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Trophic interactions between fish and other compartment communities in a tropical estuary in Brazil as indicator of environmental quality

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Abstract

Studies on fish stomach contents were carried out to assess the trophic interactions between them and other compartment communities of the Santa Cruz Channel, a tropical estuary in Brazil. Food items quality and quantity were used as a valuable tool to assess the environmental quality. The study was based on samples collected from 1995 to 1998, besides published data since 1979. Groups interactions were based on food items of 27 fish species. The Sorensen similarity index was used for cluster analysis. Many different taxa appeared in fish stomachs and there was considerable spatial and temporal variation in food eaten even for the same species. Many related food groups were registered, among which two could be considered the most important: those formed mainly by microalgae, sponges and detritus; and the other by molluscs, crustaceans, nematodes, annelids and fish. Because many fish fed from benthic and pelagic pathways they were the main organisms that linked the benthic and pelagic energy flow. The results reveal that the Santa Cruz Channel, despite human impacts, is still an ecosystem capable of supporting fish populations.

1 Introduction

Fish generally occupy higher trophic levels in the marine environment, and their abundance, distribution, and condition are considered indicators of ecosystem health [1,2]. Fish are important in estuarine food webs because they are the dominant top and midlevel carnivores, and because they often regulate, through predatory pressure, lower trophic levels [3]. Many factors cause changes in fish abundance and species composition. Among them are nutrient concentrations, turbidity from suspended sediment, phytoplankton abundance, salinity, current velocity, overfishing, wetland loss, weather and oceanic conditions, and predator abundance [4]. Fish are mobile and able to detect and react to changing environmental conditions. Tolerant fish remain in degraded coastal systems, whereas more sensitive species move to more habitable regions or simply succumb to the stress. Abundant juvenile fish and diversity in species indicate that a system provides sufficient habitat to support reproduction and growth. Juvenile fish are sensitive to anthropogenic stresses and, therefore, their abundance may indicate how much contamination exists in a system [2]. Because higher trophic levels in estuarine systems require a rich diversity of intact ecosystem functions to survive, grow, and reproduce, fish abundance and species richness can be a broad and useful indicator of estuarine health [5,6].

The Itamaraca estuarine system is used as nursery grounds by many commercially important species and this has generally been attributed to the abundant food supply in comparison to adjacent marine areas [7]. It is also a diverse area containing many different types of habitat suitable for fish. This variety of habitats, along with the complexity of fish community interactions and the migratory nature of many species makes it extremely difficult to assess the overall condition of the fish community in a estuary. Because of this problem, this paper focuses on specific, commercially and ecologically important species rather than the fish community as whole. Thus, studies on fish stomachs content were carried out to assess the trophic interactions between them and other compartment communities and to use them as indicator of the Santa Cruz Channel health, a tropical estuary in Brazil.

2 Material and methods

The Itamaracá estuarine system is located at 7°34'00"- 7°55'16" S and 34°48'48" - 34°52'24" W, about 50 km north of Recife, Pernambuco State, Brazil. It consists of the U-shaped Santa Cruz Channel with 20 km length; and there are two connections to the South Atlantic Ocean and five tributaries draining into the channel (Figure 1).

Climate is warm-humid with mean annual temperature 25°C and rainfall 1300-1800 $mm.yr^{-1}$, concentrated from March to August.

Stomach content diet composition were derived from 27 fish species most abundant in the artisanal fisheries, besides those ecologically important and those used in the local fishculture ponds. Sample were monthly collected along Santa

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Cruz Channel with a seine net, from 1995 to 1998, besides published data since 1979. A total of 5,150 fishes stomach content were analysed under a compound microscope and stereomicroscope according to Rounsefell & Everharth [8] and Hyslop [9] methodology. Cluster analysis was based on the food items and Sorensen [10] similarity index was used. The classification was the Weighted Pair Group Method Average Arithmetic's (WPGMA). It was used the Numerical Taxonomy and Multivariate Analysis System Program (NTSYS), version 2.1, from Exeter Software, USA.

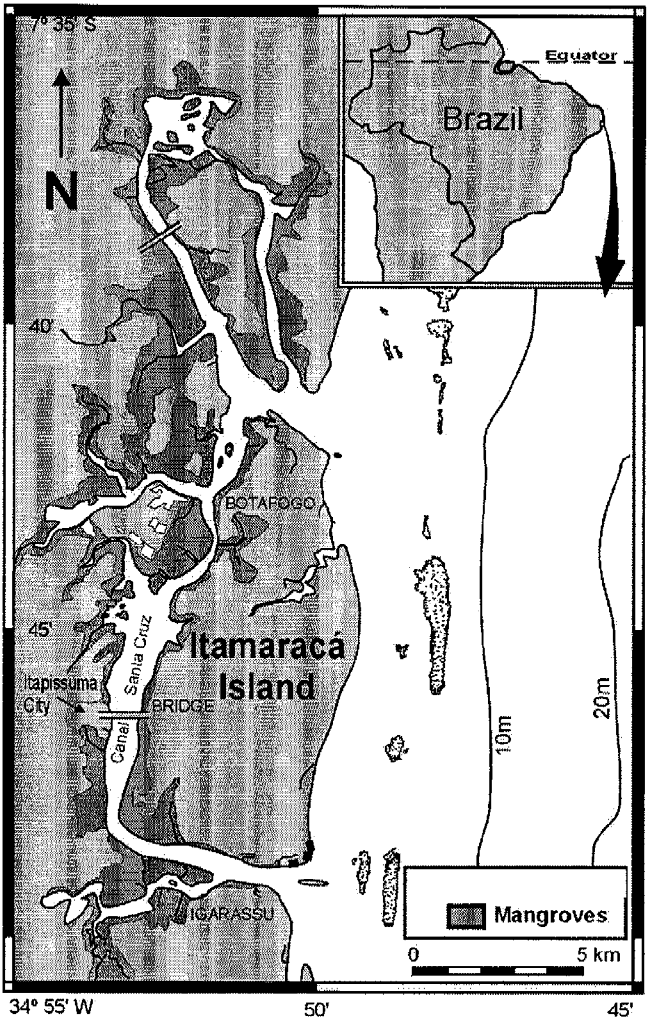

Figure 1: Itamaracá estuarine system, coast North of Pernambuco, Brazil.

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3 Results

3.1 Food items

The stomach contents items of the 27 fish species were:

- *Lycengraulis grossidens* (Agassiz, 1829) - Crustacea (43%), Pisces (20%), plants (20%), Platyhelminthes (5%) and other organisms (12%).
- *Opisthonema oglinum* (Le Sueur, 1818) – Crustacea (67%), diatoms (10%), plants (13%), Mollusca (3%), other organisms (7%).
- *Arius parkeri* (Trall, 1832) – Crustacea (51%), Pisces (19%), Mollusca (13%), plants (2%) and other organisms (5%).
- *Arius proops* (Valenciennes, 1839) - Crustacea (51%), Pisces (18%), Mollusca (14%), plants (9%) and other organisms (8%).
- *Synodus foetens* (Linnaeus, 1766) – Pisces (36%), Crustacea (22%), Mollusca (9%), other organisms (33%).
- *Mugil curema* Valenciennes, 1836 – Diatoms (55%), Cyanophyta (7%), other microalgae (5%), Superior plants (4%), animals (12%) and sand grains (17%).
- *Mugil liza* Valenciennes, 1836 - Diatoms (50%), Cyanophyta (8%), other microalgae (3%), Superior plants (7%), animals (19%) and sand grains (13%).
- *Hyporhamphus unisfasciatus* (Ranzani, 1842) - Diatoms (56%), Cyanophyta (1%), other microalgae (3%), Superior plants (32%), animals (8%), Chlorophyta (2%) and Pyrrophyta (1%).
- *Hemirhamphus brasiliensis* (Linnaeus, 1758) - Diatoms (56%), Cyanophyta (3%), Chlorophyta (3%), Superior plants (27%) and animals (11%).
- *Centropomus parallelus* Poey, 1860 – Crustacea (51%), Pisces (36%), Mollusca (2%) and other organisms (11%).
- *Centropomus undecimalis* (Bloch, 1792) - Crustacea (31%), Pisces (58%), Mollusca (2%) and other organisms (9%).
- *Oligoplites palometa* (Cuvier, 1831) - Crustacea (13%), Pisces (30%), Nematoda (21%), plants (9%) and other organisms (9%).
- *Caranx latus* Agassiz, 1831 - Crustacea (50%), Pisces (19%), Leptocardi (13%), Mollusca (9%), plants (6%) and other organisms (3%).
- *Chloroscombrus chrysurus* (Linnaeus, 1766) - Crustacea (44%), Pisces (4%), Leptocardi (4%), Mollusca (4%), plants (15%) and other organisms (29%).
- *Eucinostomus gula* (Cuvier, 1830) - Crustacea (41%), Leptocardi (17%), Mollusca (14%), Annelida (4%), plants (4%) and other organisms (10%).
- *Eugerres brasilianus* (Valenciennes, 1830) - Crustacea (21%), Annelida (7%), Cyanophyta (17%), Diatoms (12%), other plants (12%), sand grains (10%) and other organisms (21%).
- *Diapterus auratus* Ranzani, 1840 - Crustacea (14%), Annelida (8%), Cyanophyta (19%), Diatoms (21%), other plants (15%), sand grains (6%) and other organisms (17%).
- *Conodon nobilis* (Linnaeus, 1758) – Crustacea (20%), Leptocardii (27%), Mollusca (22%), worms (7%), other organisms (24%).

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- *Gobionellus oceanicus* (Pallas, 1770) – Diatoms (87%), Cyanophyta (7%), other plants (2%), Porifera (2%) and sand grains (2%).
- *Chaetodipterus faber* (Broussonet, 1782) – Crustacea (47%), Hydrozoa (11%), Mollusca (2%), plants (26%), other organisms (14%).
- *Sphyraena barracuda* (Walbaum, 1792) – Crustacea (11%), Pisces (74%), Mollusca (9%), superior plants (3%) and other organisms (3%).
- *Trichiurus lepturus* Linnaeus, 1758 - Crustacea (9%), Pisces (42%), Annelida (31%), superior plants (9%) and other organisms (9%).
- *Scomberomorus brasiliensis* Collete, Russo & Zavala-Camin, 1978 – Pisces (62%), nematode (23%) and other organisms (15%).
- *Citharichthys spilopterus* Günther, 1862 – Crustacea (74%), Pisces (12%), superior plants (7%), sand grains (6%) and other organisms (1%).
- *Achirus lineatus* (Linnaeus, 1758) – Crustacea (53%), Annelida (26%), Nematoda (4%), superior plants (3%) and other organisms (14%).
- *Symphurus plagusia* (Bloch & Schneider, 1801) – Crustacea (63%), Nematoda (20%), superior plants (8%), sand grains (4%) and other organisms (5%).
- *Sphoeroides testudineus* (Linnaeus, 1758) – Crustacea (21%), Mollusca (28%), Sipunculida (12%), plants (14%) and other organisms (25%).

Among the 27 studied species, 11 outranked in abundance and in frequency. The herbivorous *Hemirhamphus brasiliensis* (Linnaeus, 1758) and *Hyporhamphus unifasciatus* (Ranzani, 1842) that feed of diatoms (*Cocconeis* sp., *Climacosphaenia* sp., *Navicula* spp., *Nitzschia* spp., *Belerochea* sp., *Fragillaria* sp.) and of the seagrass *Halodule wrightii* Ascherson, being first order consumers.

The planktivorous *Ophistonema oglinum* (Le Sueur, 1818) feed on microcrustaceans and centric diatoms; while the fingerling of *Mugil* spp. feed on diatoms (*Amphiprora* sp., *Amphora* spp., *Cocconeis* sp., *Gramatophora marina* (Lyngbye), *Grammatophora* sp., *Gyrosigma balticum* (Ehrenberg) Rabenhorst, *Navícula* spp., *Nitzschia punctata* (Smith) Grunow, *Nitzschia* spp., *Pinnularia* sp., *Pleurosigma* spp., *Surirella* sp.), blue-green algae (*Oscillatoria* spp.), dinoflagellates (*Gymnodinium* sp.), green algae (*Cosmarium* sp.), copepods, crustacean and mollusks bivalve larvae, foraminifera and radiolarian. All these are first order consumers.

Among the detritivorous, *Mugil curema* Valenciennes, 1836 and *Mugil liza* Valenciennes, 1836 which browse on the benthic Pennales diatoms mats [*Amphipora* sp., *Amphora* spp., *Grammatophora marina* (Lyngbye) Kützing, *Navícula* spp., *Nitzschia punctata* (Smith) Grunow, *Pleurosima* spp., *Gyrosigma balticum* (Ehrenberg) Rabenhorst], followed by the Centricae diatoms (*Coscinodiscus* spp.), besides crustaceans (copepods) and mollusks.

The most abundant omnivores are *Eugerres brasilianus* (Valenciennes, 1830) and *Diapterus auratus* Ranzani, 1840 feeding on blue-green algae (*Oscillatoria* spp., *Anabaena* sp., *Merismopedia* sp., among others), diatoms (*Navicula* spp., *Pleurosigma* spp., *Cymbella* spp, *Melosira moniliformis* (Muller) Agardh, etc.), plant detritus (mangrove and seagrass), besides crustaceans (mainly copepods), annelids and animal detritus, being first order consumer.

The main carnivores are *Centropomus parallelus* Poey, 1860 which feed on crustacens (51%) (Alpheidae, Penaeidae, Porcellanidae, Grapsidae, Ocypodidae, Portunidae, Xanthidae, Sphaeromatidae, Cymothoidae, Bopyridae), followed by fishes (36%) (Gobiidae, Gerreidae e Engraulidae); *Centropomus undecimalis* (Bloch, 1792) which feed mainly on fishes (58%) (Gerreidae, Atherinidae, Haemulidae, Soleidae, Polynemidae, Eleotridae, Elopidae, Engraulidae e Clupeidae), followed by crustaceans (31%) (Grapsidade, Ocypodidae, Portunidae, Penaeidae, Aphaeidae, Palaemonidae, Cymothoidae, Calianassidae); *Scomberomorus brasiliensis* Collete, Russo & Zavala-Camin, 1978 feeding mainly on fishes (62%) (Engraulidae, Clupeidae), followed by nematodes (23%), besides other animals; *Sphyraena barracuda* (Linnaeus, 1766) feed basically of fishes (74%) of the Gobiidae family.

When considering all food items, crustacean was the most frequent food item in the fishes stomachs occurring in nearly 92% of the analyzed samples. It was mainly composed of Copepod, Isopoda, Amphipoda, Ostracoda, shrimp and crab scraps.

Fishes were found in 77% of the studied stomachs and Gerreidae, Clupeidae, Gobiidae and Engraulidae were most common. Mollusks were found also in 77% of the stomachs and both Gastropoda and Bivalvia were registered.

Plants were common (77%) in the stomachs and comprised the macroalgae Chlorophyta, Phaeophyta and Rhodophyta, besides mangrove and seagrass pieces. Nematoda, Annelida and semi-digested animal scraps were found in 48% of the stomachs. Microalgae, mainly diatoms were present in 40% of the stomachs. Sand grains were registered in 33% of the stomachs and Leptocardii comprised 25% of all studied stomachs.

3.2 Trophic classes

The studied stomachs revealed that 33% of the fishes were primary consumers, 52% were secondary consumers and 15% tertiary consumers (Table 1).

3.3 Cluster analysis of food items

Cluster analysis of food items presented 9 groups (Figure 2). Group 1 (> microalgae), Group 2 (> superior plants), Group 6 and 7 (> macroalgae) comprise the items found in the stomach of the herbivorous. Group 3 (Insect and planktonic eggs), Group 4 (Mollusca, Crustacea, Pisces, Nematode and Annelid) and Group 5 (Leptocardii and animals scraps), comprise the carnivorous of second and third order. Group 8 (Platyhelminthes, Nemertinea, Sipunculida and other worms) clustered the food of *Oligoplites palometa* and *Sphoeroides testudineus*. Group 9 (Priapulida, Arachnida) includes the food items of *Achirus lineatus*.

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Among these 9 groups, two groups were important in the food web of Itamaracá ecosystem. The first group was composed by first order trophic level, and comprised the planktofagous (*Opisthonema oglinum*), herbivorous (*Hyporhamphus unifasciatus* and *Hemirhamphus brasiliensis*), detritus eater (*Mugil curema, M. liza* and *Gobionellus oceanicus*) and omnivorous (*Chaetodipterus faber, Eugerres brasilianus* and *Diapterus auratus*). The second group clustered second order carnivorous (*Achirus lineatus, Arius parkeri, A. proops, Caranx latus, Chloroscombrus chrysurus, Conodon nobilis, Lycengraulis grossidens, Synodus foetens, Trichiurus lepturus, Sphoeroides testudineus, Citharichthys spilopterius, Symphurus plagusia, Eucinostomus gula* and *Oligoplites palometa*).

Table 1: Trophic level of 27 fish species of Itamaracá estuarine system based on stomach contents.

TROPHIC LEVEL	FEEDING HABIT	SPECIES
Primary Consumer	Planktonphagus	*Opisthonema oglinum*
	Herbivores	*Hyporhamphus unifasciatus* *Hemirhamphus brasiliensis*
	Detritivores	*Mugil curema* *Mugil liza* *Gobionellus oceanicus*
	Omnivores	*Chaetodipterus faber* *Eugerres brasilianus* *Diapterus auratus*
Secondary Consumer	Carnivores	*Achirus lineatus* *Arius parkeri* *Arius proops* *Caranx latus* *Chloroscombrus chrysurus* *Citharichthys spilopterus* *Conodon nobilis* *Eucinostomus gula* *Lycengraulis grossidens* *Oligoplites palometa* *Sphoeroides testudineus* *Symphurus plagusia* *Synodus foetens* *Trichiurus lepturus*
Tertiary consumer	Carnivores	*Centropomus parallelus* *Centropomus undecimalis* *Scomberomorus brasiliensis* *Sphyraena barracuda*

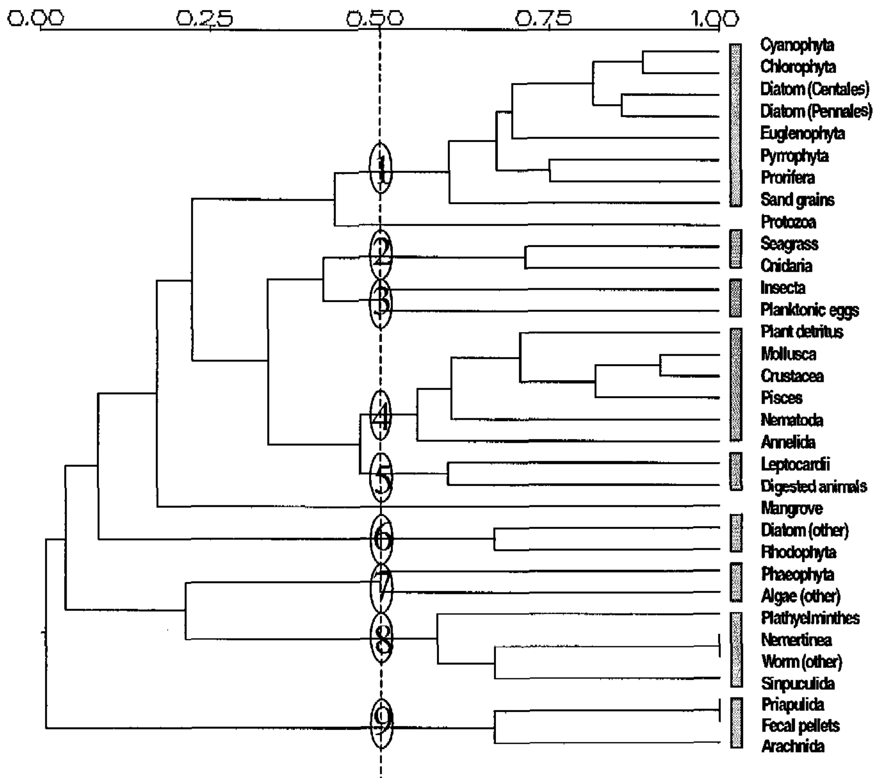

Figure 2: Cluster analysis of the stomach content food items of the fish species of Itamaracá estuarine system, Pernambuco, Brazil.

3.4 Cluster analysis of the fishes

The fishes presented 4 groups based on the stomach content (Figure 3). Group 1 associated most the carnivorous fish. Group 2 associated the nectobenthonic fishes. Group 3 clustered the planctophagous and herbivorous species. Group 4 clustered the omnivorous and detritivorous species.

4 Discussion

Fish composition, abundance, distribution, and condition are considered indicators of ecosystem health because fish integrate effects of environmental stress over space and time [2]. The fish fauna of Itamaracá is extremely diversified, composed of 145 species [11]. These fishes have been categorized as resident, marine dependent, marine and limnetic visitors [11,12]. The species composition of the community is influenced by seasons and tides, breeding behavior, feeding behavior, habitat diversity and available space, as well as other factors, such as pollution and water quality [13]. In consequence, many different taxa appear in fish stomachs and there is considerable spatial and temporal variation in food eaten even for the same specie [14].

The complexity of food sources found in fish stomachs reflects also changes in food preferences and sources as fish grow (ontogenetic changes) and the opportunistic nature of most fish species; as it was seen in our results, often the diet of a single species comprises more than 20 different food types. The whole trophic structure does not comprise specific trophic levels as fish eat food from a variety of sources [15].

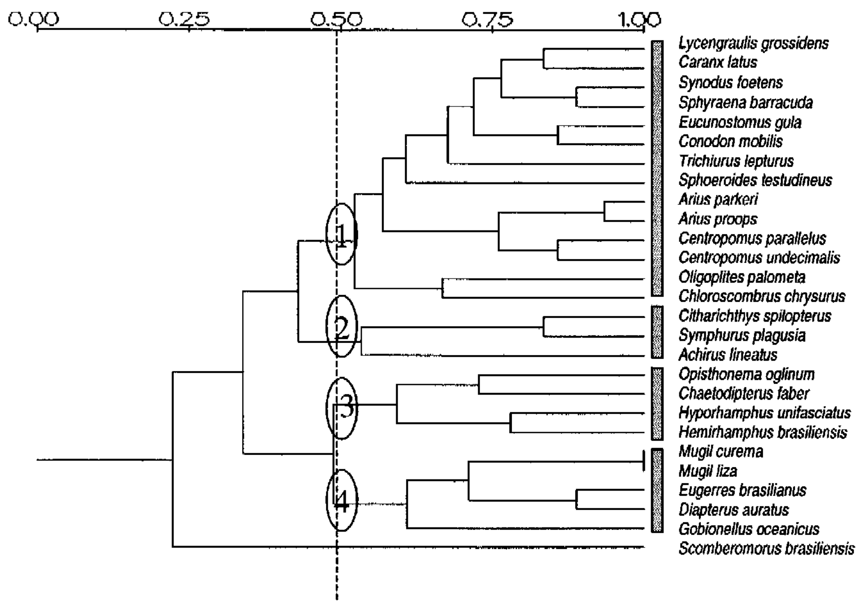

Figure 3: Cluster analysis of the 27 fish species of Itamaracá estuarine system, based on the stomach content.

The considerable variation in types and amounts of foods consumed by a species at a given location, and the similarity of major food types eaten by different species at a given location, demonstrate that diet composition of omnivores is often determined mostly by food availability. For example, Yáñez-Arancibia [16] studied food habits of the mullet *Mugil curema*, in several coastal lagoons on the west coast of Mexico. Detritus was usually 50% of the food of adults at all seasons in all lagoons studied, but the proportion of the diet that was filamentous algae varied between 0 and 28% depending on season and location. In our study, *Mugil curema* had 55% of diatoms in the stomach, but the dominant species varied along the seasons. Odum & Heald [17] mention that the most abundant fishes in an estuary tend to be omnivorous and opportunistic at all sizes.

In our study besides the omnivorous, the detritivorous and herbivorous had an important role in the trophic web of Itamaracá system indicating a health environment. The predominance of mullets and some clupeids in this area confirm that throughout the tropics some genera of these families absolutely depend on estuaries for juvenile growth [4].

Fishes differ greatly in the character of the food they consume; however, they show a basic dependence on phytoplankton and detritus through both the pelagic and benthic pathways. The pelagic pathway begins with phytoplankton, and goes to copepods, decapods, and mysids, to small fishes like anchovy and herring, then to large predators like Centropomidae. The benthic pathway begins with detritus and other organic matter, which is consumed by benthic copepods and polychaetes as well as filter feeding organisms; and then these are eaten by small dwelling fish, which are eaten by large predators like Centropomidae and Scombridae. These pathways are closely linked because many species eat both pelagic and benthic organisms, and the top carnivore is often the same fish in both pathways [18]. Because many fish feed from both benthic and pelagic pathways, they are the main organisms that link the benthic and pelagic energy flow.

The results reveal that the Santa Cruz Channel is an ecosystem where occurs an energy storage capable of supporting fishes populations of many trophic categories. Despite human impacts, species composition suggests a healthy habitat and this is still an ecosystem capable of supporting fishes populations.

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