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# A NEW PERSPECTIVE AND METHODS FOR PHEASANT MANAGEMENT

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## ABSTRACT

**We have developed a new concept and methods for management of the ring-necked pheasant, *Phasianus colchicus*. These methods have produced high-density, local populations in small areas of nonagricultural, irrigated habitat by increasing chick production and survival, and related juvenile recruitment. We use enhanced territory cover to concentrate higher-density breeding populations in such suitable management units to achieve greater chick production. We obtain higher chick survival and recruitment primarily by producing abundant insect/arthropod food for chicks and other young pheasants, achieved by management of natural cover, mainly by timely disturbance and supplemental irrigation, but without plantings. We discuss development and application of the implementation methods and their biological basis, mainly a product of our studies in combination with results of relevant British research. In field-testing this system at Grizzly Island Wildlife Area (GIWA), located in a mild-winter region in central California, pheasant production over a 3-year period (2001-2003) was approximately 4-6 times greater than from a comparable, conventionally managed area; also, in the third year, the 73 acre (29.5 ha) test unit produced >2-3 pheasants/acre (0.4 ha), approximately doubling the density record for pheasants in California. At Sodhouse Farms, a private ranch in a severe-winter region in**

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**central Oregon, prescribed implementation of the system in 2005 was followed by an increase in the pheasant bag that year from a previous average of 4 to 144, indicative of a population density as high or higher than at GIWA. These examples illustrate the potential that the concept and methods can have, in appropriate circumstances, to develop, maintain, or restore viable pheasant populations, especially in small areas of non-cropland habitat. However, the system needs to be adapted to regional or local conditions and tested more widely over longer periods to better assess the potential and role it can play in future management for pheasants, or possibly other wildlife species, which we encourage with this publication.**

## INTRODUCTION

California formerly enjoyed widespread pheasant populations, some regionally abundant (>1 bird/acre, 0.40 ha). These were generally supported by agricultural habitat consisting of irrigated field crops (Hart et al.1956). However, increasing application of new technologies and economic pressures to agriculture resulted in cleaner and more intensive farming practices following World War II. These cropland-supported populations of pheasants declined quickly and essentially disappeared as pheasant habitat attributes of farmlands were degraded and lost. The reported pheasant bag in the San Joaquin Valley of California decreased 83% from 1970 to 1986 (Hart 1990[3]).

Cropland habitat that was formerly productive for pheasants no longer produced these birds after it became generally bare soil extensively devoid of cover at frequent intervals. Many reliable sources of free surface water also disappeared, with pipeline systems replacing open ditches. In addition, extensive conversions to large-scale crop monocultures lacking essential habitat diversity were similarly unproductive of pheasants.

Further evidence that the underlying problem was loss of habitat attributes in croplands was the persistence of local populations of ringnecks in suitable non-agricultural circumstances. Such sites generally were relatively small, virtual islands of diversified habitat with greater continuity and stability, typically in wildlife or natural areas usually managed by governmental agencies. Other such habitat and local populations continued on many private hunting clubs, some fields retired from agricultural production, and similar rural properties.

Ensuring habitat conditions that would optimize or maximize these remaining local populations could help compensate for pheasant numbers lost from former agricultural habitat. Also, such a program apparently offered the best potential for restoring and maintaining viable populations of wild pheasants in both the near and long-term in California, and possibly elsewhere. However, in company with many states, California's Department of Fish and Game (CDFG) has relied mainly on wild

[3] Hart, C. M. 1990. Management plan for the ring-necked pheasant in California, California Department of Fish and Game, Wildlife Management Branch, Sacramento, California, U.S.A.

pheasant production as a free and incidental byproduct of favorable agriculture. Accordingly, effective habitat management practices appropriate for the changed circumstances had not been developed in California, or elsewhere in the U.S. that we could ascertain. Thus, determining pertinent biological and behavioral information for pheasants in these conditions and developing appropriate management strategies and methods were the first steps for such a program, which we undertook and describe here.

## CONCEPT AND METHODS DEVELOPMENT

A first phase included testing the hypothesis: Is small-area management in non-cropland habitat feasible for pheasants? If so, we needed to determine significant limiting factors for the species under these circumstances.

The second phase was to use this new information, as well as other relevant research results, to develop an appropriate concept or strategy and related management practices to reach our objectives, by methods that were generally feasible for limited management effort. This initial process extended over approximately 13 years to accomplish.

### Study Area
### Mendota Wildlife Area (MWA)

The effort began here about 1988. A unit of the CDFG system of such managed areas, MWA then consisted of 12,425 acres (5,030 ha), located in western Fresno County near the center of the San Joaquin Valley farming complex. This region has a Mediterranean climate, with winters generally mild, free of snow and ice, and with hot, dry summers. Annual precipitation averaged <7 inches (18 cm), occurring mainly from November into March. Historically semi-desert shrubland, most of MWA previously had been developed for irrigated cropland. Under later CDFG management, approximately 70% of the area had been converted mainly to managed marsh or other wetlands, with roughly 3,000 acres (1,214 ha) of interspersed uplands providing the main pheasant habitat. Area management included a controlled public-hunting program, with the annual bag of wild roosters an indicator of pheasant population levels and trends.

MWA also had other attributes required for the investigation. These included adequate land and existing upland habitat for experimental management, an irrigation water supply and facilities, farming and earthmoving equipment required for habitat development and management, and a staff of operating personnel.

The surrounding agricultural region had been highly productive for pheasants, with Fresno County ranking highest in reported pheasant bag for California in much of the 1960s. However, this hunter bag declined >90% from 1971 to 1986 (Hart 1990 [3]). The pheasant bag on MWA had not paralleled this decline, however, instead reaching the second highest bag of record (413) in 1993. Furthermore, the yearly bag had fluctuated irregularly by >400%, from a high of 450 in 1974 to a low of 102 in

1988, averaging in the low 200s, with the causes unknown or unproven.

## Methods

### Experimental Habitat Management, Phase 1

Approximately 535 acres (217 ha) of dense nesting cover were planted on MWA from 1987 through 1991 in 25 parcels distributed throughout the upland areas. The main purpose was to test the hypothesis that lack of good nesting cover was a limiting factor for the resident pheasant population.

### Radiotelemetry Study

Samples (n = 115) of wild hens were radio-tagged in the winters of 1990, 1991, and 1994 and monitored annually from late winter through early summer. This provided site-specific data on habitat use, reproductive success, and related information (Brueggemann and Hart 2003[4]).

### Other Field Studies

Two informal studies were conducted to obtain basic information on insect/arthropod production for typical chick food on MWA. The objective of one study was to correlate biomass of small invertebrates primarily with cover and soil moisture conditions, with collections from sample plots by using a vacuum collector. The other used pit-fall traps embedded in soil surfaces to correlate arthropod production and densities with moisture conditions provided by irrigation.

### Experimental Habitat Management, Phase 2

This later work concentrated primarily on developing methods of growing and managing brood cover for timely production of chick food. Various practices and combinations of using both existing and planted cover, managed mainly with irrigation and mowing, were tried. Focus later shifted to developing a simpler and more natural approach, without plantings and mainly using disturbance to develop productive brood cover from the existing natural seedbed.

### Field Observations

These generally were routine in conjunction with the radiotelemetry study. However, in the latter stages of concept development, emphasis was placed on determin-

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[4] Brueggemann, S. J. and C. M. Hart. 2003. Radiotelemetry studies of ring-necked pheasant reproduction on Mendota Wildlife Area, California. Wildlife Programs Branch Administrative report no. 2003-1, California Department of Fish and Game, Sacramento, California, U. S.A.

ing local cover conditions selected in spring by dominant roosters for establishing territories.

## RESULTS

### Experimental Habitat Management, Phase 1

Planting dense nesting cover produced no evident response from the pheasant population, as concluded from radiotelemetry results, annual checked bag, and field observations. This was despite such cover being good-quality and receiving concentrated use by waterfowl that select similar nesting cover. There was no apparent reason for pheasant hens not similarly making more concentrated use of this high-quality cover planted for them.

### Radiotelemetry (RT) Studies

Results are summarized primarily from Brueggemann and Hart (2003[4]):

1. Study hens generally were as sedentary as habitat conditions permitted. Although most home ranges in spring/early summer averaged approximately 43 acres (17 ha), hens in highly diversified habitat lived, successfully nested, and reared broods in ranges of 10-12 acres (4-5 ha).

2. Although marshes and other wetlands made up approximately 70% of MWA, they produced a disproportionately low 10% of the pheasants. Statistical analysis of the RT data showed that hens generally selected for uplands to nest and rear broods, and against wetlands for these purposes. Wet edges in these circumstances evidently did not provide favorable conditions for brood rearing.

3. Monthly mortality of study hens averaged approximately 5%, equating to an annual survival rate on the order of 40%. This indicated normal to high survival for California conditions (Hart 1955[5], Mallete and Harper 1964, Petersen et al. 1988).

4. Nesting success was high, approximately 80% for initial nests, with 11% depredation. No nests or hens were destroyed on MWA by mowing or other practices common to agricultural habitat. Study hens used nest sites with good success in essentially all cover types available. Selection of nest locations generally was for vegetative structure that provided good nest concealment, regardless of plant type or community. Nesting use of the planted nesting cover by study hens was not proportionately greater than other cover types.

5. Chick mortality was excessively high. By approximately 5 weeks of age, overall chick losses approached 85%, with nearly half the broods all dead, and with surviving broods averaging two chicks. Calculated juvenile recruitment to the fall population was 1.2 per brood, less than required for population maintenance (Trautman 1982).

6. The high loss of chicks came in the period when they were essentially totally dependent upon insects and other arthropods for food. This and other evidence, although circumstantial, pointed to lack of required insect/arthropod food as the

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[5] Hart, C.M. 1955. Pheasant survival studies in California. Western Association of State Fish and Game Commissioners, 35th Annual Conference Proceedings.

immediate cause for the high chick mortality.

7. Chick survival was inversely proportional to the size of the brood range. Large ranges typically resulted from hens quickly leading newly hatched broods on continuous, lengthy, and seemingly aimless traveling. We interpreted this to be primarily hens leading their broods to search for chick food, due to its lack in the nest vicinity, as reflected in the high chick mortality. However, their poor success indicated that hens whose home ranges did not contain productive brood cover evidently had no instinct or knowledge of where or how to find it.

## Other Field Studies

The vacuum-sampling study for potential chick food organisms was terminated due to inadequate funding before data analysis was completed. However, field-notes showed that soil areas that were moist-wet obviously produced the highest biomass of small invertebrates. Also, that as spring advanced with rising temperatures and diminishing or terminating rainfall, this biomass severely declined and essentially disappeared with the drying of surface soils and dying of annual vegetation.

The study using pit-fall traps showed similar results. High-density arthropod populations developed in suitable cover with damp-moist surface soil maintained by irrigations, typically requiring approximately 10 days to peak. However, if soil surfaces were allowed to dry, arthropods quickly disappeared. Their numbers were regenerated by renewed irrigations frequent enough to restore and maintain damp-moist surface soils, but another $\geq$10 days were required.

These studies were not replicated, and we considered the results as preliminary or indicative until confirmed by other information or later field-testing. However, they generally tended to support the pattern of emerging information as to basic factors influencing chick food production, including the role of moisture. They also were supported by findings of Hudson et al. (1994) that dry sites produced 75% fewer insects in comparison to damp sites in the Scottish Highlands.

## Field Observations

Field surveys in the springs of 1998 and 1999 showed that in California's Central Valley, locations selected by dominant roosters for establishing crowing territories typically had an abrupt edge to suitable escape cover, with the edge fronting on an open area of bare soil or low cover for crowing and displaying. Sites that had the highest concentrations of territories were several-acre patches of residual growth of tall, annual weeds on Mendota and other Wildlife Areas, so dense that hunter access lanes had been disked through them in the fall to facilitate hunting. The following spring, roosters were using the essentially bare, disked strips for crowing and display, next to the disk-developed edge of escape cover. The majority of roosters within a radius of approximately 0.5 miles (0.8 km) were concentrated at these locations, either occupying established territories or attempting to displace occupants.

## CONCEPT AND METHODS DISCUSSION

Initial results supported the concept of small-area pheasant management in this more stable, nonagricultural habitat. The RT results showed that areas as small as approximately 10-12 acres (4-5 ha) could serve reproductive needs of pheasant hens, if the habitat was adequately diversified. The sedentary characteristics of the MWA hens were not unique, as a studied pheasant population in Wisconsin was described as similarly containing a preponderance of unusually sedentary birds (Gates and Hale 1974). In addition, that hens were socially tolerant of high-density circumstances and concentrated-use areas was demonstrated in the Pelee Island study by 28 hens nesting and initiating brooding in a 1-acre (0.4 ha) field (Stokes 1954). Also, the concept of small-area management was supported generally by the European long-term experience in management of wild pheasants on relatively small shooting estates (Robertson 1997). We considered the evidence adequate to warrant further evaluation and planning for a relatively small management unit to support a local pheasant population.

Furthermore, the existing non-cropland habitat on MWA evidently served essential requirements of the adult pheasant population well. Survival of mature hens was high, generally indicative of adequate food, cover, and other habitat requirements for adult birds. Earlier evidence that pheasants did well in suitable non-cropland habitat, generally lacking in cereal grain food, has been presented for the Sandhills of Nebraska by Sharp and McLure (1945), for the Pacific Northwest by Einarsen (1945), and for a region of irrigated pasture in California by Hart et al. (1956).

Also, nesting success was high, which we considered could be largely a reflection of expansive areas of suitable nesting cover essentially free of mowing and similar destructive disturbances common to agricultural habitat. Nesting hens successfully used essentially any type of cover that provided adequate nest concealment, including the grassy/weedy complex of volunteer growth typical of fallow fields in the region. There were no indications that new management measures or emphasis were needed for such habitat elements as food and water, or nesting, escape, and winter cover for the mature populations at MWA or comparable areas.

Pheasant population dynamics at MWA obviously were driven by annual success of juvenile recruitment. The evident limiting factor was early and high chick mortality, leading to typically minimal recruitment of juveniles. All available evidence pointed to a habitual problem of generally inadequate food for young chicks. Populations of chick food organisms crashed and disappeared as annual vegetation and surface soils dried in the spring with the combination of terminating rainfall and warming temperatures typical of the Mediterranean climate, before the brood-rearing season.

In reviewing U.S. literature, we found essentially no research results or other information directly related to increasing wild chick survival in pheasants and thereby improving juvenile recruitment, other than possibly predator control infeasible for California and perhaps other circumstances. Main emphasis on reproductive factors in the U.S. has been on nesting conditions and related management, as exemplified by Robertson's (1996) analysis of 5,905 articles on pheasant nesting that were published in U.S. technical journals between 1933 and 1990. Chick survival essentially has been only measured or mortality evaluated for cause of death (Riley et al. 1998). From our perspective and objectives, this apparent void in U.S. research or effort aimed at increasing survival of wild chicks was curious, largely unrecognized or unexplored as a management potential. Thus, any attempt to increase chick survival by habitat management would be essentially a pioneering effort.

The ring-necked pheasant has long been recognized to be a short-lived species, maintained by a high reproductive potential. Under California conditions, mainly from results of the Sutter Basin study of 1952-1958, population turnover rate is approximately 78% annually. Most pheasants do not survive their first year. In breeding populations, birds <1 year old predominated (Mallete and Harper 1964).

In California, broods from initial nests usually average approximately nine chicks, assumed near the universal average (Hart unpublished data, Robertson 1996). Trautman (1982) determined that survival of approximately 3-4 young per brood typically was required for population maintenance, with >6 leading to major population increases. A high-density population was maintained over a 7-year period in Sutter Basin, California by approximately 56% survival (brood size five) to 8 weeks of age (Mallette and Harper 1964). The most explosive increase of pheasants in recent California history, achieving record-density populations after a late, wet spring in 1948, followed brood size of seven at 6 weeks of age, on the order of 60% survival (Hart et al. 1956). Stokes (1956) calculated that 40% chick survival to the hunting season led to a 650% population increase over 3 years at Pelee Island. These values varied due to different standards and circumstances, but suggested that achieving survival of approximately half or more of the annual crop of chicks could be a key factor in producing or maintaining higher densities of pheasants.

However, juvenile recruitment per brood has inherent limitations due to natural parameters of brood size, from one to approximately nine. Obviously, expectations of achieving 100% survival were unrealistic. In a low-density population with brood survival at maintenance levels of 3-4 juveniles, the reasonable potential would not appreciably exceed approximately doubling juvenile recruitment. However, achieving that on a regular basis would be no small management accomplishment, and potentially lead to a significantly higher-density population within a few years, other factors remaining equal or favorable.

What also emerged from the available information was that the moisture requirements of the ringneck's life history, especially during its inherent brood-rearing season, were not temporally synchronized with the moist period usually provided by the mainly winter/early-spring rainfall pattern of California's Mediterranean-type climate. In these or similar conditions, irrigation of cropland habitat has extended the moist/damp soil period to encompass the pheasant's annual brood-rearing phase and evidently generally has produced adequate supplies of chick food then. We considered there was little question that this moisture augmentation had been an important factor in irrigated croplands supporting high numbers of pheasants, as long as other habitat requirements were met also (Hart et al. 1956). Correcting this problem, however, appeared within the capabilities of management where irrigation is generally practiced. But it obviously needed to be a purposeful part of pheasant management in non-cropland habitat in regions without adequate late-spring/early-summer rainfall.

## Review of Relevant Factors

Finalizing management solutions required our carrying out a comprehensive review of important factors. This was necessary to be reasonably sure that we adequately understood their complexities and interrelationships before proceeding further with our objectives.

## Chick Survival

Pheasant chicks are precocial and insectivorous, having to forage soon after hatching for their food that then consists almost entirely of animal matter. Westerskov (1957) concluded that newly hatched pheasant chicks could not survive longer than 3 days without food. However, these were game farm chicks held in a still-air incubator, not subjected to chilling or other hazards in the wild that reasonably could shorten this survival period due to earlier effects of malnutrition.

Food organisms available to newly hatched chicks are limited to those on the ground or within reach on low levels of vegetation. Test feeding of live insects to penned chicks two weeks old showed that they selected the largest that could be engulfed readily, rarely ingesting individuals <3 mm in length (Whitmore 1986). In studies in England, young pheasant chicks fed on large, slow-moving insects found near ground level, including beetles, plant bugs, caterpillars, and sawfly larvae (Robertson 1997). Earlier California studies found that small beetles, *Carabidae,* predominated in the diet of chicks ≤2 weeks old, with both nymphs and adult grasshoppers, *Locustidae*, becoming a main food item of the young at ≥6 weeks of age. Juveniles were about 9 weeks old before their diet consistently was <50% insect and other animal matter, and >12 weeks old before phasing over completely to the adult diet of mainly vegetable matter (Ferrel et al. 1949, Leach et al. 1953).

However, young chicks evidently are not appreciably selective otherwise, and can do well on whatever suitably large arthropods that are readily available. This was demonstrated by may-flies, *Ephemeridae,* making up >50% of the chick diet in the high populations of ringnecks on Pelee Island (Stokes 1954). Pre-adult stages of may-flies are entirely aquatic, so only spent adults from mating swarms were available to chicks. Apparently management for producing suitable chick food need not be precise or focused to foster a specific or limited group of arthropods, but probably only a general variety of suitable size and availability.

British biologists found that chicks in broods that had <50% mortality had eaten three times more arthropods by weight than broods with greater mortality (Hill and Robertson 1988a). Related modeling further indicated that chick food abundance was important to chick survival and the level of juvenile recruitment attained. A 60% increase in arthropod food projected to a 50% gain in chick survival and a 36% increase in fall pheasant numbers (Hill and Robertson 1988b). Logic tended to support these findings and predictions. The more abundant their food, the quicker young chicks could fill their small crops and return to the warming and protection of the hen's brooding. In addition to being better nourished, this minimized the time chicks needed to spend foraging and being exposed to predation, chilling, and other natural hazards, thereby further tending to increase survival. The issue then became what cover and related habitat conditions produced this abundantly available food supply and how they could be applied on a feasible and timely basis by management.

## Productive Brood Cover

British researchers also have best determined and defined the character of productive brood cover for pheasants (Hill and Robertson 1988a, Sotherton et al. 1994, Robertson 1997), although Wight (1945) in the U.S. had reached similar conclusions. The British studies found that broadleaved, herbacious plants were typically most productive of the types of arthropods suitable for chick food; they also grew in the more open stands required for effective chick foraging. On the Seefeld Estate in Austria, managers planted various broadleafs for pheasant brood cover in strips along the edges of set-aside fields. That practice reportedly doubled pheasant brood size on this farming/shooting estate (Robertson 1997).

In the MWA circumstances, good nesting cover was plentiful, but evidently did not serve well as brood cover. In addition to grasses in these complexes being poor producers of chick food, their density at ground level, that was beneficial in concealing nests, was too difficult or impenetrable for young chicks to forage through effectively (Brueggemann and Hart 2003[4]).

## Developing or Growing Brood Cover

Our initial attempts to produce good brood cover included both timely irrigations of existing natural cover, to simulate adequate and later spring rainfall, as well as planting and irrigating commercial varieties of broadleafs, primarily legumes. In the highly favorable growing conditions of the San Joaquin Valley, these methods typically produced cover that was overly dense or quickly became so, frequently from invading plants. Also, mowing or reducing seeding rates did not correct the excessive density. We concluded that these results generally were too problematic for feasible cover management to meet our objectives.

What we were seeking was a process similar to moist soil management for growing selected native or naturalized plants for waterfowl food, accomplished primarily by water manipulation in a semi-natural process. Coincidentally, in the course of experimental field-testing of moist soil management earlier on MWA, the desired forb or broadleaved vegetation had germinated from the natural seedbed and developed after flooded fields were drained at about the end of February. Such flooding was a form of disturbance that had been followed by early successional, broadleaved vegetation after this timely drawdown.

We adapted this and related information to a prescription for producing brood cover in upland circumstances:

Initial disturbance accomplished by disking, incorporating existing vegetation and surface litter in the soil, thereby reducing areas planned for brood cover to the desired bare soil by about mid-fall. This timing is to complete the disturbance before fall or winter rains preclude equipment work in the field.

A second disturbance by deep-flooding within perimeter dikes, covering the brood-cover area for approximately the month of February. This generally killed the re-growth of annual grasses and other competing vegetation that was germinated later in the brood strips by usual fall rains in California's pheasant range.

Draining the flooded brood cover area at the end of February, for timely germination from the natural seedbed to produce early successional, weedy, or predominantly broadleaved vegetation.

We hypothesized that in mild-winter areas this process would simulate the effects on annual plant phenology of severe winters with a snow-pack, which are characteristic of the main pheasant range in North America, as well as generally the regions in Asia where these birds evolved. In regions having severe winters, winter flooding should not be required, and generally would not be feasible.

However, managing this established brood cover to be highly productive of arthropods for chick food evidently required maintaining damp/moist surface soils in it. For that at MWA and comparable locations, adequate and timely irrigations were needed, beginning at least 10 days before appreciable numbers of chicks hatched. Such irrigations to maintain moist soils and abundant chick food needed to continue through the main hatch period for initial nests and approximately 4-6 weeks longer. For most of the California pheasant range, this period was from about mid-April through mid-July. However, this process of providing productive brood cover remained untested during our work at MWA.

## Territory Cover

Late in the process of concept development there remained an unresolved, potentially overriding issue, illustrated by the MWA study hens essentially rejecting the dense nesting cover planted for them. This suggested that pheasants were not necessarily attracted to cover developed by human perceptions of what they needed and where it should be placed. This was especially critical for small-area management. Unless an adequate breeding population was attracted to and productively used cover provided in such a managed unit, efforts of this type could be largely ineffective and unproductive.

The belated key here was the timely publication by P. Robertson (1996) that emphasized the importance of territory cover and the role of the dominant rooster in management considerations. This hadn't been evident to us, at least in part due to our RT studies being flawed by not including radio-tagged roosters.

Although British and possibly other European research had refined knowledge of the rooster's role and to some degree related applications to management, these were founded on basics long well-known in pheasant biology and breeding behavior. Key were the ringneck's polygamous and territorial breeding habits. Early in the breeding season, dominant roosters seek out and select what they apparently consider the most favorable sites available for establishing exclusive territories, from which they can safely but conspicuously crow and display. To be seen and heard, they want an open area, but next to escape cover for safety. Their main objective here is to attract hens for their individual harems (Taber 1949, Robertson 1996).

However, neither sex apparently has the capacity to think ahead or instinctively make their site selections based on the presence also of suitable nesting and brood cover for future reproductive needs. Thus, the productivity of these family units in unmanaged habitat depends essentially on the chance proximities of suitable territory, nesting, and brood cover, each essential but needed in close combination for good success in reproduction and recruitment.

These characteristics make the potential productivity of a given area for pheasants, including managed units, directly proportional to the number of rooster territories it contains, other factors being equal. At this time in the annual cycle, the hens will be wherever the roosters are, and management efforts to divert or attract them elsewhere will be fruitless. Harem hens are closely tied to their dominant rooster, with British research showing that they generally nest within approximately 200 yards (183 m) of the center of his territory (Hill and Ridley 1987, Robertson 1997). We concluded that this pheasant trait could be used by managers to concentrate breeding hens where they have greatest opportunity for reproductive success, but only indirectly by first attracting roosters to establish territories there.

We learned how to do this from observing the unintended consequences of disking hunter access lanes through dense cover. Behavior of roosters in spring showed that we could use earlier disking to create open display strips artificially, placing them adjacent to, or creating, edges of existing residual or other cover tall and dense enough to serve escape needs of roosters. This practice can create circumstances that apparently are more attractive to roosters for establishing territories than perhaps most of the more naturally occurring edge in fields. Our method differed from that recommended by Robertson (1997), in being quicker, easier, more flexible, and more positive than growing shrubs to create the desired edge.

## Prototype Management Unit

For such a managed area, by then we were using the term Diversified Upland Habitat Unit, with the acronym DUHU. Furthermore, diagrammatic testing indicated that spatial requirements of a small but productive DUHU were best met by a standard 80-acre (32 ha) field. Smaller or squared fields were disproportionately lower in potential productivity, and larger areas could be managed by replicating DUHUs within them.

However, selected locations needed to have other basic attributes, including at least a residual pheasant population and suitable soils and gradient for the flood irrigation commonly used in the region, along with the water supply and related facilities required. Frequently these already existed with fallow fields previously in irrigated agriculture, also with existing grassy/weedy cover generally suitable for nesting, loafing, and escape cover. In some circumstances, possible presence of threatened or endangered species may limit necessary habitat manipulation and cause potential sites to be unsuitable.

## Configuration

The diagrammatic testing showed that the size and rectangular proportions of the standard 80-acre (32 ha) field under the U.S. land survey system apparently were the most optimum of regular fields for a planned, relatively small DUHU. The 880-yard (804 m) length enabled significant numbers of rooster territories to be aligned along its longitudinal centerline. The 440-yard (402 m) width allowed most harem hens from these central territories to nest and initiate brooding within 200 yards of this centerline, using the cover provided for them within the managed unit.

*Territory cover* – The prototype DUHU was configured (Fig.1) by first placing a strip of rooster territory cover averaging approximately 75 feet (23 m) wide along the centerline of the longitudinal axis. This can consist of a strip of any adequately tall and dense escape cover averaging approximately 50 feet (15 m) wide, flanked on each side by rooster display strips one disk wide, approximately 10-12 feet (3-4 m), made essentially bare for the spring by fall-disking. This can support a linear distribution of rooster territories on each side of the central escape cover strip.

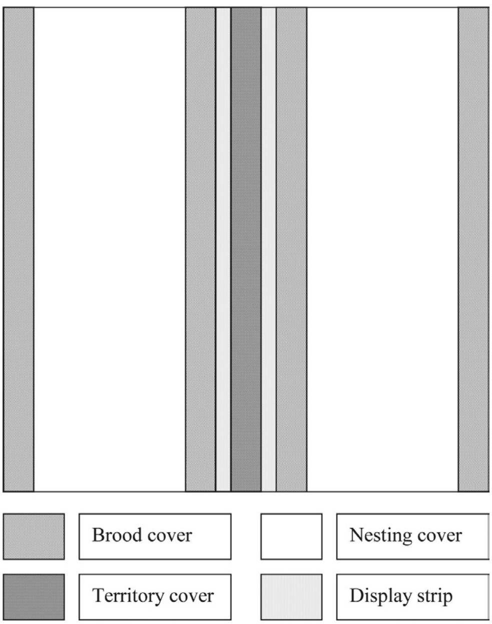


Figure 1. Concept linear configuration of cover types for prototype Diversified Upland Habitat Unit (DUHU) in standard 80-acre (32 ha) field (440 x 880 yards, 402 x 802 m), Mendota Wildlife Area, California, 2000. Diagrammatic, not to scale.

*Nesting cover* – The territory cover divided the DUHU into two smaller fields, each slightly less than 40 acres (16 ha) in area and 200+ yards (183+ m) wide. Such large, unbroken blocks of nesting cover should tend to minimize nest predation. In our working circumstances, there was adequate availability of such fallow fields with suitable nesting cover. If not existing, such nesting cover can be developed by measures appropriate to local circumstances, simply by timely irrigation in most California localities.

*Brood cover* – The objective was to provide managed brood cover within most, if not all, ranges of the DUHU harem hens, potentially enabling their early familiarization with its location and proximity to their nest sites. Further diagrammatic testing indicated this was best accomplished by positioning the brood cover in narrow strips extending the length of the two nesting fields. To avoid nesting cover fragmentation but provide an intimate relationship of these cover types, the brood strips were placed along the outer edges of the two nesting-cover blocks.

We estimated that four brood cover strips each approximately 50 feet wide (15 m) would provide adequate area if properly managed for chick food production, at least for initial field-tests. More precise proportionality may need to be determined by experimentation, but could vary with circumstances, including efficiency of management.

## Cover Intimacy

This was dictated in part by providing several habitat types within a small unit. However, we hypothesized that having these different cover elements in such intimate relationships should have beneficial effects, including conserving energy expenditure by pheasants of all ages. In addition, it should reduce or tend to limit predation by minimizing exposure to sight-hunting predators, especially raptors. These juxtapositions largely eliminated exposure and effort that came from travel distances and time to move between widely spaced habitat elements, and did away with need for travel corridors.

## Direct Management Feasibility

Direct management requirements for the planned DUHU, after initial development, were limited essentially to disking and water manipulation. Fall-disking would need to be applied to <20% of the 80-acre (32 ha) DUHU annually. This consisted of about 1.5 acres (0.6 ha) in the two crowing/display strips, and 12-13 acres (5 ha) in the brood strips. More effort would be required for water applications to the brood strips, including the winter flooding and the later irrigations. Putting the brood cover in narrow strips the length of the field also usually facilitated equipment work for development and annual disking, as well as for applying and draining water.

However, these were for the specific requirements of territory and brood cover management. They do not include what may be desirable or required for nesting or other cover enhancement or regeneration, or general maintenance of facilities.

### Evaluation

We had not yet field-tested the various elements of the prototype DUHU for effectiveness, individually or collectively. However, we were confident that they were soundly based and offered good potential for achieving our objectives. Furthermore, we considered that meaningful testing needed to be of the overall, integrated unit (DUHU). This process was transferred from MWA to another location in central California.

## GRIZZLY ISLAND FIELD-TEST

Initial evaluation of the DUHU concept and methods was conducted at Grizzly Island Wildlife Area (GIWA), another CDFG-managed area, for a main test period of 3 years, with preparatory work beginning in 2000.

### GIWA Test Area

GIWA consisted of approximately 8,600 acres (3,480 ha) located in Suisun Marsh, an approximately 88,000-acre (35,612 ha) area in the western Delta region of central California. This locality is a large part of the estuarine complex at the confluence of the Sacramento and San Joaquin rivers and their combined outflow into San Francisco Bay. Some upland areas in Suisun Marsh were farmed in an earlier era, but for approximately 50 years private land use has been essentially entirely for hunting clubs devoted to management for waterfowl habit. The climate is typically Mediterranean, but with higher precipitation and generally more temperate summers than in the San Joaquin Valley, being moderated by a prevailing on-shore flow of marine air through the adjacent San Francisco Bay area. Annual rainfall of approximately 25 inches (161 cm), based on GIWA weather-station records, averaged >3 times that at MWA, but fell mainly in the same seasonal pattern of late fall into early spring. During test years, annual rainfall was approximately 27 inches (174 cm) in 2001, 26 inches (168 cm) in 2002, and 18 inches (116 cm) in 2003.

Conditions at GIWA and its attributes for the field-test otherwise were basically similar to those of MWA but differed mainly by being in an area of tidal influence and seasonally brackish waterways; this affected species composition and growth of vegetation. However, during the high runoff period in spring and early summer, fresh water of adequate quality normally was available for irrigation and for management of fresh-water ponds and wetlands.

The pheasant population on GIWA was similarly supported mainly, as at MWA, by limited uplands interspersed through the wetlands and ponds managed primarily for wintering waterfowl, shorebirds, a restored herd of tule elk, and other wetlands-related wildlife. An exception was a large block of uplands called the Nesting Fields, totaling approximately 1,542 acres (624 ha) at the northwestern edge of GIWA.

Field 13 made up the northern approximately 500-acre (202 ha) length of this block. This field averaged approximately 0.5 miles (0.8 km) wide, and generally was subdivided laterally into cells, alphabetically designated, approaching 40 acres (16 ha) each. Gravity-flow water for flooding and irrigation was available from Shortcut Canal at the southern edge of the field, and a drainage canal to receive wastewater ran along the northern edge. Most of these cells had grown irrigated crops at one time, and offered best potential for test areas. Field 14, which generally made up the remainder of the Nesting Fields, was not currently suitable for the required irrigation.

The long-established pheasant population on GIWA currently was at a low level. In 2000, the 364 hunter-bag of wild roosters was approximately half the long-term average for the area, and 30-35% of the historic highs in the early 1980s. The checked bag of wild roosters taken in the Nesting Fields in 2000 was 89, comprising 24% of the pheasant bag for the entire GIWA.

This known bag in the Nesting Fields with requisite surveyed sex ratios enabled using a change-in-ratio method (Selleck and Hart 1956) to calculate the post-hunting season (late January) population of pheasants. This estimated breeding population for the Nesting Fields entering the 2001 reproductive season was approximately 220, an average of 14 pheasants/100 acres (40 ha). By sexes, this estimated population included 45 roosters and 175 hens, a ratio of approximately four hens per rooster.

## METHODS

This evaluation was designed to test the hypothesis of whether a DUHU-managed area was more productive of pheasants than a similar Comparison (Control) Area (CA) that was unmanaged, or for GIWA, conventionally managed.

### Test Areas and Characteristics

Of the field 13 cells not committed for other purposes, we selected contiguous cells E and F for the DUHU test site, due mainly to their suitability for irrigation between two lateral irrigation ditches supplied from Shortcut Canal. Cells M and N were designated the CA, located approximately 0.7 miles (1.1 km) away near the opposite end of field 13 (Fig. 2).

Overall areas of the two test units were approximately 73 acres (30 ha) for the DUHU and 63 acres (26 ha) for the CA. On the basis of the calculated breeding population averaging 14 pheasants per 100 acres (40 ha) in the Nesting Fields in the spring of 2001, the indicated breeding numbers of pheasants initially were approximately 10 for the DUHU and 9 in the CA, if equally distributed.

The test units were generally similar in cover conditions. However, introduced tall wheat grass, *Agropyron elongatum,* and saltbush, *Atriplex lentiformis,* were more prevalent within the DUHU, particularly along the common boundary between the two cells. Another initial difference was that much of DUHU cell 13F was temporarily deficient in cover, due to recent burning.

Essentially permanent water was equally available for both test units at their narrow ends at Shortcut Canal and the drainage canal. The CA did not have the lateral

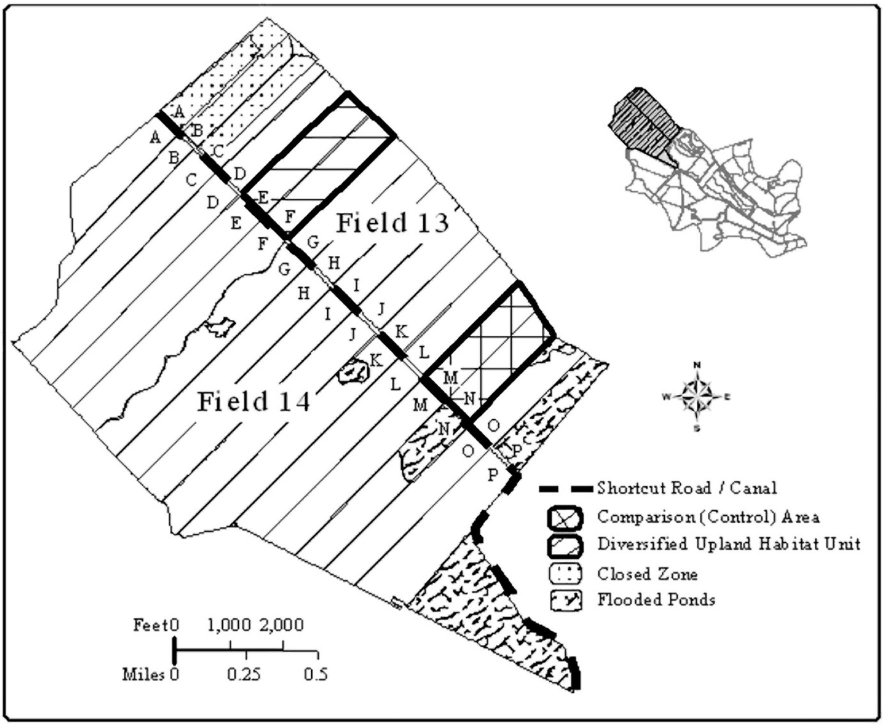


**Figure 2.** Locations and configuration of Nesting Fields block and Field 13 test units (DUHU and CA), Grizzly Island Wildlife Area, California, 2001-2003.

irrigation ditches that bounded the long sides of the DUHU, but it had adjacent or nearby ponds and wetlands (Fig. 2).

## Test DUHU Configuration

The combination of cells E and F enabled the DUHU prototype configuration (Fig.1) to be applied without appreciable modification. The dense cover on the common boundary between the two cells was developed into the central strip of territory cover by disking adjacent display strips on each side. The main body of each cell was largely potential nesting cover, with the brood cover strips averaging approximately 50 feet (15 m) wide developed along each long side of the nesting cover blocks. This positioning also minimized the potential for hens and broods to exit the nesting cover without encountering a brood cover strip.

The concept prescription was also applied by winter-flooding the brood cover strips for the month of February, and by their irrigation from mid-April to mid-July. These initial brood cover strips were a simple design. Enclosed by a confining dike or berm to contain winter flooding or irrigation water, the surface was unmodified except by disking; no sloping was done. However, irrigation and drainage were expedited by a supply/drainage ditch that was within, or bordered, the strip and extended its length. By this arrangement, water movement required to flood or drain the strip was largely limited to the lateral distance from the ditch to the outer edge of the narrow width of the brood cover strip. This increased hydraulic efficiency and reduced time required to flood the length of the brood strip from the higher end, the common method with similar checks of alfalfa and some other crops. A slight, declining gradient to the north end of the cells enabled adequate water movement and management without crosschecks and intermediate water controls.

However, in the initial development of the brood cover strips, water controls were unavailable for installation at the lower end of their supply/drainage ditches. Thus, during the first test year (2001), wastewater from irrigations could not be readily drained off the strips, but was dissipated more slowly by the joint processes of percolation and evapotranspiration. The missing water controls were installed in time for the second year, enabling quicker removal of water. This reduced the period of inundation from 1-3 three days to 6-8 hours, considerably lessening the flooded time when the brood strips were unproductive or unavailable to chicks for foraging, during test years two and three.

Also, disking the display and brood strips was not accomplished in the fall of 2001, which was a second important departure from the management prescription. By the time the required equipment became available, unusually early fall rains had made the DUHU cells too wet for disking. Management personnel later attempted to compensate by developing an additional (fifth) brood strip at the edge of cell 13D adjacent to the DUHU, where circumstances permitted during a brief dry period in early 2002. However, the effect was still that the prescribed display and brood cover strips for the DUHU were not functioning during the second test year (2002).

No habitat or related management was carried out within the CA during the test period. A change in the near vicinity was flooding cell 13P, one cell removed to the east, for a seasonal wetland or pond in the last two years of the test.

The 0.7-mile (1.1 km) gap of cells between the two test units contained GIWA's main goose-hunting area. One or more cells here were intermittently managed during September and October for production of green shoots from grasses and dry-farmed barley for attractive goose foraging during the waterfowl hunting seasons.

The test areas apparently were equally subject to usual predation, but no attempt was made to quantify or control it. Common potential predators on ringnecks included the red-tailed hawk, *Buteo jamaicensis,* northern harrier, *Circus cyaneus,* and great horned owl, *Bubo virginianus*, and for nests the raccoon, *Procyon lotor*, and striped skunk, *Mephitus mephitus.* The most notable difference in predation potential was a coyote, *Canis latrans,* den located in the territory cover of the DUHU, active during most of the test period.

## Monitoring

Comparative productivity of the two areas was evaluated by four surveys annually. In addition to overall productivity, these surveys helped to evaluate how well individual habitat elements of the DUHU configuration functioned to implement the concept.

*1) Territory surveys* – This method was adapted from the extensive area survey used by Robertson (1998), to determine the number of dominant rooster territories within a given area during breeding season. The change in technique was to walk between observation points instead of driving a vehicle, not necessary or suitable for our small test areas. The survey process used was essentially the same otherwise, with a pair of walking observers slowly and cautiously traversing around the perimeter of the test area, pausing at intervals to triangulate crowing rooster locations within the test areas by a combination of visual and auditory observations.

These surveys were made annually during suitable weather conditions at approximately the peak of the spring crowing season (early April) previously determined by crowing count surveys at GIWA, and during the daily peak crowing period in the early morning (Kimball 1949). Territory counts for a test unit were started near dawn and typically required approximately two hours to complete; this did not enable counts to be made on both areas in the same morning. These surveys were made in each test area in the same time periods by the same observers on successive days, or as close together as weather permitted.

*2 and 3) Transect flushing counts* – Two transect counts were made annually in each test unit. Results were most useful as sampling indicators of comparative population densities. The summer count was timed (late July to early August) to yield productivity data also by the ratio of juveniles/adult hen, as described by Hart et al. (2006), when samples were adequate to determine such ratios. Results are recorded in Table 1 as total numbers of pheasants counted in the transect summer counts, although also expressed in the text as J/AH (juveniles/adult hen) ratios when appropriate.

The second annual transect count was made about mid-October after juvenile recruitment was complete, and recorded by total numbers flushed in the fall transect counts (Table 1). Pheasants also were classified by sex, for a measure of relative rooster abundance approaching hunting season. However, at times pheasant numbers were so low that approximately half the transect counts yielded sample sizes too small to provide representative age or sex ratios.

Both transect flushing counts were conducted with standards long-used in California (CDFG 1959[6]). The general procedure was that the field crew, aided by flushing dogs, drove two longitudinal transects in each test area, up in one cell and back in the other, for a total transect length of approximately one mile (1.6 km) per test unit. The same crew then proceeded immediately to the other test area and repeated the process. Both counts were completed in the same morning, between approximately 0800 and 1100. Precautions included consultations between drivers, and drivers and blockers, to confirm classifications and to avoid duplicating or failing to record birds flushed, or any observed running out of transects without flushing.

4) *Hunter bag* – Hunter bag checks were made in each test area from 0800 to 1200 during the opening morning of the annual pheasant hunting seasons,

[6] CDFG. 1959. Pheasant Management Handbook, Wildlife Management Branch, California Department of Fish and Game, Sacramento, California, U.S.A.

typically in mid-November. An observer using binoculars was stationed in each test area to view hunters and determine numbers of roosters bagged there in that time period. Also, a temporary checking station was established at the hunter parking lot in field 13, to check or confirm hunter bag and location of kill during this time period. The bag check was limited to this period to ensure, to the extent feasible, that birds were bagged in the test area where produced.

## Post Field-test Monitoring

DUHU management was discontinued at GIWA at the end of the 3-year field-test (2003). Related reasons included collapse of irrigation infrastructure for the Nesting Fields, precluding the required irrigation. Some transect counts were continued to evaluate population trends and status after DUHU management was terminated (Table 1).

## Adjunct Radiotelemetry (RT) Study

This study was intended to augment other information gathered to better interpret or understand relevant pheasant behavior under DUHU management circumstances. Such information could be instructive if the field test indicated revisions in the concept or methods were needed. However, resources have not been available to complete compiling and analyzing the data.

Some incidental or general results, however, added to baseline information. Approximately comparable capture efforts for radio-tagging pheasants in or in the vicinity of the two test areas were similarly successful, suggesting that their local population densities did not differ significantly at the start of the test period. Also, in the 3 years of such monitoring, there was no movement or interchange of radio-tagged birds between the two areas, indicating that DUHU and CA ringnecks were part of separate and independent local populations.

However, the RT study did not measure productivity, the objective of the field-test. Accordingly, the results presented were not affected by the incomplete status of this adjunct study.

## Results

The DUHU test area, of course, was not an island. Thus, in the context of considering results achieved, we recognized that the active habitat management within the DUHU could have created a zone of influence that potentially benefited productivity in immediately adjacent areas. With bird movement, to some extent any such expanded production could have overlapped back into the DUHU, with a possible biasing effect regarding productivity of the managed unit. However, this was not measurable by our methods, and we considered that any such potential effects were insignificant in the magnitude of production achieved, especially in the third year, and as indicated by the MWA studies.

## Comparative Monitoring Results

By all measures, overall pheasant productivity for the 3-year test period was approximately 4-6 times greater in the DUHU than the CA (Table 1). Total pheasants recorded in the transect flushing counts were 556 for the DUHU and 146 for the CA. Rooster territories totaled 47 for the DUHU compared to 8 for the CA. Comparable hunter-bag was 52 roosters for the DUHU and 9 for the CA.

Table 1. Comparative monitoring results of pheasant production from test areas with different habitat management (DUHU vs. CA), for test period 2001-2003 and post-test 2004-2005, Grizzly Island Wildlife Area, California.

| | | | Transect counts | | |
|---|---|---|---|---|---|
| Year | Area | Territories | Summer | Fall | Bag |
| 2001 | CA | 3 | 36 | 24 | 5 |
| | DUHU | 20 | 83 | 27 | 10 |
| 2002 | CA | 2 | 12 | 43 | 3 |
| | DUHU | 7 | 49 | 29 | 27 |
| 2003 | CA | 3 | 9 | 22 | 1 |
| | DUHU | 20 | 171 | 197 | 15 |
| ---- post field test | | | | | |
| 2004 | CA | a | 4 | a | a |
| | DUHU | a | 33 | a | a |
| 2005 | CA | a | 6 | 30 | a |
| | DUHU | a | 12 | 10 | a |

However, DUHU productivity was not maximized until the 3rd year of the test, the only year that the DUHU management prescription was fully applied, which lowered the DUHU production record. The two transect counts in the 3rd year indicated pheasant population densities of >2.3 to 2.7 pheasants/acre (0.40 ha) in the DUHU, a new and significantly greater density record for pheasants in California. This high density was reflected in the hunter-bag of roosters that year, which was 15/1 in favor of the DUHU.

At the end of the 3-year test, termination of DUHU management was followed by immediate collapse of this high-density population. Limited monitoring that was continued in 2004 and 2005 indicated little difference in the low population levels of the former DUHU and CA (Table 1).

[a] Not obtained

## GIWA DISCUSSION

The first 2 years of DUHU management here amounted to essentially a pilot project, with significant problems not overcome until the 3rd year. Therefore, we consider the high productivity of that year (2003) most representative for the DUHU.

Population response in the DUHU was consistent with the concept and methods applications. In the first year (2001), the high territory numbers (20) indicated that a high-density breeding population was concentrated in the DUHU, followed by the summer transect counts showing appreciably greater pheasant numbers there than in the CA. However, the 4.6 J/AH ratio from these counts indicated only moderate chick survival in the DUHU, approximately 50% based on initial brood size of 9, although approaching twice as great as the comparable 2.6 ratio in the CA. We interpreted that chick survival and DUHU productivity were limited the first year by the reduced efficiency and availability of the brood cover strips, due to inadequate drainage facilities.

The failure to fall-disk the territory display and brood cover strips for the 2nd year rendered these managed habitat elements in the DUHU essentially non-functional that year. A reduced number (7) of rooster territories followed, with the related DUHU breeding population evidently declining by nearly two-thirds. The brood cover strip added for the 2nd year produced a measured J/AH ratio of 7.2 (indicative of approximately 80% chick survival, the highest for the test period). However, this high chick survival evidently was applicable only to significantly reduced breeding numbers at the adjacent edge of the DUHU; the transect counts showed an overall decrease in DUHU pheasant numbers from the year before. We interpreted that this area of high chick survival was too limited to overcome the effects of the reduced breeding population in the DUHU and resulting lower number of broods produced.

Fall disking was resumed for the 3rd year (2003). Making the territory cover functional again was followed by attraction of another high-density breeding population in the DUHU, with territory numbers restored to 20, the same level as in 2001. We were unable to quantify average harem size, but if we assumed that it was similar to 2001, the hen breeding population numbered approximately 80 in the 73-acre (30 ha) unit. Applying the 6.4 J/AH ratio from that summer's counts indicated potential DUHU production of approximately 512 juveniles to sub-adult age. The high numbers in the fall sampling counts further indicated that good survival and recruitment of this annual increment had extended to the fall DUHU population that year. If the territory cover had remained non-functional in 2003, we assumed that the number of rooster territories would have remained approximately the same at seven. Applying the same factors as used for the previous calculations, the hen breeding population would have been about 28, and the potential production approximately 179 juveniles in 2003, about 65% less. Primary cause of this high production and population level clearly was the increased numbers of breeding hens that had been concentrated in the DUHU due to effects of the enhanced territory cover.

These results emphasized that the role of brood cover strips was to add a production increment by increasing chick survival, but that this did not increase numbers of broods. Brood numbers were the function of the hen breeding population, and generally tend to be directly proportional to hen numbers. Thus, the GIWA results helped to confirm or clarify that in DUHU management, short-term productivity achieved is dependent more on effectiveness of territory cover, with brood cover playing a secondary role, although potentially important on an incremental basis.

Although the DUHU obviously was considerably more productive than the CA, at least equally significant was that the DUHU populations evidently exceeded records for pheasant densities. Robertson (1997) gave the highest density for a hen breeding population, in numbers of hens per 100 acres (40 ha), that he had observed as 46 at the Seefeld Estate in Austria, with 88 the highest overall record at Pelee Island in North America. The comparable breeding-hen density that we calculated for the DUHU in 2001 was an appreciably higher 110 (20 rooster territories x 4-hen harems [spring sex ratio] in 73 acres or 30 ha), with the 2003 density probably approximately the same. Obviously, attractive territory cover served to concentrate a very high-density, perhaps record, breeding population in the DUHU from a surrounding area of generally low-density pheasant numbers.

The summer and fall populations of the DUHU in 2003 also indicated record densities, definitely for California and possibly elsewhere. The two different sampling counts of 171 and 197 pheasants flushed from the DUHU transects were minimum densities of approximately 2.3-2.7 pheasants per acre (0.4 ha). This significantly exceeded the previous California fall-density record of 1.5 for the Sartain Ranch study area in 1948 (Harper et al.1951).

Furthermore, these were sampling counts, not complete or censusing counts. Projecting conservatively on the basis of what we considered reasonable estimates, that the transects covered ≤75% of the DUHU and flushing efficiency was ≤75% of the pheasants in the transects, the indicated density of the summer/fall DUHU population in 2003 was on the order of 4.5-5.5 pheasants per acre (0.4 ha).

These estimated DUHU densities would possibly equal or exceed the all-time record densities for fall pheasant populations, also accorded to Pelee Island. Maximum estimated populations there of approximately 4.5 pheasants per acre (0.4 ha), for the mid 1930s, reportedly were based largely on judgments that there were more birds then than in later years of better-documented estimates. During the 1947-1950 period of Stokes' study of Pelee Island pheasants, he estimated, by censusing methods, that maximum populations were <4 birds per acre (Stokes 1956).

## SODHOUSE FARMS FIELD-TEST

This was the first formal application of the DUHU management prescription under severe winter conditions, to the best of our knowledge. Although it served the purposes of a field-test under these circumstances, it was a practical implementation to increase numbers of pheasants in an existing low-level population on private land. A cooperative project with the landowner, it was planned and funded mainly as part of a broader project by the Natural Resources Conservation Service (NRCS), with pheasant management information provided by CDFG representatives.

## Sodhouse Farms Test Area

This property consisted of approximately 641 acres (259 ha) located about 30 miles (48 km) south of Burns, Oregon. The location lies at an elevation of approximately 4, 335 feet (1,321 m) in the Malhuer Lake basin adjacent to Malhuer National Wildlife Refuge, operated by the U.S. Fish and Wildlife Service (USFWS). Winters in this high-desert region typically are fairly severe, in that locality averaging approximately 207 nights of below-freezing temperatures and 42 inches (76 cm) of snowfall. Rainfall averaged 13 inches (33 cm), falling almost entirely from October through March.

This was a combination farming/hunting operation, with approximately 100 acres (40 ha) in irrigated agriculture and related headquarters facilities. The remaining 541 acres (219 ha) were in a wetland conservation easement enrolled in the NRCS Wetlands Reserve Program (WRP). Included were 441 acres (178 ha) of managed and natural marsh in four units. The 300 acres (121 ha) in Unit 4 also had approximately 100 acres (40 ha) in high-quality, upland nesting habitat, in combination with seasonal marsh. None of the farm, including that in irrigated agriculture, was productive pheasant habitat, as demonstrated by pheasant numbers in 2004 being described as "a few", essentially confirmed by an annual rooster bag for the farm that had not exceeded four during the current ownership.

## Methods

The same concept was applied at Sodhouse Farms as at GIWA, with the exception that winter flooding was made unnecessary by the severe winter. The implementing methods, however, were adapted to site-specific conditions. In late 2003, as part of the WRP project by NRCS, a brood cover strip approximately 0.6 miles (1 km) long, adapted from an old drainage ditch, was developed adjacent to nesting cover along the southern and southeast edges of Unit 4.

However, when irrigations were started in the spring of 2004, this brood strip adaptation proved not adequately on grade. Irrigation water could not be controlled and flooded out at low points. This initial brood cover strip was unproductive, as demonstrated by the 2004 rooster bag for the ranch remaining at four.

The obvious faults in the initial system led to their correction later in 2004, along with expansion. The original brood cover strip was redeveloped by an experienced contractor with a laser-controlled scraper, so that gradient was adequately controlled. Also, a small reservoir was constructed adjacent to the irrigation well in the southwest corner of Unit 4, to increase water volume available for flash-flooding. Another brood strip was developed extending approximately 0.6 miles (1 km) generally north from the well and reservoir location, along the eastern edge of the main upland habitat block that provided good nesting cover (Fig.3).

In addition, the design of the brood cover strip was updated to the shallow swale type that evolved mainly from the GIWA experience. For more efficient drainage, each side of the brood strip was gradually sloped into a central supply/drain ditch;

with each side approximately one disk wide; this produced a total brood strip width of approximately 25–30 feet (8-9 m), within the exterior enclosing dike or berm (Fig. 4).

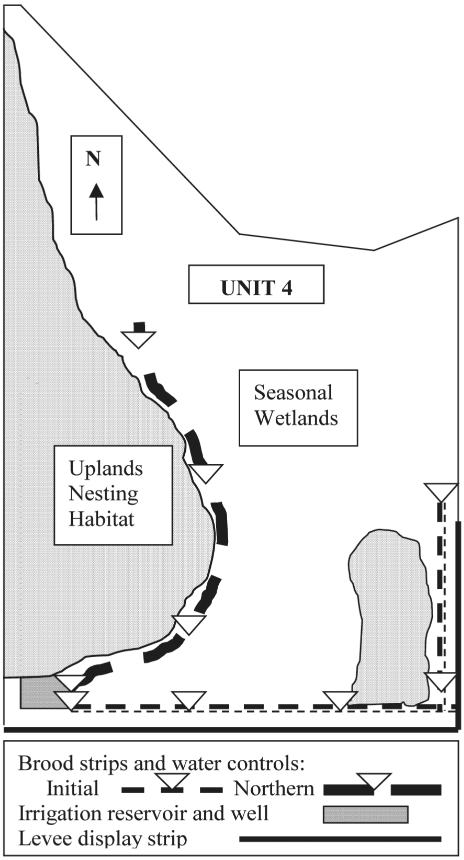


**Figure 3.** Diagrammatic map of 300-acre ( 121 ha ) Unit 4, showing configuration of habitat elements with brood cover and territory crowing/display strips, Sodhouse Farms, Oregon, 2005. Not to scale.

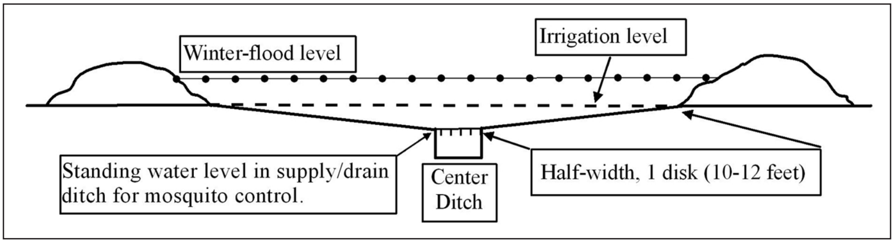


**Figure 4.** Schematic profile of shallow-swale brood cover strip recommended for flash-irrigating with DUHU pheasant management. Diagrammatic, not to scale.

The gradient of the terrain required crosschecks with water controls at about each 1-foot (30 cm) vertical fall of the brood strips, at intervals of approximately 0.2 miles (0.3 km), to control irrigation water adequately. Thus, each brood strip was a series of in-line sections, with a cascading system of irrigation. The highest section was filled first, then drained into the next section, and so on, supplemented by additional water as necessary from the reservoir and well. This re-use of water increased efficiency and reduced total water demand. The water controls used in crosschecks were 24-inch (61 cm) pipe with flashboard risers, the large diameter size no doubt enhancing capacity to flash-flood effectively. However, this was from use of on-hand components, instead of from hydraulic calculations.

The brood cover strips were disked in the fall of 2004, to incorporate residual vegetation and provide the bare soil that encouraged early successional plant growth in spring, without winter flooding. Also that fall, the top and shoulder edge of the adjacent levee paralleling the southern, or initial, brood strip was cleared for a territory display strip with use of a heavy-duty, tractor-towed mower, without disking (Fig. 3).

Irrigations of the new brood cover strips were started in early May, 2005. It required approximately one day to fill the first section of a brood strip, with the water then emptied into the next lower section. To maintain continuously moist surface soils in the brood strips, irrigations at intervals of 5–7 days were necessary, extending to about the end of July. The main weedy/herbaceous cover in the brood strips was approximately 6–8 inches (15-20 cm) tall by the time irrigation was terminated.

## Results

A survey to assess general pheasant numbers was made in early September of 2005. One biologist with two dogs flushed and classified 33 roosters and 60 hens in approximately 2 hours, covering an estimated 10% of the managed area in Unit 4. Numerous additional birds seen running or flushing wild were not recorded. Pheasants obviously were abundant in the vicinity of the brood cover strips and the related 100 acres of upland nesting habitat.

The following hunting season (2005), the hunter bag at Sodhouse Farms totaled 144 roosters. This 36-fold increase in bag suggested a similar increase in the fall pheasant population following one breeding season of prescribed DUHU management.

In the following year (2006), high water levels in adjacent Malhuer Lake overtopped levees on Sodhouse Farms. Most of the farm area, including the brood cover strips, was flooded during critical periods of the nesting and brood rearing season. The fall hunter-bag declined to 24 roosters.

DUHU management was resumed in the fall of 2006 and spring of 2007, after recovery from the flooding and related effects. The 2007 hunting season bag was 41 roosters.

## Sodhouse Farms Discussion

The magnitude of the bag increase in 2005 was both biologically and mathematically impossible to be generated in 1 year from the existing, low-level breeding population, that for years had produced a hunter-harvest of ≤4 roosters annually. Productive hens could not have increased their juvenile recruitment level 36-fold. Obviously, a significantly larger number of broods had to have been produced, which required a commensurately larger breeding population of hens. This reasonably could only have been by the same mechanism as at GIWA, through rooster territory concentration and related harem formation in the managed area of Unit 4 due to the enhanced territory cover.

Population increases from increased chick survival alone cannot produce such explosive increases in one year, as previously discussed. By that process alone, the Sodhouse Farms annual bag would have tended to increase progressively from 4 to approximately 8, 16, etc., requiring a period of several years to pyramid to the 2005 bag level. Thus, the considerable increase in production and bag in a single year obviously came primarily and initially from the role played by enhanced territory cover, similar to the conclusions for GIWA.

However, although the contribution of the managed brood cover was secondary, it no doubt was an appreciable factor in the sudden population increase. The approximately 36-fold, or similar, increase in the fall population had to have been preceded by an even greater gain in the numbers of chicks hatched, to allow for some mortality. Such considerably greater chick numbers clearly placed a much higher demand on the chick food supply to achieve the high survival. This suggested that augmenting chick food supplies with the managed brood cover played a significant role in the abrupt population increase

These productive results had been achieved by adapting the standard-field DUHU configuration used at GIWA to a large, irregular field of approximately 300 acres (121 ha), with the main nesting cover divided into two uneven blocks. The characteristic common to Sodhouse and GIWA was that both had large blocks ( ≥30-acre, or ≥12 ha) of potential nesting cover. However, at Sodhouse there was proportionately less area in territory display strips and managed brood cover, with the latter consisting essentially of a single, narrower but lengthy brood strip generally bordering the main nesting cover blocks. This success questioned the need for the replication of more and wider brood strips in the prototype DUHU as used at GIWA, at least under some circumstances. Whether such replication is feasible and worth the effort, to provide back-up insurance, is mainly a judgment decision, or arrived at after extended experience under local conditions.

The bag of 24 roosters in 2006 was reasonably close to the approximately 20% carryover (29) of adult roosters demonstrated in the California Sutter Basin studies (Mallette and Harper 1964), and possibly applicable here. This suggested, or tended to confirm, that the early-summer flooding in 2006 resulted in poor juvenile recruitment. The fall population resident at Sodhouse Farms, and bag, were likely disproportionately composed of the expected carry-over of adult birds from the high production in 2005.

The resumption of DUHU management for 2007 was followed by pheasants reportedly being plentiful essentially throughout Sodhouse Farms before and after the 2007 hunting season, based on observations of farm personnel. The hunter-bag was 41; the potential for a higher bag evidently was not realized due to lower hunting pressure than in 2005. However, in the three years of DUHU management, despite the flooding in 2006, the total rooster bag has been 209, compared to approximately 12 in the 3 preceding years.

Quantification of the Sodhouse fall population for the managed unit in 2005 can be approximated by reasonable projections from the known bag. Assuming the number bagged was a 60% harvest, fall rooster numbers totaled approximately 240. Further assuming the September survey provided an approximately representative sex ratio of 55 M/100 F, hens numbered about 436, for a total, pre-hunting season population on the order of 675. Although based on approximations, this suggested a local population of ≥5 pheasants per managed acre ( 0.4 ha ), similar to that projected at GIWA.

The high bag and bag-projected estimates essentially confirmed the conclusions from the September survey results, that pheasants obviously were abundant in the managed unit. If this estimated 10% sample of the managed area was reasonably representative, the 93 pheasants classified therein indicated total pheasant numbers approximated 900-950 in the managed unit. Close agreement from such gross approximations was unlikely, but the general order of magnitude was similar.

## GENERAL DISCUSSION

Our basic concept is simple. Concentrate a high-density breeding population of pheasants within a relatively small but suitable management unit, to produce greater numbers of chicks within the managed area. Then achieve high survival and recruitment from the increased chick numbers, primarily by producing abundant and easily available insect/arthropod food for chicks and juvenile pheasants. This concept should apply universally, although it was developed for non-agricultural habitat in the irrigated, western U.S.

But, the concept functioning as conceived depends primarily on the application methodology, after adaptation to local conditions. The two examples presented, GIWA and Sodhouse Farms, are the greatest and most obvious successes to date, to the best of our knowledge. In both, high production of pheasants was achieved from small areas of non-agricultural habitat, at least suggestive of record population densities. We consider these results adequate to demonstrate that the concept and methods can work well under both mild and severe winter circumstances.

Lesser degrees of success, however, have been difficult to evaluate conclusively. In many instances the only measure available has been seasonal bag numbers, which to be indicative usually need to be from reasonably comparable hunting pressures and accurate recording of bag, among possible variables. However, exceptions such as the two examples presented can happen, where the degree of increase is so great that cause and effect are obvious. But in other circumstances, frequently information received has been essentially anecdotal. Generally, resources have not been available to conduct the intensive monitoring by qualified personnel necessary to confirm or document such results definitively.

In addition, frequently the only basis for comparison has been the site's historical record for pheasant abundance, which typically has been inconsistent, fluctuating considerably, or undocumented. Whether this is a fair standard for such purposes, especially where annual conditions over time may have changed subtly but appreciably, is debatable. It may take a longer period of proper implementation under comparable conditions to provide a better basis for evaluation in many circumstances.

We do not intend to imply that all implementation efforts have met with some degree of success. There have been apparent failures to increase pheasant numbers significantly, if at all, and these have been similarly difficult to substantiate or quantify. However, where the cause has been obvious, it fell under the general category of the concept and methods prescription not being followed, for a wide variety of reasons. These have included not having the resources required, selecting unsuitable sites or not developing them properly, physical failures of facilities or equipment, unusual and unsuitable weather, and perhaps most frequently, various failures to irrigate the brood cover strips properly.

Thus, we do not recommend that this system of pheasant management be undertaken casually, without the required resources and commitment to follow through adequately. Some initial problems can be expected, as was the case at both GIWA and Sodhouse Farms, but these usually can be detected and corrected.

Also, although greatest success evidently has come from following our methods closely, we do not intend to imply that they cannot be improved, refined, or better adapted to some local circumstances, or more feasible alternatives developed for the purpose. Instead, we recognize that this concept and methods need to be tested more widely and over longer periods to assess what role they can play in future pheasant management, or how they can be applied to other wildlife species. That is a main reason for publishing at this time what is in part a progress report, to make generally available the concept, methods, their biological basis, and what has obviously produced good results to date.

The following review and update may be useful for those purposes:

## Territory Cover

With the two examples presented, the crowing/display strips were generally straight-line and continuous, for various reasons, including using the existing levee top at Sodhouse Farms. To maximize rooster territories within a managed unit, other configurations of these strips may be desirable to the extent feasible. We have observed (Hart unpublished data) that dominant roosters crowing in close proximity typically were not aggressive or combative if screened from each other by intervening vegetation. This suggested that manipulating the disking or mowing of display strips by curving or other irregularities could result in smaller and more numerous territories, by breaking sight lines of adjacent roosters where territories may adjoin.

In the late winter/early spring period of territory formation, in some circumstances the bare edges of brood strips evidently are attractive enough for some roosters to use them for establishing territories. This has caused some questioning of need for separate territory cover. The dynamics of these situations can be more complex than apparent. The edge used here is coincidental, and may not be the most attractive or available combination that can be developed or is needed to draw roosters from surrounding areas. The roosters using brood strip edges may be the less dominant ones that have lost competitions for the better territory sites with display strips, and are settling for what is second best or acceptable nearby. If so, this isn't necessarily indicative of these coincidental edges being as attractive as needed for the primary purpose of the territory cover. Also, the suitability of these sites may vary considerably, depending mainly on the degree to which the brood strip passes through or abuts suitable escape cover in addition to nesting cover.

In the final analysis, making territory cover more attractive by adding display strips, either by disking or mowing, is so easy to accomplish that it is imprudent to shun. As long as adequate nesting cover is maintained in the DUHU, there probably cannot be too much in enhanced territory cover, if reasonably centered in the management unit.

Such enhanced territory cover also should be useful where less intensive management is practiced. These instances could be to manipulate local breeding populations into locations evidently most favorable for reproductive success, or away from those known to be unfavorable. The latter could include alfalfa or other hay fields that will be mowed in nesting or brooding seasons.

## Brood Cover

Species composition of the broadleaved vegetation in the brood cover strips apparently is not important, only that it be predominantly forbs. From our experience, the composition of productive brood cover has varied considerably with different localities and site conditions. At GIWA, most prominent were fathen, *Atriplex triangularis*, an annual whose leaves showed considerable evidence of arthropod use, and bird's foot trefoil, *Lotus corniculatus.* Bird's foot trefoil locally is a non-native, perennial legume and can expand into undesirably large, dense clumps. However, annual disking sets this growth habit back, producing small clumps that chicks can forage around easily during the brood-rearing season.

The vegetative cover in the brood strips serves several important functions: 1) the forbs in damp/moist soil are the basic habitat for the arthropod populations that produce the abundant supplies of chick food; 2) it provides a protective canopy to prevent, or minimize, predation on hens and chicks foraging in it; 3) it screens surface soils from the excessive drying effects of direct sun and wind that cause loss of productivity and increase needed frequency of irrigations; and 4), it provides humus to increase fertility and moisture-holding capacity of the brood strip soil when disked under annually, as well as food for *Carabidae* that feed on turned-under, decaying vegetation.

As an example of the third effect, research in Kansas documented that harvested height of wheat stubble was critical; cutting wheat stubble shorter reduced screening and led to increased drying of surface soils by wind. This resulted in less growth of forbs in the stubble, so that its productivity as pheasant brood cover was significantly reduced (Rodgers 2002).

For maximizing beneficial effects, this broadleaved vegetation should completely cover the main surface of the brood strip by the time appreciable numbers of chicks start hatching, or as completely as feasible. The initial bare soil by this time is unproductive and undesirable, including potentially inviting predation where pheasants are exposed in crossing it. To best achieve such complete coverage, earlier irrigations may be desirable to stimulate or maintain desired cover growth due to lack of early spring rainfall.

Also, this early successional vegetation typically grows with stem spacing that enables young chicks to forage through it effectively. A field-test for this is to view typical brood cover from directly overhead; widely distributed bare ground should be visible through the cover canopy, between forb stems. Small patches or stringers of grass or other dense cover are not problematic unless they will appreciably block chick movement. A limited amount of added canopy and diversity of cover is desirable if chicks can forage around it readily. As the brooding season advances, some increase in cover density is typical, often from invading plants. However, by that time the generally older and larger juveniles apparently are able to cope adequately with these circumstances.

We found timely disturbance to be the main key to producing this early successional vegetation from the existing natural seedbed. We also considered there were many advantages to working with this more natural system that eliminated need for planting. The natural factors involved here were unclear from the limited depth of our work. However, our process may be selectively manipulating local plant phenology by eliminating or minimizing other plant competition, in combination with earlier and higher soil temperatures from the direct exposure of bare soil to solar radiation and rising air temperatures. But, especially for implementation elsewhere, more research may be desirable regarding the influencing factors that can be manipulated to stimulate timely production of this vegetative type locally or regionally. Alternatively, there may be different and better ways of semi-naturally producing abundant arthropods suitable for chick food, without degrading other habitat attributes.

The prescribed disking for disturbance may work satisfactorily if accomplished during fall or before winter's end, if necessary to delay this long. However, disking later in the spring can be problematic in several respects. We are unaware of this practice having produced suitable brood cover, and reports of such success from California have been premature and unsubstantiated. Typical cover resulting from spring disking here has been patchy, dense growth of grasses, usually barnyard grass (locally called watergrass), *Echinochloa crusgalli*, interspersed with excessive areas of undesirable and unproductive bare ground. This timing possibly is too late in the annual sequence of plant phenology to produce the productive forb cover that is the objective.

Furthermore, disking in spring can be disturbing or potentially destructive to ground-nesting birds and other wildlife during their reproductive season, particularly in dedicated wildlife areas. Precautions to attempt to avoid these consequences can be appreciable extra effort and problematic in themselves.

## Managed wetlands as a potential source of water for winter flooding

When pheasant brood strips are constructed near managed wetlands consideration should be given to placing them at locations where water in the wetlands can be re-used to flood the brood strips following the waterfowl hunting season. The broad strips should be flooded approximately during the month of February.

## Moisture – irrigation

Those actually handling irrigations should understand that the main purpose here differs from typical crop irrigations; such misunderstandings apparently have been cause for some failures. Irrigations to maintain predominantly damp/moist conditions in the more exposed surface soils need to be more frequent than those to replenish moisture in the underground root zone, as for crops or some cover.

Our recommendation to irrigate brood cover strips for approximately a 3-month period is to encompass the main hatch and early growth period for chicks as typical for California. This period may vary with other regions and circumstances, as well as with management objectives or feasibility. In localities where there typically is a more concentrated period for the main hatch, good results possibly could be achieved with an irrigation period of $\leq 2$ months, if properly timed.

Evolution of brood strip design evidently has increased hydraulic efficiency that has correspondingly increased productivity for greater chick survival. Brood strips obviously are temporarily unproductive or unavailable to chicks while they are covered with water. Also, holding irrigation water on too long serves no useful purpose, and can encourage undesirable marsh or wetland vegetation replacing forbs. Getting irrigation water on and off quickly, or flash-flooding, to minimize such non-productive time or effects, has been enhanced by the shallow-swale design (Fig. 4). This can be adapted to fields with existing perimeter ditches or similar circumstances by making it a half-swale. The minimal grading for sloped drainage typically can be accomplished readily with a motorgrader or other equipment with an adjustable blade.

However, where topsoils are shallow, we have observed that such sloping can scalp off much of this humus-enriched layer with its enhanced moisture-holding capacity and natural seedbed. The bare mineral soil exposed may have poor moisture-holding abilities requiring excessive irrigation, and overly sparse stands of brood cover may result. After initial development, these conditions can make it a good practice to grow an appropriate cover crop, preferably legumes, in the first season to restore humus and moisture-holding capacity to the brood strip soils, to be turned under by the initial fall-disking.

At the start of irrigations, frequent inspections of surface-soil moisture conditions in the brood strips are essential to establish a basic irrigation schedule, but one that remains flexible. Frequency of required irrigations can vary appreciably with soil types, weather conditions, and other factors; excessively sandy or similar soils can have so great a percolation rate that they aren't feasible for flood irrigation. These inspections should be in typical brood-strip cover; exposed, bare soil is not indicative because it dries much quicker. Irrigations will need to be more frequent in periods of hotter, windier weather.

In initial brood strip development for flood irrigation, especially when laser-controlled equipment is being used, excessive precision to produce a uniformly smooth and regular drainage slope should be avoided. Our experience has been that this tends to produce too much uniformity in drying rates and vegetative type. Surface irregularities that produce a minor amount of shallow puddles with temporarily wetter soils extend the drying period in these spots and provide overlap insurance against failures due to timely irrigation being too delayed. They also produce increased diversity that is desirable in brood cover vegetation.

Using sprinkler systems for irrigation has potential advantages, including economy and efficiency, although to date we have had limited experience with them. However, sprinklers can be used on irregular or steeper terrain, without the grading or leveling and irrigation infrastructure required for flood irrigation, and without its related operational requirements such as diligently tending water controls. Automatic timers can be used in many circumstances to turn sprinkler systems on and off as conditions require.

However, sprinklers require high-pressure, clean or filtered sources of water. Also, trying to use systems that are slaves to those for crop irrigations requires careful consideration. Crop irrigations are for a different purpose, and may not be frequent enough to maintain the moist surface soils needed in the brood strips. Despite sprinkler systems being more automatic, the precaution of frequent inspections still holds to ensure that irrigation needs are being met.

*Drinking water* – Maintaining drinking water sources for pheasants within the managed unit is critical. In dry, hot periods, pheasants typically water at least twice daily, and tend to loaf in the cooling microclimate near water. For them to have to travel appreciable distances, especially to outside water sources, to meet these needs can unnecessarily expose them to predation and other hazards. At least a minimum flow in DUHU ditches should be maintained for these purposes.

*Mosquito control* – Provisions for biological control of mosquitoes may be important. In appropriate circumstances, mosquito control officials have recommended that the supply/drain ditch in the brood strip be at least 2 feet deep and 3 feet wide (61 x 91 cm), and kept essentially full during the irrigation period to harbor mosquito fish, *Gambusia affinis*. This enables these fish to follow the advancing waterline during irrigations, forage on newly hatched larvae of mosquito species that lay their eggs in mud or soil, and then retreat back into the ditch as the brood strip is drained.

Monitoring by mosquito abatement personnel showed that no appreciable mosquito problems were generated by the winter flooding or irrigations of the GIWA field-test, and no additional control measures were required. Any puddles of irrigation water were temporary, usually gone within <3 days, not long enough for the cycle of adult mosquito production.

### Long-term factors

Pheasant population dynamics dictate that a key to long-term DUHU productivity will be harvesting surplus roosters and thereby maintaining high ratios of hens in the spring breeding population. Unless productivity is cropped regularly by hunting, or excess roosters otherwise removed, buildup of rooster numbers can exceed capacity of the DUHU territory cover. Excess roosters will be forced into surrounding areas to establish territories, where they will compete with DUHU roosters in attracting hens for their harems. This can draw hens out of the DUHU into unmanaged habitat where productivity is lost. Also, as rooster numbers increase proportionately in the spring population, average harem size will decrease. This can further reduce the DUHU breeding population of hens, and lower productivity of the managed unit.

Temporary solutions can be increasing efficiency of existing territory cover, as previously discussed, or adding more of this cover to the DUHU. However, there will be practical limits to such measures, and the situation will be repeated with continued high productivity and inadequate harvest of roosters.

Another factor is that the quality of nesting cover is likely to decline over time, potentially resulting in lower nesting success. Management should consider regenerating a limited proportion of the nesting cover annually, or at suitable intervals.

## Other Wildlife Benefits

Allen (2003[7]) compared bird productivity of current DUHUs in 1999-2000 with unmanaged grasslands and managed duck-nesting cover in the San Joaquin Valley. Of the 800 nests found in study plots, 66% were in the more diversified DUHUs; non-game species predominated (84%), mainly red-winged blackbirds, *Agelaius phoeniceus*, and song sparrows, *Melospizas melodia*. Production of mallards, *Anas platyrhynchos*, was six times as great as pheasants in the DUHUs, and twice as great as from the other habitat categories combined. However, these early versions of DUHUs did not include enhanced territory cover, and no study attempt was made to correlate proximities of rooster territories required for concentrated pheasant nesting.

## Northern Bobwhite Parallel

Research into causes for long-term decline in northern bobwhite, *Colinus vir-*

[7] Allen, R. W. 2003. The effect of gamebird management on nongame bird species richness, density, and nesting success in the San Joaquin Valley. Master's thesis, Humboldt State College, Arcata, California, U. S.A.

*ginianus*, revealed a parallel aspect. The early successional vegetation that provided good brood cover for pheasants also was needed by bobwhites for brood and nesting cover. However, more intensive land uses and practices, in concert with modern control measures for prevention of fires and floods, has led increasingly to less disturbance and to the resulting loss of this cover type essential for productive bobwhite habitat. Management solutions include more use of prescribed burning and other disturbance measures to restore early successional vegetation for needed nesting and brooding cover (Dimmick et al 2002[8]).

## MANAGEMENT IMPLICATIONS

The broader implications are that modern and future pheasant management should not be inhibited or limited by old traditions, beliefs, and dogma that ring-necked pheasants essentially are an agricultural species, and that their management must be based primarily on cropland habitat of landscape scale. Our work should add convincingly to previous evidence that the highly adaptable ringneck can do well in other types of habitat that provides, or can be feasibly managed to meet, their basic living and reproductive requirements, and in relatively small areas. This can open new alternatives for pheasant restoration or population enhancement, including what we present that has worked well in the irrigated pheasant range of the western U.S., from limited testing to date in regions of both mild and severe winters. Using artificially enhanced territory cover to concentrate high-density breeding populations where most appropriate for management purposes, and growing strips of productive brood cover to increase chick survival, may have essentially universal application. However, no doubt this needs to be appropriately adapted to local conditions, and tested more widely and for longer periods. Although potentially useful to wildlife agencies and organizations, perhaps similar or greater potential from this small-area management can be with individual landowners or groups interested in feasibly increasing local pheasant populations in limited areas of suitable private property. Also, the concept, and methods in part, may have application to other bird species where they suffer excessive mortality of chicks or nestlings due to inadequate supplies of insect/arthropod food.

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[8] Dimmick, R. W., M. J. Gudlin, and D. F. McKenzie. 2002. The northern bobwhite conservation initiative. Miscellaneous publication of the Southeastern Association of Fish and Wildlife Agencies, South Carolina, U.S.A.

Delta Chapter of Pheasants Forever, was loyally helpful in making flushing counts. T. Blankinship, upland game coordinator for CDFG, provided important support and assistance. We are particularly indebted to P. Robertson for invaluable aid and counsel, and for reviewing related manuscript drafts, long-distance from England. We also thank P. Lauridson and R. Rodgers for their helpful review and suggestions regarding the manuscript. Revenues from California's upland game stamp provided main financial support.

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