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CHANGING PATTERNS OF GOOSE HARVEST ON CALIFORNIA PUBLIC HUNTING AREAS

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We summarized hunter visits, success, and the magnitude and species-subspecies composition of the goose harvest recorded on California public hunting areas (PHAs) during 1950-89. Of six geographic regions, the Northeast accounted for the largest portion of the PHA harvest (55%); most of the remainder occurred in the Sacramento (30%) and Imperial (10%) Valley regions. Harvest, hunter visits, and success were low during the 1950s, but increased during the 1960s as new PHAs were added and data from Tule Lake and Lower Klamath National Wildlife Refuges (NWRs), where about half of California's PHA goose harvest occurs, became available. Success and harvest reflected declining goose abundance during the 1970s; however, hunter visits remained high on most PHAs because ducks were abundant. During the 1980s, declining populations of greater white-fronted geese, *Anser albifrons frontalis*, and cackling Canada geese, *Branta canadensis minima*, prompted restrictive regulations resulting in low harvest and success. Hunter visits were further reduced because of declining duck abundance and overall declines in hunter numbers. White-fronted geese were most prominent in the Northeast and Suisun Marsh harvest, but the lesser snow goose, *Chen caerulescens caerulescens*, was more important in other regions. Overall, the cackling Canada goose was the third most common goose harvested. The harvest of most geese peaked during 1965-74, coinciding with a peak in hunter visits, and then declined. However, the harvest of Canada geese (includes unknown proportions of western, *B. c. moffitti*, Taverner's, *B. c. taverneri*, and lesser, *B. c. parvipes*) and Ross' geese, *Chen rossi*, increased slightly throughout the study period. PHA harvest averaged 9-15% of the total state goose harvest during 1960-89. Success on PHAs was greater than statewide success until the 1980's, when restrictive regulations were imposed in zones encompassing many Sacramento Valley and San Joaquin Basin PHAs. White-fronted geese comprised a larger portion of the PHA bag than state-wide, and their decline reduced hunting opportunity for PHA

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hunters. The status of Pacific Flyway geese has improved in recent years, but intensive population management and monitoring should continue.

INTRODUCTION

More geese winter in California than in any other Pacific Flyway state, but many of these populations have suffered marked declines since the early 1950s (Fig. 1, Pacific Flyway Study Committee 1951-84, U.S. Fish and Wildlife Service unpubl. data). At least 13 different populations of geese winter in California, including the entire continental populations of Aleutian Canada geese, *B. c. leucopareia*, and tule white-fronted geese, ("tule geese"), *A. a. gambelli*, and most Ross' geese (U.S. Fish and Wildlife Service 1978, Gilmer et al. 1982). Populations nesting on the Yukon-Kuskokwim Delta of western Alaska (cackling Canada geese, ["cacklers"], and greater white-fronted geese), and on Wrangel Island, Russia (lesser snow geese, ["snow geese"]), have declined drastically in recent decades (Pacific Flyway Study Committee 1951-84; Raveling 1984, Subcommittee on White Geese 1992). Also, many Taverner's Canada geese, *B. c. taverneri*, lesser Canada geese, *B. c. parvipes*, and cacklers that once wintered in California now winter in Oregon (Johnson et al. 1979, Raveling and Zezulak 1992). In contrast, populations of snow geese from the western and central Arctic, Ross' geese and western Canada geese, have remained stable or increased (Dzubin 1979, McLandress 1979, Krohn and Bizeau 1980, Rienecker 1987). Separate management plans with specific population goals have

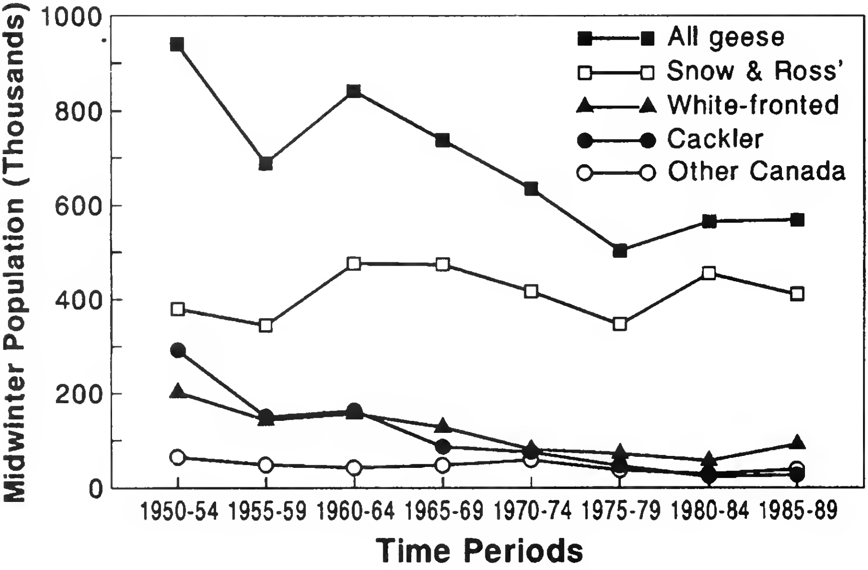

Figure 1. Average annual midwinter goose abundance in California by 5-year periods from 1950-89 (Pacific Flyway Study Committee 1951-84, U.S. Fish and Wildlife Service unpubl. data).

been developed for almost all goose populations that winter in California (U.S. Dept. of Interior and Environment Canada 1986, Childress and Rothe 1990).

Hunting regulations have been implemented and revised as each population's range was delineated and its status evaluated (Calif. Dept. Fish and Game, unpubl. data). Regulations often have been more restrictive on PHAs than elsewhere in California. For instance, hunting on PHAs typically has been restricted to 2-3 days a week. Goose hunting seasons in California were relatively liberal and stable through the 1980s in the Northeast and in other regions through the 1960s. Season variations were mostly due to split seasons and to delayed hunting on Sacramento Valley PHAs and Merced NWR to prevent crop depredation. In 1975, hunting on Tule Lake and Lower Klamath NWRs was closed after 1 P.M. Modifications to season length became commonplace in the late 1960s when restrictions were placed on the Canada goose season in the Imperial Valley to reduce harvest of Rocky Mountain population western Canada geese. After 1974, Canada goose seasons were reduced in hunting zones that included all San Joaquin Basin and most Sacramento Valley PHAs to protect the endangered (federally listed) Aleutian Canada goose. During 1985-89, Canada goose season was closed entirely and white-fronted goose season reduced on most PHAs in the Sacramento Valley. Bag limits on geese also became more restrictive. Concerns for the status of snow geese, white-fronts, and cacklers resulted in restricted bag limits starting in the 1980s. A notable exception to this trend was the lifting of the ban on the hunting of Ross' geese in 1964 and further liberalization in 1980 due to recognition of the greater number of Ross' geese in the Sacramento Valley than thought previously (Mclandress 1979).

In this paper, we summarize regional differences in species (and subspecies) composition of goose harvest and document trends in the participation and success of goose hunters on PHAs in California from 1950-89. These summaries will serve as a historical record of the harvest on PHAs and to compare harvest on public lands versus the total state harvest.

METHODS

Harvest Areas

Goose harvest data were obtained from the records of 28 PHAs on which managers operated check stations or conducted routine bag checks (Table 1, Fig. 2). PHAs included NWRs, state Wildlife Areas (WAs), and cooperative areas (Co-ops) leased by the California Department of Fish and Game (CDFG). We grouped the PHAs into 6 geographic regions: Northeast, Sacramento Valley, Suisun Marsh, San Joaquin Basin, Tulare Basin, and Imperial Valley. Harvest data were available for Tule Lake and Klamath NWRs only after 1962 and no harvest data were available for coastal PHAs. Opportunities to hunt geese on PHAs fluctuated annually because hunting on some PHAs was closed and potential hunter capacity within individual PHAs varied with habitat conditions and allowable hunting methods (e.g., blinds, free roaming).

Table 1. Years goose harvest data were collected from individual public hunting areas in California, 1950-90[1]. WA = Wildlife Area, NWR = National Wildlife Refuge.

Region/Area	1950	1960	1970	1980	1990
NORTHEAST					
Honey Lake WA	—	—	—	—	—
Madeline Plains WA	—				
Tule Lake NWR		—	—	—	—
Lower Klamath NWR		—	—	—	—
Modoc NWR			—	—	—
Butte Valley WA				—	—
Ash Creek WA				—	—
SACRAMENTO VALLEY					
Colusa NWR	—	—	—	—	—
Gray Lodge WA	—	—	—	—	—
Sutter NWR	—	—	—	—	—
Welch Co-op	–				
Grace Co-op	–				
Maxwell Co-op	–				
Delevan NWR		—	—	—	—
Sacramento NWR		—	—	—	—
SUISUN MARSH					
Grizzly Island WA	—	—	—	—	—
Joice Island WA[2]	—	—	—	—	
SAN JOAQUIN BASIN					
Merced NWR	—	—	—	—	—
Volta WA	—	—	—	—	—
Los Banos WA	—	—	—	—	—
San Luis NWR		—	—	—	—
Kesterson NWR			—	—	—
TULARE BASIN					
Mendota WA	—	—	—	—	—
Kern NWR			—	—	—
Tulare Lake Drain. Dist.				—	
IMPERIAL VALLEY					
Imperial WA	—	—	—	—	—
Perris WA			—	—	—
San Jacinto WA				—	—

[1] Hunting programs were in operation on Honey Lake, Madeline Plains, and Imperial WAs and Klamath Basin NWRs before 1950 (Kozlik 1955, Gilmer et al. 1986).

[2] Combined with Grizzly Island in 1983.

Data Collection

Gilmer et al. (1989) describe data collection methods. Goose abundance was estimated by coordinated midwinter surveys (Pacific Flyway Study Committee 1951-84, U.S. Fish and Wildlife Service, unpubl. data). Cacklers were separated from other subspecies of Canada geese ("Canada geese" or "other Canada geese"). Tule and greater white-fronted geese were not recorded separately in any surveys except during the last two years of the study when tule geese comprised about five percent of the total PHA white-front harvest (J. G. Mensik, pers. comm.). Thus, survey data for tule and greater white-fronted geese are combined as "white-front" data in this paper. Ross' geese were completely protected during 1931-62 and were not listed in PHA harvest surveys until 1963; some were undoubtedly shot and included in the snow goose total or listed as "others" so we included the 1,122 "other geese" harvested in the Ross' goose harvest totals. Ross' and snow geese were counted together in midwinter surveys and statewide harvest surveys as "white geese." Black brant, *Branta bernicla nigricans*, were rarely harvested on the PHAs we surveyed and are not discussed here. We used paired *t*-tests with 2-sided *P*-values (Huntsberger and Billingsley 1973:187)

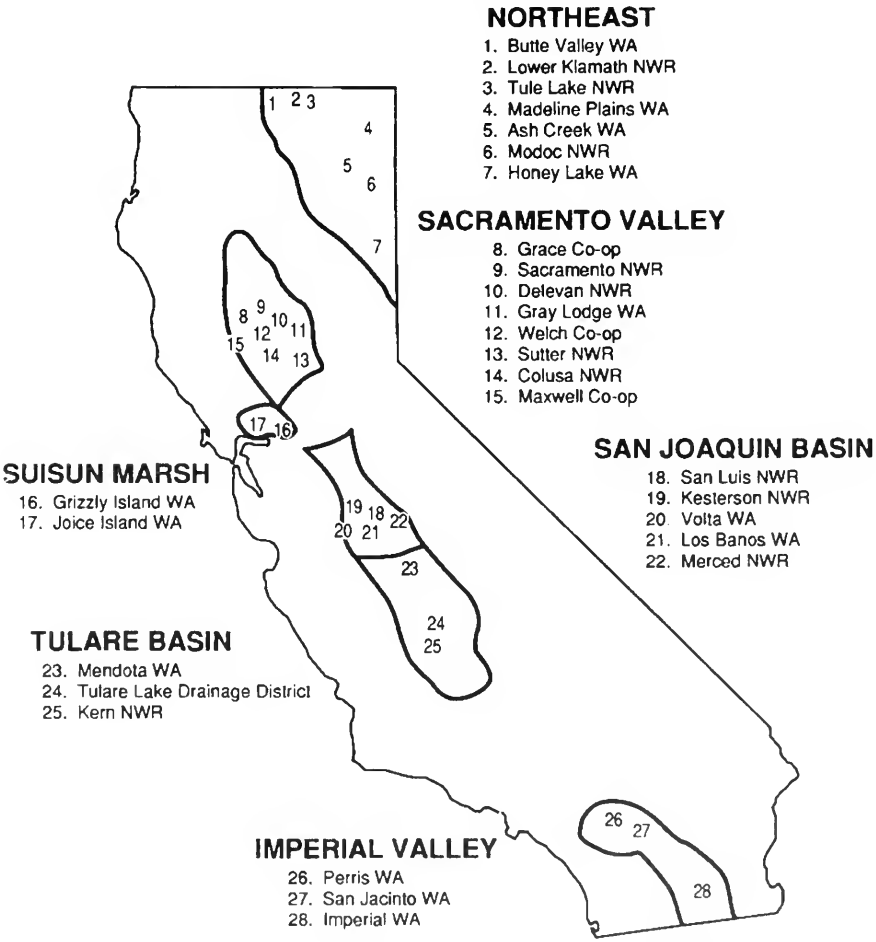

Figure 2. Location of geographic regions with public hunting areas in California.

to compare annual hunter success on PHAs (geese per hunter visit) versus state-wide success (geese per hunter day) estimated by USFWS waterfowl harvest surveys (J. C. Bartonek, pers. comm.).

RESULTS

Statewide Harvest on Public Hunting Areas

From 1950 through 1989, an average of 17,828 (range 558 to 46,404) geese were harvested each year on PHAs during 95,039 (range 9,657 to 166,646) hunter visits for an average success of 0.17 (range 0.05 to 0.38) goose per hunter visit. Overall composition of the harvest was: snow geese 38%, white-fronted geese 36%, cacklers 14%, other Canada geese 10%, and Ross' geese 2%.

Characteristics of the harvest on PHAs changed in relation to abundance of geese, harvest regulations, and number of hunters visiting PHAs. These changes are described by summarizing each of the four decades from 1950-1989.

1950s--Harvest, hunter success, and hunter visits were low during the 1950s (Fig. 3). Geese were abundant (Fig. 1) and harvest regulations were liberal, but hunter visits were low because many areas had not yet been established or opened to public hunting. In addition, harvest data were not collected at Tule Lake and Lower Klamath NWRs, where about half of California's PHA goose harvest occurs. Composition of the PHA harvest (Fig. 4) reflected wintering populations (Fig. 1), except white-front harvest increased (Fig. 5) while their abundance gradually declined.

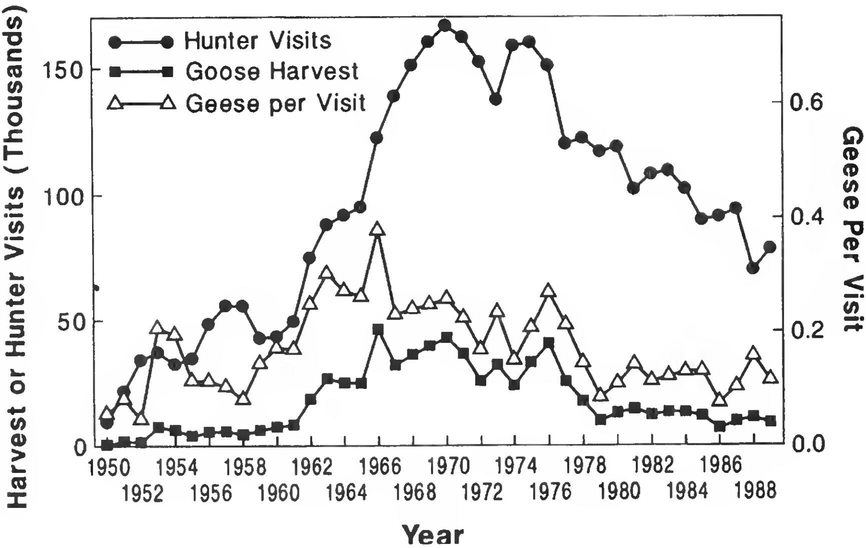

Figure 3. Annual number of hunter visits, geese harvested and hunter success (geese per visit) on public hunting areas in California from 1950-89.

1960s--Harvest, hunter success, and hunter visits increased dramatically during the 1960s (Fig. 3) as new PHAs were established and data from Tule Lake and Lower Klamath NWRs became available. White-front and cackler abundance was about half that during the 1950s, but white geese increased so overall goose abundance was similar to the 1950s (Fig. 1). Harvest regulations remained relatively liberal. The highest annual harvest (46,404 geese) and success (0.38 goose per visit) occurred during the 1966-67 season, when more geese were counted during the midwinter survey than any year of our analysis except 1951. White-fronts were the primary species harvested (Fig. 4) even though white geese were more abundant.

1970s--Declining goose abundance (Fig. 1) reduced harvest and hunter success during the 1970s despite high hunter visits (Fig. 3) and relatively liberal harvest regulations. By the 1978-79 season, goose abundance was the lowest ever recorded and harvest dropped to 17,707 with an average success rate of 0.14 goose per visit. White geese regained prominence in PHA harvest as white-fronts and cacklers declined. Harvest of Canada geese and Ross' geese remained relatively stable compared to other species (Fig. 4).

1980s--Restrictive hunting regulations and declining hunter visits resulted in relatively low harvest and hunter success during the 1980s (Fig. 3). For example, the lowest PHA harvest (6,882) and success (0.07 goose per visit) since the 1950s (when data from few PHAs were available) occurred during 1986-87. White geese were abundant but wintering white-front and cackler populations remained low (Fig. 1). Regulations were especially restrictive for dark geese (white-fronts, cacklers and

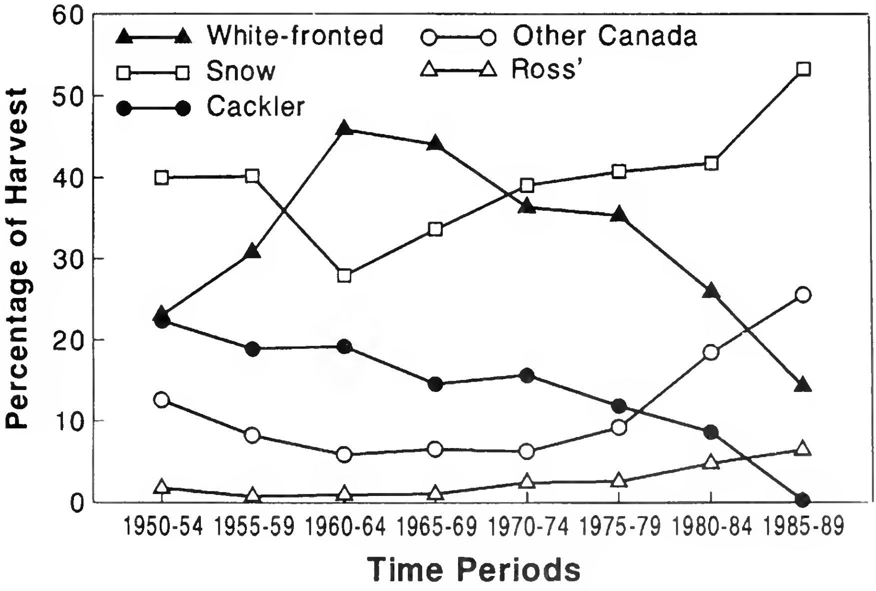

Figure 4. Average annual species composition of goose harvest on public hunting areas in California by 5-year periods from 1950-89.

other Canada geese) after 1984, resulting in white geese becoming dominant in the harvest (Fig. 4). The importance of Canada geese in the harvest increased with the decline of other dark geese (i.e., cacklers and white-fronts) and the addition of Butte Valley and Ash Creek WAs, both important Canada goose harvest areas.

Regional Harvest

The distribution of wintering geese, hunters, and PHAs in California are distinctly regional. This has had a major influence on the characteristics of the harvest.

Northeast--About 26% of all hunter visits and 55% of the total PHA harvest occurred in the Northeast region. Most PHA harvest of white-fronts, cacklers and Canada geese occurred in this region (Fig. 6). Tule Lake and Lower Klamath NWRs accounted for 91% of the region's PHA goose harvest. Hunter visits declined drastically in the region after 1974 and total harvest declined after 1969 (Fig. 7). Hunter success was highest of all regions (0.34 goose/visit), but success during the 1980s was only half that during the 1970s. White-fronts dominated the harvest until the 1980s (Fig. 8). Despite declining abundance, cacklers comprised about 15-20% of the regional harvest until 1985 when the season was closed. The importance of Canada geese increased dramatically during the 1980s as white-front and cackler abundance declined and hunting restrictions were imposed on white-fronts and cacklers. Canada geese comprised about half of the regional PHA goose harvest during 1985-89.

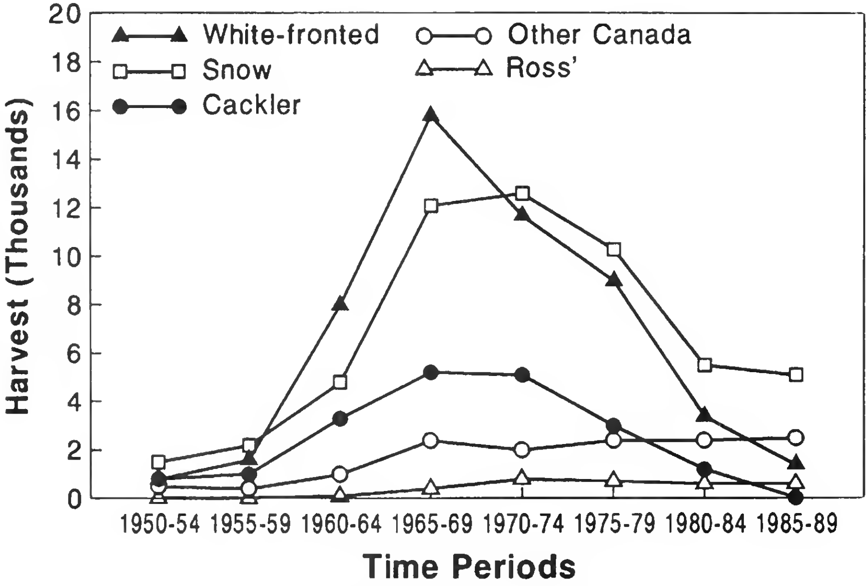

Figure 5. Average annual number of each goose species harvested on public hunting areas in California by 5-year periods from 1950-89.

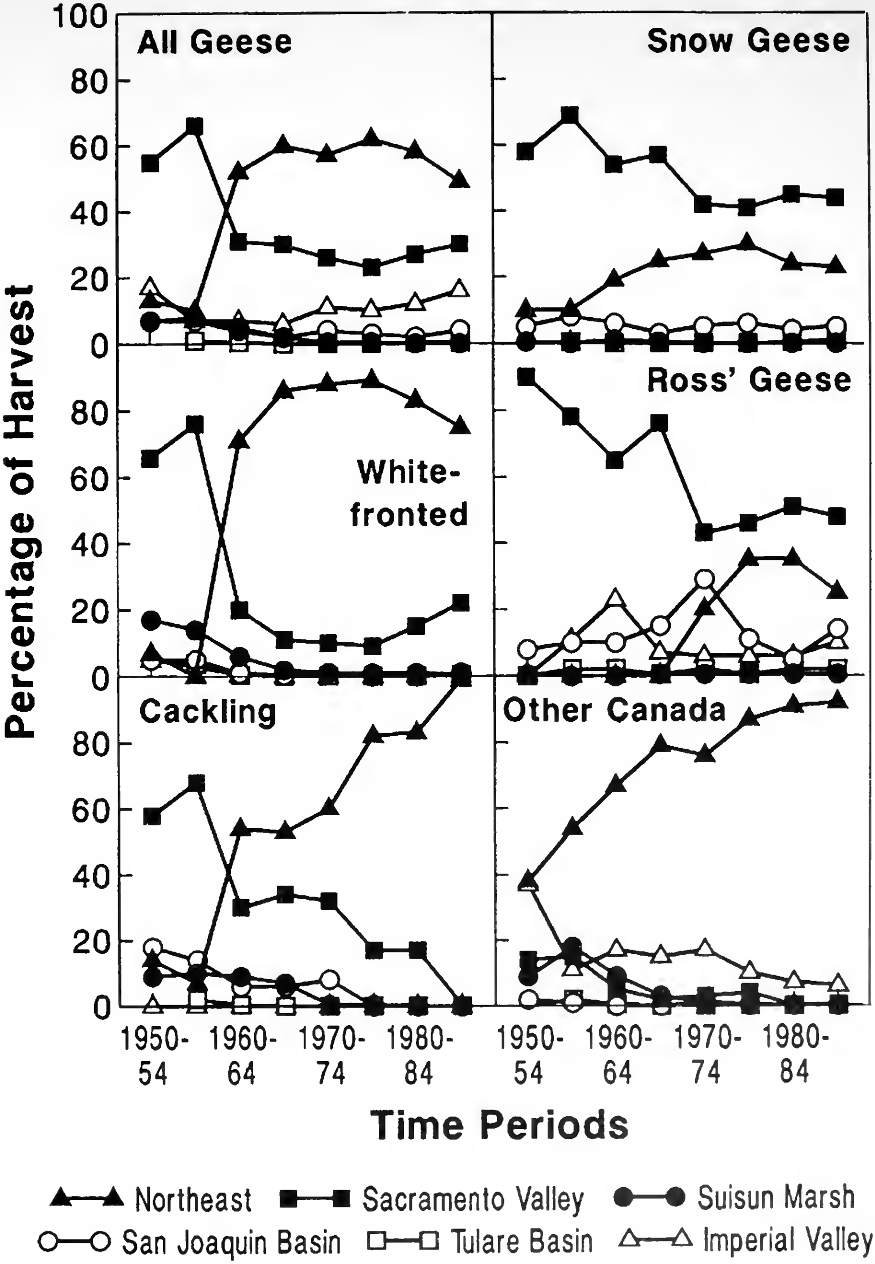

Figure 6. Percent of total California public hunting area harvest of each species occurring in each region by 5-year periods from 1950-89.

Sacramento Valley--About 27% of all visits and 30% of the total harvest on PHAs occurred in the Sacramento Valley. Most snow and Ross' geese were taken in this region (Fig. 6). About 30% of the PHA cackler harvest occurred in the region during 1960-74, but this dropped to 15% after Aleutian Canada goose protection zones were established in 1975 (Fig. 6). Sacramento and Delevan NWRs accounted for 60% of the regional PHA harvest. The addition of these sites to the PHA program during 1960-69 resulted in the increased hunter visits and total harvest (Fig. 7). Harvest

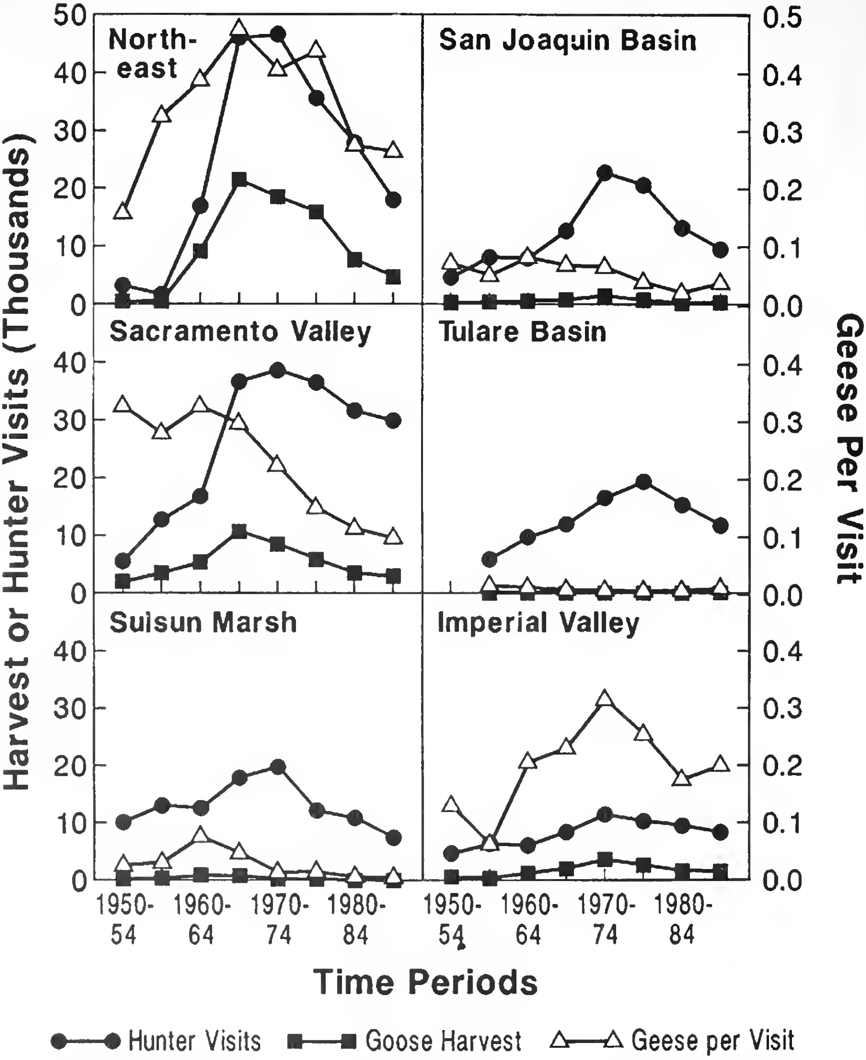

Figure 7. Average annual hunter visits, geese harvested and hunter success (geese per visit) on public hunting areas in six geographic regions of California by 5-year periods from 1950-89.

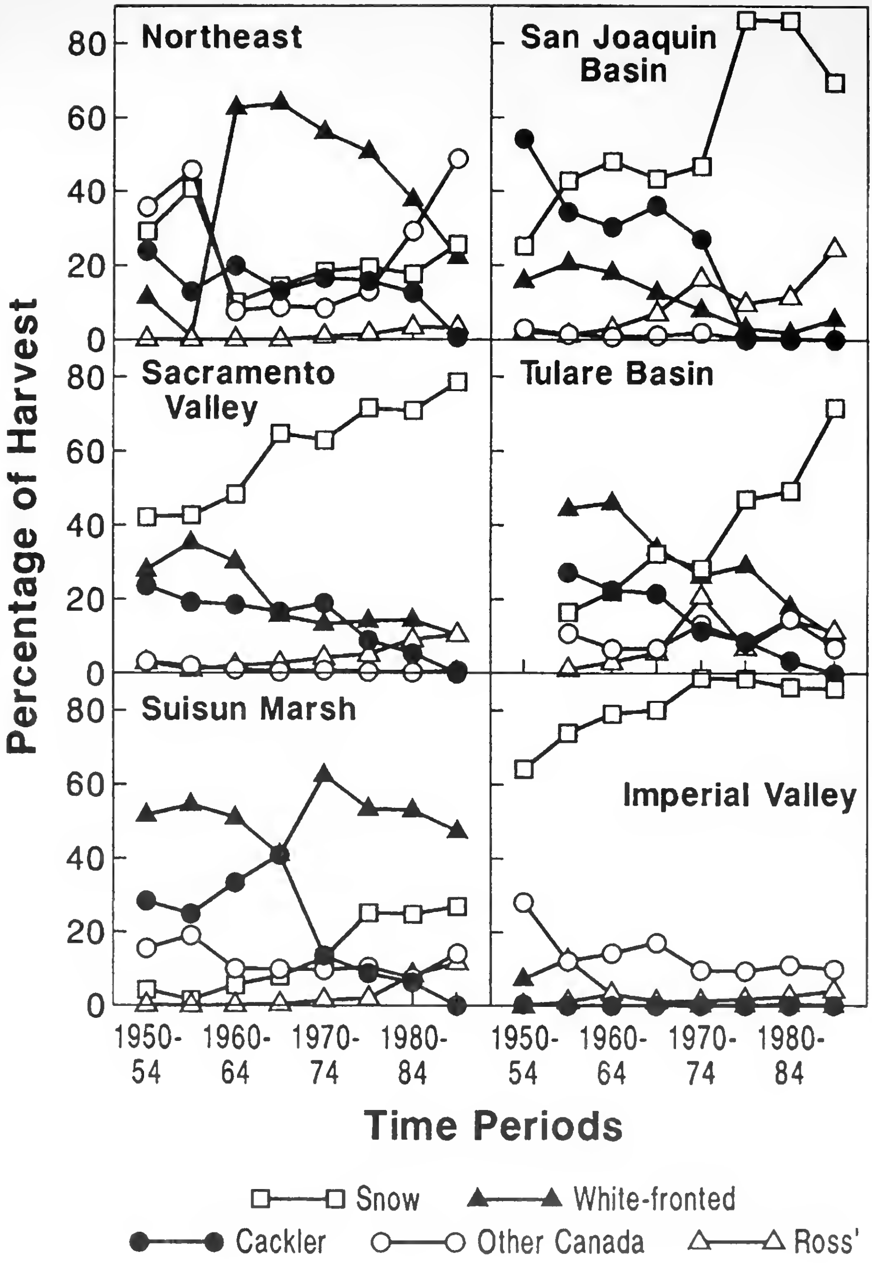

Figure 8. Average species composition of the goose harvest on public hunting areas in six geographic regions of California by 5-year periods from 1950-89.

declined after 1969 and hunter visits declined gradually after a peak in the early 1970s. Hunter success (0.22 goose/visit) was second only to the Northeast, but declined steadily after 1964. Snow geese dominated the harvest and the importance of snow and Ross' geese increased as white-fronts and cacklers declined (Fig. 8). Combined, white-fronts and cacklers comprised about half of the Sacramento Valley harvest during 1950-64, but only 10-30% thereafter. Few Canada geese were harvested on Sacramento Valley PHAs, even before Aleutian Canada goose protection zones were established.

Suisun Marsh--Grizzly Island and Joice Island WAs (combined in 1983) were the only PHAs in this region, and accounted for 14% of hunter visits and 2% of the total PHA goose harvest. Hunter visits peaked in 1970-74, but by then success was so low that goose harvest remained low (Fig. 7). Total harvest reflected hunter success (0.03 geese/visit); both peaked earlier than in most other regions. White-fronts were the most common goose shot, comprising about half of the regional PHA harvest (Fig. 8). Cackler harvest declined in the Suisun Marsh earlier than in other regions. Nearly 10% of the cacklers harvested statewide on PHAs were taken at Suisun Marsh during 1950-1969, but <1% thereafter (Fig. 6). Snow and Ross' geese increased proportionately in the harvest as cacklers declined.

San Joaquin Basin--About 13% of the hunter visits and 3% of the goose harvest occurred in this region. Most geese in the region were shot at Los Banos WA (36%), Merced NWR (29%), and San Luis NWR (16%). Hunter visits followed patterns similar to other regions (Fig. 7). Hunter success was low (0.05 goose/visit) and declined after 1964. Snow geese and cacklers each comprised about 40% of the region's harvest during 1950-74 (Fig. 8). About 10% of the PHA harvest of cacklers occurred in the San Joaquin Basin region (Fig. 6) until 1975, when harvest restrictions designed to protect Aleutian Canada geese virtually eliminated cackler harvest in the region. The importance of white-fronts also declined while Ross' geese became more common at hunter check stations. During the 1980's, hunters' bags consisted mostly of white geese (Fig. 8). Hunters harvested few Canada geese (other than cacklers) even before Aleutian Canada goose protection zones were established.

Tulare Basin--This region accounted for 12% of the total visits but only 0.4% of the total goose harvest on PHAs; most of the harvest (96%) occurred at Mendota WA. Hunter visits peaked later (1975-79) than in other regions (Fig. 7), probably because Kern NWR was added to the PHA program in 1973. Hunter success was lowest of all regions (0.01 goose/visit) with no consistent trend. Species composition of the bag was mixed and trends were similar to other regions (Fig. 8).

Imperial Valley--About 8% of the hunter visits and 10% of the total harvest on PHAs occurred in this region. Imperial WA accounted for 99.9% of the regional harvest. Harvest and success peaked later than in most other regions (Fig. 7). Hunter success (0.20 goose/visit) was higher than other southern regions. Snow geese comprised 60-90% of the annual harvest (Fig. 8), and about 25% of the total PHA snow goose harvest occurred in this region (Fig. 6). Canada and Ross' geese were the only other species commonly harvested (Fig. 8).

DISCUSSION

Public Hunting Area Harvest

Hunter Visits and Harvest-- As new areas were added to the PHA system, hunter visits and harvest increased. The opening of Sacramento and Delevan NWRs to hunting during the early 1960s increased PHA harvest, especially for white geese. Similarly, the opening of Modoc NWR in 1974 and Butte Valley and Ash Creek WAs in the 1980s increased PHA harvest of Canada Geese.

Our estimates of PHA hunter visits and harvest are low and species composition biased for the 1950s because harvest and hunting activity records were not maintained at Tule Lake and Lower Klamath NWRs even though these important goose areas were open to public hunting. Thus, differences between the 1950s and the 1960s were undoubtedly less than the available data reflect in harvest magnitude and composition, hunter success, and hunter visits. White-fronts were the most common goose harvested at Tule Lake and Lower Klamath NWRs during 1936-41 (Gilmer et al. 1986) and 1960-79, indicating that white-fronts probably dominated PHA harvest throughout the 1950s.

Waterfowl abundance influenced the number of hunters afield and affected harvest. Hunter visits to most PHAs appeared to more closely respond to duck abundance (Gilmer et al. 1989) than goose abundance, suggesting that hunters traveled to most PHAs primarily to hunt ducks; geese were harvested opportunistically. For example, hunter visits to PHAs remained high during the 1970s when goose populations were low but ducks were numerous (Gilmer et al. 1989). During the 1980s, goose populations increased but duck abundance was the lowest on record and hunter visits remained low. Exceptions to this occurred in the Northeast and Imperial Valley, where most PHAs have special goose hunting fields and hunters travel great distances to hunt in these areas (Gilmer et al. 1986). Hunter visits to the Northeast declined more abruptly than in other regions when goose abundance and goose hunting success declined. Likewise, hunter vists to the Imperial Valley did not decline as drastically as in other regions when duck populations plummeted and goose populations did not.

The effect of changing duck populations on hunter visits was most apparent on the white goose harvest which increased between 1965-69 and 1970-74 even though white goose abundance and the average white goose harvest per hunter visit declined. When duck abundance increased during 1970-74, more people hunted and the white goose harvest increased even though their abundance declined. Most white goose harvest on PHAs occurred in the Sacramento Valley.

Hunter visits to PHAs dropped after the 1970s. Although we attribute much of the decline to a decrease in waterfowl abundance other factors such as increasing recreational costs, complicated regulations, changing hunter demographics, competing recreational opportunities, and contaminant concerns undoubtedly contributed to reduced hunting interest (Pacific Flyway Study Committee 1988, Gilmer et al. 1989). Hunter visits to PHAs located far from major urban areas may be differentially reduced because hunters are probably less likely to travel long distances when the probability of success is low.

Goose Abundance and Harvest--Abundance and harvest trends differed among goose populations. The harvest of Ross' geese increased after the 1960s, especially in the two northern regions, probably because of increasing populations (McLandress 1979) as well as an increase in the daily bag limit from one to three. In contrast, the abundance and harvest of geese migrating from western Alaska (e.g., white-fronts and cacklers) declined (Raveling 1984).

Abundance of geese differed greatly among regions, and hunter success and harvest reflected a distinct north to south gradient. Most geese that winter in the Sacramento Valley migrate through northeastern California (Rienecker 1965, Bellrose 1976, Pacific Flyway Study Committee 1951-84, U.S. Fish and Wildlife Service, unpubl. data). Higher hunting success in the Northeast may have been due to juvenile and unwary geese, earlier seasons, and higher goose densities. Populations of many geese that winter in the Imperial Valley take a migration path east of the Sierra Nevada mountains (Rienecker 1965, Bellrose 1976) and the availability of these geese probably boosted harvest opportunities above that of other southern regions. Also, Canada goose closures were not needed in the Imperial Valley because Aleutians and cacklers were rarely observed there (Nelson and Hansen 1959, Woolington et al. 1979).

Cackler harvest declined earlier in the Suisun Marsh than in other regions and the reason is unclear. Regulations were similar to adjacent regions when the decline occurred, and harvest trends in the Suisun Marsh for other geese were similar to other regions. Cackler abundance may have been affected by the same habitat changes within and outside Suisun Marsh that are thought to have reduced use of the marsh by northern pintail, *Anas acuta*, (Michny 1979, Crapuchettes and Lewis 1989). Alternatively, cacklers wintering in Suisun Marsh may have been a separate subpopulation that was eliminated because of lower survival or productivity.

Regulations and Harvest--Regulations were an important factor controlling goose harvest and were effective during the late 1980s in reducing the harvest of populations in decline. For example, seasons and daily bag limits for white-fronts were reduced after 1979 and harvest declined dramatically (Fig. 5).

Harvest regulations for one population often affected harvest of other geese. Restrictions to protect Aleutian Canada geese in the Central Valley reduced harvest of all Canada geese there, especially cacklers. Conversely, when the hunting season for cacklers was closed in the Northeast and the harvest of white-fronts severely restricted, harvest of other Canada geese increased in that region. Rienecker (1985, 1987) expressed concern that overhunting had reduced the subpopulation of Canada geese that were resident in the vicinity of Tule Lake and Lower Klamath NWRs.

Public Hunting Areas versus the Entire State

Harvest Magnitude--Harvest on PHAs comprised a small portion of the total state harvest. During 1962-89, an average of 23,310 geese were harvested annually on

PHAs compared to estimates for the entire state of 159,578 determined by the USFWS waterfowl harvest survey (J. C. Bartonek, pers. comm.) and 244,984 determined by the CDFG mail questionnaire (California Department of Fish and Game, unpubl. data).

Hunter Success--Hunter success for geese averaged 24% greater (range +14% to +39%) on PHAs than for the state overall during the 1960s (PHA minus statewide success mean annual difference = 0.06, $t_{7df} = 8.48$, $P < 0.0001$) and 14% greater (range -22% to +28%) during the 1970s (PHA minus statewide success mean annual difference = 0.03, $t_{9df} = 2.74$, $P = 0.02$). However, hunting restrictions that were imposed to protect cacklers, Aleutians and white-fronts caused success to decline more precipitously on PHAs than for the state overall, so that during the 1980s, PHA success averaged 4% less (range -31% to + 21%) then statewide success (PHA minus statewide success mean annual difference = -0.01, $t_{9df} = 0.02$, $P = 0.98$). For instance, statewide success was greater than PHA success for only two years during 1962-82 but for all but one year since 1982. The steep decline in goose hunting success on PHAs that began in the late 1970s occurred because white-fronts declined, which were especially important to PHA hunters, and restrictive regulations (e.g., Canada goose season reductions, closure zones, and white-front season reductions) impacted most PHAs but a smaller portion of non-PHA lands. In contrast, duck hunting regulations on and off PHAs were more similar and during years of low abundance of one important species, the northern pintail, PHA duck hunters were able to successfully harvest other species that concentrate on PHAs. Thus, unlike goose hunting success, duck hunting success on PHAs during the 1980s remained relatively constant while state-wide success declined (Gilmer et al. 1989).

Species Composition--The composition of harvest during 1962-89 on PHAs differed from the state as a whole (J. C. Bartonek, pers. comm.). Although the importance of snow and Ross' geese in the harvest on PHAs and the state were similar, Canada geese and cacklers, combined, were less prevalent (25% vs 38%) and white-fronted geese were more prevalent (34% vs 21%) in PHA harvest. Closure zones for Canada geese reduced hunter opportunity on most PHAs but left much of the state less restricted. The absence of public hunting opportunities in key locations, like coastal areas and the Sierra foothill reservoirs, reduced the importance of Canada geese in the PHA harvest. Most PHAs are situated at areas traditionally used by white-fronts for staging and wintering.

CONCLUSIONS

Public Hunting Areas have provided goose hunting opportunity to thousands of hunters in California. Although populations of some geese are recovering from critically low levels, hundreds of thousands of geese congregate on some PHAs. Recent regulations have effectively reduced harvest for most geese. Restrictive regulations combined with low goose and duck abundance, and other factors (Pacific Flyway Study Committee 1988, Gilmer et al. 1989) have also reduced numbers of hunters. Although declines in hunter numbers, duck abundance and duck harvest are nationwide trends, the decline of goose abundance and harvest is unique to the Pacific Flyway (Bellrose 1976, J. C. Bartonek, pers. comm.). During the 1960s, 30% of the geese harvested in the United States were taken in the Pacific Flyway, but since 1974 fewer geese have been killed in the Pacific Flyway than in any other flyway. Much of the Flyway's goose population is derived from breeding grounds in western Alaska where native subsistence hunting adds substantially to other mortality factors (Raveling 1984). Progress towards solving subsistence and other goose management problems is being made (Pamplin 1986) and populations are responding (J. C. Bartonek, pers. comm.).

The outlook for the recovery of goose populations in the Pacific Flyway is improving. Efforts to sustain and increase habitats, delineate subpopulations, and refine management strategies should be continued to maintain this recovery. Future goose hunting opportunities on PHAs will depend not only upon the status of goose populations, but also on social and economic factors.

Waterfowl check stations in California provide an important opportunity to closely examine characteristics of the state harvest such as the regional distribution of harvest, subspecies composition and physiological condition of birds. We believe that a comprehensive program to collect accurate waterfowl harvest data at carefully selected check stations will provide resource managers with an effective tool in the conservation of the waterfowl resource.

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DETERMINING THE BIOLOGICAL SIGNIFICANCE OF CHANGES IN PREDICTED HABITAT VALUES FROM THE CALIFORNIA WILDLIFE HABITAT RELATIONSHIPS SYSTEM

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The California Wildlife Habitat Relationships System (CWHR) computerized database can predict the effects of habitat changes to wildlife communities by calculating differences in species composition and habitat values between two habitat conditions. Five different categories representing varying levels of change significance were used to evaluate how impact assessments might differ under a hypothetical scenario. The categories were: (1) habitat unsuitable for one habitat situation; (2) CWHR's predicted difference in overall average habitat suitability; (3) difference of at least one CWHR rating class for overall habitat suitability; (4) difference in overall average habitat suitability value of 25% or more; and (5) difference in overall average habitat suitability value of 50% or more. These categories resulted in significantly different ($P < 0.003$) effect levels (Negative and Positive Effects, Uneffected) for all wildlife groups (birds, mammals, reptiles, and all taxa) except amphibians. Predicted effects were mostly influenced by model habitat suitability ratings. Of the five categories, Habitat Unsuitable and Habitat Rating Class Difference are the most biologically-based, while Habitat Unsuitable is easiest to verify because it is based on differences in species lists only. However, of the five categories, Habitat Unsuitable resulted in the fewest number of species predicted to be negatively or positively effected.

INTRODUCTION

The California Wildlife Habitat Relationships System (CWHR) currently has habitat-relationships models for 647 wildlife species that are considered regularly occurring residents and migrants in California (Airola 1988, Timossi et al. 1994). Each species' model has suitability ratings for breeding, cover, and feeding for habitat types and seral stages from a standardized habitat classification system (Mayer and Laudenslayer 1988). These ratings, ranging from unsuitable to optimum, are converted to numeric values and averaged to calculate overall habitat values and habitat units (Timossi et al. 1994).

CWHR was designed as a planning tool to predict wildlife species communities, habitat suitabilities, and differences in habitat values between two situations for geographic locations and habitats in California (Airola 1988). CWHR has been used as a planning tool to assess impacts to wildlife communities from various land uses (Greenwood et al. 1993, California Timberland Task Force 1993), as well as predicting wildlife biodiversity in California's GAP analysis (Davis et al. 1991, Scott et al. 1993). Use of CWHR is likely to increase with additional land use regulations and the need for more information on wildlife resources in environmental impact assessments in California.

CWHR produces a list of species which are predicted to be negatively or positively effected or uneffected based on differences between two habitat situations. With CWHR, species are categorized as negatively or positively effected regardless of the difference's magnitude. For example, two wildlife species would be categorized by CWHR as negatively effected if differences in predicted habitat values were -1.0% and -100.0%, respectively. Consequently, the list of effected species may be difficult to interpret regarding biological significance of habitat differences if predicted differences are not critically evaluated.

Wildlife-habitat relationship models such as CWHR are often used as impact assessment tools by resource managers (Schroeder 1987, Van Horne and Wiens 1991, Morrison et al. 1992, Patton 1992). However, these models generally lack specific criteria for determining whether a predicted effect is biologically meaningful. The model user must interpret the output and make inferences about the magnitude of the predicted impact. This interpretation could be made easier if objective biologically-based criteria existed. Certainly, the model's predictive nature and often unknown accuracy influence the need for criteria required to determine the biological significance of the change. In the absence of these criteria, users must determine the significance of the predicted effects, and these determinations may not be completely objective or consistent.

In an effort to improve interpretation of CWHR predictions, I did this study to determine how several categories with differing significance thresholds alter interpretation of CWHR's predicted effects.

METHODS

The February 1990 CWHR version was used (results were almost identical using the beta test version of Version 5.0 which was released in August 1994). Using CWHR's two-situation comparison, arithmetic overall average habitat suitability values were calculated for all wildlife species (amphibians, birds, mammals, and reptiles) predicted to occur in two hypothetical situations for Valley-Foothill Hardwood habitat (Mayer and Laudenslayer 1988) in Tehama County, California.

In CWHR, arithmetic overall average habitat suitability values are determined by separately averaging numeric suitability ratings for breeding, feeding, and cover for each habitat type and stage specified in the query. These suitability averages for each type and stage are then averaged across all types and stages specified for each situation in the query to determine overall average suitability. In the two-situation comparison, differences between overall average suitabilities are compared between each situation, and the calculated difference is relative to the overall average suitabilities of both situations. Timossi et al. (1994) provide a more detailed explanation of average habitat suitability value calculations.

The query was done to illustrate how predicted effects to the wildlife community change with different categories of change significance. Significance as used throughout this paper has no statistical basis; it simply refers to different levels of possible biological response or change. These two hypothetical situations for Valley-Foothill Habitat were: (1) Sparse (10-24%) and Open (25-39%) canopy cover classes for Sapling (1-6 inch dbh), Pole (6-11 inch dbh), and Small (11-24 inch dbh) trees; and (2) Moderate (40-59%) and Dense (60-100%) canopy cover classes for Sapling (1-6 inch dbh), Pole (6-11 inch dbh), and Small (11-24 inch dbh) trees. No habitat elements were specified in the CWHR run. All species were retained on the CWHR-predicted list, despite the fact that some species could have been removed because of restricted geographic distribution, missing habitat elements, or missing habitat types that were assumed present by the models.

Five significance levels were chosen: (1) habitat predicted as unsuitable (overall average habitat value = 0.0) for one of the two situations (Habitat Unsuitable); (2) CWHR's predicted effects categories where any positive or negative overall average habitat difference was categorized as positively or negatively effected (CWHR List); (3) a difference of one or more CWHR habitat rating classes for overall average habitat value between situations (Rating Class); (4) a difference in average habitat values of 25% or more (25% Difference); and (5) a difference of 50% or more (50% Difference).

These categories were chosen because they represent a range of significance thresholds, and some categories may be more biologically-based than others. Each species in the CWHR output was put into one of three possible effect levels (Positive, Negative, and Uneffected) for each category based on the magnitude of difference between two situations.

Comparisons were made for predicted species lists for the five significance categories for five taxonomic groups (amphibians, birds, mammals, reptiles, and all taxa combined). Comparisons were also made among predicted-species lists for the different CWHR overall average habitat suitability rating categories. These categories included: High (overall average suitability rating ≥ 0.67); Medium (overall average suitability rating 0.66-0.34); and Low (overall average suitability rating ≤ 0.33). Due to inadequate sample sizes, species with Unsuitable ratings (overall average rating = 0.0) for at least one situation (2 amphibians, 15 birds, and 6 mammals) were combined with those with Low ratings.

X^2-tests of independence were conducted to determine whether differences in number of species predicted for a given effect level were statistically significant for the five categories. Statistical significance was set at $P < 0.05$, but the Dunn-Sidak calculation was used to reduce the probability of comparison-wise errors for multiple comparisons within the five taxonomic groups ($P < 0.005$) (Sokal and Rohlf 1981). Percent similarity indices (Krebs 1978) were calculated to determine similarity in species lists between pairwise comparisons of the significance categories.

Table 1. Similarity indices (%) for five different significance categories for five wildlife groups from a two-situation comparison using the California Wildlife Habitat Relationships System.

	Significance Category			
	CWHR	Class	25%	50%
Unsuitable	46,26,39,42,32[a]	91,63,69,79,68	73,54,73,84,62	91,67,84,90,76
CWHR		55,62,67,63,63	73,72,67,58,70	55,55,55,53,55
Class			82,79,69,95,78	46,74,65,90,72
25%				82,83,90,95,86

[a] Similarity indices calculated for number of species common to the two significance categories in the pairwise comparison. Indices for each pairwise comparison are for amphibians, birds, mammals, reptiles, and all taxa combined, respectively.

RESULTS

Each category had different numbers of species predicted for each effect level (Positive, Negative, and Uneffected) when all five categories were compared together within a taxon (Fig. 1), and all taxa had statistically different numbers of species ($P < 0.003$) *except* amphibians ($P = 0.299$). When effect level within a taxon were compared for all possible pairwise comparisons ($n = 10$) between the significance categories, the Habitat Unsuitable list was significantly different ($P < 0.001$) from: (1) the CWHR List for all taxonomic groups *except* amphibians; (2) the Rating Class for all groups *but* amphibians and reptiles; and (3) the 25% and 50% Difference lists for birds and all taxa combined. The CWHR List differed significantly ($P < 0.005$) from the Rating Class and 25% and 50% Difference lists for birds, mammals, and all taxa combined. The number of species in an effect level for all five taxonomic groups was not different for comparisons between Rating Class and 25% and 50% Difference levels.

CWHR habitat suitability ratings (Unsuitable, Low, Medium, and High) for each species may influence the predicted number of species for each effect level when comparing two habitat situations. The number of species in each rating class was significantly different ($P < 0.003$) for all groups *except* amphibians ($P = 0.895$) and reptiles ($P = 0.758$) (Fig. 2). Differences were due mostly to greater proportions of species with Low and Medium overall average habitat suitability ratings in the closed-canopy habitat situation ($\geq$ 40% canopy closure). The proportion of species in each rating class for each situation was similar for amphibians and reptiles, and there were fewer species in these two taxa compared to birds and mammals.

Similarity indices indicated that predicted species lists were most similar for the 25% and 50% Difference categories for all groups except amphibians and reptiles (Table 1). For amphibians, the index was greatest for Habitat Unsuitable with Rating Class and 50% Difference. With reptiles, the greatest indices were equal for 25% Difference with 50% Difference and Rating Class with 25% Difference. For all taxonomic groups, the lowest indices were Habitat Unsuitable with CWHR List, and amphibians had a tie with Rating Class with 50% Difference.

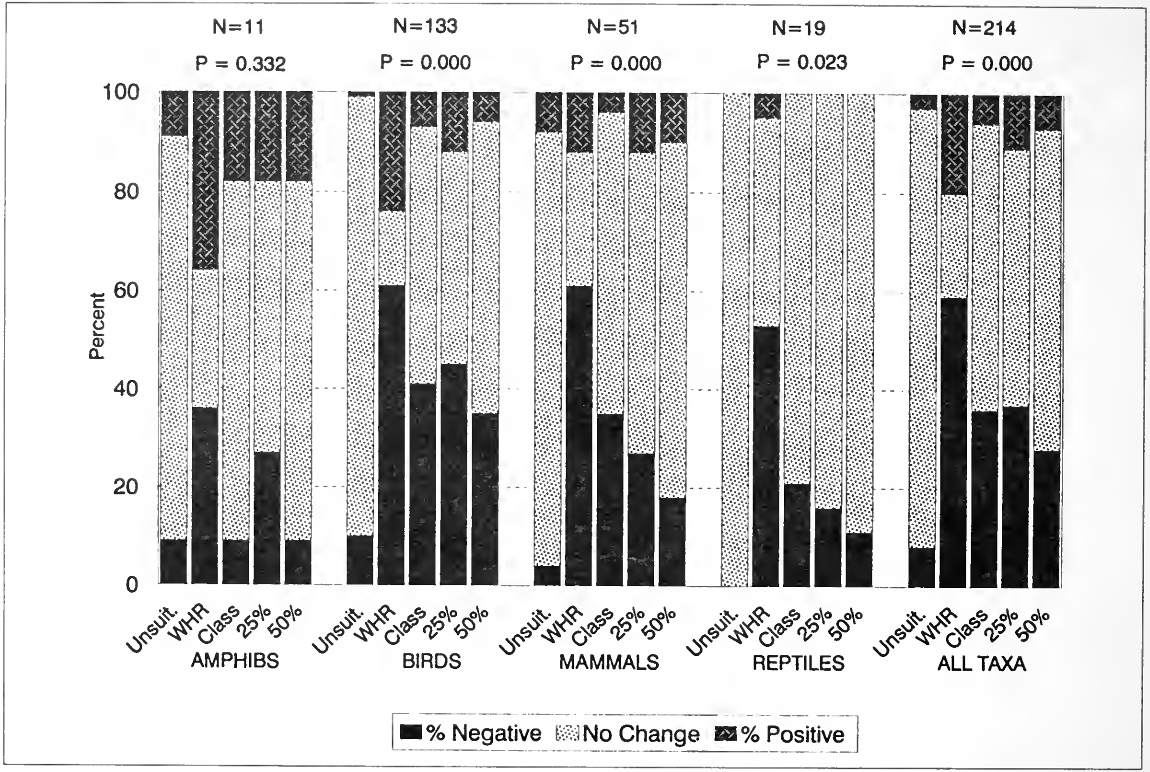

Figure 1. Percentages of species within five taxonomic groups predicted to be uneffected or negatively and positively effected under a hypothetical two-situation comparison for five different effect significance categories using the California Wildlife Habitat Relationships System. *P*-values are from X^2 tests of independence ($df = 8$) within each taxon.

For birds, most negative responses in all effect categories except Habitat Unsuitable were from species with overall average habitat ratings changing from Medium to Low ($n = 23$), High to Low ($n = 19$), or High to Medium ($n = 19$). With the CWHR bird list, 26 negative and 18 positive predictions were in the same overall rating class for both situations. Most of the Rating Class negative responses for mammals were from High to Low ($n = 11$), while most ($n = 11$) of the mammals with no change had Low overall habitat ratings. Similar patterns could not be reliably identified with amphibians and reptiles due to the small number of species.

DISCUSSION

Comparison of Significance Categories

CWHR models accomplish two primary goals for wildlife habitat models identified by Van Horne and Wiens (1991): describe habitat relationships; and predict effects to habitat perturbations. CWHR models describe habitat relationships using a standardized

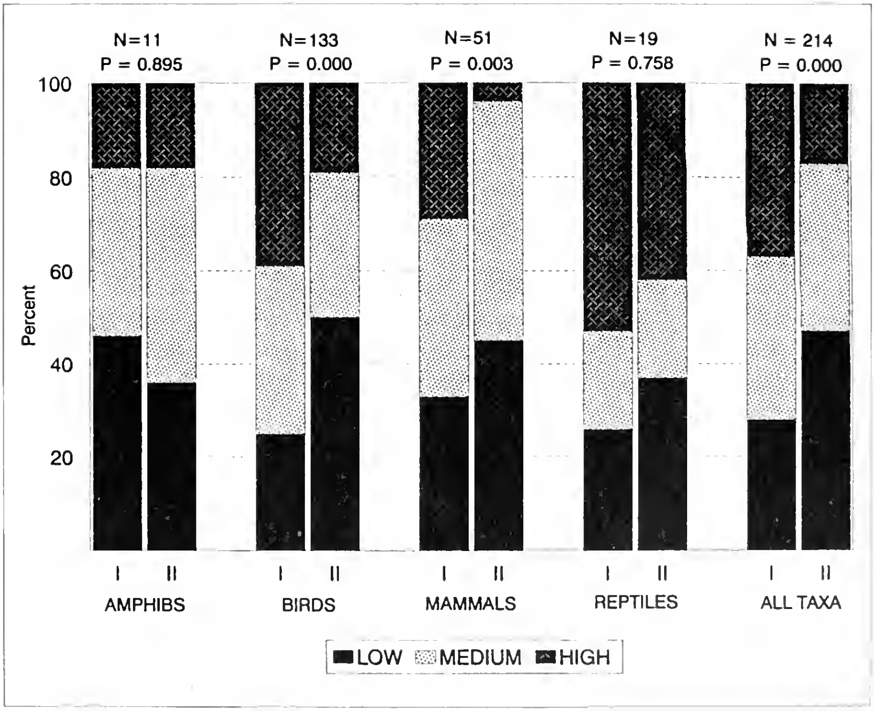

Figure 2. Comparison of percentages of species within five taxonomic groups with overall average habitat suitability ratings of Low, Medium, and High under a hypothetical two-situation comparison using the California Wildlife Habitat Relationships System. *P*-values are from X^2 tests of independence (*df* = 2) within each taxon. Situation I is open canopy classes (10-39%) of tree size classes from 1-24 inch dbh in Valley-Foothill Hardwood habitat, while Situation II is closed canopy classes (40-100%) of tree size classes from 1-24 inch dbh in Valley-Foothill Hardwood habitat. Both situations are located in Tehama County, California.

model structure and habitat classification system. CWHR also predicts the effects of habitat perturbations, but these effects can be merely classified as negative or positive regardless of the magnitude of the difference between two habitat situations. Summarizing predicted differences, regardless of magnitude, may mis-represent varying responses by wildlife when some responses may be more biologically meaningful than others. Also, predicted impacts to wildlife may be over- or under-estimated depending on the magnitude of the predicted difference.

The five different significance levels gave different numbers and lists of effected species. Therefore, the selected significance category should result in a predicted species list that is biologically realistic when using CWHR as an impact assessment planning tool. From this analysis, the Habitat Unsuitable and Rating Class Change levels appear most realistic for planning applications for the following reasons: (1) they focus more closely on gross predicted changes in habitat suitability (e.g., High to Unsuitable, High to Low, Low to Medium, etc.) rather than arbitrary levels such as 25% or 50%; (2) rating classes are more robust because they have the least reliance of the five categories on numerical habitat quality ratings (i.e., 0.0, 0.33, 0.67, or 1.0 in CWHR for breeding, feeding, and cover life requisites); (3) they are less sensitive to relatively trivial differences (e.g., ≤5% difference in overall average habitat values) between two situations that may or may not be biologically meaningful which could be mis-interpreted as insignificant or significant; and (4) there is less reliance on contrived numerical values that may or may not accurately reflect habitat suitability.

CWHR rating classes are based on varying levels of scientific information and validation. In addition, the rating classes represent an ordination of habitat suitabilities. Because of the underlying statistical assumption of a continuous distribution of numerical habitat suitabilities, the calculation of overall average habitat suitabilities may violate this assumption (see Siegel 1956). Therefore, impact assessments using CWHR List and 25% and 50% Difference categories may violate this assumption more so than Habitat Unsuitable and Rating Class categories.

Of all categories, Habitat Unsuitable resulted in the fewest positively and negatively effected species for all taxonomic groups (Fig. 1). Therefore, the Habitat Unsuitable category may substantially underestimate significant impacts, especially given the wide range of predicted habitat changes that may occur and still result in some level of habitat suitability and predicted species occurrence. For these reasons, the Rating Class category is preferred over Habitat Unsuitable.

The CWHR-predicted species list is a simple mathematical quantification of overall habitat value differences, regardless of magnitude. The user should evaluate significance of habitat value differences for each species individually. However, the CWHR categorization of positive, negative, and uneffected species presents opportunities for mis-interpretation by untrained or mis-informed CWHR users.

While the importance of predicted responses by entire wildlife communities cannot be over-emphasized, all significance levels have strengths and weaknesses (Table 2). Despite its overall greater utility and robustness, the Rating Class categorizes as uneffected those species with overall average habitat values at each extreme of the numerical values within a rating class (e.g., Situation I = 0.67, Situation II = 0.38, both

Table 2. Summary of general characteristics of five different categories used to evaluate the significance of predicted differences in overall average habitat suitability under a hypothetical two-situation comparison using the California Wildlife Habitat Relationships System.

Category	Biolog. Based	Verifiable	Sensitive to Lg. Differences in Habitat Value	Sensitive to Sm. Differences in Habitat Value	Sensitive to Modelling Errors in Habitat Ratings
Habitat Unsuitable	More	More	Yes	No	Less
CWHR List	More	Less	Yes	Yes	More
Rating Class	More	Less	Yes	Yes	More
25% Difference	Less	Less	Yes	Yes	More
50% Difference	Less	Less	Yes	No	More

[a] Characteristics of "More" and "Less" are qualitative comparative measures among the five categories.

rated as "Medium", value difference is 43%). In addition, the Rating Class may categorize as effected those species with a value at the lower end of a class in one situation and the upper end in the other situation (e.g., Situation I = 0.38, "Medium"; Situation II = 0.36, "Low"; value difference is 5%). Using a 20% buffer (10% on both sides of a habitat rating class threshold), the later case occurred for 6 of the 214 (2.8%) species in the query. Only 2 of these 6 (33%) species had overall rating differences that placed them in the 25% Difference category.

Biological Significance of Predicted Differences

Determining the biological significance of predicted differences in habitat value is complicated, and CWHR is simply a planning tool designed to provide trained, knowledgeable users with a standardized information source. The difficulty (Airola 1988, Hejl and Verner 1988, Purcell et al. 1992) in extrapolating CWHR habitat ratings to meaningful biological parameters, such as population density or productivity, with management utility complicates this determination. Also, CWHR habitat suitability ratings for many species are often not supported by field validation (England 1990, Hejl and Verner 1988, Purcell et al. 1992).

The significance of impact depends upon the magnitude of the difference, as well as population status and habitat quality. For example, species with baseline habitat values already at minimum levels may be more susceptible to significant impacts than species with baseline values near optimum levels (Conner 1979). Therefore, impact assessments should be done separately for species of management concern. In these cases, the user could select a more conservative significance level such as a 10% change in overall average habitat value, while common species may necessitate a more liberal category such as a Rating Class or 25% Difference. In addition, users should look closely at changes in habitat suitabilities for individual life requisite categories (i.e., breeding, feeding, and cover), because some life requisites may be critical.

Ramifications of Errors with CWHR Predictions

Errors may occur when CWHR-predicted differences are not manifested in field conditions. Furthermore, errors in predicted wildlife communities and habitat suitabilities will carry over to impact assessments. Predicted positive and negative effects could produce commission errors if they do not occur under field conditions. Conversely, omission errors could occur when positive or negative effects occur in the field but CWHR predicts no difference. Unfortunately, the frequency and magnitude of these errors is largely unknown because I know of no validation studies for CWHR two-situation comparisons. Again, users must cautiously evaluate model outputs to minimize commission and omission errors.

Van Horne and Wiens (1991) stated that model performance cannot be evaluated if its output is related to unobservable states, such as potential carrying capacity or maximum habitat quality. CWHR habitat suitabilities are based on differing levels of population density and frequency of occurrence. CWHR model outputs include predicted species lists and average habitat values and units. Of these outputs, the species list is the most readily observed and quantifiable, while habitat values are not because they are indices of the aforementioned biological parameters. Therefore, predicted differences in wildlife species composition between two or more situations may be the only output that can be validated to any degree.

Species composition differences were quantified in this study using the Habitat Unsuitable level. Changes in habitat ratings, habitat values, and habitat units, while inferring more precision than species lists, cannot be readily tested. Furthermore, these attributes are numerical results of nominal scales, which infers precision and accuracy that may not exist in CWHR. Also, changes in species composition typically occur only with gross changes in habitat.

Conclusions and Recommendations

Finally, CWHR is a planning tool that can predict differences in wildlife communities and habitat values between different habitat situations. These situations may be different geographic locations or habitat types, or changes in habitat with a proposed land use. The CWHR user can choose any desired significance category, but I recommend the chosen category be based on determining biologically significant differences rather than arbitrary ones. From this analysis, the more biologically reasonable categories are Habitat Unsuitable and Rating Class, while CWHR List and 25% and 50% Differences are more arbitrary. Habitat Unsuitable, while the most easily validated, resulted in the fewest number of effected species of all five categories. Rating Class appears to result in the most reasonable number and list of effected species of the five categories analyzed in this study.

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RETENTION, RECOGNITION, AND EFFECTS ON SURVIVAL OF SEVERAL TAGS AND MARKS FOR WHITE STURGEON

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We evaluated retention and effects on survival of tags and marks applied to 7,332 white sturgeon (*Acipenser transmontanus*) in the Columbia River between 1987 and 1991. White sturgeon were tagged and marked with combinations of spaghetti tags, Carlin tags, tattoos, barbel clips, leading pectoral fin-ray scars, and lateral scute removals. Spaghetti tag placements below the anterior and posterior portions of the dorsal fin had 96% and 88% retention during the first year at large. Removal of a combination of dorsal scutes provided a mark that lasts more than two years, whereas tattoos and fin-ray scars did not last as long. Barbel clips did not regenerate, but were subject to some misinterpretation and may have reduced survival rates. We recommend evaluating effects of scute removal on survival, and propose reserving removal of the second right lateral scute to indicate oxytetracycline injection and the second left lateral scute to indicate passive integrated transponder (PIT) tagging for white sturgeon studies in the Columbia River Basin.

INTRODUCTION

Three concerns in any marking or tagging study are: Will the mark be retained for the duration of the study? Is the mark recognizable by those expected to recapture the fish? Finally, does the mark affect survival of the fish (Wydoski and Emery 1983)? Tagging and marking of white sturgeon (*Acipenser transmontanus*) are particularly problematic because these fish are long-lived and programs to collect population information often last several years.

A variety of methods have been used to tag or mark sturgeons, but attempts to document success of these methods on wild sturgeons have been rare. Chadwick (1959) reported spaghetti and disk-dangler tags were shed over time and observed no difference in retention for placements below the dorsal fin, between dorsal scutes, and on the caudal peduncle of white sturgeon. Smith et al. (1990) evaluated retention of five externally visible tags (T-anchor, Carlin, Archer, Monel strap, and internal anchor) for captive shortnose, (*Acipenser brevirostrum*) and Atlantic sturgeon (*A. oxyrhyncus*). Carlin tags placed at the base of the dorsal fin and internal anchor tags had retention rates ≥80% after 180 days, but gill net entanglement was a problem with Carlin tags and severe tissue damage was associated with internal anchor tagged shortnose sturgeon released in brackish water.

Sequentially, numbered tattoos have been used to mark wild white sturgeon in Idaho (Cochnauer et al. 1985), but reports of tattoo retention are variable. Tattoos were clearly visible after one year on captive white sturgeon (Bordner et al. 1990), but were barely visible on captive shortnose sturgeon after four months (Smith et al. 1990). Removal of the leading pectoral fin ray for age determination leaves a recognizable scar, but may adversely affect survival (Kohlhorst 1979). Silver nitrate marks and barbel removal have also been tried with limited success (F. Partridge, Idaho Dep. Fish and Game, Boise, R. Pipkin, Univ. California, Davis, pers. comm.). Barbel clips on captive white sturgeon did not regenerate, but Bordner et al. (1990) expressed concern that this mark may affect the fitness of wild fish.

Retention and recognition of tags and marks are interrelated and difficult to distinguish in a field study. Estimates are further confounded by natural occurrences of marks or scars and by errors in recording data. Myhre (1966) developed a regression method to differentiate shedding from non-reporting based on an assumption that recognition rate is fixed relative to shedding loss, which occurs at a uniform rate. We defined retention as the combination of true mark retention and correct recognition of marks by samplers because our concern was the net potential for bias in population assessments based on recapture of tagged or marked fish.

During 1987-1991 we used spaghetti and Carlin tags, tattoos, barbel clips, fin-ray scars, and lateral scute removal marks on white sturgeon to estimate population characteristics in Bonneville, The Dalles, and John Day reservoirs on the Columbia River (Beamesderfer and Rien 1992). This study was not originally designed to compare mark and tag retention, but recapture data presented for the marks and tags we applied are useful for future mark-recapture experiments involving sturgeons. This paper summarizes the information on retention, recognition (including the ability of samplers to recognize the presence or absence of marks, how well marks conveyed specific information, and the incidence of 'natural' marks), and the effects of these tags and marks on survival.

METHODS

From 1987 through 1991 we tagged and marked 7,332 white sturgeon (Table 1). Combinations of marks changed over time as new information became available. White sturgeon were captured using setlines, gill nets, angling gear, and a creel survey (Elliott and Beamesderfer 1990).

All untagged white sturgeon over 84 cm fork length were double-tagged. One spaghetti tag was inserted below the anterior portion of the dorsal fin. A second tag was inserted below the posterior portion of the dorsal fin. From 1987 to 1989 the second tag was a spaghetti tag. From late 1989 to 1991 it was a Carlin tag (Table 1). White sturgeon 65-84 cm were single-tagged with a spaghetti tag in the anterior position; we believed double tagging would substantially stress these smaller fish. Spaghetti tags were made of extruded vinyl with a hollow core and were tied with an overhand knot 1 cm behind the dorsal fin. Carlin tags consisted of a circular plastic disk (1.4 cm diameter) secured by 0.5 mm diameter stainless steel wire using methods described by Wydoski and Emery (1983). Spaghetti tags and Carlin tags were sequentially numbered.

Table 1. Tags and marks applied to white sturgeon in three reservoirs of the Columbia River from 1987 through 1991.

Tags Marks[a]	87	88	89	90	91	Total
Anterior spaghetti tag only						
B	121	0	0	0	0	121
B T	2	0	0	0	0	2
B F	83	0	0	0	0	83
B S	0	202	0	0	0	202
F	0	0	0	0	19	19
F S	0	91	302	112	746	1,251
S	0	277	1,426	197	265	2,165
Anterior and posterior spaghetti tags						
None	0	1	0	0	0	1
B	115	3	0	0	0	118
B T	251	0	0	0	0	251
B T F	235	0	0	0	0	235
B F	22	1	0	0	0	23
B F S	0	50	0	0	0	50
B S	0	433	0	0	0	433
T	1	0	0	0	0	1
F S	0	174	270	0	0	444
S	0	466	676	0	0	1,142
Anterior spaghetti tag and Carlin tag						
F	0	0	0	0	17	17
F S	0	0	3	141	428	572
S	0	0	6	66	130	202
Total	830	1,698	2,683	516	1,605	7,332

[a] Marks are: B = barbel clip, T = tattoo, F = fin-ray scar, S = scute removal.

Except for one fish in 1988, all tagged fish were also marked using one or more of the following procedures: tattoos, barbel clips, removal of fin-ray sections, and removal of scutes (Table 1). We applied sequentially numbered tattoos to the pectoral girdle of 489 white sturgeon longer than 75 cm in 1987. The skin was rubbed with black tattoo ink and physical pressure was used to puncture the flesh with the needles of a 1-cm rotary tattoo. We removed a single barbel from specific positions on 1,518 fish during 1987 and 1988 to identify year of tagging. On 2,694 fish we removed right or left pectoral fin-ray sections from white sturgeon to determine age. A small hacksaw blade or coping saw was used to make two cuts through the leading pectoral fin ray. The first cut was made about 5 mm distal of the fin articulation and the second cut was made about 10 mm distal of the first. The fin-ray piece was then removed using a knife inserted between the rays as needed. Done correctly, little bleeding was associated with this procedure, but it left a recognizable scar on the leading edge of the fin. We removed one or two scutes in various combinations from the first four lateral scutes on the right and left sides on 6,461 white sturgeon beginning in 1988. Scute removal patterns corresponded to the year the fish was tagged and whether or not the fish had been injected with oxytetracycline (used to validate our aging technique). Scutes were removed by shaving them off close to the skin surface using a knife. The site of scute removal heals darker and smoother than the surrounding skin.

We compared retention of tags and marks among fish at large <1 year, 1 year, and 2+ years. Tag retention was estimated as the percent of recaptured fish with secondary marks that also had a tag:

$$\text{Tag retention} = 100 \times R_{t+m} / (R_{t+m} + R_m)$$

Where: R_{t+m} = the number of recaptured fish having a tag and secondary mark.
R_m = the number of recaptured fish having only a secondary mark.

Mark retention was estimated as the percent of recaptured fish with tags that also had the appropriate secondary mark:

$$\text{Mark retention} = 100 \times R_{t+m} / (R_{t+m} + R_t)$$

Where: R_t = the number of recaptured fish having only a tag.

This method will provide unbiased estimates of retention rates when tag\mark losses are independent of each other, even though fish losing all tags\marks may not be recognized. Evaluation of tag and mark retention was restricted to observations by our sampling crews or creel interviewers. Although use of voluntary angler recoveries would increase our sample size, anglers were not aware of the secondary marks we applied, thus they could not recognize fish that lost tags or marks. Year of tagging was determined from the tag number, or from secondary marks. We used chi-square tests of independence to compare retention of tags or marks over years at large unless half or more of the expected cell frequencies were small (<5), in which case we used Fisher's exact test (FET; Sokal and Rohlf 1981). We also used a chi-square test of independence to compare retention of spaghetti tags in anterior and posterior positions for fish at large less than one year were compared using a chi-square test of independence. Statistical comparisons were performed with the SAS "FREQ" procedure (SAS Institute 1988).

Mark recognition (presence or absence) was compared for two groups of samplers with different experience in recognizing marks. Samplers who applied marks and tags as part of their routine duties were considered to have greater expertise in mark recognition than creel samplers who were trained in the recognition of marks, but did not apply marks as part of their regular duties. We compared the rate at which mark types were identified as present on recaptures of previously marked fish between the groups, which provided insight into the importance of experience in mark identification.

The utility of marks for conveying specific information was examined by comparing recorded mark combinations when fish were tagged and when recaptured between sampler groups. Misinterpretation of marks at recapture may reflect inadequate mark application, misreading of the marks at recapture, or partial loss of marks. Regardless of the reason for the differences, the level of recording error indicates the utility of a mark to convey specific information. For example, removal of the second and fourth right lateral scutes indicates a fish was marked and injected with oxytetracycline in 1990.

The rate of natural occurrence for barbel clips, fin-ray scars, and scute removals was estimated as the percent of recaptured fish with tags that had "acquired" a mark while at large. This rate reflects loss of structures during the period at large, as well as recording errors at marking or recapture.

We examined the effect of barbel removal and fin-ray scarring on survival by comparing recapture rates between groups of fish with and without these marks. In 1988 we removed a barbel from about half the white sturgeon we tagged and released in The Dalles Reservoir each day; fish tagged in Bonneville Reservoir were excluded from this analysis because most fish were not barbel marked. In 1988 and the early part of 1989 we took fin-ray samples from about half the white sturgeon ≤124 cm that were tagged in Bonneville Reservoir each day; fish tagged in The Dalles Reservoir were excluded from this analysis because the rate of fin-ray sampling changed as our sample size needs were met. Other than the mark being tested, fish were treated similarly among groups — fish were single- or double-tagged depending on size. Recapture rates were not comparable between the barbel-clip analysis and the fin-ray sample analysis, because the test groups were from different reservoirs, sizes, and recapture efforts.

RESULTS

Samplers recovered 645 white sturgeon that had previously been tagged. Of these, all had been spaghetti tagged in the anterior position (anterior tag), 319 had been spaghetti tagged in the posterior position (posterior tag), and 30 had been tagged with a Carlin tag. Of all previously-tagged fish, 593 (92%) had retained at least one tag at recapture. Among recaptures of tagged fish, 64 had been tattooed, 204 had been barbel clipped, 174 had fin-ray sections removed (fin scarred), and 448 had lateral scutes removed (scute marks) at the time of marking.

Of the 645 recaptured white sturgeon that had been anterior tagged, 99 lost their tag prior to recapture (Table 2). Retention rates of anterior tags were significantly different among years and declined with years at large. The first-year tag retention rate for anterior spaghetti tags was significantly greater than for posterior tags (chi-square test: df = 1, $X^2 = 7.39$, $P = 0.007$). Posterior tags were lost on 42 of the 319 recaptures. Posterior tag retention also was significantly different among years and declined with years at large (Table 2). Of 30 Carlin-tagged fish recaptured, 4 had lost the tag.

First year retention did not vary significantly among marks (FET: df = 1, $P = 0.429$), but subsequently there were some distinct differences. Tattoos were

Table 2. Retention/recognition rates for various tags and marks applied to white sturgeon, Columbia River, 1987-1991.

	Years at large			Chi-square results		
Tag or mark	<1	1	2+	df	X^2	P^a
Anterior spaghetti tag						
retained	244	167	135			
lost	11	35	53			
retention rate	96%	83%	72%	2	48.37	<0.001
Posterior spaghetti tag						
retained	113	111	53			
lost	6	15	29			
retention rate	88%	88%	65%	2	36.27	<0.001
Posterior Carlin tag						
retained	19	7	—			
lost	2	2	—			
retention rate	90%	78%	—	—	—	—
Tattoo[b]						
retained	9	0	0			
lost	1	33	4			
retention rate	90%	0%	0%	2	—	<0.001[c]
Barbel clip[b]						
retained	60	83	35			
lost	4	5	4			
retention rate	94%	94%	88%	2	—	0.653[c]
Fin-ray scar[b]						
retained	81	31	28			
lost	4	17	2			
retention rate	95%	64%	93%	2	25.55	<0.001
Scute removal[b]						
retained	206	96	111			
lost	8	4	1			
retention rate	96%	96%	99%	2	2.41	0.300

[a] Retention rates among 'years-at-large' groups are considered significantly different if $P \leq 0.05$.

[b] Numbers reflect fish examined for a particular mark, not all previously marked fish recaptured.

[c] Fisher's exact test results.

retained only during the first year after application (Table 2). Barbel clips were retained by 93% of recaptures and retention rate did not vary significantly among years at large. Fin scars were retained by 86% of recaptures. The trend in long term retention of fin scars retention was not clear, but retention varied significantly among years and was greatest during the first year at large. Scute marks were retained by 97% of recaptures and retention rate did not vary significantly among years.

Table 3. Recaptures of tagged white sturgeon by mark type, similarity of mark combinations and positions recorded at recapture to those recorded at marking (recognition), and experience of personnel, Columbia River, 1987-1991. Personnel with modest experience were creel clerks who were trained in mark recognition but did not apply marks; expert personnel tagged and recaptured fish as part of their regular duties. Fish were examined without knowledge of the original marks applied.

		Experience of personnel			
		Modest		Expert	
Mark type applied	Recognition at recapture	*n*	Percent	*n*	Percent
Tattoo	Identical	2	17%	3	9%
	Present [a]	0	0%	4	11%
	Absent	10	83%	28	80%
Barbel clip	Identical	31	68%	129	89%
	Present [a]	9	20%	9	6%
	Absent	6	13%	7	5%
Fin-ray scar	Identical	6	38%	111	75%
	Present [a]	3	18%	20	14%
	Absent	7	44%	16	11%
Scute removal	Identical	37	74%	349	93%
	Present [a]	4	8%	23	6%
	Absent	9	18%	4	1%

[a] The correct type of mark was seen but the exact position or combination of marks recorded at recapture was different from that recorded at marking, or the tattoo number did not match.

Tattoo recognition was low among all samplers due to the low retention after one year (Table 3). Tagging crews saw and correctly recorded barbel clips, fin scars, and scute marks more often than creel samplers. Of these marks, fin scars were the most difficult to recognize by both groups of samplers. Fin-scar recognition increased with experience; they were recognized twice as often by tagging crews as by creel samplers.

All marks had low natural occurrence rates: 3% of 362 for barbel loss, 6% of 380 for fin scars, and 5% of 104 for scute loss.

We tagged and released 635 barbel-clipped and 548 unclipped white sturgeon in The Dalles Reservoir in 1988. Respective recapture rates were 16% and 22%. The recaptures were significantly different (chi square test: df = 1, X^2 4.993, $P = 0.025$).

During 1988 and early 1989 in Bonneville Reservoir we tagged and released 578 fin-scarred fish and 549 that were not fin scarred. We recaptured 13% and 11% of these, respectively. The recaptures were not significantly different (chi square test: df = 1, X^2 0.903, $P = 0.342$).

DISCUSSION

Double-tagging white sturgeon remains the most satisfactory method of ensuring high tag retention rates over a period of several years. Posterior spaghetti tag retention was lower in the first year than anterior tags or Carlin tags, and retention rates for all tags declined over time. Small samples of Carlin tags precluded statistical comparisons of retention with spaghetti tags, but both were retained at high rates in the first year after tagging. Unless Carlin tags are retained at significantly higher rates, we would recommend spaghetti tags, because of easier application and because Carlin tags may increase catchability with gill nets (Smith et al. 1990).

Although spaghetti tags were the most effective of the tags that we examined, the style of spaghetti tag we used is still unsatisfactory. Spaghetti tags left a wound that we occasionally saw on fish at large more than one year, and tag numbers became difficult to read over time. Legibility of tags is particularly important in studies that depend on voluntary tag returns from anglers. Anglers must be able to recognize the tag to report harvest of tagged fish. Evaluation of tag types that may be less irritating to the fish and remain more legible is recommended. Passive integrated transponder (PIT) tags and visible implant tags may be less irritating (Duke et al. 1990, Haw et al. 1990, Smith et al. 1990); however, PIT tags cannot be read without special equipment and visible implant tags become difficult to read in white sturgeon due to pigment and scarring over the tag (L. Beckman, National Biological Survey, Cook, Washington, pers. comm.). Latex-coated spaghetti tags with a stainless steel wire core may improve legibility and retention over vinyl hollow core spaghetti tags (J. DeVore, Washington Department of Fish and Wildlife, Battle Ground, Washington, pers. comm.). We are now evaluating a molded nylon dart tag similar to that described by Gutherz et al. (1990) on wild white sturgeon. The dart head is designed to encourage muscle tissue adhesion and may improve long-term tag retention.

Scute marks appear to be an ideal secondary mark. Scute removal provided a long-term mark that is recognizable by samplers with varying levels of experience and combinations of scute marks may be used to convey much information about fish at tagging. However, further work is needed to evaluate the effect of scute marks on survival. We removed the second right lateral scute to identify fish that had been injected with oxytetracycline (OTC). We propose that this mark be reserved region-wide to indicate OTC treatment and further propose reserving removal of the second left lateral scute as a standard to indicate a white sturgeon that has been PIT tagged. The PIT tag has shown promise as a long-term tagging technique for sturgeons, but one problem is the lack of a readily identifiable external mark (Smith et al. 1990).

Retention of tattoos, barbel clips, fin scars, and scute marks was similar in the year of tagging, but retention declined for tattoos and fin scars in subsequent years. Barbel clips were retained over long periods, but reduced recapture rates of barbel-clipped fish suggest reduced survival. In contrast, removing a section of the leading pectoral fin ray did not reduce recapture rates, suggesting survival was not affected. Kohlhorst (1979) observed that removal of the first pectoral fin ray resulted in "substantial" (36% higher) mortality of white sturgeon during the first year following removal. The difference in mortality rate may be due to the difference in technique: Kohlhorst removed the entire fin ray starting just distal to the area forming the articulation, whereas we removed a small (10 mm) section of the fin ray.

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AN OBSERVATION OF HIGH FECUNDITY OF SPOTTED OWLS IN CALIFORNIA

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Miller (1974) published a detailed account of her seven years of observations of a pair of northern spotted owls (*Strix occidentalis caurina)* in the Inverness area of Marin County, CA. In one of the years that the pair produced young, they fledged three owlets.

In 1975, forester J. Berry observed a spotted owl in Crawford Gulch, tributary to Dutch Bill Creek, Sonoma County, CA. This observation was made the year after a moderate to heavy selection harvest of redwood (*Sequoia sempervirens*) and Douglas fir (*Pseudotsuga menziesii*) occurred in the gulch (California Department of Forestry and Fire Protection/Timber Harvest Plan 1-75-5408 SON).

On 18 April 1992, J. Berry and this author revisited the area and located a male spotted owl. On 18 May, a female owl was located nesting in a 93 year old, 44-inch diameter breast height (dbh) Douglas fir. The site was revisited on 18 June and a female spotted owl and three owlets were observed 150 ft downhill from the nest in a five inch dbh California bay (*Umbellularia californica*). Four domestic mice were provided to the adult owl. The mice were picked up by the adult and fed to the owlets starting with the largest and proceeding down to the smallest owlet.

After consulting the California Department of Fish and Game owl database, I found that in 1992, seven pairs of northern spotted owl and 65 California spotted owls (*Strix occidentals*) were reported to have had triplets. This compared to zero reported in 1990 or 1991, one for each species in 1989, and two sets of northern spotted owl triplets in 1988. It appeared that 1992 was a year with higher than normal production of triplet owlets per nesting pair.

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