IMPACT OF THE MOSQUITOFISH (*GAMBUSIA AFFINIS*) ON A RICE FIELD ECOSYSTEM WHEN USED AS A MOSQUITO CONTROL AGENT

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ABSTRACT. The use of the mosquitofish, *Gambusia affinis*, for rice field mosquito control at the rate of 224 g/ha (0.2 lb/acre) did not affect the population densities of copepods, ostracods, corixids, dragonflies, belostomatids and aquatic beetles but did reduce the densities of cladocerans, mayflies, damselflies, notonectids and chironomids significantly. The reduction of insects and crustacean densities did not cause mosquito larval resurgence.

INTRODUCTION

The mosquitofish, *Gambusia affinis* (Baird and Girard), is native to central North America from southern Illinois to Alabama and Texas (Moyle 1976). The fish was introduced into California in 1922 (Lenert and Stuart 1926) and has since become well established over the state. It is still the only effective biological agent widely used for mosquito control in California (Washino and Hokama 1967, Bay 1969, Hoy and Reed 1970, Hoy et al. 1972).

Although the impact of *G. affinis* on aquatic organisms in plastic wading pools (Hurlbert et al. 1972) and in small seminatural experimental ponds (Walters and Legner 1980, Hurlbert and Mulla 1981) has been reported, the effect of the fish on nontarget organisms when used as a mosquito control agent under operational conditions is not well known. The study was undertaken to determine the impact of the use of *G. affinis* for mosquito control purposes in a rice field ecosystem in the San Joaquin Valley of California.

MATERIALS AND METHODS

Four rice fields on the Koda Farms, South Dos Palos, California were used for this study (Fig. 1). The fields no. 8 (11 ha) and 9 (11 ha) located south of the deep drainage ditch were stocked with *G. affinis* at a rate of ca. 0.2 lb/acre (224 g/ha) by the Fresno Westside Mosquito Abatement District on May 6 and fields no. 4 (10.5 ha) and 5 (8 ha) (north of the drainage ditch) were left unstocked and used as experimental checks.

Planktonic, nektonic and benthic organisms associated with rice fields were sampled by 2 methods: dipping and trapping. Dip samples were taken with standard white enameled dippers (450 ml capacity) and Husbands' concentrators (Husbands 1969) using fine nylon screen vials (200 mesh). Fifty dip samples (ca. 20 liters of sample water) were taken weekly from each field by transecting the field from north to south (Fig. 1). All samples were placed into vials containing 95% ethyl alcohol for later examination in the laboratory.

Gees® minnow traps were slightly modified by lining the inner sides of the traps with window screen. These were used to study the abundance of nektonic organisms and their seasonal fluctuation. Each week 5 unbaited traps were set in each field (Fig. 1) on a morning and retrieved the following morning. All organisms captured were counted and tabulated in the field and then released at the respective capture sites. The sampling was started on June 18 and continued until August 31, 1980.

To determine the impact of mosquitofish on aquatic organisms, the Student's *t*-test with paired observations (Ostle 1954) was used. Our Null hypothesis was $\mu_D=0$; number of paired samples observed was 11 and significant level used was 5%.

The principal references to the taxonomy of planktonic organisms were the articles by Brooks (1959), Tressler (1959) and Yeatman (1959). Insect specimens were identified using Usinger (1956), Darby (1962), Zimmerman (1970) and Menke (1979). Insect identifications were then re-examined against our reference collection.

RESULTS AND DISCUSSION

Although the initially extremely small-sized mosquitofish were stocked in May, by early June large numbers of fry were observed in rice fields to which fish had been introduced. Detailed study of population growth and density estimation of mosquitofish in rice fields will be reported in this Journal in a future paper.

The rice field ecosystem supports a great number of organisms. Sixty-three species were regularly collected (Table 1). Crustaceans predominated by number in the individual collections with ostracods being the most abundant followed by cladocerans and copepods. There

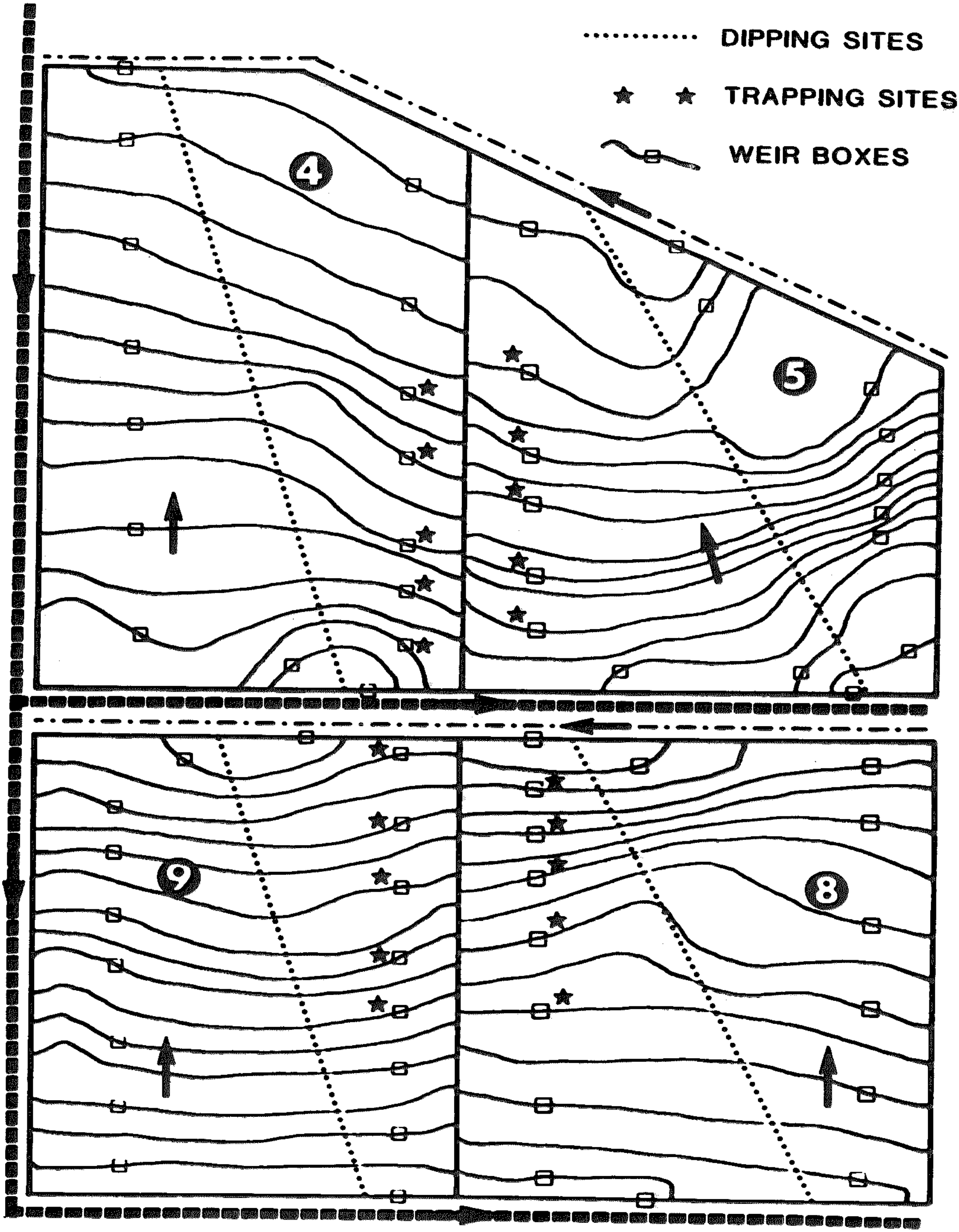

Fig. 1. Study area showing sampling sites, weir box location and irrigation water movement (arrows).

Table 1. A list of aquatic organisms found in rice fields in South Dos Palos, California.

Higher taxon	Scientific name	Common name
Monogononta		
Ploima	*Asplanchna* spp.	Rotifers
Oligochaeta		
Plesiopora	*Aulophorus furcatus* (Müller)	Aquatic earthworms
Hirudinea		
Pharyngobdellida	*Erpobdella* spp.	Leeches
Crustacea		
Cladocera	*Ceriodaphnia* spp.	Cladocerans
	Simocephalus spp.	
	Scapholěberis kingi Sars	
	Macrothrix rosea (Jurine)	
	Alona spp.	
Eucopepoda	*Cyclops vernalis* Fischer	Copepods
	Diaptomus spp.	
Podocopa	*Chlamydotheca unispinosa* (Baird)	Ostracods
	Chlamydotheca arcuata (Sars)	
	Cypris subglobosa Sowerby	
	Stenocypris spp.	
Decapoda	*Plocambraus claki* (Girard)	Crayfish
Insecta		
Ephemeroptera		
Baetidae	*Callibaetis* spp.	Mayflies
Odonata		
Aeshnidae	*Anax junus* (Drury)	Dragonflies
Coe nagrionidae	*Enallagma civile* (Hagen)	Damselflies
	Ischnura cervula Selys	
Hemiptera		
Gerridae	*Gerris* spp.	Water striders
Belostomatidae	*Belostoma flumineum* Say	Giant water bugs
Corixidae	*Corisella decolor* (Uhler)	Water boatmen
Notonectidae	*Notonecta unifasciata* Guerin	Back swimmers
	Buenoa scimitra Bare	
Veliidae	*Microvelia pulchella* Westwood	Broad-shouldered water striders
Coleoptera		
Dytiscidae	*Hygrotus lutescens* (Le Conte)	Predaceous diving beetles
	Laccophilus mexicanus mexicanus Aube	
	Laccophilus mexicanus atristernalis Crotch	
	Laccophilus maculosus decipiens LeConte	
	Rhantus gutticollis (Say)	
	Colymbetes spp.	
	Liodessus affinis (Say)	
	Thermonectur basillaris (Harris)	
	Cybister explanatus LeConte	
	Hydrovatus brevipes Sharp	
Hydrophilidae	*Berosus stylifer* Horn	Water scavenger
	Hydrophilus triangularis Say	
	Tropisternus lateralis (F.)	
	Tropisternus ellipticus (LeConte)	
	Helophorus spp.	
	Enochrus hamiltoni pacificus Leech	
Curculionidae	*Bagous tingi* Tanner	Weevils
Diptera		
Culicidae	*Culex tarsalis* Coquillett	Mosquitoes
	Anopheles freeborni Aitken	
Chironomidae	*Chironomus* spp.	Midges
	Goeldichironomus holoprasinus (Goeldi)	
	Pentaneur monilis (L.)	
	Polypedilum spp.	
	Procladius culiciforms (L.)	
	Corynoneura spp.	
	Cricotopus sylvestris (F.)	
	Paralauterborniella spp.	
	Paratanytarsus spp.	

Table 1. (*Continued*)

Higher taxon	Scientific name	Common name
Ephydridae	*Brachydeutera argentata* (Walker)	Shore flies
Ceratopogonidae	*Culicoides variipennis* (Coquillett)	Biting midges
Tabanidae	*Chrysops* sp.	Horseflies
	Tabanus spp.	
Tipulidae	*Limonia* spp.	Crane flies
Arachnida		
Acarina	*Arrenurus* spp.	Mites
	Hydrachna spp.	
Osteichthyes		
Microcyprini	*Gambusia affinis* (Baird and Girard)	Mosquitofish
Amphibia		
Salientia	*Hyla* spp.	Frogs
	Rana spp.	

were more crustaceans collected than insects, but insects dominated in the species composition; the most abundant insects were dytiscid beetles (adults and larvae) followed by damselfly nymphs, notonectid bugs and chironomid midges. Mosquito larval and belostomatid collections were small, but were consistently found during the study period. Few mosquitofish were collected from the unstocked check rice fields.

Considerable reduction of crustacean populations was observed in rice fields stocked with fish (Fig. 2); however, only cladoceran populations were significantly reduced by fish predation ($t = 4.29$; $P > 0.001$). Copepod and ostracod populations were also reduced in the early season when rice plants were still short but overall reductions caused by the predation were not significant ($t = 0.602$ and 1.29, respectively). Hurlbert et al. (1972) have reported that the voracious feeding habit of mosquitofish completely depleted crustacean populations in plastic wading pools (2 m diam). Hurlbert and Mulla (1981) have also reported that cladoceran (*Ceriodaphnia* and *Daphnia*) populations were completely exterminated from the 4 × 6 m seminatural ponds stocked with 450 mosquitofish/pond during a 10 month period. However, under the actual rice field mosquito control conditions, even cladoceran populations have maintained a considerable density throughout the study period (Fig. 3).

Generally insect populations were affected by the fish predation; fewer insects were collected from rice fields stocked with fish. Mayfly nymphs (*Callibaetis* spp.) are usually very abundant in shallow open water ponds; they can avoid predation (Miura et al. 1979). However in the rice fields with dense submerged vegetation, they were very few (Fig. 4) and their population was significantly reduced by predation ($t = 2.78$; $P > 0.01$). A great number of damselfly nymphs were collected from the study area and significant evidence ($t = 5.48$; $p > 0.001$) of reduction was detected. Reed and

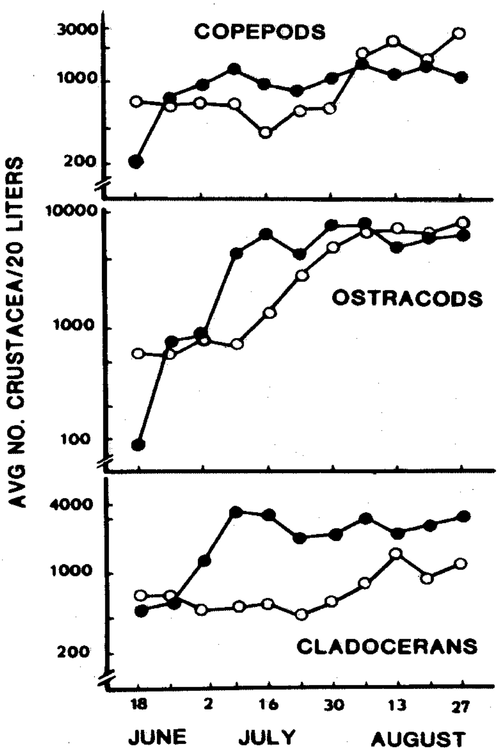

Fig. 2. Density of crustacean populations collected from rice fields in the presence of mosquitofish (open dots) and in their absence (solid dots).

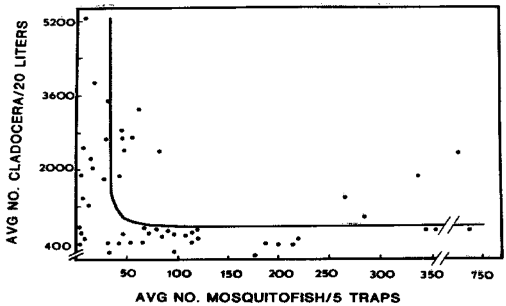

Fig. 3. An eye fixed line showing the relationship between density of mosquitofish population and abundance of cladocerans in rice fields.

Hoy (1970) and Farley and Younce (1977) also found the results similar. More dragonfly nymphs were collected from rice fields stocked with fish indicating no mosquitofish predations on the nymphs (Fig. 4), the Student *t*-value was 5.48; probability was less than 0.001. This finding is generally in agreement with the reports of Washino and Hokama (1967), Walters and Legner (1980) and Miura et al. (1979), but contradicts the report of Farley and Younce (1977).

Notonectid, corixid and belostomatid bugs were regularly collected (Fig. 5), but among them only notonectid bugs (ca. 80% *Notonecta unifasciata* and 20% *Buenoa scimitra*) were significantly reduced ($t = 4.49$; $p > 0.001$); corixids (mostly *Corisella decolor*, $t = 1.96$; $P > 0.1$) and *Belostoma* densities, are not changed. Although collections of belostomatid bugs were very small, significantly more bugs were collected from the fields with fish, thus indicating fish had little effect on the bugs ($t = 4.15$; $P > 0.001$). In fact we observed many times that the larger instar and adult belostomatids prey on smaller mosquitofish. The results obtained from our study on 3 groups of hemipterans are generally in agreement with the reports of Washino and Hokama (1967), Ahmed et al. (1970), Farley and Younce (1977) and Miura et al. (1979).

Both notonectid and corixid densities were

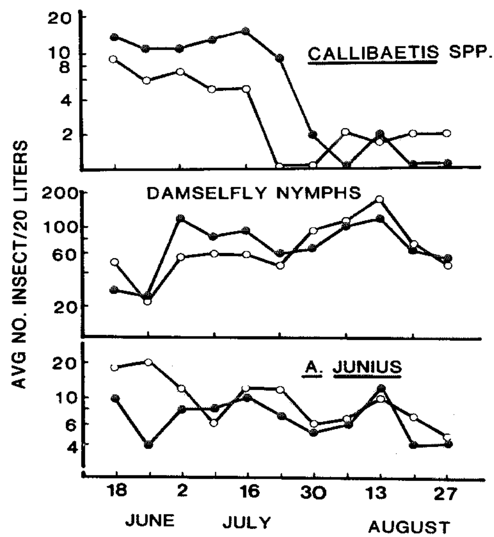

Fig. 4. Density of mayfly, dragonfly and damselfly nymphs collected from rice fields in the presence of mosquitofish (open dots) and in their absence (solid dots.)

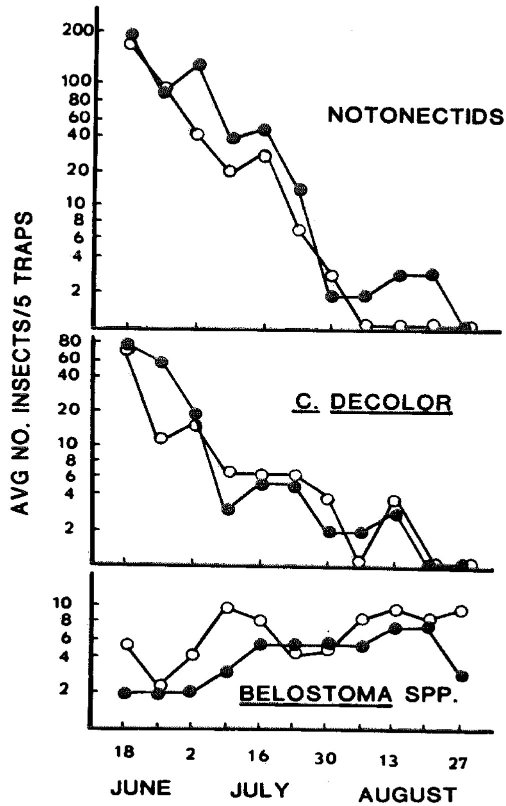

Fig. 5. Density of corixid, notonectid and belostomatid bugs collected from rice fields in the presence of mosquitofish (open dots) and in their absence (solid dots).

extremely high in the early season, however, their densities declined gradually in both stocked and unstocked fields. Although *Gambusia* prey on these bugs (Miura et al. 1979, Farley 1980), this steady reduction of the densities is more likely due to the gradual elimination of their "open water" habitat caused by the normal growth of rice plants (Fig. 6). There is a significant negative correlation between rice plant height and population densities of bugs ($r = -0.79$; $p > 0.01$).

Gambusia have been known to prey upon coleopterous larvae (Hess and Tarzwell 1942, Washino and Hokama 1967, Walters and Legner 1980) but dytiscid and hydrophilid beetles were least affected by the predation (Fig. 7). The *t*-value for adult dytiscids was 0.659 and larvae 0.329; adult hydrophilids was 1.24 and larvae 1.82.

The efficacy of mosquitofish for control of *Culex tarsalis* Coq. in California rice fields is well documented (Hoy and Reed 1970, 1971, Hoy et al. 1971, 1972). As expected, a rate of 0.2 lb/acre of stocking of fish was enough to suppress *Cx. tarsalis* densities significantly (Fig. 8) ($t = 3.40$; $P > 0.001$). Washino (1968) and Ahmed et al. (1970) reported that chironomid larvae and pupae are the most important prey organisms in rice fields for mosquitofish based on gut sample studies, our data also indicate a singificant reduction of chironomid populations in rice fields stocked with fish (Fig. 8) ($t = 3.79$; $P > 0.001$).

Although no phytoplankton or algal samples were taken during the study period, special attention was paid to detect any abnormal event such as phytoplanktonic or algal blooms or their sudden extinctions in the fields; however, we did not observe any such event.

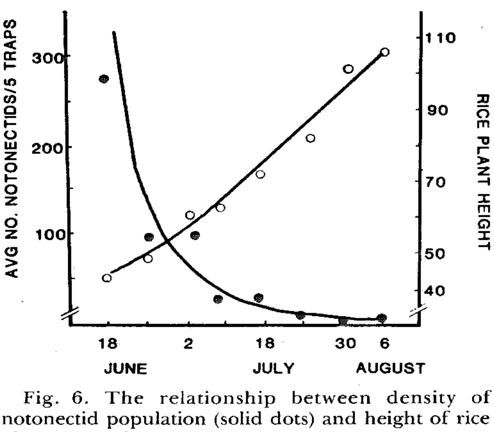

Fig. 6. The relationship between density of notonectid population (solid dots) and height of rice plant (open dots).

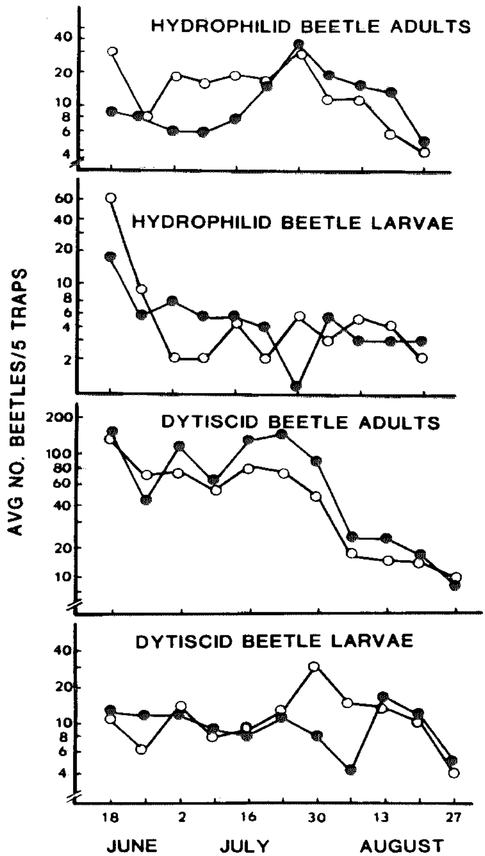

Fig. 7. Density of aquatic beetles collected from rice fields in the presence of mosquitofish (open dots) and in their absence (solid dots).

SUMMARY

The aquatic fauna of rice fields is remarkably rich. Sixty-three species or species groups of organisms were regularly collected by dipping and trapping. Mosquitofish (0.2 lb/acre) used for mosquito control did not significantly affect the seasonal population densities of copepods, ostracods, corixids, dragonflies, belostomatids and aquatic beetles. The fish did reduce densities of cladocerans, mayflies, damselflies. notonectids and chironomid midges significantly, but these populations were not exterminated. The reduction of mosquito predators and zooplanktonic organisms did not cause mosquito resurgence or phytoplanktonic blooms.

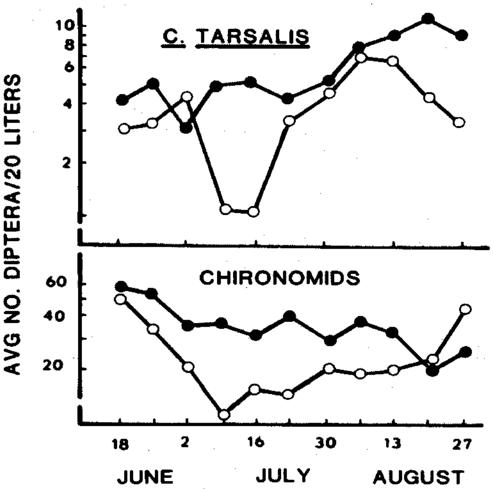

Fig. 8. Density of *Cx. tarsalis* and chironomid larvae collected from rice fields in the presence of mosquitofish (open dots) and in their presence (solid dots).

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