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Contents

Change in Editorship of *California Fish and Game*

With Volume 96 of *California Fish and Game*, Vern Bleich will assume the role of Editor-in-Chief. Vern replaces Ken Hashagen, who has overseen editorial responsibilities since 2004 and has served this journal with dedication and enthusiasm. I look forward to maintaining the high standards that Ken and the many previous editors have established.

Additional changes will occur among the Associate Editors. Nina Kogut (Marine Region) will replace Tom Barnes (Marine Region), who served as an Associate Editor for many years, and Nina will share responsibilities with Pete Kalvass for manuscripts dealing with marine resources. Jeff Villepique (Inland Deserts Region) and Scott Osborn (Wildlife Branch) will share editorial responsibilities for manuscripts addressing the conservation or management of terrestrial and marine mammals. Nina, Jeff, and Scott will join the other Associate Editors (Walt Beer, Dave Lentz, Kevin Shaffer, Liam Davis, Pete Kalvass, James Harrington, Joel Trumbo, and Paul Hofmann), all of whom I've been privileged to serve with under Ken's editorship (but only one of whom I've ever met!). Thank you Tom and Ken for contributing your editorial expertise to California Fish and Game. To Jeff, Scott, and Nina, welcome aboard; and, to the other Associate Editors, thank you for agreeing to continue on.

California is a huge state and the Department of Fish and Game is large and diverse. An early decision to spend my career in one of the most remote parts of California precluded much in the way of professional interactions with the other Associate Editors. Nevertheless, all have worked together to establish the high standards necessary to maintain the reputation of *California Fish and Game* as a respected scientific journal. In 2010, *California Fish and Game* will begin its 96th year, and it remains California's longest continuously published scientific journal, as noted by previous Editor-in-Chief, Eric Loft.

I look forward to receiving many, many manuscripts, and to working with the Associate Editors and the authors to continue to enhance the reputation of this journal, and to making it the best it can be. I encourage all potential authors, whether from academia, resource management agencies, or other organizations to consider *California Fish and Game* as an appropriate and desirable outlet for your work as it relates to research, conservation, and management of those species occurring among the flora and fauna of California.

— *Vernon C. Bleich*, Incoming Editor-in-Chief

FIELD ASSESSMENT OF BAYLUSCIDE TREATMENTS FOR THE CONTROL OF NEW ZEALAND MUDSNAIL *POTAMOPYRGUS ANTIPODARUM* IN A CONCRETE-LINED CANAL

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ABSTRACT

Survival of New Zealand mudsnail, *Potamopyrgus antipodarum,* was tested against exposure to Bayluscide[R] (active ingredient: nicolosamide) in a concrete-lined irrigation canal. Concentrations of niclosamide in water and sediment were monitored in the canal. Test snails in live cages were exposed to niclosamide concentrations of approximately 1 mg/L for eight or 17 hours. The results of this study indicate that almost complete mortality of New Zealand mudsnails is achieved at 1 mg/L for eight hours. No additional mortality was seen in the 17-hour treatments. The half-lives of niclosamide in water and sediment were 1.8 and 1.6 days, respectively.

INTRODUCTION

New Zealand mud snails (NZMS), *Potamopyrgus antipodarum,* were first reported in Europe during the 1800s and in North America (Idaho) in 1987. NZMS are parthenogenic livebearers and are typically 4- to 5-mm shell length at adulthood. NZMS quickly colonize habitable waters, and were discovered in California in the Owens River in 2000 and have since spread to creeks and rivers in 18 counties. NZMS have the potential to reach population densities of up to 300,000 per m^2 in the western United States (Richards et al. 2001) and disrupt the food chain by displacing native invertebrates (Kerans et al. 2005). Fish populations can decline as a consequence. Their ability to reach high densities suggests that they might have the potential to impede water delivery systems.

The Putah Creek South Canal is a concrete canal that is used to deliver water to agricultural users and domestic water treatment plants. NZMS were first discovered in the canal in 2005 and the population has been variable since. The Solano County Water Agency operates the canal and has funded projects to study possible control methods for the snail. Copper sulfate was tested in the canal as a treatment against NZMS during routine copper sulfate treatments for algae control (Trumbo 2008[1]). NZMS in live cages were exposed weekly for 13 weeks. The high rate of NZMS survival during the treatments

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[1] Trumbo, J. 2008. Field assessment of copper sulfate treatments for the control of New Zealand Mudsnail, *Potamopyrgus antipodarum* in the Putah Creek South Canal. California Department of Fish and Game Pesticide Investigations Unit. 4 pages.

suggested that copper sulfate is not an effective treatment at the concentrations used for algae control.

Bayluscide (active ingredient: niclosamide) is a lampricide and molluscicide. Previous work by the California Department of Fish and Game (CDFG) found that when NZMS were exposed to Bayluscide in the laboratory for 4 hours and 8 hours, the 96-h LC_{50} values were 1.726 mg/L and 0.423 mg/L, respectively (California Department of Fish and Game 2007[2]). In laboratory bioassays performed by Montana Fish, Wildlife, and Parks, 100% of NZMS were killed when exposed to 4 mg/L niclosamide for 12 hours[3]. Niclosamide toxicity does not appear related to temperature, however it is more toxic at lower pH values because of increased lipid solubility (Bills and Marking 1976). In order to confirm the effectiveness of Bayluscide for NZMS control in a field setting, a treatment was made in a concrete-lined canal using a concentration of 2 mg/L (as niclosamide). Water and sediment samples were collected to assess the environmental fate and persistence of Bayluscide in the canal environment. Bayluscide has been shown to break down rapidly in natural systems, with half-lives in water and sediment of 0.83 and 3.9 days, respectively (Dawson 2003).

In addition to NZMS, other invasive mollusks have been found recently in the waterways of California. Zebra mussels, *Dreisssena polymorpha,* and quagga mussels, *Dreissena rostriformis bugensis,* also have the potential to clog waterways[4]. Treatment strategies, such as use of Bayluscide, may need to be developed for these organisms as well.

METHODS

The Allendale Canal in the Solano Irrigation District delivery system was chosen for the field trial of NZMS against Bayluscide. The treatment was performed after the end of irrigation season so that there would be no pesticide exposure to crops. Four sites were chosen to monitor snail survival and concentrations of niclosamide in water and sediment (Table 1 and Fig. 1): a control site upstream of the project (Site C) and three sites in the treatment area (Sites 1 through 3). A fifth site (application Site A) was also used to monitor Bayluscide concentrations in sediment.

NZMS were collected from Putah Creek, counted, sized, and placed in numbered live cages. A total of 50 snails of varying sizes were placed in each cage. Cages were kept at a constant temperature during transport. Cages were placed in outer atria cages and locked shut. Cages (three per site) were weighted and placed in the canal at four different sites C, 1, 2, and 3 prior to Bayluscide treatment.

The Bayluscide application was made on 15 October 2008. The emulsifiable concentrate formulation (20% active ingredient) was applied for 8 hours. Canal flows during the application period were approximately 2 cfs. A total of 14,800 ml (3.9 gallons) was used for the application. At the time of the application, discharge from the canal was blocked.

The intended application method, the use of a float box, was revised after it became clear that a 10-fold dilution of the formulated product did not mix readily with water. This poor mixing resulted in an inability to maintain a constant flow out of the float box. The

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[2] California Department of Fish and Game. 2007. Aquatic Toxicology Laboratory Report P-2454. Elk Grove, California.

[3] Don Skaar, Montana Fish, Wildlife, and Parks Department, personal communication.

[4] California Department of Fish and Game http://www.dfg.ca.gov/invasives/quaggamussel

float box method was replaced with the use of single nozzle boom placed across the canal. In order to maintain constant flow, the nozzle was removed allowing the pesticide mix to flow directly out of the hose. After trying several different dilutions, the following dilution and application rate was selected: 30 oz of Bayluscide mixed in 15 gals of water (approximately 1.5%) applied at a drip rate of 440 ml/10 seconds. The drip rate was checked and corrected, if necessary, every 10 minutes. The mixed material was under constant agitation and was applied at a tank pressure of 30 PSI.

Live cages were retrieved from Site 2 after 8 hours of treatment. Live cages at the other two sites and the control site were retrieved 9 hours after the treatment ended (17 hours since the beginning of treatment). Snails were rinsed from the cages into beakers for counting. Snails were considered dead if they were separated from their shells or if they did not move or attach to the beaker for 15 minutes.

Water samples were collected at Sites C, 1, 2, and 3 at 5 and 10 hours after the start of treatment and on Day 1, 2, 5, and 7. Sediment samples were taken at all sites on Days 1, 5, and 7 post-treatment. Samples were analyzed for niclosamide by the CDFG Water Pollution Control Laboratory using LC/MS.
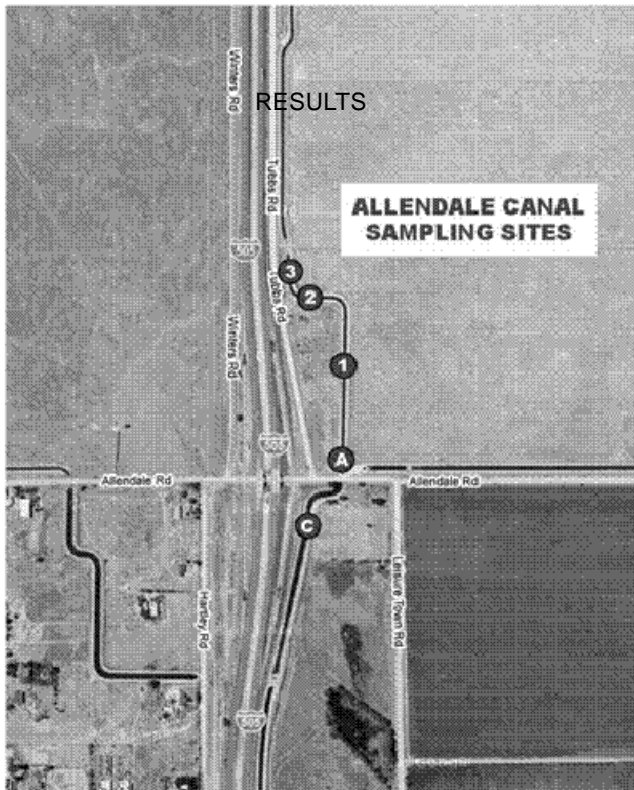
RESULTS

Figure 1. Sampling Sites on Allendale Canal. Site C = control site. Site A = application site. Sites 1 – 3 = downstream sites.

Although Bayluscide was applied with an intended concentration of 2 mg/L, the measured concentration was closer to 1 mg/L (Table 2) Niclosamide has a relatively high adsorption coefficient (k_{oc}) ranging from 148 to 2,213 (Dawson et al. 1986) and it is likely that it was removed from the water column by adsorption to sediment.

Snail survival was similar at the three sites on the treated canal (Table 1). Eight hours of treatment at approximately 1 mg/L provided nearly 100% mortality of test snails. Snails that survived in the treatment cages showed less movement than snails in the control cages. During the treatment of the Allendale Canal, small unidentified warm-water fish in the treatment area were observed in distress and dying a short time after exposure started. This was expected as fish and snails exhibit similar sensitivity to niclosamide.

After 7 days in water, niclosamide had degraded from approximately 1 mg/L to between 0.01 (Site 4) and 0.11 mg/L (Site 3) (Table 2). It was difficult to determine individual half-lives for the different sites, as there appeared to be additional movement of the chemical downstream for a few days after application. The half-life of niclosamide in water (average of all sites) was 1.8 days. Intralaboratory precision was determined by analyzing laboratory splits. Relative percent difference (RPD) was acceptable (<20%) in four of the five sets of split samples. Accuracy was determined by analyzing laboratory control spikes and matrix spikes. Recovery was acceptable in all four spiked samples (RPD between 70 and 130%).

Sediment half-life averaged 2.6 days for all sites. Not surprisingly, the highest concentration of niclosamide in sediment was at the site of the application (Site 5) (Table 2). Intralaboratory precision was determined by analyzing laboratory splits. RPD was acceptable (<20%) in four of the five sets of splits. Accuracy was determined by analyzing laboratory control spikes and matrix spikes. Recovery was acceptable in all four spiked samples (RPD between 70 and 130%).

Table 1. New Zealand Mudsnail Survival (**%**). Site 1 cages were exposed to niclosamide for 8 hours. Other sites were exposed for 17 hours.

Cage (50 snails/cage)	Snail Survival (%)			
	Control	Site 1	Site 2	Site 3
1	100	0	4	0
2	94	0	0	8
3	100	6	2	0
Average	98	2	2	3

[5] Trumbo, J. 2008. Field assessment of copper sulfate treatments for the control of New Zealand Mudsnail, *Potamopyrgus antipodarum* in the Putah Creek South Canal. California Department of Fish and Game Pesticide Investigations Unit. 4 pages.

Table 2. Niclosamide Concentrations in Water and Sediment

Station	Water (mg/L)						Sediment (mg/g, fresh weight)		
	5 hours	10 hours	Day 1	Day 2	Day 5	Day 7	Day 1	Day 5	Day 7
C	0	0	0	0	0	0	0	0	0
1	0.847	1.33	1.21	0.781	0.55	0.088	1.54	0.7	0
2	0.396	0.913	0.968	0.792	0.385	0.11	1.45	0.72	0.07
3	0.099	0.451	0.77	0.869	0.528	0.01	0.26	0.57	0
A							1.46	1.1	0.3

DISCUSSION

Bayluscide was effective at killing NZMS at 1 mg/L for 8 hours in slowly flowing natural water. However, eradication was not complete and higher concentrations could likely be required to accomplish complete eradication. Complete eradication is desirable as survivors can quickly repopulate the habitat, possibly with more resistant individuals. Bayluscide broke down rapidly in water and sediment with half-lives of 1.8 and 2.6 days, respectively. It is likely that a higher flow rate would allow for more complete mixing, and possibly, a higher success rate.

Bayluscide shows promise in the eradication of other invasive invertebrates, such as quagga mussels and zebra mussels. Toxicity values for snails, mussels, and fish are all similar (Table 3). Of the eighteen chemicals tested for effectiveness against zebra mussel by the United States Fish and Wildlife Service, Bayluscide was among the top three most selective (Waller et al. 1993).

Other treatments have been proposed for NZMS control, such as copper sulfate and potassium permanganate. Field trials for copper sulfate control of NZMS were performed last year in the Putah South Canal and the material proved to have little effect on the snails (Trumbo 2008[5]). Potassium permanganate has been used to control invasive mollusks in water supply systems and may also be worth further analysis.

Table 3. Toxicity values for aquatic organisms to niclosamide.

Organism	Genus	Toxicity range (mg/L)
Snail (48-h)	*Viviparus*	57
	Oncomelania	64 - 78
Zebra mussel (48-h)	*Dreissena*	15 - 17
Lamprey (9-h)	*Ichthyomyzon*	30 - 40
Trout (48-h)	*Oncorrhynchus*	47

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[5] Trumbo, J. 2008. Field assessment of copper sulfate treatments for the control of New Zealand Mudsnail, *Potamopyrgus antipodarum* in the Putah Creek South Canal. California Department of Fish and Game Pesticide Investigations Unit. 4 pages.

Future research may be able to identify the minimum effective dosage for niclosamide, as well as its efficacy against other invasive mollusks. Repeated applications should also be tested to provide complete eradication. Subsequent studies should place the test animals in clean water for at least 24 hours to determine if the effects of the treatment are reversible.

ACKNOWLEDGMENTS

LITERATURE CITED

Bills, T. D. and L. L. Marking. 1976. Toxicity of 3-trifluoromethyl-r-nitorphenol (TFM), 2'5-dichloro-4''nitrosalicylanilide (Bayer 73), and a 98:2 mixture to fingerlings of seven fish species and to eggs and fry of coho salmon. U.S. Fish and Wildlife Service, Investigations in Fish Control 69.

Dawson, V. K. 2003. Environmental fate and effects of the lampricide Bayluscide: a review. Journal of Great Lake Research 29:475-492.

Dawson, V. K., D. A. Johnson, and J. L. Allen. 1986. Loss of lampricides by adsorption on bottom sediments. Canadian Journal of Fisheries and Aquatic Science 43:1515-1520.

Kerans, B. L., M. F. Dybdahl, M. M. Gangloff, and J. E. Jannot. 2005. *Potamopyrgus antipodarum*: distribution, density, and effects on native macroinvertebrate assemblages in the Greater Yellowstone Ecosystem. Journal of North American Benthological Society 241:123-138.

Richards, D. C., L. D. Shinn, and G. T. Lester. 2001. Spatial distribution of three snail species, including the invader *P. antipodarum antipodarum* in a freshwater spring. Western North American Naturalist 61:375-380.

Waller, D. L., J. J. Rach, W. G. Cope, and L. L. Marking. 1993. Toxicity of candidate molluscicides to zebra mussels (*Dreissena polymorpha*) and selected nontarget organisms. Journal of Great Lakes Research 19:695-702.

FACTORS TO CONSIDER WHEN REPROVISIONING WATER DEVELOPMENTS USED BY MOUNTAIN SHEEP

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ABSTRACT

Mountain sheep, *Ovis canadensis*, occur in a naturally fragmented population structure, but have been extirpated from much of their historical distribution. Further, extant populations are subject to disruption of movement corridors, which exacerbates fragmentation. Water developments have been established to enhance the probability of persistence of the subpopulations that comprise metapopulations of those large herbivores, but such developments sometimes become dry. Suggestions are presented to help managers prioritize the order in which to reprovision water in the event that multiple developments become dry simultaneously. Given that a metapopulation contains habitat patches of differing quality, and that large subpopulations usually exhibit greater genetic diversity than small populations, reprovisioning is best prioritized in terms of benefits to (1) small, isolated subpopulations that are most subject to stochastic events and least likely to receive immigrants; (2) large, well-connected subpopulations in which intervention might be expected to benefit many individuals and, thereby, provide more potential colonists than would smaller, isolated subpopulations; and (3) small, well-connected subpopulations that are most apt to receive immigrants from nearby subpopulations.

Elevation, rainfall, and availability of water influence the persistence of mountain sheep, *Ovis canadensis,* in desert ecosystems (Epps et al. 2004), and no large populations are known to exist in the absence of reliable sources of surface water (Wehausen 2007[1]). Because some movement corridors have been disrupted, and habitats occupied by mountain sheep are being increasingly fragmented, potential benefits of developing water sources to mitigate impacts of anthropogenic activities are receiving increased attention (Dolan 2006). Broyles (1995) questioned the value of wildlife water developments; nevertheless, they are used extensively to enhance habitat for mountain sheep (Bleich et al. 2005, Krausman et al. 2006). Despite being largely reliable, wildlife water developments occasionally become dry as a result of insufficient precipitation or mechanical failure (Bleich and Pauli 1990); if that occurs., management goals cannot be met and conservation objectives become more difficult to achieve. Further, if >1 development is dry, managers either must determine which to reprovision (i.e., refill with water), or prioritize the order in which they are to be reprovisioned.

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[1] Wehausen, J. D. 2007. Wilderness and guzzlers for desert bighorn sheep. Desert Report, December 2007:49.

In this note, I summarize recommendations (Bleich 2008[2]) that will be useful to managers when ≥2 water developments are dry simultaneously. It is my hope that these suggestions will help ensure that fiscal and logistical resources are expended most effectively, and with the greatest benefit to the conservation of mountain sheep.

Traditionally, mountain sheep populations were defined by the isolated mountain ranges they inhabited (e.g., Buechner 1960, Weaver 1973). It has become increasingly evident, however, that those large herbivores occur as metapopulations that are comprised of individual populations occupying disjunct geographic areas (Schwartz et al. 1986; Bleich et al. 1990, 1996; Bailey 1992; Krausman 1997; Epps et al. 2007). Moreover, the importance of small, seemingly isolated populations to the conservation of mountain sheep has been increasingly realized (Krausman and Leopold 1986; Schwartz et al. 1986; Bleich et al. 1990, 1996; Krausman 1997).

In the western United States, management and conservation of mountain sheep are based largely on the concept of a metapopulation structure (Torres et al. 1994, 1996; Singer et al. 2000; Epps et al. 2003). Extirpation of any population has serious implications for metapopulation persistence, particularly given the philopatric behavior and conservative colonization rates of mountain sheep (Geist 1971, Festa-Bianchet 1991, Bleich et al. 1996). Thus, loss of >30% of historical populations from California (Epps et al. 2003) is disconcerting; similar trends exist among other states inhabited by those specialized ungulates (Trefethen 1975).

Despite blockage of intermountain movement corridors and disruptions of connectivity by anthropogenic barriers (Epps et al. 2005a), available evidence indicates that opportunities for colonization still exist (Epps et al. 2005b). Wildlife water developments play a potentially important role in maintenance of connectivity among populations because they (1) allow mountain sheep to make use of otherwise suitable habitat that lacks reliable sources of surface water; (2) increase the probability of pioneering individuals encountering surface water in areas that otherwise provide suitable habitat; (3) enhance the likelihood of immigrants encountering conspecifics; or, (4) increase survival rates during periods of thermal stress or drought. Thus, wildlife water developments have the potential to increase population size, enhance survival, and facilitate genetic exchange; resultant increases in fitness have implications for gene flow and rates of colonization (Bleich 2008[2]). Indeed, the positive influences of wildlife water developments on the number, size, and stability of mountain sheep populations (Wehausen 2007[1]) have implications for metapopulation function and, hence, for persistence of the species.

There is agreement that small populations of mountain sheep are more vulnerable to extirpation when compared to large populations (Berger 1999, Wehausen 1999), and that demographic consequences of declines can be severe (Lande 1988). As a result, persistence of small populations can be impacted to a greater extent by a numerically equivalent loss of individuals when compared to large populations. Under some circumstances the loss of a large population could, nevertheless, be more damaging to metapopulation function than the loss of a small one. Large populations likely possess greater genetic diversity (Frankham 1996) and potentially produce more emigrants (Bailey 1992), both of which are essential to metapopulation function. Some populations occupy areas of better quality habitat and

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[2] Bleich, V. C. 2008. Reprovisioning wildlife water developments: considerations for determining priorities to transport water. Society for the Conservation of Bighorn Sheep, Pasadena, California, USA.

thereby have access to more abundant resources than mountain sheep inhabiting small, isolated mountain ranges (Bailey 1992); as a result, those populations generally are larger and better able to withstand environmental stressors. In contrast, small populations that occupy marginal habitat are more vulnerable yet they, along with habitat that is occupied occasionally by transient individuals, can play important roles in maintaining connectivity (Schwartz et al. 1986; Bleich et al. 1990, 1996). Hence, when it is necessary to reprovision >1 dry water development, I recommend managers consider the tradeoffs associated with the potential extirpation of a small population in the context of the partial loss of a larger population, and that degree of isolation of each population receives serious consideration by managers faced with any such decision.

Two factors, distance to the nearest population and the number of proximate populations, have important implications for metapopulation function. Both play roles in connectivity (Epps et al. 2006), and thereby influence the probability of a geographic area being colonized by mountain sheep following an extirpation. As a result distances to, and the number of, proximate populations, influence the probability of dispersing individuals encountering resources necessary to survive, or of encountering conspecifics in a new area. Other factors being equal, the more isolated a population is, the more vulnerable it is. Persistence of small, isolated populations is more apt to be impacted by water shortages than is the persistence of populations having greater potential for connectivity to other areas inhabited by mountain sheep. Thus, when >1 development is dry, I suggest that the potential for connectivity with other areas inhabited by mountain sheep be considered in the context of benefits to the metapopulation as a whole, and how metapopulation function will best be served by ensuring availability of water.

Although the density of mountain sheep might be quite low (e.g., <1 individual/km^2) in a given area, total numbers of animals still can be greater than where mountain sheep occur at higher densities (Bleich 2008[2]). Thus, population density could present a misleading indicator of need to reprovision a water development, and thereby result in transport of water to a lower-priority area than would consideration of absolute numbers alone. Hence, population density in a given geographic area is a less important indicator of need to reprovision water than is population size. Among subpopulations occupying a single mountain range, however, the simultaneous presence of ≥ 2 dry developments will necessitate a decision regarding which to refill. In such situations, the relative abundance of animals in the vicinity of each dry development becomes a meaningful consideration, and transport of water to the development likely to benefit the greatest number of sheep is recommended. Such fine-scale information on relative abundance of mountain sheep within mountain ranges is, unfortunately, largely unavailable.

Despite the importance of population size to conservation objectives, I encourage managers to ensure that water is available to the greatest number of populations in need of that resource during the hot season. Using Weaver's (1973) suggestions or Turner's (1973[3]) estimates of water demands, managers can calculate the amount needed by a population during thermally stressful periods. For example, 25 mountain sheep would "require" approximately 10,000 L of water over the summer according to Weaver's (1973) criteria, and I suggest that transporting excess water to a single development while neglecting to

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[3] Turner, J. C. 1973. Water, energy and electrolyte balance in the desert bighorn sheep, *Ovis canadensis*. Ph.D. dissertation, University of California, Riverside, USA.

reprovision another would be neither prudent nor of benefit to overall conservation objectives.

The length of time that a water development has been dry should play an important role in the decision making process. Lack of surface water during summer over multiple years has potentially greater impacts on a population than an absence of water over a shorter period of time, because annual impacts likely are cumulative. Alternatively, if a development has been dry for several years, it could be argued that any impacts to the population that used that development already have occurred, and that if a development upon which sheep currently are dependent is not reprovisioned, the impacts would be disproportionately greater. If managers adhere to the recommendations presented herein, such situations are unlikely to occur; nevertheless, when setting priorities to reprovision dry water developments, I suggest managers assess impacts already incurred by the respective population(s).

Clearly, availability of alternative water sources is an important consideration when prioritizing areas to reprovision. It seems intuitive that the need to reprovision dry water development(s) in areas having alternative water sources is less than in those areas without alternative sources. The potential value of an alternative source is diminished, however, if it has not previously received regular use by members of the population. Hence, when deciding which of several developments to reprovision, I suggest managers give serious consideration to the amount of use alternative water sources previously have received.

Male and female mountain sheep segregate for much of the year (Bleich et al. 1997), and different parts of a mountain range can be used primarily by one sex or the other and with the result that males and females sometimes use separate water sources (Whiting 2008[4]). In desert ecosystems, sexual segregation generally peaks during spring and early summer, but males and females aggregate for breeding during late summer and early fall (Bleich et al. 1997, Rubin et al. 2000). During thermally stressful periods, females and young are most closely tied to surface water and visitation rates are high (Bleich et al. 1997). I suggest that dry developments in areas used predominately by females and young receive a higher priority for reprovisioning than areas used predominately by males. By providing water at those developments, physiological needs of males likely will be met because they join females during the hottest time of the year (Bleich et al. 1997). Thus, sex and age structure of the population, combined with the seasonal distributions of males and females, are important considerations when prioritizing efforts to reprovision dry developments.

Decisions to reprovision a dry development will be influenced by the methods available to implement that task. If water can be provided without undue fiscal or logistical commitments, as when it can be transported by motor vehicle, those situations are best resolved as they arise. If >1 development is dry, I suggest that managers distribute their effort to ensure that anticipated needs of the greatest number of populations are met. It would not be a sound strategy to provide more water than necessary at one development at the expense of another if the anticipated needs of both (or several) can be met. The same strategy will be applicable even when aerial transport of water is the only means by which developments can be reprovisioned. I suggest that neither level of difficulty nor cost are important factors when determining which development(s) to reprovision, or the amount of water to be transported.

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[4] Whiting, J. C. 2008. Behavior and ecology of reintroduced Rocky Mountain bighorn sheep. Ph.D. dissertation, Idaho State University, Pocatello, USA.

Management prescription (i.e., whether the population is harvested or not) is of less importance than most other factors. Harvest strategies include removal of animals for translocation or by hunting; in one setting, females will be disproportionately selected for removal and, in the latter, mature males will be disproportionately targeted. In both situations, the population likely is large and healthy, or it would not be managed under either of those strategies (Bleich 2008[2]). Thus, management prescription alone is unimportant relative to most other factors when prioritizing actions to be undertaken.

The observations, experiences, and resulting opinions of individuals familiar with specific geographic areas warrant some consideration, particularly if they have been compiled over extended periods of time and under a variety of environmental conditions. Nevertheless, when prioritizing efforts to reprovision dry water developments, I suggest the vulnerability of a population as perceived subjectively is much less meaningful than are other factors.

In summary, managers are encouraged to reprovision developments as they become dry, rather than waiting until >1 development no longer provides water. If, however, managers are faced with multiple dry developments, I recommend they do so with the objective of ensuring water is available to the greatest number of populations, but without compromising the persistence of those that are large. Given that a metapopulation of mountain sheep consists of occupied (and potentially unoccupied) habitat patches of differing quality, and that large populations likely exhibit greater genetic diversity than small ones, I suggest actions to reprovision dry water developments are best implemented in the context of benefits to (1) small, isolated populations that are most subject to stochastic events and least likely to receive immigrants; (2) large, well-connected populations in which intervention would be expected to benefit many individuals and, thereby, provide more potential emigrants than smaller, isolated populations; and (3) small, well-connected populations that are most likely to receive immigrants from nearby areas.

ACKNOWLEDGMENTS

LITERATURE CITED

Bailey, J. A. 1992. Managing bighorn habitat from a landscape perspective. Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council 8:49-57.

Berger, J. 1999. Intervention and persistence in small populations of bighorn sheep. Conservation Biology 13:432-435.

Bleich, V. C., and A. M. Pauli. 1990. Mechanical evaluation of artificial watering devices built for mountain sheep in California. Pages 65-72 in G. K. Tsukamoto and S. J. Stiver, editors. Wildlife water development. Nevada Department of Wildlife, Reno, USA.

Bleich, V. C., J. D. Wehausen, and S. A. Holl. 1990. Desert-dwelling mountain sheep: conservation implications of a naturally fragmented distribution. Conservation Biology 4:383-390.

Bleich, V. C., J. D. Wehausen, R. R. Ramey II, and J. L. Rechel. 1996. Metapopulation theory and mountain sheep: implications for conservation. Pages 353-373 *in* D. R. McCullough, editor. Metapopulations and wildlife conservation. Island Press, Covelo, California, USA.

Bleich, V. C., R. T. Bowyer, and J. D. Wehausen. 1997. Sexual segregation in mountain sheep: resources or predation? Wildlife Monographs 134:1-50.

Bleich, V. C., J. G. Kie, E. R. Loft, T. R. Stephenson, M. W. Oehler, Sr., and A. L. Medina. 2005. Managing rangelands for wildlife. Pages 873-897 *in* C. E. Braun, editor. Techniques for wildlife investigations and management. Sixth edition. The Wildlife Society, Bethesda, Maryland, USA.

Broyles, B. 1995. Desert wildlife water developments: questioning use in the southwest. Wildlife Society Bulletin 23:663-675.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildlife Monographs 4:1-174.

Dolan, B. F. 2006. Water developments and desert bighorn sheep: implications for conservation. Wildlife Society Bulletin 34:642-646.

Epps, C. W., V. C. Bleich, J. D. Wehausen, and S. G. Torres. 2003. Status of bighorn sheep in California. Desert Bighorn Council Transactions 47:20-35.

Epps, C. W., D. R. McCullough, J. D. Wehausen, V. C. Bleich, and J. L. Rechel. 2004. Effects of climate change on population persistence of desert-dwelling mountain sheep in California. Conservation Biology 18:102-113.

Epps, C. W., P. J. Palsbøll, J. D. Wehausen, R. R. Ramey II, and D. R. McCullough. 2005a. Highways block gene flow and cause rapid decline in genetic diversity of desert bighorn sheep. Ecology Letters 8:1029-1038.

Epps, C. W., J. D. Wehausen, P. J. Palsbøll, and D. R. McCullough 2005b. Using genetic analyses to describe and infer recent colonizations by desert bighorn sheep. Pages 51-62 *in* J. Goerrissen and J. M. André, editors. Sweeney Granite Mountains Desert Research Center 1978-2003: a quarter century of research and teaching. University of California Natural Reserve Program, Riverside, USA.

Epps, C. W., P. J. Palsbøll, J. D. Wehausen, G. K. Roderick, and D. R. McCullough. 2006. Elevation and connectivity define genetic refugia for mountain sheep as climate warms. Molecular Ecology 15:4295-4302.

Epps, C. W., J. D. Wehausen, V. C. Bleich, S. G. Torres, and J. S. Brashares. 2007. Optimizing dispersal and corridor models using landscape genetics. Journal of Applied Ecology 44:714-724.

Festa-Bianchet, M. 1991. The social system of bighorn sheep: grouping patterns, kinship, and dominance rank. Animal Behavior 42:71-82.

Frankham, R. 1996. Relationship of genetic variation to population size in wildlife. Conservation Biology 10:1500-1508.

Geist, V. 1971. Mountain sheep. A study in behavior and evolution. University of Chicago Press, Chicago, Illinois, USA.

Krausman, P. R. 1997. The influence of landscape scale on the management of desert bighorn sheep. Pages 349-367 *in* J. A. Bissonette, editor. Wildlife and landscape ecology: effects of pattern and scale. Springer-Verlag, New York, New York, USA.

Krausman, P. R., and B. D. Leopold. 1986. The importance of small populations of desert bighorn sheep. Transactions of the North American Wildlife and Natural Resources Conference 51:52-61.

Krausman, P. R., S. S. Rosenstock, and J. W. Cain III. 2006. Developed waters for wildlife: science, perception, values, and controversy. Wildlife Society Bulletin 34:563-569.

Lande, R. 1988. Genetics and demography in biological conservation. Science 241:1455-1460.

Rubin, E. S., W. M. Boyce, and V. C. Bleich. 2000. Reproductive strategies of desert bighorn sheep. Journal of Mammalogy 81:769-786.

Schwartz, O. A., V. C. Bleich, and S. A. Holl. 1986. Genetics and the conservation of mountain sheep *Ovis canadensis nelsoni*. Biological Conservation 37:179-190.

Singer, F. J., V. C. Bleich, and M. A. Gudorf. 2000. Restoration of bighorn sheep metapopulations in and near western national parks. Restoration Ecology 8(4s):14–24.

Torres, S. G., V. C. Bleich, and J. D. Wehausen. 1994. Status of bighorn sheep in California, 1993. Desert Bighorn Council Transactions 38:17-28.

Torres, S. G., V. C. Bleich, and J. D. Wehausen. 1996. Status of bighorn sheep in California, 1995. Desert Bighorn Council Transactions 40:27-34.

Trefethen, J. B. (editor). 1975. The wild sheep in modern North America. Winchester Press, New York, New York, USA.

Weaver, R. A. 1973. California's bighorn management plan. Desert Bighorn Council Transactions 17:22-42.

Wehausen, J. D. 1999. Rapid extinction of mountain sheep populations revisited. Conservation Biology 13:378–384.

ESTIMATING FISH LENGTH FROM VERTICAL MORPHOMETRIC PARAMETERS

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ABSTRACT

Fish lengths are important for resource assessment and management, particularly when methods to obtain age or weight are impractical or harmful to the resource. Underwater videos are commonly used to monitor fisheries because they are less invasive than other sampling methods. However, because of a fish's continuous lateral flexion while swimming and angle to the viewer, its length is often difficult to estimate from videos. In many cases, vertical morphometric parameters may be measured more accurately than horizontal parameters. To evaluate vertical parameters as predictors of length, regression equations were developed for species observed in underwater videos along the California coast, including kelp greenling, *Hexagrammos decagrammus*, lingcod, *Ophiodon elongatus*, black rockfish, *Sebastes melanops*, and blue rockfish, *S. mystinus*. A separate regression was calculated for combined rockfish, *Sebastes* spp., to serve as a monitoring tool until sufficient samples are collected for more specific regressions. Species combined were gopher rockfish, *S. carnatus*, copper rockfish, *S. caurinus*, black and yellow rockfish, *S. chrysomelas*, yellowtail rockfish, *S. flavidus*, quillback rockfish, *S. maliger*, black rockfish, *S. melanops*, vermilion rockfish, *S. miniatus,* blue rockfish, *S. mystinus*, China rockfish, *S. nebulosus*, canary rockfish, *S. pinniger*, and olive rockfish, *S. serranoides*. Vertical parameters were depth at mid-orbit, depth at pelvic fin origin, depth at anal fin origin, and least depth at caudal peduncle. Relationships between each vertical parameter and fork length were strongly correlated for individual species ($r \geq 0.973$) and combined rockfish species ($r \geq 0.947$).

INTRODUCTION

Fish length measurements are important for resource assessment and management (Petrell et al. 1997; Harvey et al. 2001a, 2002b; Cadiou et al. 2004), including evaluation of population age structure and biomass for harvest regulations and habitat protection. Fish lengths are particularly useful when methods to obtain age or weight are impractical as part of a sampling program (Karpov et al. 1995). Less invasive monitoring tools have been identified as priorities for collecting length or age data (Naiberg et al. 1993; Robins et al. 2000; Harvey et al. 2003). Researchers have used various techniques, including underwater video and still images (Klimley and Brown 1983; Naiberg et al. 1993; Harvey and Shortis 1996; Petrell et al. 1997; Love et al. 2000, 2006; Yoklavich et al. 2000, 2002; Harvey et al. 2001a, b, 2002a, b, 2003; Cadiou et al. 2004; Rochet et al. 2006). However, length is often difficult to estimate from videos because of continuous lateral flexion and variable orientation of swimming fishes toward the camera (Klimley and Brown 1983; Naiberg et al. 1993; Harvey et al. 2002a, 2003; Rochet et al. 2006).

Measurements of live fish (Naiberg et al. 1993; Harvey et al. 2002b, 2003), artificial models (Harvey et al. 2002b; Rochet et al. 2006), dorsal views of swimming fish (Klimley and Brown 1983), and allometric relationships of squid (Zeidberg 2004), dolphins (Bräger and Chong 1999), and whales (Ratnaswamy and Winn 1993; Dawson et al. 1995) have been evaluated for length estimation in photographs or videos. Accuracy and precision of length measurements decline substantially when fish models are oriented 60 degrees or more away from the camera (Harvey et al. 2002b). Techniques that provide depth perception such as visual estimates by divers and stereoscopic cameras (e.g., Harvey et al. 2002a, b; Yoklavich et al. 2000, 2002) still do not correct for angle of incidence. Current methods are also limited to simultaneous views of the head and tail (Harvey et al. 2002b), suggesting the need to evaluate whether vertical morphometric parameters at various points along the lateral axis may be used to estimate length.

The vertical axis of a fish is typically oriented perpendicular to the bottom either because of swim bladder position (e.g., scorpaenids) or behavioral orientation to the substrate (e.g., hexagrammids). Assuming perpendicular orientation, and given the camera angle relative to the bottom and distance to a fish, actual height can be measured with a trigonometric function. If equations can be developed from vertical parameters to predict length, then these parameters may be used as surrogates for length in video analysis. In any given video image, the clearest view of a fish may include only the anterior, middle, or posterior body region. Therefore, vertical parameters should be evaluated at various locations along the lateral axis. Given improvements in video and photographic quality, even relatively small features such as caudal peduncle depth may become a practical proxy for body length. The impetus for this research was the need to estimate biomass by species in addition to fish counts obtained from underwater video surveys. The objective of this study was to publish fish lengths and vertical parameters for a subset of nearshore species observed in video surveys along the coasts of California and Oregon. Reported here are results for kelp greenling, *Hexagrammos decagrammus*, lingcod, *Ophiodon elongatus*, black rockfish, *Sebastes melanops*, and blue rockfish, *S. mystinus*. Results are also reported for 11 combined rockfish, *Sebastes* spp., to serve as a monitoring tool until sufficient samples are collected for more specific regressions. Combined species include gopher rockfish, *S. carnatus*, copper rockfish, *S. caurinus*, black and yellow rockfish, *S. chrysomelas*,

yellowtail rockfish, *S. flavidus*, quillback rockfish, *S. maliger*, black rockfish, *S. melanops*, vermilion rockfish, *S. miniatus,* blue rockfish, *S. mystinus*, China rockfish, *S. nebulosus*, canary rockfish, *S. pinniger*, and olive rockfish, *S. serranoides*. These results, once published, will then be applied *in situ* to further evaluate their utility in estimating length.

METHODS

Measurements

All parameters were measured to the nearest millimeter with calipers for vertical parameters and measuring boards for length. Vertical parameters were measured at four locations: depth at mid-orbit; depth at pelvic fin origin; depth at anal fin origin; and least depth at caudal peduncle (Fig. 1). Fork length was measured from the most anterior part of the closed mouth to the center of the fork (e.g., Holt 1959; Laevastu 1965; Miller and Lea 1972; Anderson and Gutreuter 1983), or to the median caudal rays for fish without forked tails.
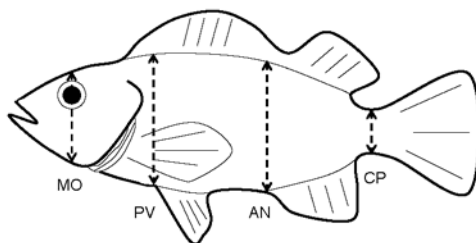
Figure 1. Vertical parameters measured on fish species observed in underwater videos along the California coast. (MO = depth at mid-orbit; PV = depth at pelvic fin origin; AN = depth at anal fin origin; CP = least depth at caudal peduncle)

Samples

Attempts were made to cover a wide range of sizes greater than or equal to 110 mm (Chen 1971). Fresh and preserved samples and sexes were combined (Chen 1971; Karpov and Kwiecien[1] 1988a). Preserved specimens were measured from the California Academy of Sciences collection on 23 and 24 June 2008. Fresh specimens were measured from sport and commercial catch in Crescent City (29 May 2008), Eureka (11 Jun 2008), Santa Cruz (28 Jun 2008), and Fort Bragg (10 Aug 2008), California.

Analyses

Following database entry and verification by two individuals, original measurements were plotted for exploratory analysis and detection of possible errors. Dependent and independent variables, fork length and vertical measurements, respectively, were transformed

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[1]Karpov, K. and G. Kwiecien. 1988a. Conversions between total, fork, and standard lengths for 41 species in 15 families of fish from California using fresh and preserved specimens. California Department of Fish and Game, Marine Resources Administrative Report No. 88-9. 14 pp.

using natural logarithms to reduce heteroskedasticity of variance around the dependent variable (Snedecor and Cochran 1989, p. 290). For each species, four regressions were calculated, one for each vertical variable against fork length.

RESULTS

Initial plots (Figs. 2-6) indicated no outliers in our data. For single species, each vertical parameter correlated highly with fork length (Table 1; $r \geq 0.973$). The lowest correlation with fork length was depth at mid-orbit for black rockfish, and the highest was depth at pelvic fin origin for lingcod (Table 1; $r = 0.997$). Vertical parameters and fork length were also highly correlated for combined rockfish (Table 1; $r \geq 0.946$), with depth at mid-orbit having the lowest correlation and depth at anal fin origin having the highest (Table 1; $r = 0.975$).
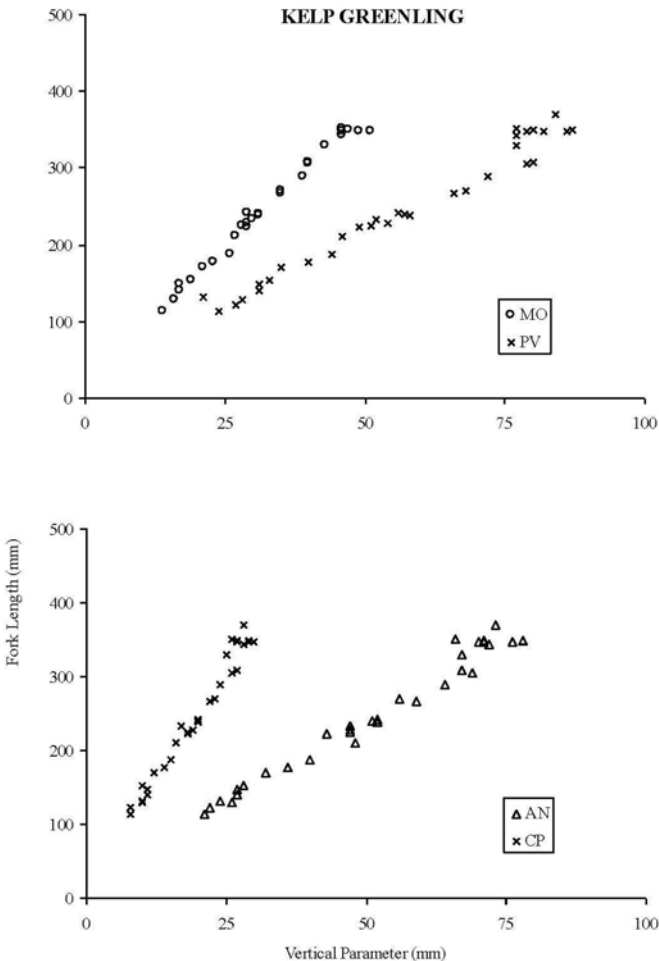
Figure 2. Scatter plots of non-transformed fork lengths and vertical parameters for kelp greenling. (MO = depth at mid-orbit; PV = depth at pelvic fin origin; AN = depth at anal fin origin; CP = least depth at caudal peduncle)
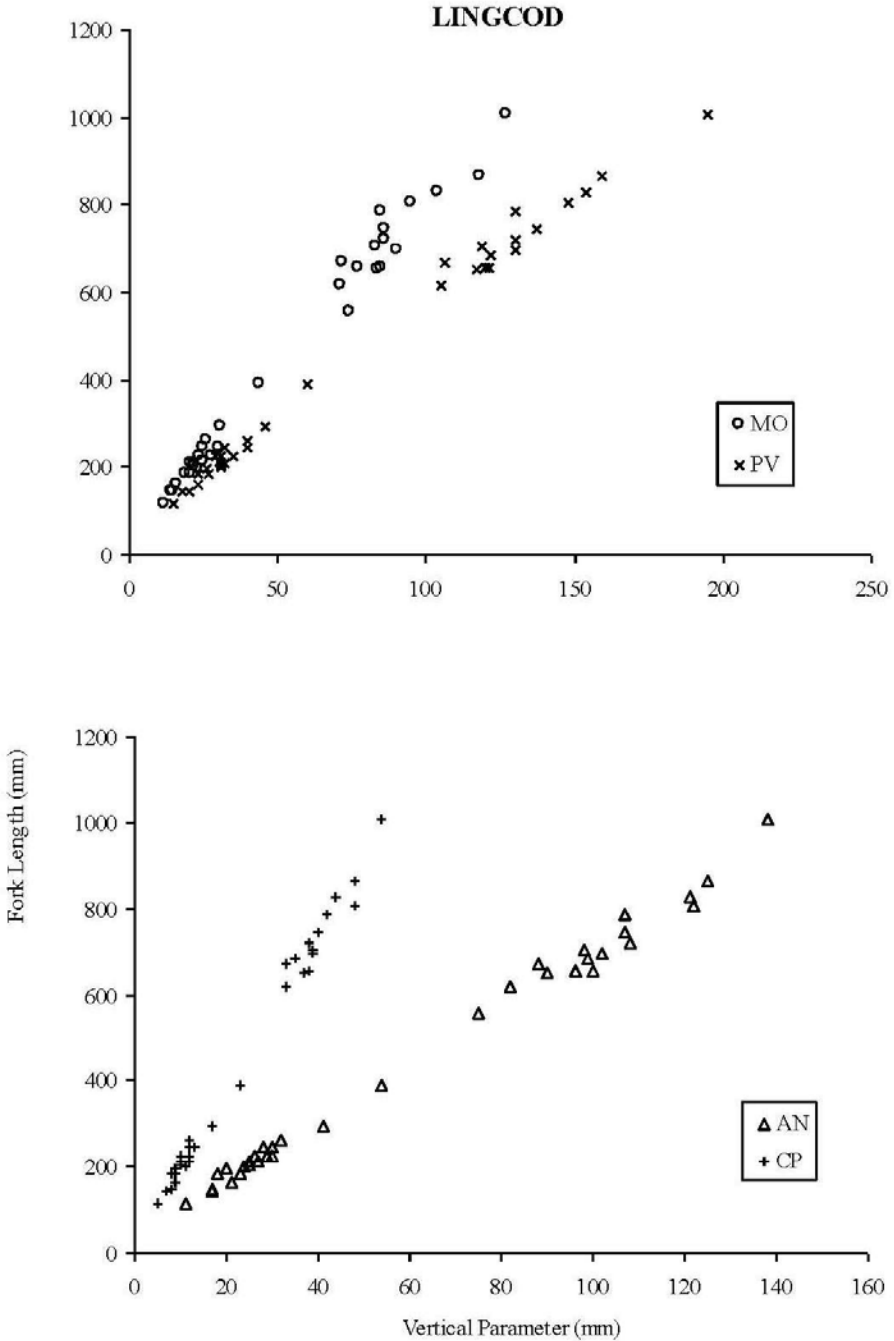
Figure 3. Scatter plots of non-transformed fork lengths and vertical parameters for lingcod. (MO = depth at mid-orbit; PV = depth at pelvic fin origin; AN = depth at anal fin origin; CP = least depth at caudal peduncle)

BLACK ROCKFISH
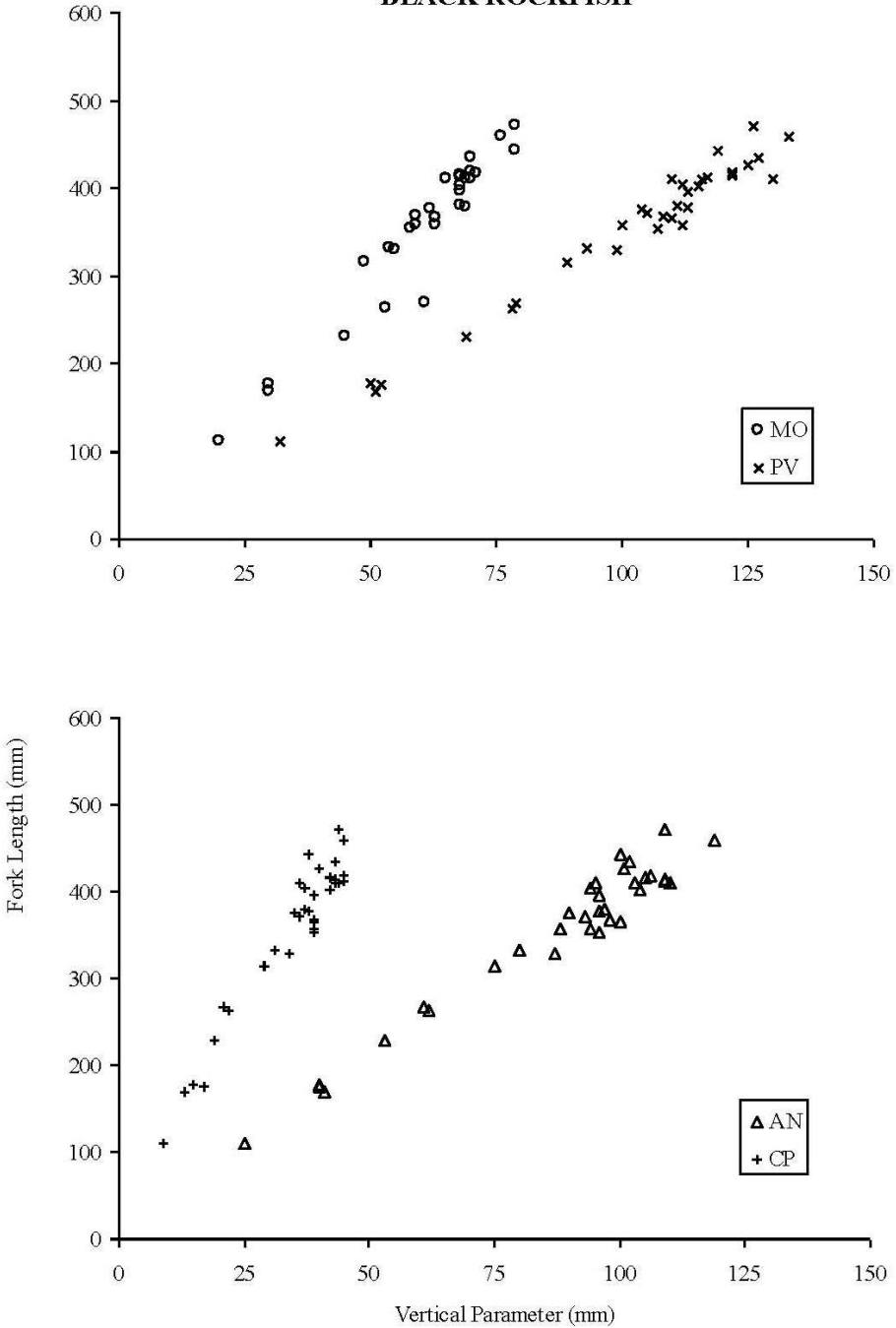
Figure 4. Scatter plots of non-transformed fork lengths and vertical parameters for black rockfish. (MO = depth at mid-orbit; PV = depth at pelvic fin origin; AN = depth at anal fin origin; CP = least depth at caudal peduncle)
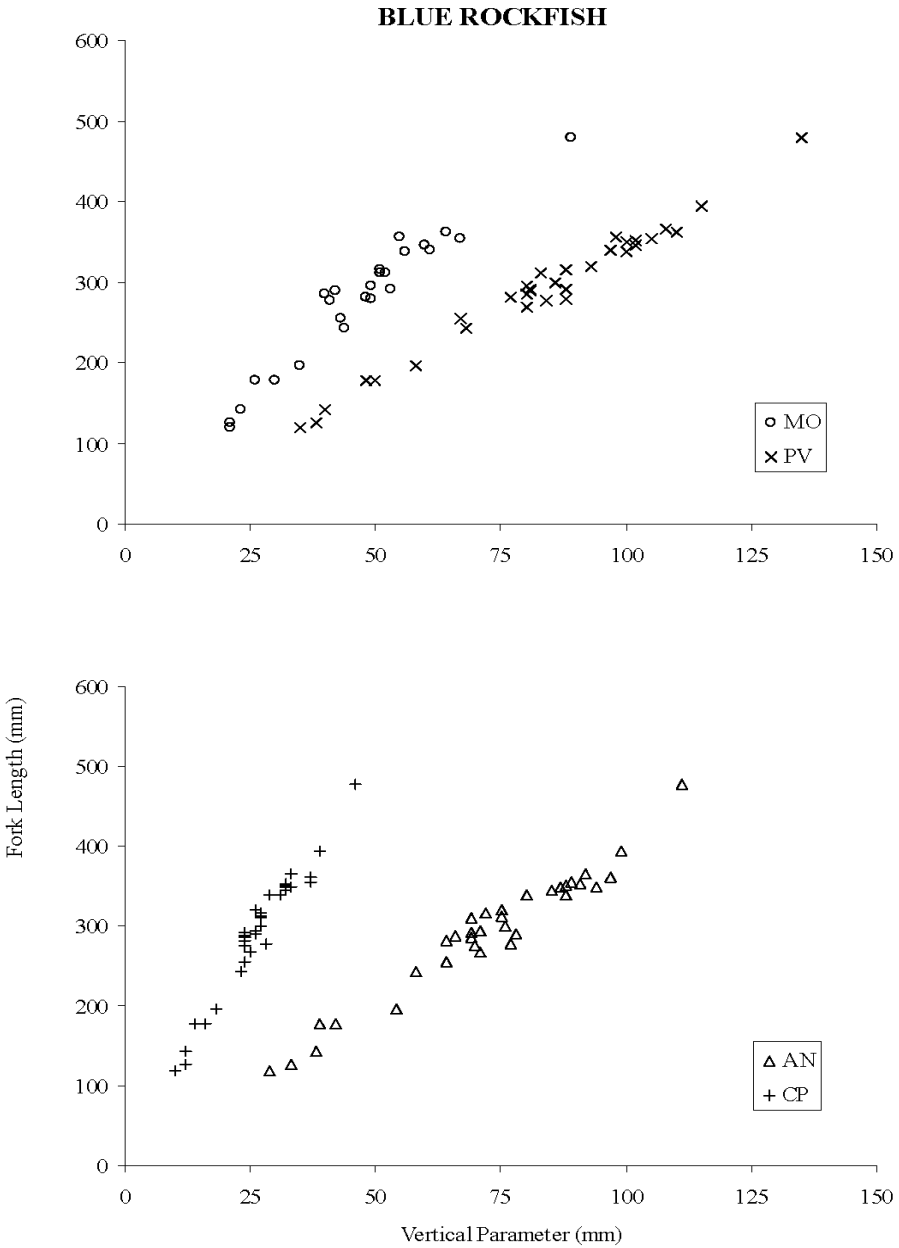
Figure 5. Scatter plots of non-transformed fork lengths and vertical parameters for blue rockfish. (MO = depth at mid-orbit; PV = depth at pelvic fin origin; AN = depth at anal fin origin; CP = least depth at caudal peduncle)
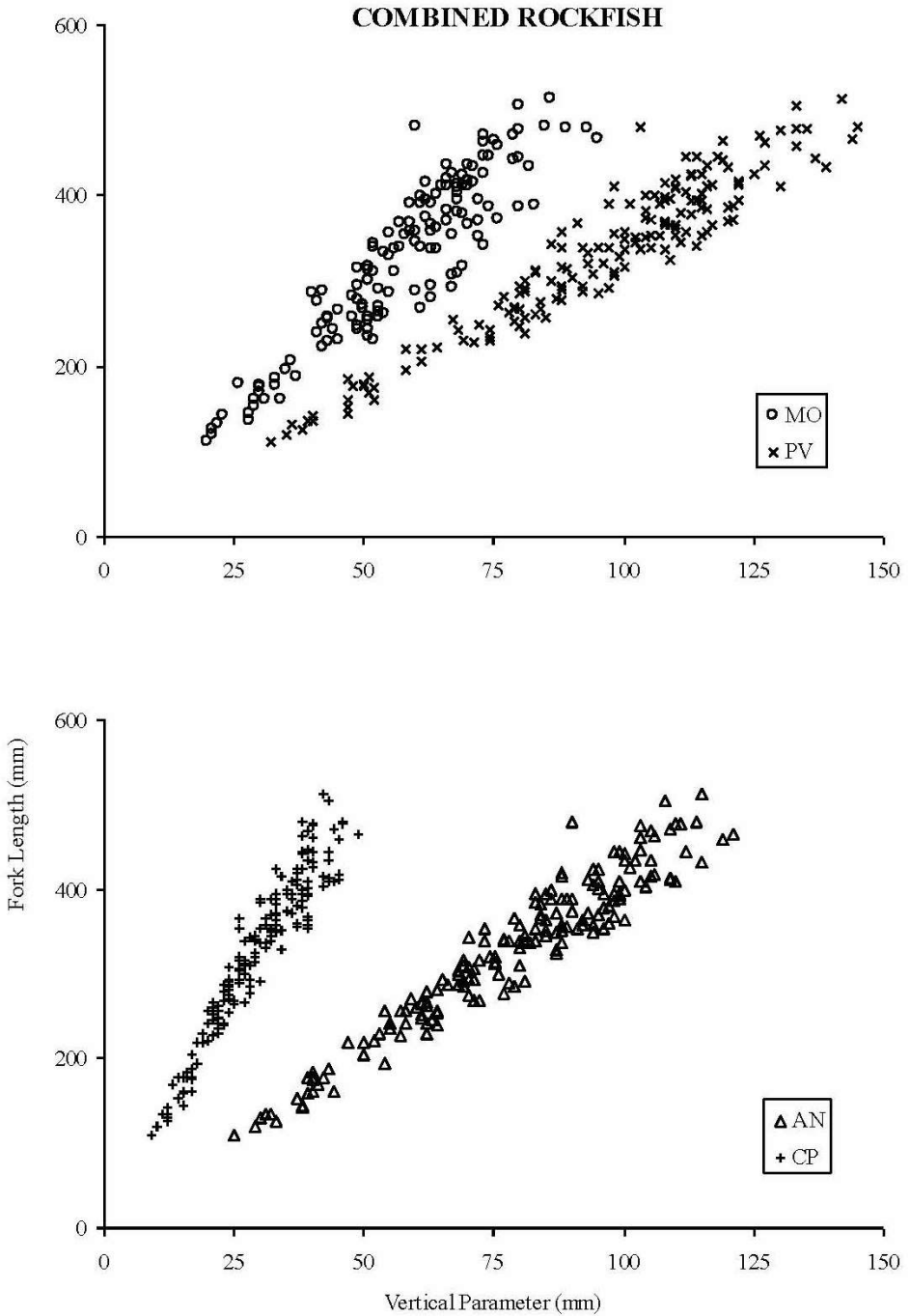
Figure 6. Scatter plots of non-transformed fork lengths and vertical parameters for combined rockfish (gopher rockfish, copper rockfish, black and yellow rockfish, yellowtail rockfish, quillback rockfish, black rockfish, vermilion rockfish, blue rockfish, China rockfish, canary rockfish, and olive rockfish). (MO = depth at mid-orbit; PV = depth at pelvic fin origin; AN = depth at anal fin origin; CP = least depth at caudal peduncle)

Table 1. Sample number, vertical size range, and regression equation values for predicting fork length from vertical parameters of kelp greenling, lingcod, black rockfish, blue rockfish, and combined rockfish (gopher rockfish, copper rockfish, black and yellow rockfish, yellowtail rockfish, quillback rockfish, black rockfish, vermilion rockfish, blue rockfish, China rockfish, canary rockfish, and olive rockfish). (MO = depth at mid-orbit; PV = depth at pelvic fin origin; AN = depth at anal fin origin; CP = least depth at caudal peduncle)

Regression: $Y=\exp(a)*X^b$, Y=Fork Length (mm), X=Vertical Parameter (mm)

Vertical Parameters/ Species	n^*	r	Vertical Parameter (mm)** min	max	Regression Values*** $\exp(a)$	b	$S_{y \cdot x}$
MO							
kelp greenling	28	0.995	14	51	10.960	0.898	3.368
lingcod	34	0.996	12	127	12.645	0.903	16.142
black rockfish	30	0.973	20	79	4.828	1.045	2.867
blue rockfish	25	0.977	21	89	7.937	0.925	3.023
rockfish spp.	143	0.946	20	95	5.880	0.990	15.347
PV							
kelp greenling	32	0.986	21	87	7.977	0.850	4.791
lingcod	35	0.997	15	195	12.026	0.842	17.991
black rockfish	34	0.993	32	133	3.276	1.011	3.582
blue rockfish	34	0.991	35	135	3.750	0.984	3.383
rockfish spp.	173	0.973	32	145	3.399	1.003	17.913
AN							
kelp greenling	32	0.990	21	78	7.652	0.885	4.640
lingcod	36	0.996	11	138	13.042	0.865	17.696
black rockfish	34	0.989	25	119	6.161	0.906	3.967
blue rockfish	34	0.981	29	111	4.427	0.978	3.336
rockfish spp.	175	0.975	25	121	4.609	0.978	18.536
CP							
kelp greenling	32	0.989	8	30	18.152	0.878	4.662
lingcod	35	0.994	5	54	24.138	0.922	16.343
black rockfish	34	0.979	9	45	20.170	0.809	4.350
blue rockfish	34	0.983	10	46	14.869	0.910	3.602
rockfish spp.	175	0.969	9	49	14.968	0.911	19.656

* Sample numbers were smaller for depth at mid-orbit because of flared branchiostegal rays obstructing measurement. Samples were also missing from some vertical parameters when fish escaped to water before all measurements were taken.

** Miniumum and maximum vertical parameters for combined rockfish (rockfish spp.) varied by species. Vertical measurements for combined rockfish are the minimum and maximum overall. The combined regression will be used for similarly shaped species until more specific regressions are available.

*** For nineteen samples, total length was measured instead of fork length. To include these samples in the regressions, fork lengths were converted from total length for eight black rockfish, four china rockfish, one copper rockfish, one gopher rockfish, and five quillback rockfish with equations provided by Echeverria and Lenarz (1984). Fork lengths for two lingcod were converted from total length with equations provided by Karpov and Kwiecien[1] (1988a).

DISCUSSION

We selected four vertical parameters based on their previous use by researchers, feasibility of obtaining precise measurements, and practicality of measuring these parameters from video data in the future. For example, in sample videos of live fish in their natural habitat, pelvic fin origin was easier to determine than was the posterior gill margin or the dorsal fin origin. Morphometrics widely used for a variety of taxa are depth at pelvic fin origin (e.g., Phillips 1957; Miller 1988; Chen and Shao 1996), depth at anal fin origin (e.g., Phillips 1957; Holt 1959; Laevastu 1965; Miller 1988; Chen and Shao 1996), and least depth at caudal peduncle (e.g., Phillips 1957; Holt 1959; Laevastu 1965; Miller 1988; Kottelat 1990; Chen and Shao 1996; Compagno 2001; Coelho and Erzini 2008). Systematists have measured body depth at the anterior margin of the orbit (Kottelat 1990) and from the orbital crest down through the center of the pupil (Holt 1959; Laevastu 1965); however, mid-orbit depth from the top of the head (North et al. 2002) was seen more easily in sample videos. Depth at mid-orbit was not measured when branchiostegal rays were locked in a flared position, obstructing measurement. We therefore had the fewest samples for this parameter (Table 1). This factor may also limit the utility of depth at mid-orbit as a predictor of length from videos of the anterior body region. Depth at mid-orbit and least depth at caudal peduncle lack defined reference marks, which may also increase the likelihood of error in measurements (Harvey et al. 2003). Another possible limitation is that these measurements are small relative to length. Nevertheless, the two parameters were observed in videos of the anterior and posterior body regions and were measured in anticipation of technological advancements improving video resolution or for applications using still photography.

We chose fork length because it is consistent with other protocols for monitoring marine fish species (e.g., Holliday et al.[2] 1987) and is practical for visual data. Extreme or maximum total length, measured to the end of the pinched tail (Holt 1959; Laevastu 1965; Anderson and Gutreuter 1983), has also been used as a standard (e.g., Holt 1959; Hubbs and Lagler 1959; Miller and Lea 1972; Karpov and Kwiecien[3] 1988b; Karpov et al. 1995) but was not practical for our study which included preserved specimens. Measurements for species in our study can be compared to standard length or extreme total length with conversion equations provided by Echeverria and Lenarz (1984) and Karpov and Kwiecien[1] (1988a). Natural total length is a useful alternative to fork length for video analysis. Conversions between standard length, fork length, and natural total length are available for many marine and fresh water fish species (Gaygusuz et al. 2006), but not for species reported here. The conversions are important for estimates of biomass because weight-length relationships for various species have been developed from different body length measurements. However, because many species in this study have lobed or squared tails, natural total length and fork length are identical. For species with variably forked tails, differences between fork length and natural or extreme total length may be negligible concerning the level of accuracy for biomass estimates. Lengths estimated using visual

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[2]Holliday, M., Deuel, D., and W. Scogen. 1987. Marine Recreational Fisheries Statistics Survey, Pacific Coast 1986. U.S. Department of Commerce, NOAA/NMFS Current Fisheries Statistics. No. 8393. 114 pp.

[3]Karpov, K. and G. Kwiecien. 1988b. Marine Recreational Fisheries Statistics Survey for Northern and Central California. Quarterly Report No. 19, January-March 1984. California Department of Fish and Game, Marine Resources Administrative Report No. 88-19. 281 pp.

survey by divers and submersible (Yoklavich et al. 2000, 2002; Love et al. 2000, 2006) most closely approximate fork length or natural total length but not extreme total length. Depending on the study comparison, fork lengths estimated using our methods can be converted to either standard length or extreme total length (Echeverria and Lenarz 1984; Karpov and Kwiecien[1] 1988a) or used as a proxy for natural total length.

Error terms of fork lengths tend to be proportional to the fork length. For this reason we used natural logarithm transformations (Snedecor and Cochran 1989). Variances in the transformed space are homogeneous, thereby meeting a basic assumption for linear regression. However, it should be noted that when anti-logged, transformations can result in a slightly negative bias in predicted values (fork lengths). Our lower size limit was likely to have avoided ranges exhibiting departure from linearity, which has been observed for some morphometrics in rockfish smaller than 110 mm in length (Chen 1971). If allometry existed, the data transformations also allowed for description of those relationships in linear terms (Huxley 1932; Martin 1949; Chen 1971; Ratnaswamy and Winn 1993; Bräger and Chong 1999; Zeidberg 2004). The variation we observed may be explained by geography, season, sex, measuring precision, or preservation method—factors that were assumed to have little or no effect on the regressions. Preservation can shrink fish variably depending on the solution, duration in solution, and morphometric parameter (Holt 1959). In a study on mackerel, body depth shrank more than body length in some solutions (Holt 1959). If preservation affected morphometric parameters similarly in our study, the predicted value (fork length) would be positively biased. Ideally, the regressions should be calculated from fresh fish only. However, we were unable to collect sufficient sample numbers and sizes from recreational and commercial catch alone, requiring an additional 45% preserved specimens. Fresh and preserved specimens have been combined for other morphometric analyses of rockfish (Chen 1971). The high correlations (Table 1) we observed indicate that any biases were minimal.

We had sufficient samples to analyze kelp greenling, lingcod, black rockfish, and blue rockfish (Table 1). For other species, either our sample number or the length range was inadequate to calculate regressions. However, for our work, lengths by species are still needed to estimate biomass from videos. We therefore combined data from several rockfish species to calculate relationships to be used until more specific regressions are available. Although the combined regressions include variable rockfish body shapes, from fusiform (e.g., olive rockfish) to more deep-bodied species (e.g., gopher rockfish), they are useful for estimation of overall biomass in our study areas. Biomass estimates may then be updated by species as more regressions are calculated.

Use of these regressions for estimating length and weight is supported by high correlations (Table 1). When possible, predicted fork lengths may also be averaged from more than one vertical parameter regression. While absolute accuracy may decrease with larger fish, the level of discrimination should be appropriate for age structure and biomass estimates from videos when lengths are corrected for camera distance and tilt angle (Figure 7). These regressions may also be used to update existing analyses of underwater videos, in which the most ideal views may be of anterior, middle, or posterior body regions.

Future research should evaluate accuracy and precision of the regressions for estimating lengths from videos of live, swimming fish with known body measurements. Evaluations should also include estimates by experienced divers trained to estimate size by eye, a technique widely used for visual sampling (e.g., Harvey et al. 2002a, b; Yoklavich et al. 2000, 2002). True mean length is likely to be underestimated in such surveys because of sinusoidal

a = height as seen on screen $\cos(\alpha) = a/c$
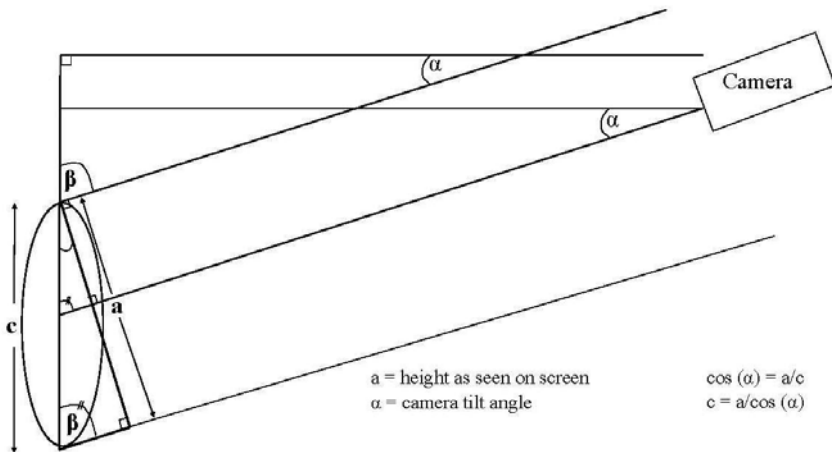α = camera tilt angle $c = a/\cos(\alpha)$

Figure 7. Geometry and mathematical proofs for estimating vertical parameters of fish observed in underwater videos along the California coast. (a = height of fish as observed in camera = side of triangle adjacent to angle alpha); c = actual height of fish = hypotenuse of right triangle)

fish movement (Naiberg et al. 1993; Harvey et al. 2002a, 2003; Rochet et al. 2006) and the unknown angle relative to the viewer (Naiberg et al. 1993). However, accuracy of vertical parameters depends on video clarity, regression error, and accurate estimation of camera angle.

ACKNOWLEDGMENTS

LITERATURE CITED

Anderson, R.O., and S.J. Gutreuter. 1983. Length, weight, and associated indices. Pages 283-324 *in* Fisheries Techniques, Nielsen, L.A. and D.L. Johnson, eds. American Fisheries Society, Bethesda, Maryland.

Bräger, S. and A.K. Chong. 1999. An application of close range photogrammetry in dolphin studies. Photogrammetric Record 16:503-517.

Cadiou, J., V. Trenkel, and M. Rochet. 2004. Comparison of several methods for *in situ* size measurements of moving animals. Pages 438-444 *in* Proceedings of The Fourteenth International and Polar Engineering Conference, Toulon, France, May 23-28, 2004.

Chen, L-C. 1971. Systematics, variation, distribution, and biology of rockfishes of the subgenus Sebastomus (Pisces, Scorpaenidae, Sebastes). Bulletin of the Scripps Institute of Oceanography, University of California Press 18:1-104.

Chen, I-S., and K-T. Shao. 1996. A taxonomic review of the gobiid fish genus *Rhinogobius* Gill, 1859 from Taiwan, with descriptions of three new species. Zoological Studies 35:200-213.

Coelho, R. and K. Erzini. 2008. Identification of deep water lantern sharks (Chondrichthyes: Etmopteridae) using morphometric data and multivariate analysis. Journal of the Marine Biological Association of the United Kingdom 88:199-204.

Compagno, L. 2001. Sharks of the World: An annotated and illustrated catalogue of shark species known to date. Volume 2: Bullhead, mackerel and carpet sharks (Heterodontiformes, Lamniformes and Orectolobiformes). FAO Species Catalogue for Fishery Purposes. 269 pp.

Dawson, S.M., Chessum, C.J., Hunt, P.J. and E. Slooten. 1995. An inexpensive, stereo-photographic technique to measure sperm whales from small boats. Report of the International Whaling Commission 45:431-436.

Echeverria, T. and W.H. Lenarz. 1984. Conversions between total, fork, and standard lengths in 35 species of *Sebastes* in California. Fishery Bulletin 82:249-251.

Gaygusuz, O., Gursoy, C., Ozolug, M., Tarkan, A.S., Acipinar, H., Bilge G., and Filiz, H. 2006. Conversions of total, fork and standard length measurements based on 42 marine and freshwater species from Turkish waters. Turkish Journal of Fisheries and Aquatic Sciences 6:79-84.

Harvey, E. and M. Shortis. 1996. A system for stereo-video measurement of subtidal organisms. Marine Technical Society Journal 29:10-22.

Harvey, E., Fletcher, D., and M. Shortis. 2001a. A comparison of the precision and accuracy of estimates of reef-fish lengths made by divers and a stereo-video system. Fishery Bulletin 99:63-71.

Harvey, E., Fletcher, D., and M. Shortis. 2001b. Improving the statistical power of visual length estimates of reef fish: a comparison of estimates determined visually by divers with estimates produced by a stereo-video system. Fishery Bulletin 99:72-80.

Harvey, E., Fletcher, D., and M. Shortis. 2002a. Estimation of reef fish length by divers and by stereo-video. A first comparison of the accuracy and precision in the field on living fish under operational conditions. Fisheries Research 57:257-267.

Harvey, E., Shortis, M., Stadler, M., and M. Cappo. 2002b. A comparison of the accuracy and precision of measurements from single and stereo-video systems. Marine Technical Society Journal 36:38-49.

Harvey, E., Cappo, M., Shortis, M., Robson, S., Buchanan, J., and P. Speare. 2003. The accuracy and precision of underwater measurements of length and maximum body depth of southern bluefin tuna (*Thunnus maccoyii*) with a stereo-video camera system. Fisheries Research 63:315-326.

Holt, S.J. 1959. Report of the international training center on the methodology and techniques of research on mackerel (*Rastrelliger*). Food and Agriculture Organization of the United Nations ETAP Report 1095. 195 pp.

Hubbs, C.L. and K.F. Lagler. 1958. Fishes of the Great Lakes Region. Cranbrook Institute of Science Bulletin 26, Bloomfield Hills, Michigan. 213 pp.

Huxley, J.S. 1932. Problems of relative growth. Methuen, London. 276 pp.

Karpov, K.A., D.P. Albin, and W.H. Van Buskirk. 1995. The marine and recreational fishery in northern and central California: A historical comparison (1958-1986), status of stocks (1980-1986), and effects of changes in the California current. California Department of Fish and Game, Fish Bulletin 176. 192 pp.

Klimley, A. and S. Brown. 1983. Stereophotography for the field biologist: measurement of lengths and three-dimensional positions of free-swimming sharks. Marine Biology 74:175-185.

Kottelat, M. 1990. Indochines nemacheilines: A revision of nemacheiline loaches (Pisces: Cypriniformes) of Thailand, Burma, Laos, Cambodia, and southern Viet Nam. Verlig Dr. Friedrich Pfiel, Munchen, F.R. Germany. 262 pp.

Laevastu, T. 1965. Manual of methods in fisheries biology. Food and Agriculture Organization of the United Nations, Rome, Italy. Manual in Fishery Science 9:1-51.

Love, M., Caselle, J., and L. Snook. 2000. Fish assemblages around seven oil platforms in the Santa Barbara Channel area. Fishery Bulletin 98:96-117.

Love, M., Schroeder, D., Lenarz, B., and G. Cochrane. 2006. Gimme Shelter: The importance of crevices to some fish species inhabiting a deeper-water rocky outcrop in southern California. California Cooperative Oceanic Fisheries Investigations Reports 47:119-126.

Martin, W.R. 1949. The mechanics of environmental control of body form in fishes. University of Toronto Studies, Biological Series 58. University of Toronto Press, Canada. 81 pp.

Miller, P. 1988. New species of *Coryrogobius*, *Thorogobius*, and *Wheelerigobius* from West Africa (Teleosti: Gobiidae). Journal of Natural History 22:1245-1262.

Miller, D. and R. Lea. 1972. Guide to the Coastal Marine Fishes of California. California Fish Bulletin 157:249 pp.

Naiberg, A. Petrell, R., Savage, C., and T. Neufeld. 1993. Non-invasive fish size assessment method for tanks and sea cages using stereo-video. Pages 372-381 *in* Techniques for Modern Aquaculture, Wang, J.K., ed. American Society for Agricultural Engineering.

North, J.A., Farr, R.A., and P. Vescei. 2002. A comparison of meristic and morphometric characters of green sturgeon *Acipenser medirostris*. Journal of Applied Ichthyology 18:234-239.

Petrell, R., Shi, X., Ward, R., Naiberg, A., and C. Savage. 1997. Determining fish size and swimming speed in cages and tanks using simple video techniques. Aquacultural Engineering 16:63-84.

Phillips, J. 1957. A Review of the Rockfishes of California (Family Scorpaenidae). California Fish Bulletin 104:158 pp.

Ratnaswamy, M. and H.E. Winn. 1993. Photogrammetric estimates of allometry and calf production in fin whales, *Balaenoptera physalus*. Journal of Mammalogy 74:323-330.

Robins, C., Polacheck, T., Preece, A., and Caton, A. 2000. Southern bluefin tuna fishery. Pages 159-168 *in* A. Caton and K. McLoughlin, editors, Fishery Status Reports 1999: Resource Assessments of Australian Commonwealth Fisheries. Bureau of Rural Sciences, Canverra, Australia.

Rochet, M., J. Cadiou, and V.M. Trenkel. 2006. Precision and accuracy of fish length measurements obtained with two visual underwater methods. Fishery Bulletin 104:1-9.

Snedecor, G. W. and W. G. Cochran, 1989. Statistical Methods, 8th edition. Iowa State University Press, Ames, Iowa.

Yoklavich, M., Greene, H., Cailliet, G., Sullivan, D., Lea, R., and M. Love. 2000. Habitat associations of deep-water rockfishes in a submarine canyon: an example of a natural refuge. Fishery Bulletin 98:625-64.

Yoklavich, M., Cailliet, G., Lea, R.N., Greene, H.G., Starr, R., De Marignac, J., and J. Field. 2002. Deepwater habitat and fish resources associated with the Big Creek Marine Ecological Reserve. CalCOFI Report Volume 43:120-140.

Zeidberg, L.D. 2004. Allometry measurements from *in situ* video recordings can determine the size and swimming speeds of juvenile and adult squid *Loligo opalescens*. Journal of Experimental Biology 207:4195-4203.

THE USE OF EASTERN SACRAMENTO VALLEY VERNAL POOL HABITATS BY GEESE AND SWANS

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ABSTRACT

We studied the fall-winter use of Sacramento Valley high-terrace vernal pools and associated grassland habitats by geese and swans from November 1999 through March 2003.

During each of nine diurnal and six nocturnal (1999-2000 field season only) surveys, we recorded the presence or absence of each species and subspecies, as well as flock sizes, habitats used, and activity patterns. Although all goose and swan species and most subspecies that winter in the Central Valley were observed using study area habitats, lesser Canada/Taverner's cackling geese, *Branta canadensis parvipes/Branta hutchinsii taverneri*, Ridgway's cackling geese, *B. h. minima*, and western Canada geese, *B. c. moffitti*, were observed most regularly and in the greatest numbers. In general, Canada and cackling geese (hereafter white-cheeked geese) used study area habitats from November through March, with regular use by large flocks of small and mid-sized subspecies in December and January. Smaller numbers of western Canada geese used study area habitats from December through the end of March, with the largest flocks occurring from late December through February. Monthly occurrence and maximum flock size values for lesser Canada/Taverner's cackling geese differed significantly throughout this 4-year study, although changes in these variables in successive months did not. Monthly changes in these variables for all other white-cheeked geese were insignificant. Following their arrival in November and early December, white-cheeked geese used artificial stock ponds as nocturnal roost sites and then departed for disjunct foraging habitats during the day. Small and mid-sized subspecies roosted primarily on vernal pools, beginning in late December or January, following the onset of ponding; most roosting western Canada geese continued to use stock ponds through the end of March.

With the growth of herbaceous vegetation beginning in late December or January, small and mid-sized white-cheeked geese shifted to a general pattern of day-long grazing activities on study area pastures. This regular and predictable shift suggests a pattern of long-term traditional use. We believe, therefore, that the protection of these remnant high-terrace vernal pool landscapes may be critical to the maintenance of California's small and mid-sized white-cheeked goose populations throughout the winter, during spring migration, and also to their success during the subsequent nesting season.

INTRODUCTION

The loss of North American wetland habitats since the 1800's due to agricultural expansion and urbanization resulted in long-term continental population declines in waterfowl (Anatidae) (Baldassare and Bolen 1994). A series of droughts throughtout the prairies of the United States and Canada beginning in the 1970's along with changing agricultural practices led to further declines in many duck populations (e.g., northern pintails) (Miller and Duncan 1999, Fleskes and Gilmer 2004). However, since the development and implementation of the North American Waterfowl Management Plan in 1986, most waterfowl populations have recovered dramatically.

Up to 60% of the waterfowl migrating down the Pacific Flyway during the fall use Central Valley (CV) wetlands (Heitmeyer et al. 1989), with the majority of these migrants wintering in the Sacramento Valley. Only 5% of California's historic wetlands still exist (Heitmeyer et al. 1989, Holland 1998), and of these wetlands, high-terrace and alkali vernal pools are among the rarest and least studied (Bogiatto and Karnegis 2006, Silveira 2000). The use of Sacramento Valley vernal pools by waterfowl and other waterbirds has been well documented (Grinnell et al.1930, Baker et al. 1992, The Nature Conservancy 1994, Silveira 1998, Silveira 2000), although only a single study focuses on the use of high-terrace pools by ducks (Bogiatto and Karnegis 2006), and none document the use of these habitats by geese and swans.

The objectives of our study were to (1) describe the goose and swan community using eastern Sacramento Valley high-terrace vernal pools and associated uplands during the fall and winter, (2) determine seasonal patterns of occurrence and flock sizes for each taxon, (3) describe the daily activity patterns of each taxon, and (4) describe the specific habitat types used by each taxon.

STUDY AREA

Our study area included the vernal pools and grasslands on the original 619-ha parcel of The Nature Conservancy's (TNC) Vina Plains Preserve (VPP), located east of State Highway 99, and south of Lassen Road, 21 km north of Chico in southern Tehama County, California (122:03:10W 39:55:59N) (Fig. 1). This vernal pool complex lies on a terrace between the foothills of the Cascade Range and the floodplain of the Sacramento River. A subterranean durapan, formed from the consolidation of eroded sediments from the Tuscan Basalt Formation, prevents water percolation and causes rapid accumulation of water in the heavy clay loam or silt-lined pool basins (TNC 1994). This parcel of the preserve consists of four fenced pastures, each containing numerous pools surrounded by an upland community dominated by native and exotic grasses and forbs. All pastures are grazed by cattle on a rotational basis, beginning in late fall, and historically, TNC has used prescribed burns to control exotic grasses such as medusa head, *Taeniatherum caput-medusae*. Our study area also included the two southern-most pastures (472 ha) of the Earl Foor Ranch Conservation Area (EFRCA), located directly north of Lassen Road which forms the northern border of the VPP (Fig. 1). These pastures also contain numerous vernal pools as well as several artificial stock ponds for cattle. EFRCA stock ponds generally contain water by October, well in advance of vernal pool ponding (Table 1). Like the VPP, EFRCA pastures, also dominated by exotic and native grasses and forbs, are rotationally grazed by cattle.
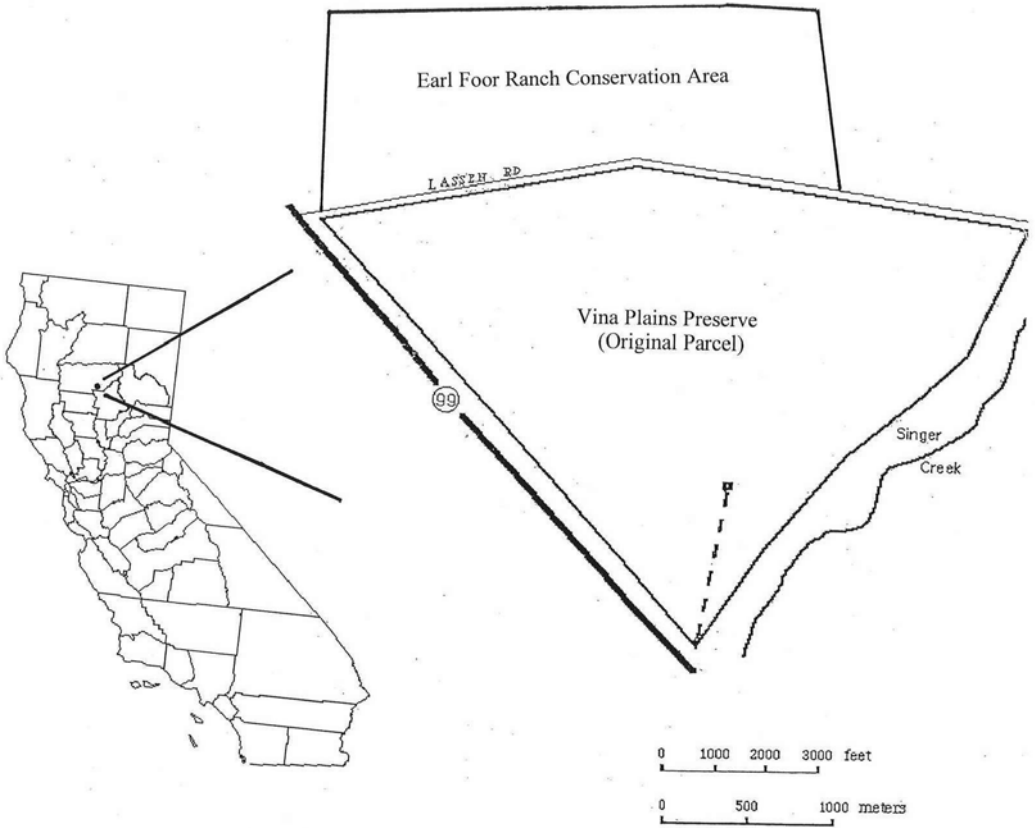
Figure 1. Location of the Vina Plains Study Area in Tehama County, California.

METHODS

We studied the use of vernal pool and associated uplands by geese and swans during the fall and winter months, from November 1999 through March 2003. During the 1999-2000 field season, we conducted 12 - 15 3-hr field surveys each month. Survey time periods were as follows: 1-hr post-sunset – 4-hr post-sunset; 4-hr pre-sunrise – 1-hr pre-sunrise; 1-hr pre-sunrise – 2-hr post-sunrise; 3-hr post-sunrise – 6-hr post-sunrise; and 2-hr pre-sunset – 1-hr post-sunset. We attempted to cover all survey periods equally with three surveys each per month, and with a maximum of one survey per day.

Diurnal and nocturnal (auditory) surveys were conducted along Hwy. 99 and Lassen Road by vehicle, whereas remote portions of the study area were surveyed on foot. During field surveys, we used binoculars, two 20-60X Kowa spotting scopes, head lamps, and topographic maps of the study area.

Data collected during field surveys included species and subspecies identification, flock location, the number of individuals per flock, flock arrival and departure times, the most common flock behavior within each habitat, and the presence or absence of cattle by pasture.

Table 1. Ponding chronology for the vernal pools on the Vina Plains, Tehama County, California, Fall 1999 – Winter 2003.

Field season	Initial ponding[1]	Desiccation[2]
1999-2000	19-21 Jan. 2000	8-10 Apr. 2000
2000-2001	10-12 Jan. 2001	19 Mar. – 4 Apr. 2001
2001-2002	23-25 Nov. 2001	Still ponded – 15 Apr. 2002
2002-2003	13-14 Dec. 2002	Still ponded – 16 Apr. 2003

[1] Most large vernal pools (surface area $\geq 15,000$ m^2) ponded

[2] Most large vernal pools desiccated

We present maximum flock sizes and percent occurrence values by month, with percent occurrence defined as the percentage of survey-days per month in which each taxon was present, and with maximum flock size defined as the maximum number of individuals from each taxon observed during a 3-hr survey. We determined flock sizes through complete counts or collaborative estimates by members of the survey crew.

Numbers of geese in flocks detected during nocturnal surveys were quantified during return visits to the study area at sunrise.

We tested for significant patterns of change in monthly occurrence and maximum flock size for each white-cheeked goose subspecies using the Friedman Two-Way Analysis of Variance by Ranks test, the null hypothesis being that monthly values throughout this 4-yr study were the same. When monthly patterns of change were significant, we used the Wilcoxon-Mann-Whitney test to compare values in successive months (e.g., November vs December, December vs January, etc.), the null hypothesis being that percent occurrence and maximum flock size values in successive months were the same.

We eliminated nocturnal surveys from our protocol beginning in Fall 2000, because our data from 1999-2000 suggested that nocturnal use of the Vina Plains was limited to roosting activity on vernal pools and stock ponds. As a result, to control for survey time periods among years, we used only data collected during the three diurnal sampling periods for our statistical analyses.

RESULTS

Goose and Swan Taxa Observed

Except for the Aleutian cackling goose, *Branta hutchinsii leucopareia*, and the tule white-fronted goose, *Anser albifrons elgasi*, all goose and swan taxa which regularly winter in the Sacramento Valley were observed using habitats on the Vina Plains (Table 2). However, two Canada goose subspecies, *Branta canadensis parvipes*, the lesser Canada goose, and *B. c. moffitti*, the western Canada goose, as well as Ridgway's race (Mlodinow 2008) of the cackling goose, *B. h. minima*, were the most frequently observed and abundant goose taxa throughout this study (Tables 2 and 3, Fig. 2). Also, flocks of lesser Canada geese often

Table 2. Percent occurrence values for geese and swans on the Vina Plains, Tehama County, California, November 1999 - March 2003.

TAXA	% Occurrence (Frequency)				
	Nov	Dec	Jan	Feb	Mar
Tundra Swan (*Cygnus columbianus*)	0 (0)	3.2 (1)	9.7 (3)	10.7 (3)	6.5 (2)
Greater White-fronted Goose (*Pacific subspecies*) (*Anser albifrons frontalis*)	0 (0)	12.9 (4)	9.7 (3)	7.1 (2)	9.7 (3)
Snow Goose (*Chen caerulescens*)	0 (0)	0 (0)	0 (0)	0 (0)	6.5 (2)
Ross' Goose (*Chen rossii*)	13.6 (3)	3.2 (1)	3.2 (1)	0 (0)	0 (0)
Western Canada Goose (*Branta canadensis moffitti*)	4.5 (1)	19.4 (6)	51.6 (16)	75.0 (21)	74.2 (23)
Lesser Canada Goose (*B.c. parvipes*) / Taverner's Cackling Goose (*Branta hutchinsii taverneri*)[1]	50.0 (11)	71.0 (22)	71.0 (22)	10.7 (3)	0 (0)
Ridgeway's Cackling Goose (*B.h. minima*)	18.2 (4)	35.5 (11)	25.8 (8)	10.7 (3)	3.2 (1)
Cackling Goose (*B.h. taverneri ?*) X Greater White-fronted Goose	0 (0)	9.7 (3)	0 (0)	0 (0)	0 (0)

[1] The 4-yr pattern of monthly change in % occurrence is significant (X^2_1 = 10.105, df = 4, p = .041),); results of month-to-month comparisons were not significant (all p-values > .05).
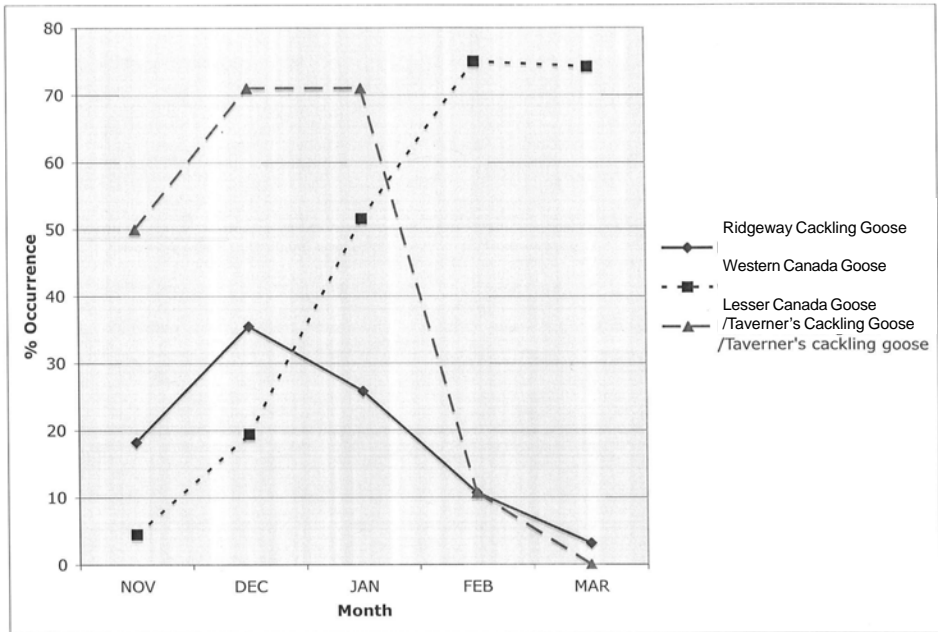
Figure 2. Seasonal occurrence of Canada and cackling geese on the Vina Plains, Tehama County, California, Fall 1999 – Spring 2003.

included individuals which were morphologically consistent with Taverner's cackling geese, *B. h. taverneri*, which tend to be somewhat smaller and darker than lesser Canadas (Yocom 1972, Johnson et al. 1979, Bellrose 1980).

Nevertheless, although genetically distinct (Shields and Wilson 1987a, b, Van Wagner and Baker 1990, and others), the lack of distinct morphological features makes the separation of these two geese all but impossible in the field (pers. comm., J. S. Sedinger, University of Alaska, Fairbanks, pers. comm., P. F. Springer, retired, Cooperative Research Unit, Humboldt State University, Arcata). Therefore, because of this taxonomic ambiguity, we combined data for lesser Canada and Taverner's cackling geese, and will refer to them collectively.

Our definitive identification of the lesser Canada goose was made possible through the tracing of a neck-banded bird observed in January 2001 (blue collar with the alphanumeric code MF6). This particular goose, a 3.5-year-old female, was banded near Anchorage, Alaska in 1998 (pers. comm., T. Rothe, Waterfowl Coordinator, Alaska Department of Fish and Game, Anchorage).

Greater white-fronted geese (Pacific race), *Anser albifrons frontalis*, snow geese, *Chen caerulescens*, Ross's geese, *C. rossii*, and tundra swans, *Cygnus columbianus*, occurred infrequently throughout this study (Tables 2 and 3). Individuals or small numbers of these goose taxa were generally observed within flocks of grazing or roosting white-cheeked geese, and except for one swan observed loafing on an EFRCA stock pond, all swan observations were of single or small numbers of birds foraging or loafing on VPP vernal pools.

We also observed two hybrid geese which appeared to be crosses between greater white-fronted and cackling geese (Tables 2 and 3). The hybrids, which shared morphological

Table 3. Maximum flock size for geese and swans on the Vina Plains, Tehama County, California, November 1999 - March 2003.

TAXA	Maximum Flock Size				
	Nov	Dec	Jan	Feb	Mar
Tundra Swan (*Cygnus columbianus*)	0	12	42	26	7
Greater White-fronted Goose (*Pacific subspecies*) (*Anser albifrons frontalis*)	0	1	11	6	9
Snow Goose (*Chen caerulescens*)	0	0	0	0	10
Ross' Goose (*Chen rossii*)	20	1	0	0	0
Western Canada Goose (*Branta canadensis moffitti*)	1	102	69	51	14
Lesser Canada Goose (*B.c. parvipes*) / Taverner's Cackling Goose (*Branta hutchinsii taverneri*)[1]	330	1200	1300	25	0
Ridgeway's Cackling Goose (*B.h. minima*)	230	475	475	12	2
Cackling Goose (*B.h. taverneri ?*) X Greater White-fronted Goose	0	2	0	0	0

[1] The 4-yr pattern of monthly change in maximum flock size is significant ($X^2_r = 12.05$, df = 4, p = .019); results of month-to-month comparisons were not significant (all p-values > .05).

features with both species, were observed during three surveys in December 2002, and always in close association with two other geese, one adult white-fronted goose and another bird that was morphologically consistent with Taverner's cackling goose.

Our focus thoughout the remainder of this paper will be on white-cheeked geese, as they were the most regularly occurring taxa on the Vina Plains.

Chronology, Percent Occurrence, and Flock Size

Lesser Canada/Taverner's cackling geese were the most abundant and among the most regularly occurring taxa using study area habitats during the fall and winter (Tables 2 and 3, Fig. 2). These mid-sized white-cheeked geese were observed from November through February, although they occurred most regularly in late December and January. Although the 4-yr pattern of change in monthly occurrence for these geese was significant ($p = .041$), differences in values from successive months were not (all p-values > .05). Monthly maximum flock sizes, which ranged from 0 – 1300 geese, also showed a significant pattern of change ($p = .019$), although month-to-month comparisons did not (all p-values > .05).

Western Canada geese were observed on the Vina Plains from November through March, although they occurred most regularly from January through the end of our field season in late March (Table 2, Fig. 2). The 4-yr pattern of monthly changes in occurrence and maximum flock size were not significant. Maximum flock sizes ranged from 0 – 102 geese, although flocks of 100 or more birds were observed only in December 2001 (Table 3).

Ridgway's cackling geese, the smallest of the white-cheeked geese, used Vina Plains habitats from November though March, although we observed them most regularly in late
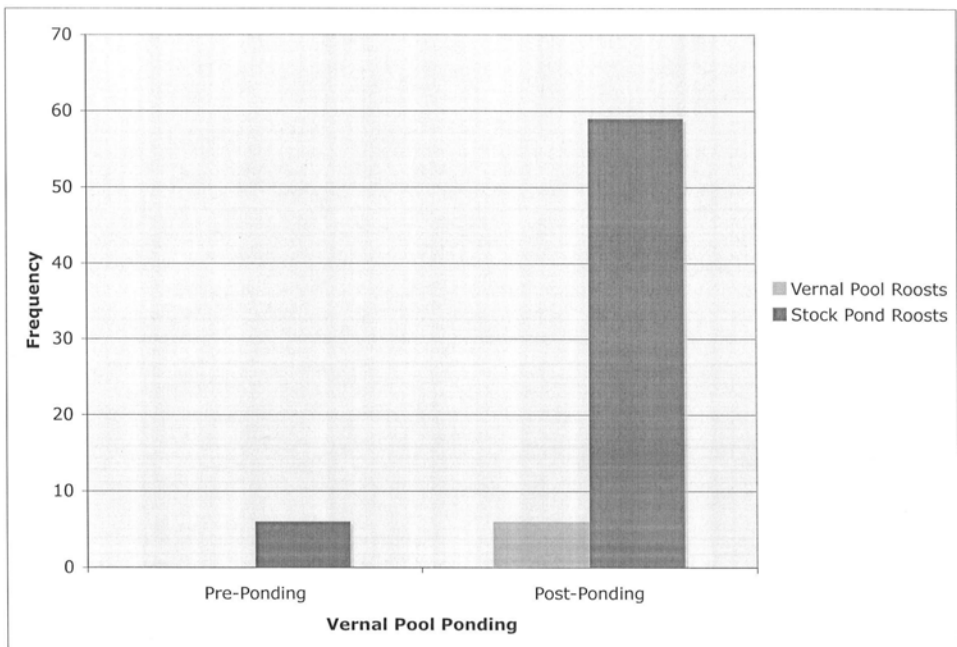
Figure 3. Use of Vina Plains vernal pools and artificial stock ponds as roost sites by western Canada geese, Fall 1999-Spring 2003.
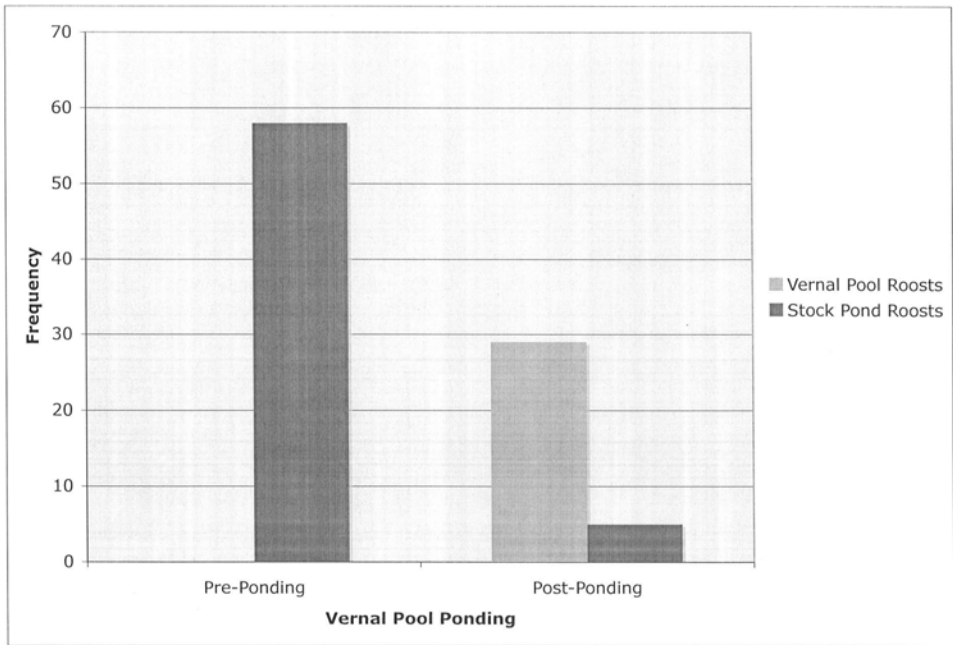
Figure 4. Use of Vina Plains vernal pools and artificial stock ponds as roost sites by Ridgway's cackling geese and lesser Canada/Taverner's cackling geese, Fall 1999 – Spring 2003.

December and January (Table 2, Fig. 2). Maximum flock sizes ranged from 0 – 475 birds, although flocks of over 100 birds were observed only in November and December 2002, and January 2003 (Table 3). The 4-yr pattern of monthly changes in percent occurrence and maximum flock size were not significant.

Habitat Use and Daily Activity Patterns

In general, the daily activity pattern of white-cheeked geese included nighttime roosting activities on artificial stock ponds and vernal pools (Figs. 3 and 4), as well as periods of morning and afternoon grazing on pastures. We also documented some use of study area ponds and pools as midday roost sites.

More specifically, geese arrived at night roost ponds from 14-48 min post-sunset, with the earliest arrival times recorded in January and February and on cloudy evenings. Morning departure times from night roosts ranged from 14 min pre-sunrise to 52 min post-sunrise, with the earliest departures recorded in November and early December.

These early morning departures and late evening arrivals in the fall are consistent with diurnal movements to disjunct foraging habitats (Raveling 1969, Raveling et al. 1972, Owen 1980). The latest morning departures were recorded from late December through January as well as on overcast mornings. Arrival and departure times were more or less consistent for all white-cheeked geese.

Following morning departures from roost ponds, white-cheeked geese grazed for brief periods of 15-45 min on study area pastures throughout November and early December, with lengthy, sometimes day-long departures to foraging habitats disjunct from the Vina Plains. We believe that geese were likely moving to agricultural areas in order to take

advantage of waste grains such as rice and corn. A shift to more extended periods of grazing on Vina Plains pastures occurred in late December or early January following the start of the growing season. In general, white-cheeked geese grazed Vina Plains pastures for 2-3 hours in the morning after leaving the night roost, and for 2-3 hours in the afternoon before returning to stock pond or vernal pool night roosts. It should be noted that 46 of 47 (97.9%) observations of foraging geese occurred on pastures previously or concurrently grazed by cattle.

The use of stock ponds or vernal pools as midday roost sites by small and mid-sized white-cheeked geese was minimal, with more consistent use by western Canada geese, which we often observed grazing near their roost ponds or in pastures located 1-2 km from roost ponds; they generally returned to their night roost pond or another nearby pond during the midday hours. These geese arrived at midday roosts from 3-3.5-hr post-sunrise, and then moved off to afternoon foraging sites from 2-2.5-hr pre-sunset. From late February through March, most of the western Canada geese spent the entire day on or adjacent to EFRCA stock ponds (Fig. 3).

Small and mid-sized white-cheeked geese did not return to their night roosts during the midday in November and early December. Beginning in late December, use of midday roost ponds by these smaller taxa was more variable, with flocks often remaining on Vina Plains pastures throughout the day. This pattern of prolonged, often day-long grazing (hyperphagia) is thought to facilitate the accumulation of endogenous body reserves necessary for migration and reproduction (McLandress and Raveling 1981).

DISCUSSION

The low numbers and irregular occurrence of tundra swans, greater white-fronted geese, snow geese, and Ross's geese on these high-terrace landscapes (Table 2) is not surprising. Large populations of these species (Scott 1972, Owen 1980) roost primarily within large Sacramento Valley wetland complexes, and feed mostly on rice and other waste grains in nearby agricultural fields throughout the fall and winter (McLandress 1979, Bellrose 1980, Owen 1980).

Prior to the onset of vernal pool ponding (Table 1), use of study area habitats by white-cheeked geese was limited to roosting activities on EFRCA stock ponds.

Small to mid-sized subspecies began using vernal pools as roost sites immediately following the beginning of ponding (Fig. 4), with a subsequent shift to diurnal grazing on Vina Plains pastures. This shift in foraging behavior is likely due to the availability of high protein and more easily digestible grasses and forbs at the onset of the growing season (Raveling 1979a, Raveling 1979b, Raveling and Zezulak 1991).

Western Canada geese used Vina Plains habitats from December through March, although their numbers were relatively low (Tables 2 and 3, Fig. 2). The largest flocks occurred from late December through February, with low numbers of what were likely local, non-migratory individuals remaining on the study area through late March.

As these large geese are more aquatic than smaller white-cheeked geese (Owen 1980), the bulk of their population tends to winter in agricultural areas of the Sacramento Valley, roosting within large managed marshlands, on lakes and reservoirs, and along rivers.

Although they were occasionally observed on or near vernal pools, western Canada geese continued to use EFRCA stock ponds as roost sites following vernal pool ponding

(Table 1, Fig. 3), with most grazing activity occurring in pastures adjacent to these culturally maintained ponds.

Numbers of up to several hundred Ridgway's cackling geese used Vina Plains vernal pools and pastures, with the most regular use and the largest flocks occurring in late December and January (Tables 2 and 3, Fig. 2). In 1984, when their population was at an all-time low, it was estimated that up to 85% of these birds wintered in the CV (Mlodinow et al. 2008). The current figure is at 5% of an estimated 193,300 geese, with the remaining 95% wintering in the lower Columbia River Valley of Washington and Oregon, and the Willamette Valley of western Oregon (Mlodinow et al. 2008, USFWS 2008, USFWS 1999). According to Raveling (1978), these sorts of shifts often suggest changes in winter resource availability. Although reasons for this migratory "short stopping" remain unclear, it is thought that this particular shift may have been stimulated by drought conditions in California during the period from 1986-1992, as well as an increase in winter forage availability (e.g., ryegrass agriculture) in areas of Washington and Oregon (USFWS 1999). Based on this well documented shift in winter distribution, coupled with the historic loss of California's vernal pool landscapes (Holland 1978, Holland 1998), we suspect that the use of these habitats by Ridgway's cackling geese was much greater in the past.

Large flocks of up to 1300 lesser Canada/Taverner's cackling geese were present on the Vina Plains from December through January (Tables 2 and 3, Fig. 2). Most observed roosting activities of these geese as well as Ridgway's cackling geese shifted from stock ponds to vernal pools following the onset of ponding (Fig. 4). Based on current estimates, approximately 10,000 lesser Canada/Taverner's cackling geese winter in central California (Mlodinow et al. 2008). As these birds likely move into California from late October though mid November, and as their northern migratory movements have been documented in the Columbia River Basin as early as mid February, our occurrence and flock size data suggest that Sacramento Valley vernal pool habitats provide resources to a significant portion of this wintering population(s).

Traditional use of migration routes as well as wintering, staging, and breeding habitats has been well documented for geese and other waterfowl (Hochbaum 1955, Raveling 1979c, Owen 1980). We believe that the regular and predictable shift by small and mid-sized white-cheeked geese from artificial stock ponds to vernal pools following the onset of ponding, and from disjunct foraging sites to study area pastures is consistent with a pattern of long-term traditional use. Also, it is likely that usage of these habitats would have been greatest from initial pool ponding in late December or January until spring migration.

Additionally, based upon their continued use of relatively deep stock ponds throughout the winter and spring, we think it likely that historic and prehistoric use of these shallow vernal pools by western Canada geese would have been minimal.

Traditional roost sites are thought to serve as important reunification and communication centers for goose family units and subflocks (Raveling 1969, Raveling 1970). Considering that the selection of a roost site is likely based on that pond's ability to provide adequate protection from predators and harsh environmental conditions, it can be argued that maintaining the quality of traditional roosting and foraging habitats, such as those on the Vina Plains, may be critical to the maintenance of California's small and mid-sized white-cheeked goose populations during the winter, spring migration, and also to their success during the subsequent nesting season. Accordingly, we suggest that large, intact vernal pool landscapes on elevated terraces along the east side of the Sacramento Valley should be protected as part of a long-term management strategy for both small and mid-sized

white-cheeked geese. Although we did not test for the effects of cattle grazing on the selective use of upland habitats by these geese, our data suggest that traditional levels of rotational grazing on Vina Plains pastures should be maintained

ACKNOWLEDGMENTS

LITERATURE CITED

Baker, W. S., F. E. Hayes, and L. W. Lathrop. 1992. Avian use of vernal pools at the Santa Rosa Plateau Preserve, Santa Ana Mountains, California. Southwestern Naturalist 37: 392-403.

Baldassarre, G. A., and E. G. Bolen. 1994. Waterfowl ecology and management. John Wiley & Sons, Inc., New York. 609pp.

Bellrose, F. C. 1980. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pennsylvania. 540pp.

Bogiatto, R. J., and J. D. Karnegis. 2006. The use of eastern Sacramento Valley vernal pools by ducks. California Fish and Game 92(3): 125-141.

Fleskes, J. P., and D. S. Gilmer. 2004. Habitat selection by female northern pintails wintering in the Grassland Ecological Area, California. California Fish and Game 90 (1): 13-28.

Grinnell, J., J. Dixon, and J. M. Linsdale. 1930. Vertebrate natural history of a section of northern California through the Lassen peak region. University of California Publications of Zoology 35: 1-594.

Heitmeyer, M. E., D. P. Connelly, and R. L. Pederson. 1989. The Central, Imperial, and Coachella Valleys of California. Pages 475-505 *In:* Habitat management for migrating and wintering waterfowl in North America. L. M. Smith, R.L. Pederson, and R. M. Kaminski, editors. Texas Tech. University Press, Lubbock, Texas.

Hochbaum, H. A. 1955. Travels and traditions of waterfowl. University of Minnesota Press, Minneapolis, Minnesota. 301pp.

Holland, R. F. 1978. The geographic and edaphic distribution of vernal pools in the Great Valley, California. California Native Plant Society Special Publication No.4. Sacramento, California. 12pp + 2 maps.

Holland, R. F. 1998. Great Valley vernal pools, photorevised, 1996. Pages 71-75 *In*: Ecology, Conservation, and Management of Vernal Pool ecosystems, C. W. Witham, E. T. Bauder, D. Belk, W. R. Ferren Jr., and R. Ornduff, editors. Proceedings from a 1996 Conference. California Native Plant Society, Sacramento, California.

Johnson, D. H., D. E. Timm, and P. F. Springer. 1979. Morphological characteristics of Canada Geese in the Pacific Flyway. Pages 56-80 *In:* Management and Biology of Pacific Flyway Geese, R. L. Jarvis and J. C. Bartonek, editors. Oregon State University Booksores Inc., Corvallis, Oregon.

McLandress, M. R. 1979. Status of Ross' Geese in California. Pages 255-265 *In:* Management and Biology of Pacific Flyway geese, R. L. Jarvis, and J. C.Bartonek, editors. Oregon State University Bookstores, Inc. Corvallis, Oregon.

McLandress, M. R., and D. G. Raveling. 1981. Hyperphagia and social behavior of Canada geese prior to spring migration. Wilson Bulletin 93(3): 310-324.

Miller, M. R., and D. C. Duncan. 1999. The northern pintail in North America: status and conservation needs of a struggling population. Wildlife Society Bulletin 27 (3): 788-800.

Mlodinow, S. G., P. F. Springer, B. Deuel, L. S. Semo, T. Leukering, T. D. Schonewald, W. Tweit, and J. H. Barry. 2008. Distribution and identification of cackling goose (*Branta hutchinsii*) subspecies. North American Birds 62 (3): 344-360.

Owen, M. 1980. Wild geese of the world. B. T. Batsford Ltd., London. 236pp. Pacific Flyway Council. 1999. Pacific Flyway management plan for the cackling   Canada   goose. Cackling Canada goose Subcomm., Pacific Flyway Study Comm.   (c/o   USFWS), Portland, Oregon. Unpubl Rept. 36pp + appendices.

Raveling, D. G. 1969. Roost sites and flight patterns of Canada geese in winter. Journal of Wildlife Management 33 (2): 319-330.

Raveling, D. G. 1970. Dominance relationships and agonistic behavior of Canada Geese in winter. Behaviour 37: 291-319.

Raveling, D. G., W. E. Crews, and W. D. Klimstra. 1972. Activity patterns of Canada geese during winter. Wilson Bulletin 84 (3): 278-295.

Raveling, D. G. 1978. Dynamics of distributionof Canada geese in winter. Transactions of the North American Wildlife and Natural Resources Conference 43: 206-225.

Raveling, D. G. 1979a. The annual cycle of body composition of Canada geese with special reference to control of reproduction. Auk 96: 234-252.

Raveling, D. G. 1979b. The annual energy cycle of the cackling Canada goose. Pages 81-93 *In:* Management and biology of Pacific Flyway Geese, R. L. Jarvis, and J.C. Bartonek, editors. Oregon State University Bookstores, Inc. Corvallis, Oregon.

Raveling, D. G. 1979c. Traditional use of migration and winter roost sites by Canada geese. Journal of Wildlife Management 43 (1): 229-235.

Raveling, D. G. 1984. Geese and hunters of Alaska's Yukon Delta: management problems and political dilemmas. Transactions of the North American Wildlife   and   Natural Resources Conference 49: 555-575.

Raveling, D. G., and D. S. Zezulak. 1991. Autumn diet of cackling Canada geese in relation to age and nutrient damand. California Fish and Game 77 (1): 1-9.

Scott, P. 1972. The swans. Houghton Mifflin Co., Boston. 242pp. Shields, G. F., and A. C. Wilson. 1987a. Subspecies of the Canada goose (*Branta canadensis*) have distinct mitochondrial DNAs. Evolution 41: 662-666.

Shields, G. F., and A. C. Wilson. 1987b. Calibration of mitochondrial DNA evolution in geese. Journal of Molecular Evolution 24: 212-217.

Silveira, J. G. 1998. Avian uses of vernal pools and implications for conservation   practice. Pages 92-106 *In*: Ecology, Conservation, and Management of Vernal Pool ecosystems. C. W. Witham, E. T. Bauder, D. Belk, W. R. Ferren Jr., and R. Ornduff, editors. Proceedings from a 1996 Conference. California Native Plant Society, Sacramento, California.

Silveira, J. G. 2000. Alkali vernal pools at Sacramento National Wildlife Refuge. Fremontia 27 (4), 28 (1): 10-18.

The Nature Conservancy. 1994. Vina Plains Preserve Handbook. Compiled by the Vina Plains Preserve Docent Committee, revision 2.1. 62pp.

U.S. Fish and Wildlife Service. 2008. Waterfowl population status, 2008. U. S. Department of the Interior, Washington, D. C. 65pp.

Van Wagner, C. E., and A. J. Baker. 1990. Association between mitochondrial DNA and morphological evolution in Canada Geese. Journal of Molecular Evolution 31: 373-382.

Yocom, C. F. 1972. Weights and measurements of Taverner's and Great Basin Canada geese. Murrelet 53: 33-34.

OCCURRENCE OF JUVENILE MEXICAN LOOKDOWN, *SELENE BREVOORTII* (GILL, 1863), IN SEAL BEACH, CALIFORNIA

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Jacks (Family Carangidae) represent 55 species in 15 genera in North America (Nelson et al. 2004). Within this family, the lookdowns and moonfishes (Genus *Selene*) include six species that are morphologically distinct from other jacks by having highly compressed bodies and steep anterior head profiles. Three of these species occur along the Pacific coast and the Gulf of California: Mexican moonfish, *Selene orstedii* Lutken, 1880; Pacific moonfish, *S. peruviana* (Guichenot, 1866); and Mexican lookdown, *S. brevoortii* (Gill, 1863). The Mexican lookdown is considered a Panamic species that has a range extending from San Diego Bay in southern California (Lea and Walker 1995, Lea and Rosenblatt 2000), to Isla San Lorenzo, Peru (Chirichigno and Velez 1998, as cited in Love et al. 2005), including the Gulf of California (Smith-Vaniz 1995). However, prior to its occurrence in San Diego Bay in the 1990s, Mexican lookdown was only reported as far north as Magdalena Bay, Baja California Sur (Walford 1947, as cited in Lea and Walker, 1995), a temperate-tropical oceanographic boundary. This paper documents the first occurrence of juvenile Mexican lookdown in California and an approximate 150-km northern range extension. Juvenile Mexican lookdown are distinguished from adults by relatively long, filamentous anterior dorsal spines, larger pelvic fins, and dark, interrupted vertical bars on the body (Smith-Vaniz 1995). As they mature, the markings on the body fade, the anterior dorsal spines shorten in length, the pelvic fins reduce in size, and the anterior lobes of both the second dorsal rays and anal rays elongate (Smith-Vaniz 1995, Humann and Deloach 2004).

While conducting monthly surf zone sampling on the morning of 18 November 2008, biologists with the California Department of Fish and Game captured juvenile Mexican lookdown in two consecutive beach seine hauls at Seal Beach, California (33º44'15''N, 118º06'16''W). The first lookdown (63 mm SL) occurred in the seine with no other fish species, while the second, smaller lookdown (62 mm SL) occurred with three topsmelt, *Atherinops affinis*, and one jacksmelt, *Atherinopsis californiensis*. The sea floor temperature at 4 m depth ranged from 16.6 to 16.9 ºC, and the tide was flooding (0.6 to 0.7 m).

Both specimens are catalogued in the Los Angeles County Museum of Natural History (LACM) fish collection (LACM 56886-1). Each specimen had long filamentous anterior dorsal spines, although the second dorsal spine of the larger specimen was much shorter than the first (Fig. 1). Both juveniles had large black-tipped pelvic fins and silvery bodies with iridescent blue highlights. Interestingly, the dark interrupted vertical bars on the body were more apparent on the larger specimen, while the smaller specimen had a faint bar extending dorsally from the eye to the anterior dorsal fin (Fig. 1). Morphometrics and meristics of the two specimens are reported in Table 1.

Whereas the northern transport of larvae and/or juveniles via vessel ballast water is a potential, though not probable, mode of arrival for juvenile Mexican lookdown[1], here we discuss oceanographic influence. The presence of juvenile Mexican lookdown at Seal
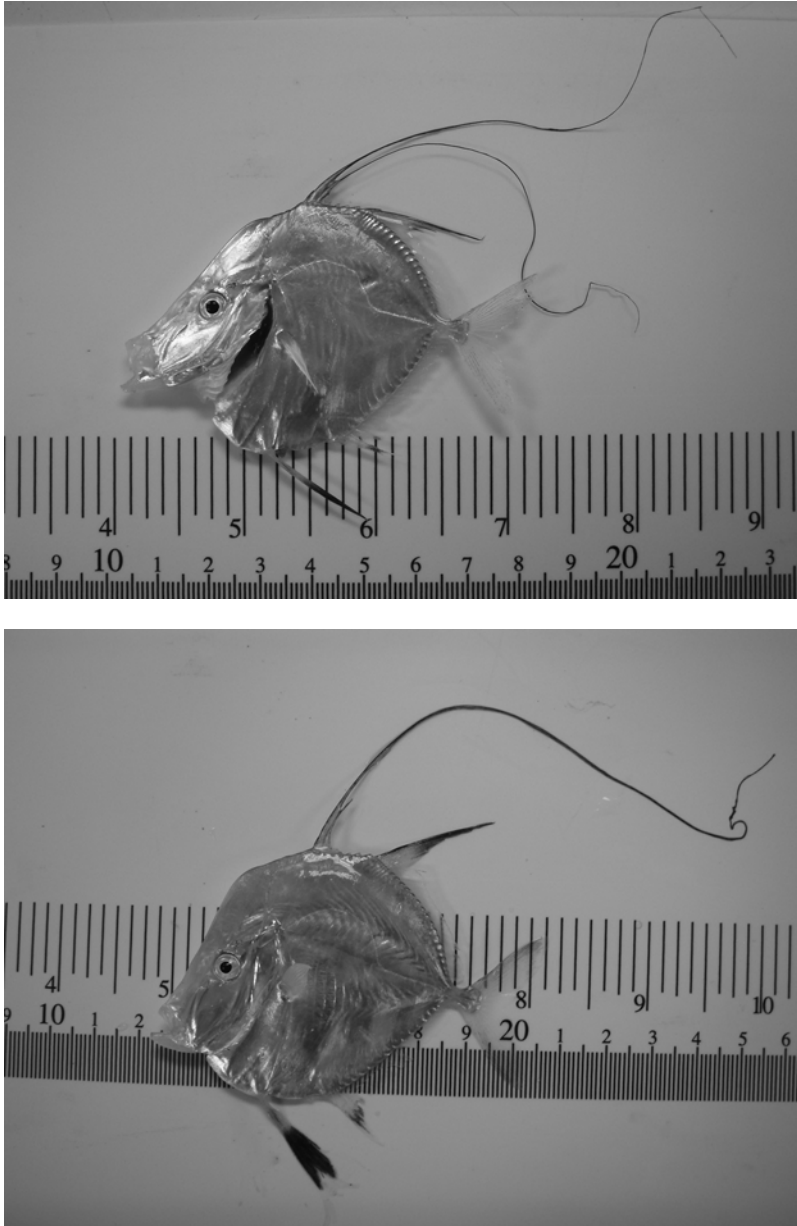
Figure 1. Juvenile Mexican lookdown, *Selene brevoortii*, captured by beach seine at Seal Beach, California, 18 November 2008. The smaller (top) and larger (bottom) specimens measured 62 and 63 mm standard length, respectively. Photographs by E.T. Jarvis.

Table 1. Morphometric and meristic characteristics of juvenile Mexican lookdown, *Selene brevoortii*, captured by beach seine at Seal Beach, California, 18 November 2008.

Characteristic[a]	Specimen 1	Specimen 2
Standard length (mm)	63	62
Total length	1.32	1.27
Fork length	1.14	1.08
Head length	0.49	0.50
Eye diameter	0.10	0.10
Snout length	0.24	0.24
Maxillae length	0.13	0.11
Pectoral length	0.30	0.27
Predorsal length	0.73	0.66
Preanal length	0.60	0.65
Length to D2	0.86	0.82
Body depth at D2	0.81	0.73
Dorsal fin elements	VIII+I,21	VIII+I,21
Anal fin elements	I,18	I,18
Lateral line scutes	present[b]	present[b]
Gill rakers (left)	8+33	7+31

[a]Characteristics listed here are based on those reported by Lea and Walker (1995). Length measurements are represented as a proportion of standard length.

[b]Lateral line scutes could not be precisely enumerated. Lea and Walker (1995) reported 'none' present for an adult Mexican lookdown deposited at Scripps Institution of Oceanography (SIO 93-192).

Beach suggests successful larval recruitment in southern California, although the larval source is unknown. The size of the captured juveniles, in addition to the reported larval transformation length and spawning season of Mexican lookdown (8.2 mm to > 38 mm, January – April; Moser 1996), suggests the fish were spawned in the spring of 2008. The occurrence of adult Mexican lookdown in California waters in 1993 and 1997-98, along with other Panamic fishes, was attributed to adult movement coincident with warm water oceanographic conditions (Lea and Walker 1995, Lea and Rosenblatt 2000). However, since the 1997-98 El Niño, the Southern California Bight (SCB) has not experienced a similar oceanographic event that would facilitate long range larval dispersal into California waters. Moreover, the California Current system has been in a cool phase since the 1997-98 El Niño, and southern California experienced one of the strongest La Niña conditions of the last few decades during the 2007-08 season (McClatchie et al. 2008). Although southern California waters were representative of La Niña conditions in 2007-08, ocean patterns off Baja California

[1]In the fall of 2008, other unusual species occurrences were identified in the recreational fish catch farther north in Santa Monica Bay, southern California (green jack, *Caranx caballus*, and spot, *Leiostomus xanthurus*; T. Carpenter, Pacific States Marine Fisheries Commission, personal communication).

did not show evidence of a response to the La Niña event; in fact, sea surface temperatures were unusually high (McClatchie et al. 2008). If unknown or undocumented populations of Mexican lookdown have persisted farther north into Baja California or even San Diego Bay since the 1997-98 El Niño, net poleward flow of SCB coastal currents during summer months (Hickey 1993, McClatchie et al. 2008) may have facilitated successful local recruitment. It is interesting to note that both California localities of Mexican lookdown occurrences are in close proximity to warm water effluent of power generating stations (South Bay Power Plant in San Diego and Haynes Power Generating Station in Seal Beach), which may provide suitable year-round temperatures for adults and recruits.

ACKNOWLEDGMENTS

LITERATURE CITED

Hickey, B.M. 1993. Physical Oceanography. Pages 19-70 in: M.D. Dailey, D.J. Reish, and J.W. Anderson, editors. Ecology of the Southern California Bight: A synthesis and interpretation. University of California Press, Berkeley and Los Angeles, California, USA.

Humann, P. and N. Deloach. 2004. Reef fish identification. Baja to Panama. New World Publications, Inc. Jacksonville, Florida, USA.

Lea, R.N. and H.J. Walker, Jr. 1995. Record of the bigeye trevally, *Caranx sexfasciatus*, and Mexican lookdown, *Selene brevoorti*, with notes on other carangids from California. California Fish and Game 81:89-95.

Lea, R.N. and R.H. Rosenblatt. 2000. Observations on fishes associated with the 1997-98 El Niño off California. California Cooperative Oceanic Fisheries Investigations Reports 41:117-129.

Love, M.S., C.W. Mecklenburg, T.A. Mecklenburg, and L.K. Thorsteinson. 2005. Resource inventory of marine and estuarine fishes of the West Coast and Alaska: a checklist of North Pacific and Arctic Ocean species from Baja California to the Alaska-Yukon border. U.S. Department of the Interior, U.S. Geological Survey, Biological Resources Division, Seattle, Washington, USA, OCS Study MMS 2005-030 and USGS/NBII 2005-001.

McClatchie, S., R. Goericke, J.A. Koslow, F.B. Schwing, S.J. Bograd, R. Charter, W. Watson, N. Lo, K. Hill, J. Gottschalck, M. L'heureux, Y. Xue, W.T. Peterson, R. Emmett, C. Collins, G. Gaxiola-Castro, R. Durazo, M. Kahru, B.G. Mitchell, K.D. Hyrenbach, W.J. Sydeman, R.W. Bradley, P. Warzybok, and E. Bjorkstedt. 2008. The State of the California Current, 2007-2008: La Niña conditions and their effects on the ecosystem. California Cooperative Oceanic Fisheries Investigations Reports 49:39-76.

Moser, H.G. (ed.) 1996. The early life stages of fishes in the California Current Region. California Cooperative Oceanic Fisheries Investigations Atlas No. 33.

Nelson, J.S., E.J. Crossman, H. Espinosa-Perez, L.T. Findley, C.R. Gilbert, R.N. Lea, and J.D. Williams. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico. Sixth edition. American Fisheries Society Special Publication 29, Bethesda, Maryland, USA.

Smith-Vaniz, W.F. 1995. Carangidae. Jureles, pámpanos, cojinúas, zapateros, cocineros, casabes, macarelas, chicharros, jorobados, medregales, pez pilota. Pages 940-986 in: W. Fischer, F. Krupp, W. Schneider, C. Sommer, K.E. Carpenter, and V. Niem, editors. Guia FAO para Identification de Especies para lo Fines de la Pesca. Pacifico Centro-Oriental. 3 Vols. FAO, Rome.

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