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FACTORS AFFECTING THE PRESENCE OF NESTING BURROWING OWLS IN AN AGRICULTURAL LANDSCAPE

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ABSTRACT.—We examined factors that influenced the presence of nesting Western Burrowing Owls (*Athene cunicularia hypugaea*) along roadsides and irrigation water-conveyance systems within an intensive agricultural area in Imperial Valley, southeastern California. We conducted walking line-transect surveys along randomly selected 1-km segments of roads to examine the types of roadside attributes and agricultural crops that were associated with the presence of nesting Burrowing Owls. Occupied burrows were more likely to be located along roadsides adjacent to fields where crops were present, but we found no obvious association with any particular type of crop. However, the type (concrete delivery canal or earthen drainage ditch), number, and location of irrigation trenches between the road and the agricultural field affected the likelihood of detecting owl nests. We failed to detect any effect of trench depth or whether the road was paved on the presence of Burrowing Owls. We found more occupied burrows on roads running north/south than on those going east/west. Our results suggest that water delivery methods, trench construction, and maintenance practices affect suitability of agricultural areas for Burrowing Owls in the Imperial Valley of California.

KEY WORDS: *Burrowing Owl*; Athene cunicularia; *agriculture*; *California*; *Imperial Valley*; *nesting habitat*; *nest-site selection*; *Salton Sea*.

FACTORES QUE AFECTAN LA PRESENCIA DE *ATHENE CUNICULARIA* EN UN PAISAJE AGRÍCOLA

RESUMEN.—Examinamos los factores que influencian la presencia de individuos reproductivos de *Athene cunicularia hypugaea* a lo largo de caminos y sistemas de regadío en un área en que se realiza agricultura intensiva en Imperial Valley, en el sudeste de California. Realizamos censos en transectos lineales de 1 km caminando a lo largo de segmentos de caminos escogidos al azar para examinar el tipo de atributos de estos caminos y tipo de plantaciones que estaban asociados con la presencia de individuos de *A. c. hypugaea* que se encontraban anidando. Las madrigueras ocupadas tuvieron una mayor probabilidad de estar localizadas a lo largo de caminos con plantaciones agrícolas, pero no encontramos asociaciones con algún tipo especifico de plantación. Sin embargo, el tipo (canal de concreto o canal de drenaje de tierra), número y ubicación de los canales de regadío entre los caminos y el campo agrícola afectaron la probabilidad de detectar nidos. No pudimos detectar un efecto de la profundidad del canal de regadío o un efecto de si el camino era pavimentado o no sobre la presencia de las lechuzas. Encontramos más madrigueras ocupadas en caminos con dirección este/oeste. Nuestros resultados sugieren que el método de irrigación, el tipo de canal y de prácticas de mantenimiento afectan la calidad de las áreas agrícolas para *A. c. hypugaea* en Imperial Valley, California.
[Traducción del equipo editorial]

The Western Burrowing Owl (*Athene cunicularia hypugaea*) is listed as endangered in Canada and populations have declined in many areas of the U.S. (Sheffield 1997, Kirk and Hyslop 1998, Desmond et al. 2000, Conway and Pardieck 2006). Observed population declines prompted a recent petition for state listing in California (Miller 2007), and Burrowing Owls are currently listed as a species of National Conservation Concern in the U.S. (Klute et al. 2003, U.S. Fish and Wildlife Service

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2008). However, the Imperial Valley of California is one of the few areas in the U.S. where Burrowing Owl populations increased significantly during the past 35 yr (Sauer et al. 2008). For example, estimated breeding density increased from 3.3 pairs/km² in 1966–67 (Coulombe 1971) to 8.3 pairs/km² in 2000 (Rosenberg and Haley 2004). These past increases in the Imperial Valley were an important consideration in the decision to not list the species as threatened or endangered in the state of California. However, numbers have declined from 95 owls in 1996 to 9 owls in 2008 along one Breeding Bird Survey route in Imperial Valley (Sauer et al. 2008). Moreover, recent and planned changes in land-use and water-delivery practices in the Imperial Valley may be causing dramatic changes in habitat suitability for Burrowing Owls (Rosenberg and Haley 2004, Miller 2007).

Historically, Burrowing Owls nested primarily in areas of short grasses or other sparse vegetation (Coulombe 1971) where black-tailed prairie dogs (*Cynomys ludovicianus*) or other colonial fossorial mammals created burrows. However, Burrowing Owls have colonized urban and agricultural environments and their breeding densities can be relatively high in some of these landscapes. For example, Burrowing Owls are often found nesting adjacent to airport runways, within freeway interchanges, on the fringes of golf courses, and along berms of roadsides and irrigation trenches (Holmes 1998, Klute et al. 2003, Smith et al. 2005, Conway et al. 2006). The agricultural areas within the Imperial Valley of southeastern California are thought to support the highest densities of Burrowing Owls in the U.S. (DeSante et al. 2004, Rosenberg and Haley 2004). Recent estimates suggested that California supports ca. 9300 breeding pairs of Burrowing Owls and that 60–70% of those breeding pairs occur in the Imperial Valley (Klute et al. 2003, DeSante et al. 2004).

Despite the importance of this agricultural area to the status of Burrowing Owls in California, the factors associated with burrow occupancy in the Imperial Valley of California have not been examined. Our goal was to identify the physical and land-use factors associated with Burrowing Owl nest burrows in the Imperial Valley. Specifically, we examined the effects of the following features on burrow occupancy: the type of crops in the adjacent field, surface condition of the road (paved or earthen), number of irrigation trenches adjacent to the road, trench type(s), whether the trench(es) had been recently maintained, the distance from the road to the trench(es), prevailing aspect of the road shoulder, and the type of road shoulder present. This information may help resource managers maintain features within these agricultural lands to benefit Burrowing Owls in the face of changing land use.

STUDY AREA

The study area was near Sonny Bono-Salton Sea National Wildlife Refuge (SSNWR), Imperial County, California (33°2′N, 115°37′W). Average daily high temperature is 34.4°C and 39.4°C for May and June respectively, with only a trace of rainfall during these months. Average annual precipitation is 7.9 cm (The Weather Channel 2009). This area of Imperial County is characterized by intensive agriculture and geothermal power plants. The Imperial Valley supports a large population of Burrowing Owls associated with agricultural fields, which are irrigated via concrete-lined water-delivery trenches, with excess water removed via earthen trenches (Rosenberg and Haley 2004). These trenches run parallel to earthen and paved roads, which are arrayed in a grid pattern to the south and to the east of the Salton Sea. Most of the Burrowing Owls in the study area nest within round-tailed ground squirrel (*Spermophilus tereticaudus*) burrows in the sides of the earthen trenches or under the edges of concrete trenches around the margins of the agricultural fields. Many different crops are grown in the Imperial Valley and their relative abundance varies annually, but the 10 most common crops grown in the valley over the past 3 yr include: alfalfa (*Medicago* spp.), wheat (*Triticum aestivum*), Sudan grass (*Sorghum bicolor*), Bermuda grass (*Cynodon dactylon*), lettuce (*Lactuca* spp.), sugar beets (*Beta vulgaris*), carrots (*Daucas carota*), Kliengrass (*Panicum coloratum*), broccoli (*Brassica oleracea*), and onions/onion seed (*Allium cepa*). Natural vegetation not associated with crop production was minimal due to the intensity of agriculture, but included salt cedar (*Tamarix* sp.), yellow paloverde (*Parkinsonia microphylla*), mesquite (*Prosopis* sp.), creosote bush (*Larrea tridentata*), desert sunflower (*Geraea canescens*), and arrowweed (*Pluchea sericea*).

METHODS

All roads within the study area were divided into 117 1-km segments (73 north/south and 44 east/west segments) using TOPO mapping software (Na-

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tional Geographic, San Francisco, California, U.S.A.). We randomly selected 42 of these 117 segments (21 north/south and 21 east/west segments) for surveys. We conducted walking surveys (Conway and Simon 2003) on each of the 42 segments (each segment consisted of two parallel roadside transects where owls might nest, one on either side of the 42 road segments for a total of 84 individual transects) between 20 May and 27 June 2005. These dates correspond with the late incubation and early nestling periods for Burrowing Owls in this area; average dates of hatching were 16 May–3 June (Rosenberg and Haley 2004). We conducted all surveys between 30 min after sunrise to 4 hr after sunrise, or between 3 hr before sunset until sunset. We conducted surveys only if wind speed did not exceed 16 km/hr (Rosenberg and Haley 2004) and ambient temperature did not exceed 38°C. During surveys, the observer walked slowly along one side of the road looking for nest burrows and then walked along the other side of the road on the way back to the starting location. We treated the two 1-km stretches on each side of a 1-km road segment separately because our explanatory variables (see list below) were typically different in the fields on the two opposite sides of the same road. Nest burrows at this time of year have signs that indicate use by owls, including manure and whitewash (Smith and Conway 2007, Garcia and Conway 2009). We may have overlooked some nests, but detection probability of burrows occupied by nesting Burrowing Owls is very high during breeding-season surveys, especially during walking surveys and in agricultural areas such as this (Rosenberg and Haley 2004, Conway et al. 2008). We recorded the number of burrows with signs of occupancy and the total number of suitable nest burrows along each 1-km transect. Suitable nest burrows were those that were excavated by fossorial mammals (primarily round-tailed ground squirrels) or any other holes that we believed to be suitable for Burrowing Owls.

We also recorded the following physical features along each 1-km transect: prevailing aspect of the road shoulder (N, E, S, or W), number of trench banks, number of trench banks that were easily visible to the surveyor from the roadside, the type of trench, road substrate (paved or not), whether the trenches adjacent to the road had recently been maintained (yes or no), average depth of the trenches (in meters), distance of the nearest trench from the road, and the type of crop in the adjacent field (alfalfa, hay, Sudan grass, fruits/vegetables, other crops, or none). The physical features listed above sometimes changed during the 1-km transect (e.g., the crop in the adjacent agricultural field changed from hay to onion seed). Hence, we recorded the total length (in m) for each type of feature along the 1-km transect. For example, a 1-km transect might have had 230 m of alfalfa, 550 m of onion seed, and 220 m of noncrop. We calculated the percentage of each crop on each transect by dividing the length of road with that type of crop divided by the total length of the transect. We recorded the portion of the 1-km transect that had the following features adjacent to the roadside: an earthen trench, a concrete trench, signs of recent trench maintenance, paved road, and earthen road shoulder. Length of each portion of each transect was measured using a handheld Global Positioning System receiver. We measured the depth of each trench by measuring the distance from the upper ground surface to either the bottom of the trench or the water level (for trenches with water).

Trenches that had received recent maintenance were obvious because they were clear of vegetation, often had flowing water, and (in some cases) maintenance workers were observed cleaning the trench. Concrete trenches were typically well maintained. Earthen trenches that had not been recently maintained typically had overgrown vegetation and stagnant water. Many of the earthen trenches were not well maintained.

We recorded the type of shoulder along the roadside, which refers to the number and types of trenches adjacent to the road along the 1-km transects. We classified each portion of each transect as having one of the following six shoulder types: (1) one earthen trench with two banks, (2) one concrete trench with two banks, (3) two parallel concrete trenches with four banks, (4) two parallel earthen trenches with four banks, (5) one earthen trench and one concrete trench; four banks, (6) other (mostly areas with no trenches).

We used a stepwise logistic regression with forward variable selection (SPSS Statistics 17.0), where the response variable was presence of an occupied Burrowing Owl nest (i.e., whether or not we detected ≥1 Burrowing Owl nest). The 1-km transect was the sampling unit ($n = 84$) in the regression analysis. We used the criteria $P = 0.10$ to enter and $P = 0.15$ to leave for variable retention at each step in

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Table 1. Factors associated with presence of Burrowing Owl nests in Imperial Valley of California based on stepwise logistic regression (n = 84 1-km roadside transects). The response variable in the model was the presence (0 or 1) of an occupied Burrowing Owl nest. Aspect of roadside shoulder was a categorical variable (with four categories, and hence three dummy variables) that described the prevailing aspect of the roadside shoulder (e.g., a north-south road had two banks along its shoulder, one that faced east and one that faced west).

VARIABLE	*B*	SE	WALD	DF	*P*	EXP(*B*)
Aspect of roadside shoulder			8.3	3	0.039	
East facing aspect	−1.66	0.894	3.45	1	0.063	0.190
South facing aspect	−2.74	0.987	7.71	1	0.005	0.064
West facing aspect	−1.28	0.823	2.42	1	0.120	0.278
Road length without crops (m)	−0.002	0.001	4.33	1	0.037	0.998
Road length with concrete trench (m)	−0.002	0.001	2.50	1	0.114	0.998
Road length with unmaintained trenches (m)	−0.001	0.001	1.93	1	0.165	0.999
Number of trench banks visible	0.211	0.097	4.74	1	0.029	1.234
Distance to nearest trench (m)	−0.008	0.004	5.24	1	0.022	0.992
Constant	0.985	1.210	0.66	1	0.416	2.677

the stepwise procedure because this was an exploratory analysis. We also conducted a General Linear Model (SPSS Statistics 17.0) with average number of trench banks as the response variable and aspect of the roadside shoulder as a fixed factor to examine whether differences in number of nests detected along roadsides with different aspects was a function of differences in the number of trenches.

RESULTS

We located 55 burrows with signs of occupancy and 367 suitable (but apparently unoccupied) burrows along the 84 1-km transects. The number of occupied burrows along a 1-km transect varied from 0 to 6 (64% had 0 occupied burrows). We were more likely to detect Burrowing Owl nests on roads adjacent to fields that had crops present, but we failed to find an association with any particular types of crops (Table 1, Fig. 1). Transects with predominantly earthen trenches (rather than concrete trenches) and those where the trenches had been recently maintained were more likely to have owls present ('Road length with concrete trench' and 'Road length with unmaintained trenches' were both negatively associated with presence of owls; Table 1). Orientation of the road was also associated with the likelihood of owl nest detection. Occupied burrows were more often located on roads that ran north/south (i.e., where the aspect of the roadside shoulders faced west and east) compared to roads that ran east/west (Table 1, Fig. 2A). We detected more trenches (and hence more trench banks) on roads that ran north/south than east/west. The number of occupied burrows detected was positively associated with the mean number of banks along a road (Fig. 3). We failed to detect any effect of trench depth or whether the road was paved on the presence of Burrowing Owls.

DISCUSSION

Many previous studies have reported that Burrowing Owls are positively associated with agriculture in many parts of their distribution (Orth and Kennedy 2001, DeSante et al. 2004, Rosenberg and Haley 2004, Conway et al. 2006, Moulton et al. 2006). However, only one previous study (Rosenberg and Haley 2004) examined the features within agricultural ecosystems that were correlated with presence of breeding Burrowing Owls. Our results suggest that the probability of Burrowing Owls nesting along a roadside in the Imperial Valley of California appeared to be influenced more by the presence and management of the water delivery systems in the adjacent agricultural field than by the types of crops growing in the field. Roadsides with a higher number of banks were more likely to have Burrowing Owls present; transects with two parallel trenches side by side (and hence four banks) were more likely to have owls than transects with fewer trenches parallel to the road. The number of banks along a roadside appeared to influence whether owls were present, as the number of banks was positively correlated with the number of occupied burrows. Round-tailed ground squirrels may find it easier to

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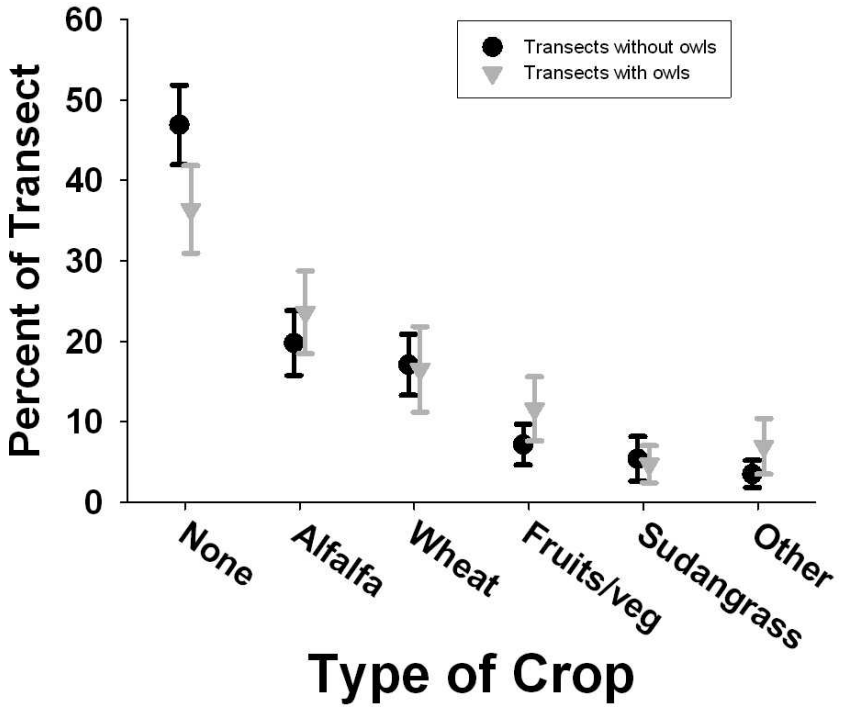


Figure 1. Mean (±SE) percent of 1-km road transects that had each of six types of agricultural use in Imperial Valley, California. We detected ≥1 Burrowing Owl nest on 30 of the 1-km transects and 0 Burrowing Owl nests on 54 of the transects.

burrow in the disturbed ground (or in the gaps between the concrete and the soil) associated with these trenches. We likely detected fewer nests along roadside shoulders that faced south for two reasons: (1) there were fewer trench banks along these stretches (Fig. 2B), and (2) trench banks along these stretches either faced south or north (because trenches were always parallel to roadside shoulders and each trench has two banks that face opposing directions) and burrows in south-facing trench banks may not provide sufficient shade during the heat of the day. Similarly, culverts in Texas with east-west orientations were more likely to be occupied by wintering Burrowing Owls than those with north-south orientations (Williford et al. 2009).

Burrowing Owl nests occurred less frequently along roadsides that did not have crops of any kind. This result contradicts a previous study in the Imperial Valley, in which researchers found that radio-marked Burrowing Owls foraged in areas without crops more than was expected based on availability (Rosenberg and Haley 2004). We did not find an association with alfalfa, but Rosenberg and Haley (2004) reported that owls foraging far from their nests were more likely to forage in hay and alfalfa fields and speculated that alfalfa fields may have higher rodent densities. Wintering Burrowing Owls in Texas were positively associated with culverts surrounded by crop stubble (Williford et al. 2009). Our results suggest that the methods and frequency with which irrigation trenches are maintained (i.e., cleared of vegetation, scoured of soil) can affect the occurrence of Burrowing Owl nest sites. Indeed, management of the irrigation system has been identified by others as the largest management concern for Burrowing Owls in the Imperial Valley (Rosenberg and Haley 2004).

Numbers of Burrowing Owls in the Imperial Valley appear to be influenced by both the availability of nest burrows and food availability. Most artificial burrows are quickly occupied after installation (C. Conway unpubl. data), suggesting that variation in local breeding densities within the Imperial Valley is influenced by the availability of nest burrows. The presence of irrigation water likely leads to increases in prey availability both directly (by increasing the

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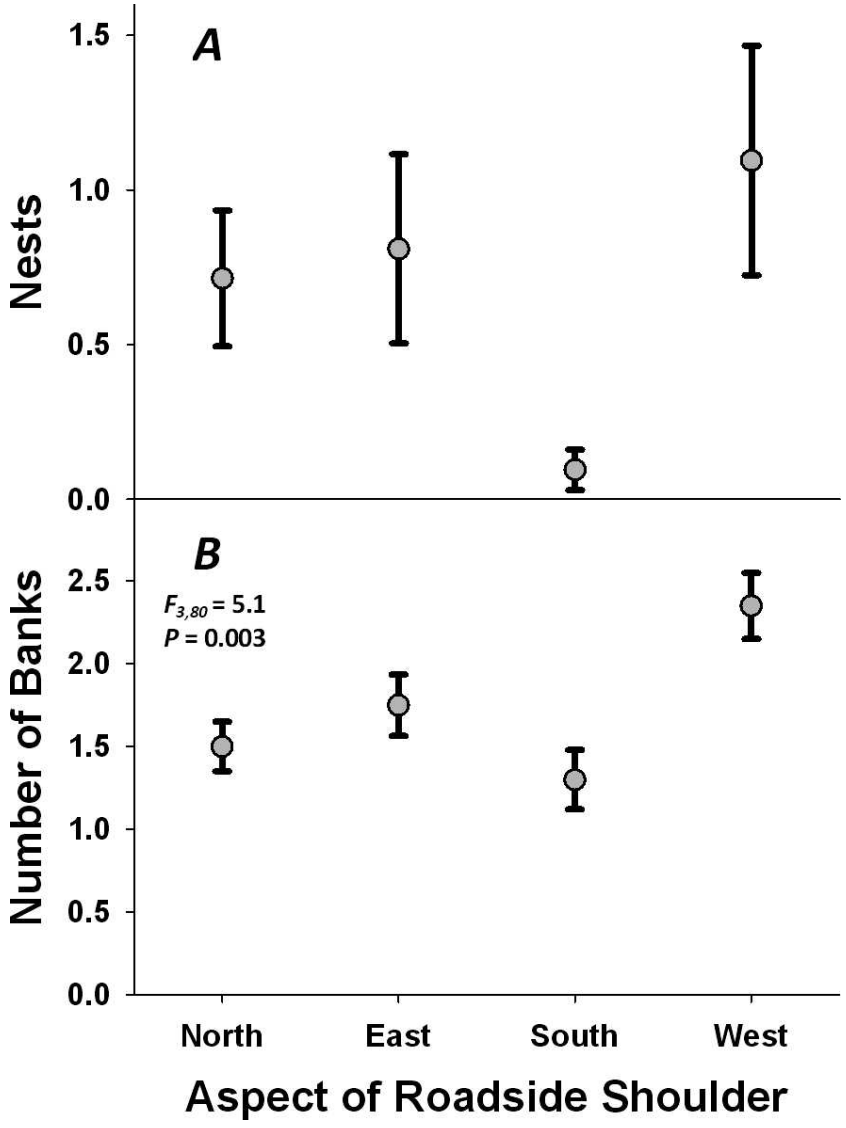


Figure 2. (A) Number of Burrowing Owl nests, and (B) number of trench banks along roadside shoulders whose aspects face each of four cardinal directions in Imperial Valley, California. We surveyed an equal number (21) of 1-km transects whose roadside shoulders had aspects that faced each of the four cardinal directions.

local abundance of amphibians, aquatic insects, bats, and other prey) and indirectly (by sustaining nearby crops whose foliage supports higher local abundance of herbivorous insects and small mammals). More thorough and more rigorous research is needed in the Imperial Valley to better quantify the specific features of the agricultural ecosystem that affect suitability for breeding Burrowing Owls. Future studies should incorporate larger sample sizes and a larger geographic scope to better evaluate the effects of different management actions on occupancy or persistence of breeding Burrowing Owls.

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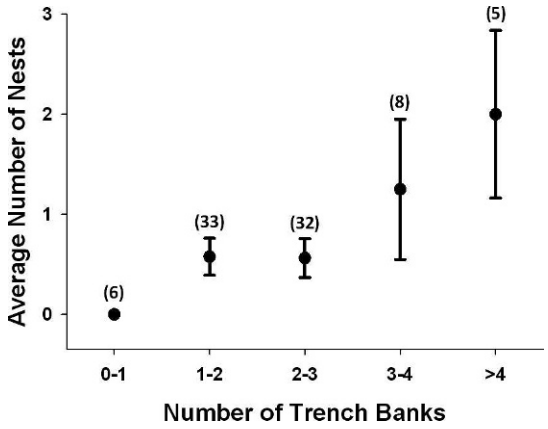


Figure 3. The number of Burrowing Owl nests along a 1-km roadside transect was positively associated with the average number of trench banks along the roadside. We used a weighted average of the number of trench banks for each transect because the number of banks was seldom consistent along an entire 1-km transect (and hence the weighted average was rarely an integer). Error bars represent ±1 SE and numbers in parentheses above the error bars represent the number of transects.

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