LIMITATIONS IN RADIOTRACER DETERMINATION OF CONSUMER TROPHIC POSITIONS[1]

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Abstract. Trophic transfer studies on wild radish (*Raphanus raphanistrum*) and ragweed (*Ambrosia artemisiifolia*) both indicated variations in the time of P^{32} uptake by herbivore species. This variation resulted from rapid temporal changes in plant organ availability with subsequent changes in consumer feeding patterns. Specific trophic positions of major herbivores were determined only by correlating phenological changes in plant organ availability with the uptake curves, abundances and feeding adaptations of consumer species. It was concluded that P^{32} uptake curves cannot be used alone in determining trophic positions unless a long-term stability in producer-consumer relationships is demonstrated.

Radionuclide tracers have been used in past studies to determine the trophic positions of consumer species (Ball and Hooper 1963; Odum and Kuenzler 1963; Marples 1966; Wiegert, Odum and Schnell 1967). Radioisotopes such as P^{32} have been incorporated in producer species with the tag subsequently followed as it passes along food chains. The shape of the P^{32} uptake curves of consumer species was used to determine their trophic position. In general, herbivores were reported to reach peak levels of radioactivity quite rapidly with time lags occurring before predators and saprophagous species become labeled. Intermediate uptake patterns were interpreted as indicating feeding from multiple trophic levels.

Questions arise concerning the generalized use of species uptake curves for trophic separation. Difficulty in trophic separation may develop under dynamic conditions where producer-consumer relationships are rapidly changing. Herbivores which either begin feeding or shift food sources part way through a tracer study might show uptake curves similar to predator species. The uptake curves of predatory species may also vary considerably under these conditions depending on which prey sources are utilized.

Unexpected uptake patterns have resulted in past studies, the most notable of which led to the isolation of a horseweed-aphid-ant food chain (de la Cruz and Wiegert 1967). Other uptake curves which were intermediate and thus difficult to interpret have usually been treated as indicating multiple food sources. Little attention has been focused, however, on the phenological changes in plant organ components and their isotope activity, both of which can vary rapidly (Shure and Pearson 1969). Differences in the time of isotope uptake by consumer species may represent feeding from separate plant organs rather than different or multiple trophic levels. Leaf foliage was the sole plant organ apparently considered in previous food chain studies (Wiegert et al. 1967).

This paper concerns the interpretation of P^{32} uptake curves in relation to plant organ changes and its implications for future trophic separation in tracer studies. The data were collected during a radionuclide tracer study of the temporal changes in trophic relationships during early succession in a New Jersey old-field ecosystem (Shure 1968, 1969).

METHODS

Trophic transfer studies were conducted in 1968 on ragweed (*Ambrosia artemisiifolia*) and wild radish (*Raphanus raphanistrum*), the two dominant producers in an early old field on the Piedmont of New Jersey. The specific tracer techniques were patterned after those of Wiegert et al. (1967) and have been presented in detail elsewhere (Shure 1969). In general, P^{32} was added to 200 plants in several different studies using a "stem-well" method (Wiegert and Lindeborg 1964). Herb-stratum arthropods and cryptozoan species were then sampled on seven sample dates over a 42-day period. Samples of plant organs were also collected periodically to determine the fate of the isotope within the producer and for estimating mean concentration factors of consumer species. All arthropod species groups and plant samples were centered intact on 2.5-cm diameter planchettes and radioassayed using an organic quenched G.M. detector (Baird Atomic EWT-64) with a 1.4-mg/cm^2 end window and a decade scaler (Baird Atomic model 135). Samples were then dried for 24 hours at 100°C and weighed to obtain activity density (cpm/mg) estimations. P^{32} uptake curves were then plotted for major consumer species.

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Results

Wild radish was labeled as it reached peak standing crop biomass (Shure 1969). Rapid phenological changes in wild radish resulted during the trophic transfer study. Flowers were dying at the start of the study with seed development in its early stages. Most leaves had died by day 10 as the plants were completing their development. Seed production occurred mainly through day 14 with most seeds disseminated by 25 days post-tagging. Only dead radish material and its seed crop were available for consumption during the remainder of the study.

Uptake curves for major components of the wild radish food web are presented in Figure 1. Species included in the upper portion illustrate the generalized trophic separation of uptake curves presented in past studies. The plant bug, *Lygus pratensis*, fed from the internal juices of different plant organs. Damsel bugs (*Nabis alternatus, Nabis americoferus*) were predators on plant bugs and other small species, while fungus weevils (*Trigonorhinus tomentosus*) utilized either radish litter or seed material. Definite time lags were present in the P^{32} uptake by these species which represent successive trophic levels.

The uptake curves of those species included in the lower portion of Figure 1 also would appear to represent successive trophic levels. Instead, the curves represent successive P^{32} buildups in three specialized herbivores which were observed feeding from different plant organs. Aphids (*Hyadaphis erysimi*) which reached population peaks during the first week of the study were consuming internal juices from the stems of wild radish. Winged forms developed as the plants dried up and the aphids were gone from the field by the end of the second week of the study. Flea beetles (*Phyllotreta chalbeipennis*) peaked next in both abundance and radioactivity, feeding solely on wild radish seeds during seed development. Peak activity density of *Phyllotreta* was reached during the final week of seed development. Both the abundance and radioactivity of *Phyllotreta* then declined following seed pod dissemination. The final herbivore uptake peak occurred for a field cricket (*Gryllus pennsylvanicus*) which was primarily herbivorous on radish seeds available in the litter. Other wild radish herbivores also exhibited similar time lags in P^{32} uptake depending on their roles as leaf, stem or seed feeders.

Predators also varied in the time and duration of P^{32} uptake depending on their specific prey sources. The additional uptake curve in Figure 1 represents the larvae of a ladybird beetle (*Coccinella novemnotata*) which was the major predator on aphid herbivores of wild radish. The uptake of P^{32} by these predaceous larvae was more rapid than for most herbivore species.

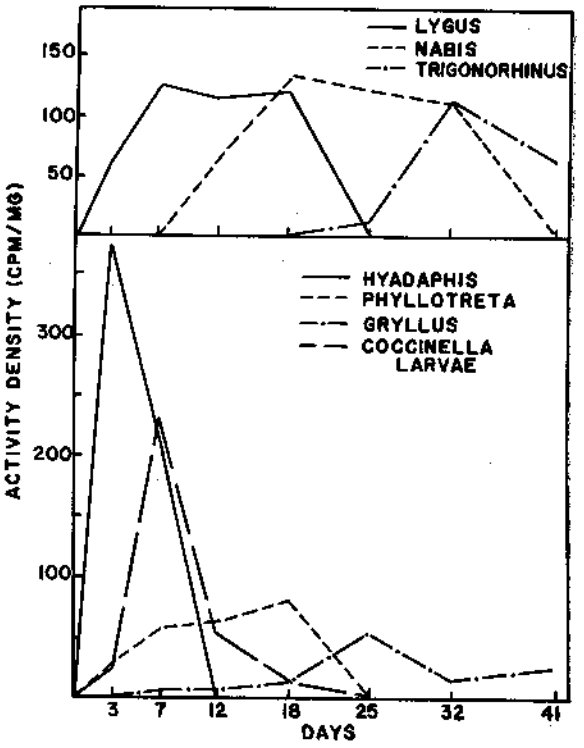

FIG. 1. P^{32} uptake curves of major consumers of wild radish. Lines connect mean activity density (cpm/mg) values for the entire species sample collected on the dates indicated.

A similar phenomenon occurred when ragweed was labeled early in its development. Only leaf foliage was present when the tracer study was initiated. Inflorescences appeared after the first week of the study, thereby adding an additional food source for resident consumers. Seed development had also begun by the end of the study.

Uptake curves for five major ragweed herbivores are shown in Figure 2. The variation from the generalized trophic separation in past studies is quite obvious. All five species peaked in P^{32} activity at successive intervals. Differences in herbivore uptake curves again resulted from the consumption of plant organs which were available at different time intervals. Leafhoppers (*Empoasca erigeron, Empoasca alboneura*) fed from the internal juices of leaves or stems while the plant bug, *Reuteroscopus ornatus*, also consumed fluids from leaves or stems and possibly from inflorescences at later periods. *Plagiognathus politus*, another plant bug, fed mainly from the internal juices in pollen stalks which became available part way through the study. *Lygus pratensis* and the

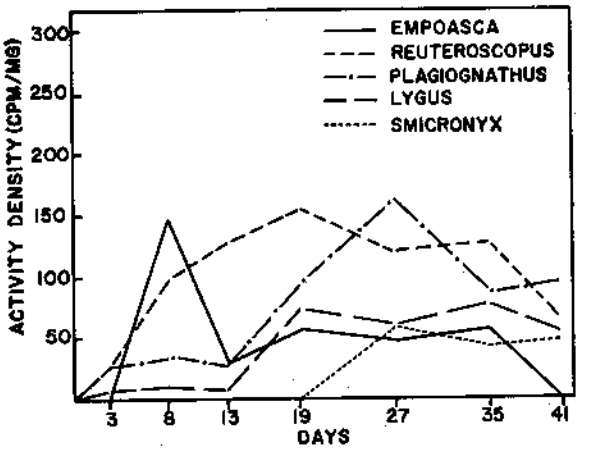

FIG. 2. P^{32} uptake curves of major consumers of ragweed. Lines connect mean activity density (cpm/mg) values for the entire species sample collected on the dates indicated.

snout beetle, *Smicronyx corniculatus*, both fed from pollen stalks initially with indications of seed utilization later in the study (Shure 1969).

Population fluctuations of these herbivore species were also related to food source availability. Most species peaked in abundance when their respective food source became available (Shure, 1969). Specific food source identifications were confirmed through field observations of feeding behavior.

DISCUSSION

Trophic separation solely from P^{32} uptake curves was not possible for many consumer species of the old field studied. This was due to the rapid successional changes in host plant or plant component availability with subsequent changes in consumer feeding patterns. Herbivores which either began feeding or shifted their feeding to different plant organs part way through a study showed delayed uptake curves similar to predator species. Specific trophic positions of these herbivores were determined only by correlating the phenological changes in plant organ availability with the uptake curves, abundances and feeding adaptations of consumer species. Trophic positions were then verified by field observations.

The use of P^{32} uptake curves for trophic separation, such as suggested in past studies (Odum and Kuenzler 1963, Wiegert et al. 1967), appears limited to certain conditions. Rapid changes in either plant organ availability, P^{32} distribution within producer organs or the occurrence of specialized herbivores may all produce wide variation in P^{32} uptake by herbivore species. These rapid changes may be absent in geographical areas with long growing seasons. Possible changes in plant organ availability and consumer abundances should be considered, however, before this assumption is verified. If not, then erroneous trophic separation is possible. Uptake curves thus cannot be used alone in the determination of trophic positions unless a long-term stability in producer-consumer relationships can be demonstrated.

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