models were fit to the number of various types of motor vehicle crashes occurring in North Carolina by month from January 1991 through December 1995. These models were used to estimate any changes in the number of alcohol-related crashes that coincided with implementation of the lower BAC limit. Structural time series models were fit to the data using the software package STAMP (Structural Time Series Analyser, Modeler and Predictor) developed at the London School of Economics and ESRC Centre in Economic Computing (Harvey, 1989).

The components of structural time series models consist of a level, a trend, seasonal factors, effects due to various “regression variables” and intervention effects (see Harvey, 1989, for a thorough discussion of these models). The level, trend, and seasonal factors can either vary stochastically over time, to accommodate the possibility that they do not remain constant, or be constrained to take on fixed values. Regression variables can include autoregressive terms (lagged values of the response variable) as well as other explanatory factors associated with the response variable. In the models that follow, two basic types of intervention effects were considered. One includes a step shift in the level of the series at the point of intervention; the other hypothesizes a change in the trend or slope (rather than an abrupt shift) of the series beginning at the time of intervention. The objectives of model development are to construct a model that produces essentially uncorrelated residuals, has statistically significant parameters, and fits the data series as well as possible.

As an illustration of the modeling procedure, consider the following model fit to the data series of monthly alcohol-related crash frequencies. The model was fit using a log transformation, so the response variable was $\log_e$ (alcohol related crashes)[6]. The model contains a stochastic level, stochastic slope, and stochastic seasonal factors. Three regression variables were included: an autoregressive term at lag 7, the log of all crashes (to control for amount of travel), and a variable that represents the number of weekends in each month (since alcohol-related crashes are more common on weekends). The intervention variable was a unit step-function occurring in October 1993. Results from this model are shown in table 2.

Table 2. Parameters for model of North Carolina alcohol-related crashes ($\log_e$), 1991 - 1995

Parameter	Estimate	s.e.	t-ratio	p-value
Level*	-3.23	2.23	-1.450	.156
Trend*	-.007	.0014	-4.661	<.0001
$\log_e$ (A-R crashes, at lag 7)	.469	.121	3.850	.0001
$\log_e$ (all crashes)	.644	.181	3.556	.001
Weekends	.053	.010	5.55	<.0001
Intervention (Lower BAC limit)	-.008	.025	-.330	.744

* level and trend estimates represent final estimates at end of series.

Test for Seasonality $\chi^2_{(11)} = 33.79$, p = .0004

Residual Autocorrelations	***Goodness-of-Fit***
Q(5) = 4.30	$R^2 = .874$
Q(10) = 11.55	$R^2_D = .780$
Q(15) = 12.38	$R^2_S = .624$

For simplicity, estimates of the 11 seasonal parameters are not shown, but rather only an overall test for seasonality. There is a significant seasonal component in alcohol-related crashes during the time period from 1991 through 1995.

Information concerning residual autocorrelation is presented by the three values of the Ljung and Box Q-statistic. This statistic Q(k) is based on the sum of squares of the first *k* residual autocorrelations and is approximately distributed as χ^2 with $k - \tau$ degrees of freedom, where τ is the number of stochastic components in the model. Thus, values of Q(k) that remain at a value of *k* or smaller tend to indicate that the residuals are sufficiently uncorrelated. Thus, for Table 2 above,

$$Q(k) = Q(5) = 4.30 \simeq 5 = k$$

6 Time-series analyses often use log-transformations because data transformed in this way exhibit more desirable mathematical properties.

and similarly for Q(10) = 11.55 $\simeq$ 10 and Q(15) = 12.38 $\simeq$ 15. These suggest that the residuals in the model for alcohol-related crashes are reasonably uncorrelated. Note that k = 5, 10 and 15 are selected to be representative of the possible range of residual autocorrelations.

Three goodness-of-fit measures are also shown for the model. R^2 is a measure of the overall fit of the model, part of which is due to the trend and seasonal factors. R^2_D is a measure of the goodness-of-fit of the detrended series (that is, with any general trend removed) and R^2_S the fit of the deseasonalized series (i.e., with seasonal fluctuations removed).

The estimated intervention effect shown in table 2 is quite small and is not statistically significant (p = .744). This estimate represents a decrease in the value of the logarithm of alcohol-related fatal crashes by .008 beginning in Oct. 1993 and persisting through the end of the series.

When the change in slope or trend (in October, 1993), rather than a step shift, was modeled, the estimated effect was .006. Thus, the effect is a slight increase in the (downward) slope of the series, but again, the estimate is not statistically significant (t = .951, p = .348).

The models described above represent the *number* of alcohol-related crashes per month as a function of the monthly frequencies of all crashes, seasonality, general trend and number of weekends per month. We also tried an alternative approach, modeling the *proportion* (or percent) of all crashes that were alcohol-related to see if changes could be detected that coincided with the 0.08% legislation. Specifically, we constructed a data series where $P_t \equiv$ percent of all crashes in month *t* that were alcohol-related, and time series models were fit to P_t, $\log_e(P_t)$, and $\text{logit}(P_t) = \log_e(P_t/(100-P_t))$ Models fit to each of these three data series were of the same structure and produced similar estimates of intervention effects. Hence, only results for the logit models are reported below.

Because the new BAC limit may have affected only more serious crashes, which are most likely to be alcohol-related, we conducted additional analyses to examine the percent of all fatal and serious injury crashes that were alcohol-related. Although reporting of alcohol involvement in North Carolina crashes is considered to be quite good, surrogate measures of alcohol-involved crashes are sometimes used to supplement analyses that are based on officers' judgments about alcohol involvement. Hence, additional analyses were conducted using each of the following as the 'response' variable:

- percent of all crashes that occurred during nighttime hours (between the hours of 8:00 p.m. and 4:00 a.m.), and

- percent of all fatal and serious injury crashes occurring during nighttime hours.

The results obtained when fitting models to logit transforms of each of the series described above are presented in table 3.[7] Two separate models were fit to each data series – one with a step shift at time of intervention (October 1, 1993) and one with a change in slope at time of intervention. None of these effects was statistically significant in any of the models.

[7] More extensive description of these models is given in Appendix A.

Table 3. Parameters for logit models of various indicators of alcohol-involved North Carolina crashes, 1991 - 1995.

Outcome Variable	Modeled intervention effect	Estimate	s.e.	p-value
Percent of crashes involving alcohol S *all levels of severity*	Shift in level	-.038	.038	.320
	Change in trend	.001	.009	.866
Percent of crashes involving alcohol S *severe and fatal crashes only*	Shift in level	.023	.058	.698
	Change in trend	-.0001	.003	.986
Percent of crashes occurring at night S *all levels of severity*	Shift in level	-.022	.022	.308
	Change in trend	.001	.003	.762
Percent of crashes occurring at night S *serious and fatal crashes only*	Shift in level	.050	.040	.222
	Change in trend	.003	.002	.288

Comparison of North Carolina Crash Trends to Other States

Although none of the analyses indicate that the lower BAC limit had an effect on alcohol-related crashes, it was thought that perhaps the effect of the new law might have been to prevent an upturn in alcohol-involved crashes that appeared to be afoot nationally. It is possible that the rate of decline in alcohol-related crashes was already so great in North Carolina when the new law came into effect that it could not produce an added benefit. We reasoned that perhaps having this law in place as the broader trend in alcohol-related crashes leveled might serve to mitigate that effect in North Carolina. Accordingly we compared the trend in alcohol-related fatal crashes in North Carolina with that in eleven other states that have had consistently high rates of testing for alcohol among fatally injured drivers (> 80% for each year 1991 - 1995).[8] The mean testing rate for these 11 states was 89.9% (vs. 85.3% for NC) for the five year period.

Data on BAC's of drivers killed in motor vehicle crashes in North Carolina and the 11 other states were obtained from the Fatality Analysis Reporting System (FARS). The data covered the time period from January 1990 through December 1995. Over this time period, 26.1% of drivers killed in motor vehicle crashes in North Carolina were reported to have BAC's of 0.10% or higher. In the other states this

[8] The states selected were Colorado, Connecticut, Hawaii, Illinois, Massachusetts, Montana, New Mexico, Oregon, Rhode Island, Washington, and Wisconsin. Among these states, Oregon, Hawaii, and New Mexico have 0.08% BAC limits. However, only the New Mexico law, which also changed in 1993, presents a problem for this analysis. The law in Oregon did not change during the analysis period and Hawaii's change only applied to the final few months of the period. Including New Mexico in this analysis has a slight tendency to work against finding an effect of the North Carolina law. However, because of its relatively small population, excluding New Mexico from the analysis would not materially change the results.

percentage ranged from 30.8% (Massachusetts) to 44.1% (Montana). The overall rate of alcohol involvement for the 11 states combined was 36.8%.

Three monthly data series were created:

- P the percent of all fatally injured drivers in North Carolina having BAC's $\geq$ 0.10%

- P the percent of all fatally injured drivers in the 11 comparison states with BAC's $\geq$ 0.10%

- P the logit transform of the proportion of all killed drivers with BAC's $\geq$ 0.10% among the 12 states that were North Carolina drivers

Time series models were then fit to each of these data series. The data series for percent of fatally injured North Carolina drivers with BAC $\geq$ 0.10% was essentially a random series (i.e., there were no significant autocorrelations). In this case the basic time series model reduced to a regression line fit to the data points. The estimated model parameters are shown in table 4. When added to the model, neither a step shift (p = .728) in October 1993, nor a change in trend component (p = .765), was statistically significant.

Table 4. Regression statistics for percent of fatally injured North Carolina drivers with BAC $\geq$ 0.10% by month, 1990 - 1995.

Parameter	Estimate	s.e.	t-statistic	p-value
Intercept	31.90	1.16	27.57	<.0001
Trend	-.159	.028	-5.79	<.0001

Goodness-of-Fit
R^2 = .324
R^2_D = .500

The data series for the percent of fatally injured drivers with BAC's $>$ 0.10% in the group of comparison states was also an essentially random series with a slight downward trend. The autocorrelation function, however, suggested that the data contained some seasonal variation. Thus a model that contained a fixed level, fixed slope and stochastic seasonal effects was fit to this series. Results are summarized in table 5.

Table 5. Regression statistics for percent of fatally injured drivers in 11 comparison states with BAC $\geq$ 0.10% by month, 1990 - 1995.

Parameter	Estimate	s.e.	t-statistic	p-value
Level	40.64	.713	56.96	< .0001
Trend	-.107	.017	-6.25	< .0001

Test for Seasonality $\chi^2_{(11)} = 17.27$, p = .100

Residual Autocorrelations	***Goodness-of-Fit***
Q(5) = 5.00	$R^2 = .383$
Q(10) = 11.25	$R^2_D = .471$
Q(15) = 17.38	$R^2_S = .199$

Thus both series show general decreases in alcohol involvement over time, though the rate of decrease is slightly greater for the North Carolina series (-.159 vs -.107).

A more direct way of examining alcohol-related fatalities in North Carolina relative to those in the comparison states is to consider the proportion of all fatally injured drivers with BAC > 0.10% who were North Carolina drivers. A model was fit to the logit transform of this proportion. Parameter estimates for the best fitting model to this series are shown in table 6.

Table 6. Parameter estimates for best fitting model for North Carolina alcohol-related (BAC $\geq$ 0.10%) fatalities relative to those in 12 States, 1990 - 1995.

Parameter	*Estimate*	*s.e.*	*t-statistic*	*p-value*
Intercept	-1.95	.276	-7.06	< .0001
Trend	-.004	.002	-2.10	.039
Autoregressive Lag 1	.147	.119	1.23	.236
Autoregressive Lag 5	-.325	.119	-2.74	.008

Residual Autocorrelations	***Goodness-of-Fit***
Q(5) = 6.71	$R^2 = .165$
Q(10) = 10.58	$R^2_D = .495$
Q(15) = 16.20	

This series also displays a slight downward trend (.004) in the proportion of alcohol-related crashes involving North Carolina drivers during the period from 1990 through 1995. Intervention effects added to the model did not approach statistical significance for either a shift in level (p=.862) or a change in trend (p=.509).

These results confirm earlier analyses, again showing that alcohol-related crashes have been declining in North Carolina over the past several years but that no specific effects are found that can be attributed to the lowered *per se* illegal BAC limit.

Analyses of BAC Data for Fatally Injured Drivers in North Carolina

Evaluations of drinking-driving interventions often look only at fatal crashes. There are two reasons to do this. First, having a much greater involvement of alcohol, fatal crash rates are probably more sensitive indicators of drinking-driving. Second, measurement of alcohol involvement is generally better in fatal crashes.

Hence, in addition to the data extracted from FARS, information on BAC's of killed drivers was also obtained from the North Carolina Medical Examiner's (ME) office. These data covered the time period January 1991 - December 1995. From these data, two monthly time series were constructed and analyzed. The first was the monthly percent of all fatally injured drivers who had BAC's $\geq$ 0.10%. This is essentially the same as one of the data series extracted from FARS, although the beginning of the time interval is 1991 rather than 1990. Where the time intervals overlap, the agreement between the two series is close but not identical.

The behavior of the ME data series is quite similar to that from FARS. Namely, the data series is essentially a random series with no significant autocorrelation structure. A straight line fit to the data contains a significant negative (or decreasing) trend, $p < .0001$. Neither a shift in level nor a change in trend effect was statistically significant, $p = .113$ and $p = .325$, respectively.

The second data series was a month-by-month series of mean BACs for fatally injured drivers in North Carolina crashes whose BAC's were0.10% or higher. The mean of these monthly means was 0.21% and over the 60 month interval the values ranged from 0.16% to 0.26%. This series did contain some significant autocorrelations but did not exhibit any long term trends. A model fit to this series contained a fixed level and autoregressive terms at lags 5 and 6. Adding a linear trend term to the model yielded an estimated trend of .00011 with a standard error of .00016 ($p = .460$). Similarly, neither a shift in level nor a change in trend intervention was significant, with p-values of .254 and .598, respectively.

In summary, the proportion of fatally injured drivers having BAC's $\geq$ 0.10% has continued its decline through 1995, but with no abrupt changes that can be attributed to the 0.08% law. The mean BAC of fatally injured drivers with BAC's $\geq$ 0.10%, on the other hand, has remained relatively constant with an overall mean of 0.21%.

The failure to find an effect that might be attributed to the lower BAC limit in North Carolina, considering a variety of indicators of alcohol involvement, suggests that the law has not had the intended effect. There are a number of possible reasons for this. First, and perhaps most likely, is simply that reducing the legal limit does not affect drinking-driving behavior. There are other possible explanations. It may be that the proportion of the drinking-driving population that such a law would affect had already changed their behavior before the limit was lowered in North Carolina, where drinking-driving is less common than in other states. Or, similarly, given the dramatic decline in alcohol-related crashes that was occurring in North Carolina during the early 1990s, it may be that any possible effects of reducing the BAC limit were simply obscured by a broad change in drinking-driving behavior that was already occurring.

Yet another possible explanation for the failure of an effect to materialize for the lower BAC limit is that this new, lower level was not sufficiently well publicized. There was relatively little media attention to the 0.08% law, either when it was being considered, when it passed, or when it was enacted. On the other hand, beginning about 14 months after the BAC limit was lowered, there was a great deal of publicity about DWI enforcement in conjunction with the "Booze-it-and-Lose-it" campaign, which featured sobriety checkpoints in every North Carolina county. Most publicity about DWI enforcement in North Carolina does mention the BAC limit of 0.08%, though there was no particular mention that the limit was lower than it had been previously.

One important consideration in the analysis of crashes where alcohol involvement is judged rather than measured is the possibility that the new law may have increased officers' sensitivity to alcohol involvement, either individually or, perhaps, via organizational policy (having signaled to law enforcement agencies that drinking-driving was of heightened concern to the legislature). In the present situation, increases in officers' sensitivity to alcohol involvement would work against our finding an effect of the law. If the proportion of alcohol-involved crashes actually decreased, while officers' diligence in reporting alcohol involvement increased, the latter would tend to mask the former. However, the failure to find any change in alcohol involvement in fatal crashes or surrogate measures of alcohol involvement suggests that real effects of the 0.08% law are probably not being masked by changes in alcohol detection where officer judgment is central.

Another possible explanation for the failure to detect an effect of the new law is that it was not being enforced. If persons with BACs of 0.08-0.09% were not being arrested, or if those arrested at that level were not being prosecuted or convicted, that information would begin to spread and would dilute, or eliminate, any possible effect of the new law. To address this possibility, changes in DWI arrests and convictions following implementation of the 0.08% law as well as possible effects on the court system were examined.

Changes in DWI Arrests and Convictions

It was expected that the number of arrests for DWI would increase following enactment of the 0.08% law. For example, roadside survey data from Ohio and Minnesota indicate that lowering the illegal BAC from 0.10% to 0.08% would have increased the number of nighttime drivers who are in violation of the DWI law by 44% to 52% in those states (Foss & Perrine, 1990; Foss, Beirness & Sprattler, 1994).

We had hoped to examine the trend in DWI arrests as part of this study. This would have been complicated by the variety of overlapping special enforcement efforts that have occurred in North Carolina during the 1990s, but these could likely have been dealt with satisfactorily. However, a serious disruption in the availability of driver history file data occurred as the North Carolina Division of Motor Vehicles revised their data system. As a result we were not able to track arrest and conviction data as we had hoped.

An HSRC study using data obtained before the disruption, however, does provide an indication of changes in DWI arrests that occurred following implementation of the new BAC limit (Foss, Martell & Stewart, 1995). The proportion of persons arrested with BACs below 0.10% increased 20-fold immediately after the lower BAC limit took effect, going from less than 1% to approximately 10% of DWI arrests. Arrests of persons with ‘marginally’ illegal BACs of 0.10-0.11% appear to have increased somewhat as well. However, the overall number of arrests did not increase. Whether this reflects a general downward shift in BACs among the driving population, or that fact that officers’ time was more often spent arresting more prevalent types of drinking drivers **S** those with lower, but still illegal, BACs **S** is not known. In view of data reported above showing no apparent change in drinking-driving as a result of the new law, it appears that the latter explanation is more likely.

In sum, the 0.08% BAC law did not affect the size of the case load in the North Carolina Substance Abuse Treatment system. However, the make-up of the population of individuals screened for alcohol/substance abuse problems did change by virtue of an influx of persons arrested with lower BACs, who were less likely to be diagnosed as needing treatment for alcohol use problems. Hence, although persons with BACs of 0.08-0.09% may not have been arrested in proportion to their prevalence, they were by no means being overlooked by law enforcement officers.

Changes in DWI Case Loads for Prosecutors and the Courts

It is of interest to know what effect the new law has had on the criminal justice system. Although the study of California's 0.08% BAC limit indicated little effect on case loads, there was still some concern that an overload might result in North Carolina. In addition, it is possible that persons with low BAC arrests were less likely to be charged or convicted, which might undermine the effect of the new law. To determine whether any of these effects may have occurred, we conducted key informant interviews with county prosecutors (or their representatives) from six counties selected to provide a rough representation of the state.

Figure 9 shows the counties where interviews were conducted. These represent both urban and rural counties as well as the three naturally occurring geographic regions of the state: the western/mountain region, the more heavily populated and industrialized Piedmont (central) region, and the eastern/coastal region.

Among the main issues pursued were (1) whether the new law produced a notable increase in the workload for prosecutors; (2) what, if any, effect the law had on the way cases were prosecuted; (3) whether prosecutors were less likely to charge persons arrested with low BACs; or (4) whether judges appeared to have viewed cases with marginal BACs at time of arrest (i.e., 0.08-0.09%) any differently from the way they viewed marginal BACs (0.10-0.11%) prior to the law.

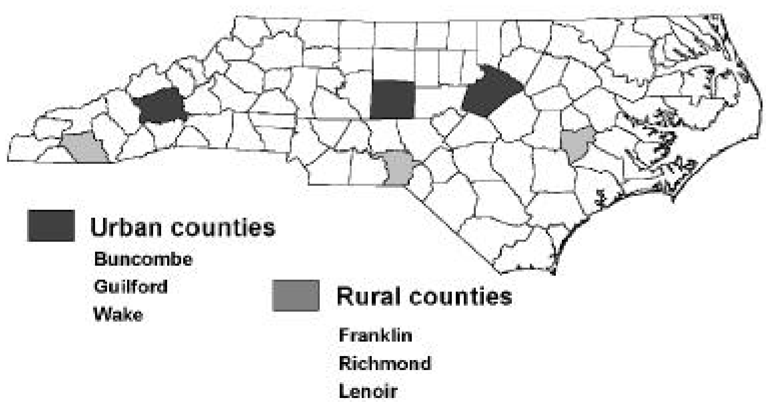

Figure 9 Counties where prosecutors were interviewed.

These interviews produced no evidence that the new law had increased the perceived number of arrests, or that persons with BACs of 0.08-0.09% were not being charged or convicted. Because there was no apparent effect of the 0.08% law on prosecutors' case loads, procedures, or conviction rates, we did not pursue discussions with representatives from a larger sample of counties.

❑ Comparison of North Carolina Alcohol-related Fatal Crashes with Those in Other States

As a final set of analyses for this study, we examined several indicators of alcohol involvement in North Carolina fatal crashes compared to fatal crashes in the 37 U.S. states that did not have an 0.08% BAC limit at any time during the period 1991 - 1996. These analyses looked at the six criterion variables reported in the NHTSA preliminary study of the effects of 0.08% laws in the first five states to enact such laws (described below; NHTSA, 1994).

Alcohol use, and its involvement in crashes, has been on the decline for many years in the U.S. Therefore, it is necessary to include an appropriate comparison group (state or states) when examining changes in alcohol involvement in crashes across time to evaluate the effect of an intervention, such as the reduction of the BAC limit. Although there is some appeal to choosing a comparison group that is 'similar' to the state under consideration, it is difficult to know the relevant characteristics upon which states should be matched. Hingson et al. (1996) have been criticized for, among other things, their choice of comparison states (Scopatz, 1998). Although there is merit to the arguments advanced by both sides on this issue, it is probably impossible to convincingly argue that a particular state is the best (or even an appropriate) match to any other state. Consequently, rather than comparing alcohol involvement in North Carolina crashes with those of any particular state or subset of states, we elected to compare North Carolina with all states that had a BAC limit of 0.10% during the entire period we examined (January 1, 1991 **S** December 31, 1996).[9]

As mentioned above, there are shortcomings in every indicator of alcohol involvement in crashes. If we rely only on police reports of alcohol involvement, there is the likelihood that some alcohol-related crashes are misjudged as not involving alcohol. If we rely only on data where a driver's BAC was objectively measured, a large and unrepresentative proportion of crashes are excluded from analysis. To address this problem, several years ago the National Highway Traffic Safety Administration developed a technique to estimate alcohol involvement in fatal crashes where no objective measure of alcohol was obtained (Klein, 1986). Using discriminant function analyses it is possible to estimate, with a substantial degree of precision, the likelihood that a crash involves a drinking driver, given other characteristics of the crash, the driver and the vehicle he/she is driving. These estimates[10] of alcohol involvement are used by the NHTSA in their analyses of alcohol involvement in fatal crashes and are included in publicly distributed crash data files. The estimates provide an indication of whether a driver involved in a fatal crash had a non-zero BAC (i.e., > 0.01%) and also the probability that the driver's BAC was in excess of 0.10%, the legal limit in most states. We examined two criterion variables, using Klein's estimation procedures, for all drivers involved in fatal crashes:

- Any alcohol involvement by a driver (BAC $\geq$ 0.01%) and
- Whether there was evidence of alcohol in excess of 0.10% for a driver.

For completeness, and to parallel various other studies of alcohol use by drivers in fatal crashes, we also looked at the following four variables, comparing North Carolina with the 37 other states:

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9 The following states had an 0.08% BAC limit in effect for at least some portion of the period from 1991 to 1996 and were, therefore, excluded from the analyses: Alabama, California, Florida, Hawaii, Kansas, Maine, New Hampshire, New Mexico, Oregon, Utah, Virginia, Vermont.

10 It is important to note that although we refer to these as estimated values, since they result from use of an estimation procedure, a large proportion of these data represent an actual measurement. When a measurement is present, the 'estimated BAC' is the measured value. Only in those instances where no BAC measurement is available do the data actually include estimated values.

- Police-reported alcohol involvement
- Single vehicle nighttime crashes (a traditional proxy or surrogate measure for drinking-driving)
- Single vehicle nighttime crashes by male drivers (another commonly used proxy measure for drinking-driving)
- Estimated alcohol involvement (based on police report, driver record of previous alcohol citation, and measured BAC)

As noted above, each of these measures taken alone has shortcomings. The most appropriate way to address this problem is to look at each of the measures to see whether a consistent picture emerges. If the 0.08% law has a clear and strong effect, that should be detectable using any one of the measures–and the effect should appear with all of them. Should there be inconsistencies in results among the measures, we believe that based on the strengths and weaknesses of each, more credence should be given to findings based on the two variables based on the statistical estimation procedures. The other four measures are less robust in that, in one way or another, they incorporate only some of the information that the estimates include.

The most appropriate, though statistically complex, way to examine the effect of a point-in-time intervention, such as enactment of a law, is through the use of statistical modeling procedures to examine a series of data points, as was done in the analyses reported above. However, prior to conducting detailed time-series analyses for each of the several indicators of alcohol-involvement in fatal crashes for North Carolina and the 37 comparison states, we decided to first do a simple before-after comparison. We planned to conduct time-series analyses using only those indicators that showed a clear effect in the simple before-after comparison.

The following analyses consider all drivers involved in fatal crashes between 1991 and 1996, as reported in the NHTSA Fatality Analysis Reporting System (FARS). This provides data for a 33 month period prior to implementation of the 0.08% law in North Carolina and 39 months following its enactment. For ease of comparison with other analyses in the literature, we used the same statistical measures as those employed by Hingson et al. (1996), that is, a ratio of relative risks of alcohol involvement comparing North Carolina to the other 37 states.[11]

Driver BAC of 0.01% or Greater

During the 33 months prior to enactment of the 0.08% law, 24.4% of drivers involved in a fatal crash in North Carolina had an estimated BAC of 0.01% or greater. That declined to 20.1% in the 39 months immediately following enactment of the lower BAC limit, which is a statistically significant decline of 17.4% ($p < .001$). The risk ratio for alcohol involvement at this level before vs. after enactment of the law is 1.21, with a 95% confidence interval of 1.14 to 1.29. Among the 37 states without an 0.08% BAC limit, there was a decrease in estimated alcohol involvement, from 28.1% to 24.5%, a decline of 12.8%, which is also statistically significant ($p < .001$). The before-after risk ratio for these 37 states is 1.15, with a 95% confidence interval of 1.13 to 1.16. The comparison of the change in these states vs. North Carolina, given by the ratio of these two risk ratios, is 1.06. Although this reflects a 6% greater decline in North Carolina, the 95% confidence interval for this ratio is .98 to 1.14, indicating that the difference in declines between North Carolina and the other states is not statistically significant.

[11] We wish to gratefully acknowledge the assistance of Dr. Tim Heeren, Boston University, who provided detailed information on their calculations.

Hence, the conclusion is that the proportion of drivers involved in fatal crashes who had a BAC above 0.01% declined significantly, and to about the same degree in both North Carolina and the other 37 states.

Table 7. Drivers age 21 or older in fatal crashes with estimated BAC of 0.01%, 1991 - 1996, North Carolina vs. 37 states without 0.08% BAC limit before and after enactment of 0.08% limit in North Carolina.

	North Carolina		**Other 37 States**	
	≥ 0.01%	**< 0.01%**	**≥ 0.01%**	**< 0.01%**
Before (1/1/91 to 9/30/93)	24.4% (1,014)	75.6% (3,147)	28.1% (24,027)	71.9% (61,487)
After (10/1/93 to 12/21/96)	20.1% (1,093)	79.9% (4,337)	24.5% (26,272)	75.5% (81,005)
Decline	17.4%*		12.8%*	
Risk Ratio (before/after)	1.21		1.15	
95% Confidence Interval	[1.14, 1.29]		[1.13, 1.16]	
* p < .001	RR_{NC}/RR_{37} = 1.06, 95% CI = .98 to 1.14			

Driver BAC of 0.10% or Greater

We would not necessarily expect that lowering the BAC limit to 0.08% would reduce the proportion of drivers who had any alcohol in their system, which the previous analysis examined. Many drivers with a positive – but low – BAC are below both the former and new BAC limits. If the law is effective, however, it should reduce the proportion of drivers with higher BACs. In particular, we would expect a decrease in the proportion of drivers with BACs above 0.10% in North Carolina compared with states that retained a 0.10% BAC limit. We turn to that analysis now, the results of which are summarized in Table 8.

Table 8. Drivers age 21 or greater in fatal crashes with estimated BAC $\geq$ 0.10%, 1991 - 1996, North Carolina vs. 37 comparison states.

	North Carolina		**Other 37 States**	
	$\geq$ 0.01%	**< 0.01%**	**$\geq$ 0.01%**	**< 0.01%**
Before (1/1/91 to 9/30/93)	22.2% (924)	77.8% (3,237)	23.8% (20,383)	76.2% (65,131)
After (10/1/93 to 12/21/96)	18.3% (991)	81.7% (4,439)	20.7% (22,211)	79.3% (85,066)
Decline	17.8%*		13.1%*	
Risk Ratio (before/after)	1.22		1.15	
95% Confidence Interval	[1.14, 1.30]		[1.13, 1.17]	
* p < .001	RR_{NC}/RR_{37} = 1.06, 95%, CI = .97 to 1.15			

Prior to enactment of the 0.08% law, 22.2% of drivers involved in a fatal crash in North Carolina had an estimated BAC of 0.10% or greater. That declined to 18.3% in the 39 months immediately following enactment of the lower BAC limit, a decline of 17.8% ($p < .001$). The risk ratio for alcohol involvement at this level before vs. after enactment of the law is 1.22, with a 95% confidence interval of 1.14 to 1.30. There was a somewhat smaller decrease in alcohol involvement at this level in the other 37 states, from 23.8% to 20.7%. This 13.1% decrease is also statistically significant ($p < .001$). The before-after risk ratio for these 37 states is 1.15, with a 95% confidence interval of 1.13 to 1.17. The direct comparison of the change in these states vs. North Carolina, given by the ratio of these two risk ratios, is 1.06. The 95% confidence interval for this ratio is .97 to 1.15, indicating again that the difference in declines between North Carolina and the other states is not statistically significant.

The changes in the percent of persons with estimated BAC above 0.10% are nearly identical to the changes in persons having any alcohol (BAC above 0.01%). Both measures provide the consistent finding that the decline in drivers with a positive BAC, or a high BAC, in North Carolina was slightly greater than in the other states, but not significantly so.

Police-reported Alcohol Involvement

A fairly direct measure of alcohol involvement in crashes is the investigating officer's report of whether there is evidence of alcohol use by a driver. Although police officers appear to be quite good at determining whether a driver has been drinking, a variety of factors can interfere with their ability to accurately determine alcohol use. Perhaps the greatest problem is the difficulty in determining low levels of alcohol use, for which there are few obvious indicators. Another problem is that factors at the crash scene, for example, the need to deal quickly with seriously injured persons, may inhibit the officer's ability to fully assess whether a driver has been drinking. Nonetheless, this is an indicator that is commonly used to measure whether alcohol is involved in a crash. Table 9 presents results of the analysis of this variable for North Carolina and the 37 other states.

Table 9. Police-reported (PR) alcohol involvement 1991 - 1996, North Carolina vs. 37 comparison states.

	North Carolina		**Other 37 States**	
	PR-Alcohol	**No Alcohol**	**PR-Alcohol**	**No Alcohol**
Before (1/1/91 to 9/30/93)	17.6% (731)	82.4% (3,430)	19.8% (16,953)	80.2% (68,561)
After (10/1/93 to 12/21/96)	13.4% (725)	86.6% (4,705)	17.1% (18,325)	82.9% (89,125)
Decline	24.0%*		14.0%*	
Risk Ratio (before/after)	1.32		1.16	
95% Confidence Interval	[1.22, 1.41]		[1.14, 1.18]	
* p < .001	RR_{NC}/RR_{37} = 1.13, 95% CI = 1.03 to 1.25			

Prior to enactment of the 0.08% law, police officers reported that 17.6% of drivers in fatal crashes in North Carolina had been drinking. That declined to 13.4% in the 39 months immediately following enactment of the lower BAC limit, a rather dramatic decline of 24%. The risk ratio for police-reported alcohol involvement before vs. after enactment of the law is 1.32. There was a smaller decrease in police reports of alcohol involvement in the other 37 states (14.0%). The before-after risk ratio for these 37 states is 1.16. The ratio of these changes between North Carolina and the other states is 1.13, indicating a significantly greater decline in North Carolina than in states that did not have an 0.08% BAC limit.

It is instructive to look at the changes in police-reported alcohol involvement by quarter for the period 1991 through 1996 shown in Figure 10.a. It is apparent that although a simple before-after comparison of the proportions of drinking drivers in crashes reported by police suggests a decline following implementation of the 0.08% BAC limit in North Carolina, that is an inappropriate conclusion. The reduction in police-reported alcohol involvement in North Carolina relative to the other states began in the second quarter of 1992, 18 months prior to implementation of the lower BAC limit, and approximately a year before legislation to lower the limit was introduced in the North Carolina General Assembly. During 1991, police reports of alcohol involvement in North Carolina fatal crashes were nearly the same as in the 37 states that did not reduce their BAC limits. It is that high rate, rather than a decrease following enactment of the 0.08% BAC limit, that produces a significantly greater decline in North Carolina than in the other states from the 33 months prior to the 0.08% law to the 39 months following its implementation.

Figure 10a

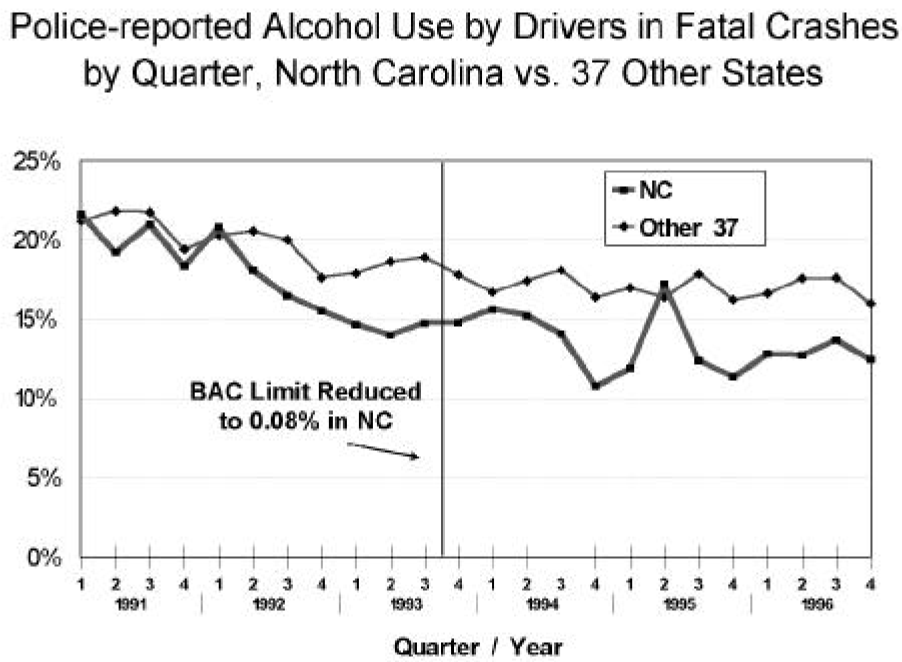
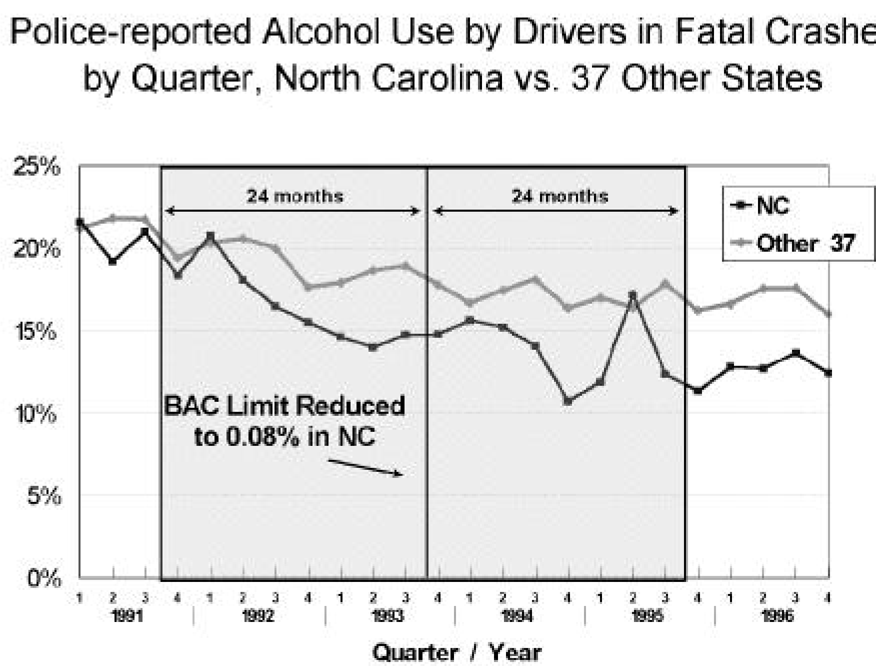


Figure 10b

Clearly there was a change in alcohol involvement, as reported by police officers. However, in view of



its timing, it is not reasonable to believe that the change resulted from the lower BAC limit. The divergence between North Carolina and the other states occurred prior to the law. Selection of a different time period for analysis – for example, 24 months prior to and 24 months following enactment of the lower BAC limit – more accurately conveys what occurred prior to the new law (see Figure 10.b.). These before-after time periods are also matched for seasonal effects–covering identical months of the year. The ratio of relative risks comparing North Carolina to the other states for this four year period is 1.07 [.95, 1.20]. That is, there appeared to be a somewhat greater decline in police-reported alcohol use by drivers in fatal crashes, but the difference is not statistically significant.

Another pertinent consideration here is that the North Carolina "Booze-It-and-Lose-It" program was implemented in November, 1994. This effort included the conduct of 3,185 sobriety checkpoints throughout the state between November, 1994 and July, 1995, in conjunction with extensive media coverage of this enforcement activity. The dip in the percent of police-reported alcohol involvement in crashes shown in Figure 10 is coincident with the period during which the Booze-It-and-Lose-It program was at the peak of activity.[12] It is not possible to include the effects of this program in the simple before-after analyses reported here, as was done with earlier time-series analyses. However, it is clear from other time-series analyses (Foss & Stewart, 1998) that there was a reduction in alcohol-involved fatal and serious injury crashes for approximately eight months as a result of the Booze-It-and-Lose-It program. Hence, some of the post-1993 decline in alcohol-involvement in fatal crashes may be attributable to this program. That further undermines our confidence in the effect of the 0.08% BAC limit.

Single Vehicle Nighttime Crashes

Prior to development of the algorithm to estimate alcohol involvement for individual drivers involved in fatal crashes, it was common practice to use surrogate or proxy measures of alcohol involvement. That was a crude way of accomplishing what the estimation procedure does in a more statistically sophisticated fashion. Because crashes that occur at night are more likely to involve alcohol, and those that are single-vehicle crashes are even more likely to be alcohol-related, the incidence of such crashes has been used as an indicator of the extent of drinking-driving. Table 10 presents results of the analysis of single vehicle nighttime (8 p.m. to 4 a.m.) crashes among drivers over age 21 for North Carolina and the 37 other states.

Prior to enactment of the 0.08% law, 16.6% of fatal crashes in North Carolina were single vehicle nighttime crashes. That declined to 15.0% in the 39 months immediately following enactment of the lower BAC limit, a decline of 9.6%. The risk ratio for SVN to other type crashes before vs. after enactment of the law is 1.11. There was a nearly identical decrease in SVN crashes in the other 37 states, from 17.0% to 15.2%, a decline of 10.4% ($p < .001$). The before-after risk ratio for these 37 states is 1.12. The ratio of these changes between North Carolina and the other states is .99, indicating a virtually identical decline in SVN crashes.

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[12] However, there is no apparent explanation for the sharp increase during the 2nd quarter of 1995. That increase reflects only 15 cases out 456 crashes, and does not appear nearly so dramatic in other measures of alcohol involvement.

Table 10. Drivers in single vehicle nighttime (SVN) crashes 1991 - 1996, North Carolina vs. 37 comparison states.

	North Carolina		Other 37 States	
	SVN	**Other**	**SVN**	**Other**
Before (1/1/91 to 9/30/93)	16.6% (691)	83.4% (3,470)	17.0% (14,513)	83.0% (71,001)
After (10/1/93 to 12/21/96)	15.0% (815)	85.0% (4,615)	15.2% (16,320)	84.8% (90,957)
Decline	9.6%		10.4%*	
Risk Ratio (before/after)	1.11		1.12	
95% Confidence Interval	[1.01, 1.99]		[1.10, 1.14]	
p < .05 * p < .001	RR_{NC}/RR_{37} = .99, 95% CI = .90 to 1.09			

Single Vehicle Nighttime Male Driver Crashes

Another, somewhat more refined, proxy measure of alcohol involvement is a single vehicle nighttime crash by a male driver. Table 11 presents results of the analysis of these crashes for North Carolina and the 37 other states.

Table 11. Drivers in single vehicle nighttime male (SVN-M) driver crashes 1991 - 1996, North Carolina vs. 37 comparison states.

	North Carolina		Other 37 States	
	SVN-M	**Other**	**SVN-M**	**Other**
Before (1/1/91 to 9/30/93)	12.7% (530)	87.3% (3,631)	13.7% (11,712)	86.3% (73,802)
After (10/1/93 to 12/21/96)	11.7% (633)	88.3% (4,797)	12.1% (12,988)	87.9% (94,289)
Decline	8.5%‡		11.6%*	
Risk Ratio (before/after)	1.09		1.13	
95% Confidence Interval	[.99, 1.20]		[1.11, 1.16]	
‡ p < .01 * p < .001	RR_{NC}/RR_{37} = .97, 95% CI = .87 to 1.08			

Prior to enactment of the 0.08% law, 12.7% of fatal crashes in North Carolina were single vehicle nighttime male driver crashes. That declined to 11.7% in the 39 months immediately following enactment of the lower BAC limit, a decline of 8.5%. There was a somewhat greater decrease in SVN-M crashes in the other 37 states (11.60%). The ratio of these changes between North Carolina and the other states is .97 [.87, 1.08], indicating a non-meaningful difference in these changes.

Estimated Alcohol Involvement

In its examination of the first five states that reduced their BAC limit to 0.08%, the NHTSA used a variable described as 'estimated alcohol,' which was based on three factors: Police-reported alcohol involvement, evidence of a previous alcohol violation on the driver's record, and a positive measured BAC value. The report of this analysis does not give a detailed explanation of how this variable was created. We attempted to conduct a similar analysis as follows: "Estimated driver alcohol use" was considered to be positive if the driver had one or more DWI convictions on his/her record, *or* if there was an alcohol-related charge, *or* if the results of an alcohol test registered a BAC of $\geq$0.01%. Table 12 presents results of the analysis of these crashes for North Carolina and the 37 other states.

Table 12. Drivers' estimated alcohol involvement in fatal crashes 1991 - 1996, North Carolina vs. 37 comparison states.

	North Carolina		**Other 37 States**	
	Yes	**No**	**Yes**	**No**
Before (1/1/91 to 9/30/93)	25.0% (1,041)	75.0% (3,120)	24.7% (21,155)	75.3% (64,359)
After (10/1/93 to 12/21/96)	20.4% (1,110)	79.6% (4,320)	21.9% (23,458)	78.1% (83,819)
Decline	18.3%*		11.6%*	
Risk Ratio (before/after)	1.22		1.13	
95% Confidence Interval	[1.15, 1.30]		[1.12, 1.15]	
* p < .001	RR_{NC}/RR_{37} = 1.08, 95% CI = 1.00 to 1.17			

Prior to enactment of the 0.08% law, 25.0% of drivers in fatal crashes in North Carolina were estimated to have been drinking. That declined to 20.4% in the 39 months immediately following enactment of the lower BAC limit. For the other 37 states, estimated drinking declined by 11.61%. The ratio of these changes between North Carolina and the other states is 1.08, indicating a greater relative decrease in estimated alcohol involvement for North Carolina. Again, however, inspecting this variable for 24 months prior to and following the lowered BAC limit suggests that the change seen above results not so much from the effects of the law as from the fact that drinking-driving in North Carolina was comparable to that in the other states in 1991 and early 1992, but then declined relative to other states during the 18 month period prior to enactment of the 0.08% limit. Comparing only the 48 months immediately surrounding the reduction of the BAC limit, the ratio of relative risks is 1.05 [.95, 1.15], a non-significant (p > .20) difference.

Summary of Before-After Analyses

Table 13 provides a summary of the findings of the various analyses reported above. For completeness it also includes analyses for the 48 month period October 1, 1991 - Sept. 30, 1995. The 48-month period was examined to more closely parallel the periods reported in the initial analyses by NHTSA (1994) and to equalize seasonal effects in the before-after periods. The only two measures that show a significantly greater decrease in North Carolina than in the states that retained a BAC limit of 0.10% during 1991-1996 are police-reported alcohol involvement and estimated alcohol involvement.[13] Considering analyses of time periods more proximate to the change in the North Carolina BAC limit, and taking seasonality into account, these findings disappear.

Table 13. Summary of findings from FARS data, North Carolina vs. 37 other states, 72- and 48-month analysis periods

	Analysis Period			
Criterion Measure	**1991-96 (33 months before, 39 months after)**		**48 Months (24 mos. before, 24 months after)**	
	Ratio of RRs	**95% CI**	**Ratio of RRs**	**95% CI**
Alcohol > 0.01%	1.06	.98, 1.14	1.04	.94, 1.14
Alcohol > 0.10%	1.06	.97, 1.15	1.02	.92, 1.13
PR-Alcohol	**1.13**	**1.03, 1.25**	1.07	.95, 1.20
SVN	0.99	.90, 1.09	0.97	.92, 1.16
SVN-M	0.97	.87, 1.08	0.93	.81, 1.06
Est. Alcohol	**1.08**	**1.00, 1.17**	1.05	.96, 1.15

Comparison of North Carolina with other states

North Carolina has a reputation for being tough on drinking drivers as is reflected in the comprehensiveness of its DWI laws. It was one of only three states to receive an A- rating by MADD in its recent review of state DWI laws. In addition, beginning in late 1994, North Carolina implemented an extensive high visibility DWI enforcement program (Booze-It-and-Lose-It), which resulted in 3,185 DWI checkpoints being conducted throughout the state between November of 1994 and July, 1995. For these and perhaps other reasons, it may be that North Carolina is an atypical state in terms of drinking-driving.

It is difficult to know whether any characteristics on which a state may differ from others with respect to traffic safety laws or programs is a meaningful one – a factor that should be taken into account when deciding whether any findings from that state should be generalized to other states. We can, however, examine whether various indicators of drinking-driving are dramatically different in North Carolina when compared to the rest of the nation. To address this issue, Table 14 compares North Carolina with the 37 states on each of the six criterion measures examined above prior to enactment of the 0.08% law. It is clear that there are some statistically meaningful differences. For example, 1.7% fewer drivers involved in fatal crashes in North Carolina between 1991 and 1993 had a high BAC ($\geq$ 0.10%); 2.3% fewer were reported by the investigating officer to have been drinking. On the other hand, there were negligible and non-significant differences on several other measures.

[13] It is important to keep in mind that these are not independent findings, since police-reported alcohol involvement is one of the elements of the 'estimated alcohol' measure.

In sum, although there are some statistically significant differences between North Carolina and other states, the magnitude of these differences is relatively small. Hence, it would not appear that during the early 1990s North Carolina was so atypical with respect to drinking-driving, that we should hesitate to generalize findings from this or other studies of drinking drivers, to the U.S. in general.

Table 14. Comparison of North Carolina with 37 comparison states on six measures of drinking-driving in fatal crashes for 1991 - 1993.

Measure	NC	37 States	Difference	z
BAC Over .01%	24.1%	27.9%	-3.8%	5.54*
BAC Over .10%	22.0%	23.7%	-1.7%	2.65*
Police-Reported Alcohol	17.4%	19.7%	-2.3%	4.11*
SVN	16.3%	16.8%	-0.5%	0.88
SVN-M	17.1%	18.2%	-1.1%	1.57
Estimated Alcohol	24.8%	24.5%	0.2%	0.35

*Note. z-test for difference of proportions. $p < .01$

❑ CONCLUSION

There appears to have been little clear effect of the lower BAC limit in North Carolina. Survey data indicate that the general public believes the new law was well-publicized. Although awareness of the new lower limit was not particularly high nearly 18 months after the law took effect, frequent drinkers did evidence a substantial degree of awareness that the law had changed and about what the new BAC limit was. As is typical in North Carolina, enforcement of the lower limit was vigorous and strict. Hence, it appears that the most likely explanation for the lack of a demonstrable effect of the lower BAC limit is that the drinking-driving population in North Carolina at the time the lower limit took effect was simply unresponsive to this change. Whether that is because, following a substantial reduction in drinking-driving behavior, the remaining drinking-drivers in North Carolina represented a ‘hard core’ that cannot be affected by such broad policies, or that this particular policy simply does not have the potential to measurably affect drinking drivers in general, is unknown.

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Appendix A

Detailed presentation of stochastic time series models fit to various types of alcohol-related North Carolina crashes as summarized in Table 3 .

Note. The models for percent of alcohol-related fatal or serious injury crashes (table 3.b.) contain no stochastic components. Hence, these reduce to simple regression models. These models also contain no seasonal factors. As a result residual autocorrelations are only computed through lag 14, and, hence, Q(14) is presented for these models rather than Q(15) as is reported for other series. Similarly since no seasonal patterns were found, no value of R^2_S is computed for these models.

Table 3. Parameters for logit models of various indicators of alcohol-involved North Carolina crashes, 1991 - 1995.

3. a. PERCENT OF CRASHES INVOLVING ALCOHOL S all levels of severity

Components of Model:

- P Stochastic level, trend, seasonal
- P Autoregressive term at lag 7,
- P Number of weekend days per month

Intervention (1)	***estimate***	***s.e.***	***t-ratio***	***p-value***
Shift in level	-.038	.038	-1.007	.320
		Residual Autocorrelations	***Goodness-of-Fit***	
		Q(5) = 2.26	R^2 = .941	
		Q(10) = 6.88	R^2_D = .679	
		Q(15) = 10.64	R^2_S = .549	

Intervention (2)	***estimate***	***s.e.***	***t-ratio***	***p-value***
Change in trend	.001	.009	.168	.866
		Residual Autocorrelations	***Goodness-of-Fit***	
		Q(5) = 1.98	R^2 = .940	
		Q(10) = 8.88	R^2_D = .673	
		Q(15) = 14.09	R^2_S = .541	

3. b. PERCENT OF CRASHES INVOLVING ALCOHOL S severe and fatal crashes only.

Components of Model:

- P Fixed level, fixed trend

Intervention (1)	***estimate***	***s.e.***	***t-statistic***	***p-value***
Shift in level	.023	.058	.390	.698
		Residual Autocorrelations	***Goodness-of-Fit***	
		Q(5) = .442	R^2 = .759	
		Q(10) = 7.00	R^2_D = .470	
		Q(14) = 7.86		

Intervention (2)	***estimate***	***s.e.***	***t-statistic***	***p-value***
Change in trend	-.0001	.003	-.017	.986
		Residual Autocorrelations	***Goodness-of-Fit***	
		Q(5) = .426	R^2 = .758	
		Q(10) = 7.13	R^2_D = .468	
		Q(14) = 8.09		

Table 3. Results for Logit Models (Continued)

3. c. PERCENT OF CRASHES OCCURRING AT NIGHT S all levels of severity

Components of Model:

- Stochastic level, trend, seasonal
- Autoregressive term at lag 4
- Number of weekend days per month

Intervention (1)	***estimate***	***s.e.***	***t-statistic***	***p-value***
Shift in level	-.022	.022	-1.033	.308
		Residual Autocorrelations	***Goodness-of-Fit***	
		Q(5) = 3.25	R^2 = .760	
		Q(10) = 5.88	R^2_D = .694	
		Q(15) = 11.26	R^2_S = .432	

Intervention (2)	***estimate***	***s.e.***	***t-statistic***	***p-value***
Change in trend	.001	.003	.305	.762
		Residual Autocorrelations	***Goodness-of-Fit***	
		Q(5) = 3.63	R^2 = .733	
		Q(10) = 5.72	R^2_D = .659	
		Q(15) = 12.03	R^2_S = .368	

3. d. PERCENT NIGHTTIME CRASHES S serious and fatal crashes only

Components of Model:

- Fixed level, fixed trend, stochastic seasonal
- Number of weekend days per month

Intervention (1)	***estimate***	***s.e.***	***t-statistic***	***p-value***
Shift in level	.050	.040	1.240	.222
		Residual Autocorrelations	***Goodness-of-Fit***	
		Q(5) = 3.26	R^2 = .610	
		Q(10) = 7.68	R^2_D = .633	
		Q(14) = 11.15	R^2_S = .446	

Intervention (2)	***estimate***	***s.e.***	***t-statistic***	***p-value***
Change in trend	.003	.002	1.075	.288
		Residual Autocorrelations	***Goodness-of-Fit***	
		Q(5) = 2.30	R^2 = .611	
		Q(10) = 8.58	R^2_D = .633	
		Q(15) = 12.48	R^2_S = .447	