Trophic Paths of the Tamiahua Fish Community: An ECOPATH II Approximation

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ABSTRACT

To estimate the mean annual biomass, consumption rates, and trophic paths of the fish community in the Tamiahua coastal lagoon, the ECOPATH II model was used. Tamiahua Lagoon is located adjacent to the Gulf of Mexico with a total area of 88,000 hectares (ha). It has significant inflow from rivers and two wide passes connect with the sea.

Data used were collected between 1984 and 1987. Fish species use the system in different ways; only those that are resident in the lagoon throughout their lives were analyzed individually. Published data were used where necessary.

Results showed the importance of each prey group to predators according to their food intake value. The high relative importance of primary producers in the system was surprising. In previous studies of coastal systems, benthos and detritus were the base of the trophic web, but the modeling results presented here do not show this. According to model calculations, the system imports a significant quantity of detritus. This might be due to the fact that the system is not closed, contrary to the closed-system assumption used in the present application. Rivers have a great inflow into the lagoon, and this was not supplied to the model.

KEYWORDS: ECOPATH II model, fish community, trophic web, Tamiahua Lagoon.

INTRODUCTION

Caddy and Sharp (1986) stated that good fisheries management policy has to be supported by good ecology. It is important to understand the ecological relationships, not only of the species being fished, but also of the whole community since we are dealing with a system in which the species caught do not live in isolation. Food-web analysis has great potential as a tool for fisheries management research.

Several methods have been proposed to achieve the goal of multispecies fisheries management. Polovina (1984 a,b) presented a model, ECOPATH, in which the standing stock and production budget could be estimated. Christensen and Pauly (1990) modified the ECOPATH model (naming it ECOPATH II) in a way that more information about the system could be obtained and the need for certain inputs could be calculated by the model. ECOPATH II has several virtues and some disadvantages. Despite the latter, the model has proved to be a good tool for estimating biomass within species or trophic groups.

Tamaihua Lagoon is a typical coastal lagoon, located in the western Gulf of Mexico (Figure 1). It has a total area of 88,000 ha and connects to the ocean by two passes. Several rivers discharge into the lagoon. Significant temperature and salinity fluctuations occur during the year. In autumn several storms provide more fresh water from rivers; in spring the system is more stable. Important fisheries exist, primarily for mullets, croaker, mojarra, catfish, and crustaceans such as shrimp and blue crab.

Because of the importance of this lagoon to fisheries, the ECOPATH II model was used to estimate fish community trophic paths and the annual biomass of its components. In the model the lagoon was treated as a closed system because the magnitude of riverine inflows of organic detritus was not known. Since the lagoon is not a closed system, it was necessary to evaluate how treating it as a closed system affected the final results of the model.

METHODS

Conceptually, the Tamiahua system can be viewed as a set of boxes, representing species, connected by lines indicating trophic linkages (Figure 2). Data used as input to the model were collected from December 1984 through January 1987. During this period, 79 species of fish were collected, several of which use the lagoon as nursery and feeding area. Only those species resident in the lagoon throughout their lives were analyzed individually. The number of individual species considered was seven (Table 1), and of these, two species of *Anchoa* were combined into one box. Other boxes of the model were Shrimp, Zooplankton, Phytoplankton, Detritus, Decapods (other than shrimp), and Other Fishes. These latter boxes consist of several species, but all species pooled in a box are part of the same guild within the lagoon.

Parameters like P/B (production/biomass) and Q/B (consumption/biomass) were calculated when possible, and published data from systems similar to Tamiahua were used. Although Tamiahua is an important fishing area, fishery data were not available; so catches were not supplied to the ECOPATH II model.

RESULTS

Estimates of mean annual biomass, trophic level, and omnivory index are provided in Table 2 and Figure 3; the food web scheme is presented in Figure 2. Anchovy biomass, known to be 0.1 g/m^2, was not supplied to the model in order to test the accuracy of model calculations. It can be seen that the ECOPATH II model estimate of anchovy biomass (0.082 g/m^2) is quite near to the observed value. Similarly, good results were obtained for other boxes.

TAMIAHUA LAGOON

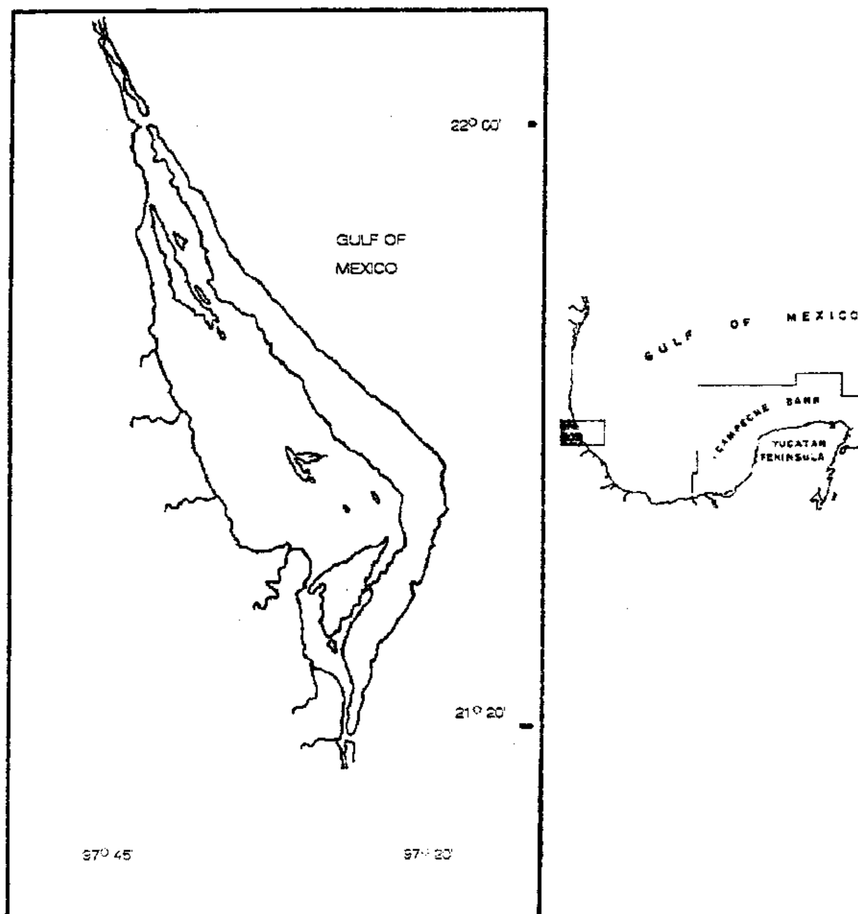

Figure 1. Location of Tamiahua Lagoon and adjacent rivers. Also shown are Campeche Bank and Yucatan Peninsula, where Celestun Lagoon is located.

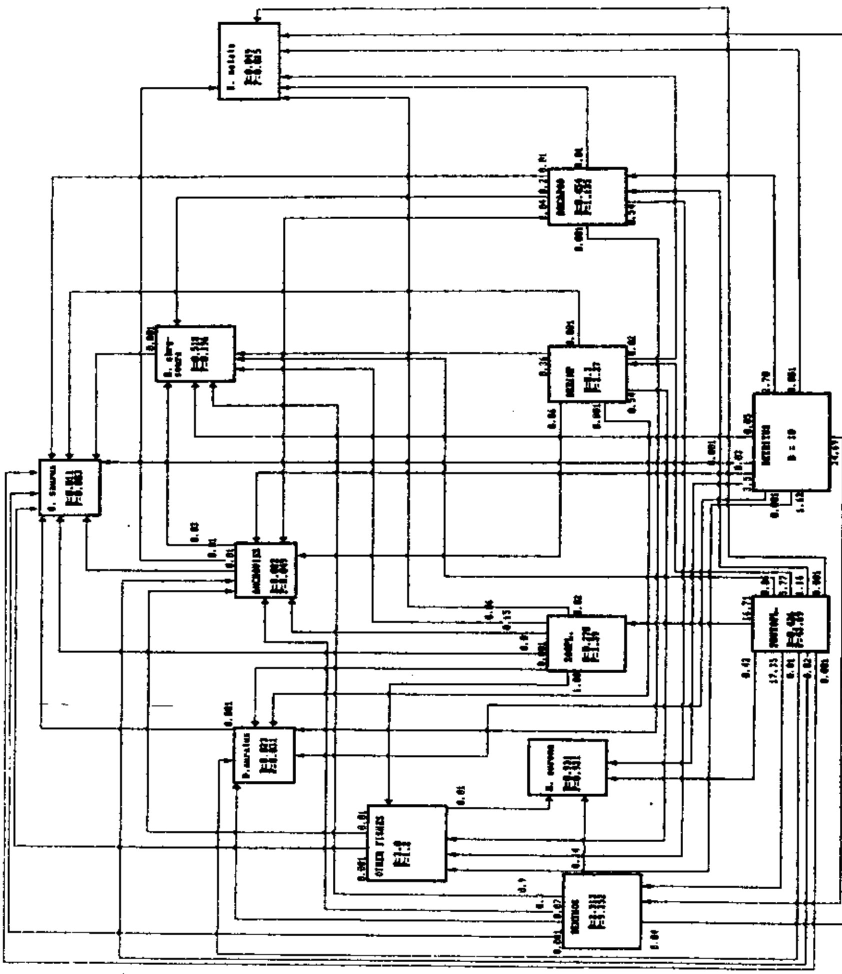

Figure 2. Food web scheme for the fish community of Tamiahua Coastal Lagoon, Mexico. The vertical position corresponds to trophic level calculated by the ECOPATH II model. Units are grams per square meter for Biomass (B) and Production (P) grams per square meter per year. See Table 1 for key names of each box. Cannibalism paths were omitted.

Table1. Predator prey matrix for Tamiahua Lagoon fish community; numbers are the proportion of utilization of the prey. These data were used as input to ECOPATH II model.

	ZP	BC	ANC	DA	MC	OS	SHR	OD	OF	BEN	SN
Zooplankton (ZP)	-	0.035	0.353	0.036	-	0.234	-	-	0.200	-	0.193
Bairdiella chrysoura (BC)	-	-	-	-	-	0.088	-	-	-	-	-
Anchovies (ANC)	-	0.019	-	-	-	0.176	-	-	-	-	0.097
Diapterus auratus (DA)	-	-	-	-	-	0.088	-	-	-	-	-
Mugil curema (MC)	-	-	-	-	-	-	-	-	-	-	-
Oligoplites saurus (OS)	-	-	-	-	-	-	-	-	-	-	-
Shrimps (SHR)	-	0.217	0.141	0.021	-	0.035	-	-	0.100	-	0.214
Other Decapods (OD)	-	0.120	0.099	0.024	-	0.172	-	-	0.100	-	0.057
Other Fishes (OF)	-	-	0.014	-	0.002	0.088	-	-	-	-	-
Benthos (BEN)	-	0.545	0.291	0.760	0.058	0.088	-	-	0.300	0.100	0.395
Strongylura notata (SN)	-	-	-	-	-	-	-	-	-	-	-
Phytoplankton (PHP)	1.000	0.035	0.041	0.135	0.103	0.022	1.000	0.300	-	0.300	0.040
Detritus (DET)	-	0.029	0.062	0.025	0.837	0.009	-	0.700	0.300	0.600	0.004

Table 2. Biomass, trophic levels and omivory indexes calculated from ECOPATH II model for Tamiahua Lagoon fish community.

Box	Biomass g/m^2	Trophic Level	Omnivory Index
Zooplankton	0.2780	1.0000	0.0000
Bairdiella chrysoura	0.5180	2.1500	0.1010
Anchovies	0.0820	2.0300	0.1126
Diapterus auratus	0.0230	2.0800	0.2099
Mugil curema	0.9310	1.3100	0.0273
Oligoplites saurus	0.0110	2.4900	0.2804
Shrimps	0.3000	1.0000	0.0000
Other Decapods	0.4540	1.2000	0.0166
Other Fishes	3.0000	1.8900	0.1743
Benthos	2.3130	1.3000	0.1269
Strongylura notata	0.0490	2.1900	0.1489
Phytoplankton	0.0426	0.0000	0.0000
Detritus	10.0000	0.2800	0.2018

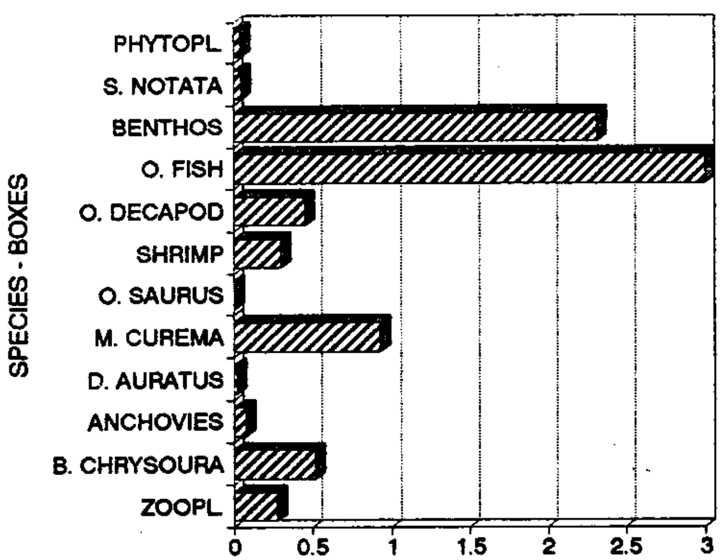

Figure 3. Wet biomass for the species and boxes of Tamiahua fish community used as input for, or calculated by, the ECOPATH II model.

The highest trophic level in the model system was 2.49 for *Oligoplites saurus*, which in this food web was the top predator, followed by *Bairdiella chrysoura*. At the same time, the number of paths shows that *O. saurus* has a mean path number of 3.18, followed by *B. chrysoura* with 2.78. These values indicate the average number of routes an element takes to get to the predator. As trophic web structure gets more complicated, the average number of paths to top predators is higher.

From the food web, the Detritus and Phytoplankton boxes have the most number of paths to predators. Detritus has an important path to the Benthos box. Detritus biomass is too small to provide the detritus required by the rest of the system according to the model results. Although all boxes within the system are sources of detritus, they are not sufficient to support the system. It is therefore concluded, as calculated by the model, an importation of detritus from adjacent systems of 30 $g/m^2/yr$ is necessary for the system to be stable.

The biomass of the Other Fishes box could be overestimated since it includes all species that migrate outside the lagoon. In the Decapods box the opposite may occur since the sampling method used was more selective for fish than for other kinds of organisms.

DISCUSSION

The biomass calculated by the model for those boxes where observed values existed, but were deliberately excluded as a test, resulted in values close to observed ones. With the good background information available for this ecosystem, this predictive capability could be used to approximate the biomass production of commercially important species. Although biomass results were in close approximation with observed values and the relationships between boxes in the food web seem reasonable, such estimates of biomass production would still have to be taken with caution.

The resulting form of the food web is interesting and of great value. Knowledge of the number of paths an element takes to a predator is important for the possible estimation of the biomass or energy lost in this route (Kay *et al.* 1989). At present, the model lacks some relevant time delays, so the real time an element takes in route could be calculated more explicitly.

In feeding ecology studies, the trophic position of a species has been controversial, as has the different methodologies of estimating trophic position (Caddy and Sharp, 1986; Paine, 1980; Pimm, 1980a,b; Yodzis, 1984). Here, the trophic level of each species or box calculated by ECOPATH II is in accordance to its food supply and the proportion used of each component. Nevertheless, the trophic index of a species has little meaning if it is not compared. The trophic level obtained for *Bairdiella chrysoura* was 2.15 in Tamiahua, 3.5 in the coastal lagoon of Celestun, Yucatan (Chavez *et al.*, 1990), and 2.15 off the Yucatan shore (Vega *et al.*, 1990). These differences could be related to different food availability in these systems. In Tamiahua, the food availability may be so great that the species does not have to seek food at several trophic levels. In the case of Celestun, food is distributed in patches, making it less available and forcing the species to feed at more trophic levels and on several food items. With respect to the whole system, the low trophic levels of the other species or boxes, as well as the low omnivory indices, could indicate a compressed trophic web. This reflects the fact that the system does not support large carnivorous species.

Model boxes should be formed of species of the same guild. This is important since significant calculations are based on the feeding habits of these boxes, and a mixture of guilds in a single box could make results difficult to interpret. A more simplified model of the system is needed; the system should be divided into compartments in such a way that information loss is minimized. The model could potentially be used to experiment with alternative trophic configurations, obtaining linkage strengths (Paine, 1980), and then calculating which species could be joined as a box and which could not.

The model estimated the additional detritus required to support a steady-state system. Unfortunately, estimates of detritus flow into the lagoon from rivers are not available, so the magnitude of the value returned by the model cannot be validated. However, the quantity predicted is not far from what one could expect in the system.

Phytoplankton appeared to be an important box within the food web. It is a significant factor for several of the lower trophic boxes that, following the trophic paths, are relevant for top species in the web. This importance has not been found in other works, where it has been said that detritus and benthic organisms are the base for the trophic web (DeSylva, 1975). For Tamiahua, this is also the case in general, but the importance of phytoplankton for system maintenance must be emphasized.

LITERATURE CITED

Caddy, J.F. and G.D. Sharp. 1986. *An ecological framework for marine fishery investigations.* FAO Fisheries Technical Paper. (283): 152 pp.

Chavez, E., M. Garduno, and F. Arreguin-Sanchez. 1990. Trophic dynamic structure of Celestun Lagoon, South Gulf of Mexico. Statutory Meeting of the International Council for the Exploration of the Sea, October, 1990 (ms).

Christensen, V. and D. Pauly. 1990. *A draft guide to the ECOPATH II program (ver 1.0).* ICLARM Software 6, 22 pp.

DeSylva, D.D. 1975. Nektonic food webs in estuaries. Pages 420-447 in L.E. Cronin, ed. *Estuarine Research.* Academic Press Inc., New York, NY.

Kay, J.J., L.A. Graham, and R.E. Ulanowicz. 1989. A detailed guide to network analysis. Pages 15-61 in F. Wulff, J.G. Field, and K.H. Mann, eds. *Network Analysis in Marine Ecology.* Springer-Verlag, New York, NY.

Paine, R.T. 1980. Food webs: linkage, interaction strength and community infrastructure. *Journal of Animal Ecology* **49**: 667-683.
Pimm, S.L. 1980a. Properties of food webs. *Ecology* **61**(2):219-225.
Pimm, S.L. 1980b. Are food webs divided in to compartments? *Journal of Animal Ecology* **49**: 879-898.
Polovina, J.J. 1984a. Model of coral reef ecosystem. I. The ECOPATH model and its applications to French Frigate Schoals. *Coral Reefs* **3**(1):1-11.
Polovina, J.J. 1984b. An overview of the ECOPATH model. *Fishbyte* **2**(2):5-7.
Vega, M.E., F. Arreguin-Sanchez, and M. Hernandez. 1990. Trophic fluxes in beach seine fishery of the Campeche Bank. Statutory Meeting of the International Council for the Exploration of the Sea, October, 1990. (ms.)
Yodzis, P. 1984. How rare is omnivory? *Ecology* **65**(1):321-323.