UNIversidade federal do Paraná

José Hugo Das Gondim Guanais

Food web structure, flows, and the impact of fishing in a subtropical estuary (Southeast Atlantic)



Pontal do paraná

2019Jose hugo dias gondim guanais

FOOD WEB STRUCTURE, FLOWS, AND THE IMPACT OF FISHING IN A SUBTROPICAL ESTUARY (SOUTHEAST ATLANTIC)

Tese apresentada ao curso de Pós-Graduação em Sistemas Costeiros e Oceânicos, Setor de Ciências da Terra, Universidade Federal do Paraná, como requisito parcial à obtenção do título de Doutor em Sistemas Costeiros e Oceânicos.

Orientador: Prof. Dr. Henry Louis Spach

Coorientador: Prof. Dr. Ronaldo Angelini

\_\_\_\_\_\_\_\_\_\_\_\_

pontal do paraná

2019

**Mantenha essa página em branco para inclusão da ficha catalográfica após a conclusão do trabalho.**

TERMO DE APROVAÇÃO

**Mantenha essa página em branco para inclusão do termo/folha de aprovação assinado e digitalizado.**

Utilize o estilo **Texto**. Dedicatória dedicatória dedicatória dedicatória dedicatória dedicatória dedicatória dedicatória dedicatória dedicatória dedicatória dedicatória dedicatória dedicatória dedicatória dedicatória dedicatória.

agradecimentos

A Universidade Federal do Paraná, representado pelo Centro de Estudos do Mar, e ao Programa de Pós Graduação em Sistemas Costeiros e Oceânico pela disponibilização da estrutura física, intelectual e acadêmica.

A Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), pela bolsa concedida no período de realização do meu doutorado.

Ao Henry, meu amigo e orientador.

Ao Ronaldo Angelini, por todo aporte intelectual

Aos Professores Maikon Di Domienico, Leonardo Sandrini, Paulo Ricardo Schwingell, Jorge Iván Sánchez Botero por aceitarem compor a banca avaliadora desta tese, e pelas valiosas contribuições para o produto final.

Ao Laboratório de Biologia de Peixes pela companheira e risadas.

Familia

Pouco se sabe, porém pouco importa. (Watd P, 2016.)

resumo

Para entender melhor as complexas interações tróficas no ambiente estuarino e como a pesca afeta a estrutura e o funcionamento de um sistema estuarino subtropical, um modelo trófico em estado estacionário (para o ano de 2014) foi construído usando o software Ecopath with Ecosim. O Complexo Estuarino de Paranaguá (PEC) é um ecossistema subtropical e rico em nutrientes do Atlântico Sudoeste (Brasil) que sustenta a pesca em pequena escala com cinco frotas diferentes. Nosso resultado mostrou que o nível trófico mais alto foi para o grupo Seabird I (TL = 3,79). A eficiência média da transferência trófica estava mais próxima do valor teórico de 10%, e 48% dos fluxos de energia são dos detritos e 52% são das cadeias alimentares de pastoreio. O modelo PEC foi considerado no estágio inicial da maturação, pois a produção primária era muito maior que a respiração e a biomassa. Os índices de conectividade, onívora e reciclagem apresentaram valores dentro do esperado para estuários subtropicais. Uma série temporal de cinco anos (2014-2018) foi usada para calibrar o modelo e simulações de 15 anos foram realizadas até 2033, testando o aumento e a diminuição dos cenários do esforço de pesca. Os cenários com um aumento de 50% e 100% indicaram efeitos nos indicadores tróficos, corroborando a análise de biomassa relativa simulada que mostra que espécies com níveis tróficos mais altos respondem mais visivelmente à mudança do esforço de pesca. Caso contrário, o esforço de pesca aumentando em espécies com níveis tróficos intermediários parece mais sustentável.

Palavras-chave: Estrutura trófica; Complexo estuarino de Paranaguá; Ecopata com Ecosim; Baiacu

ABSTRACT

To achieve a better understanding of the complex trophic interactions in the estuarine environment and how fisheries impact on structure and functioning of a subtropical estuarine system, a steady-state trophic model (for the year 2014) was built using the Ecopath with Ecosim software. The Paranaguá Estuarine Complex (PEC) is a subtropical and rich-nutrient ecosystem of Southwest Atlantic (Brazil) which sustains small scale fisheries with five different fleets. Our result showed that the highest trophic level was for Seabird group I (TL = 3.79). The average trophic transfer eﬃciency was closer to the theoretical value of 10%, and 48% of the energy ﬂows are from the detritus, and 52% are from grazing food chains. The PEC model was considered in the early stage of maturation since the primary production was much higher than respiration and biomass. Connectance, omnivory, and recycling indexes presented values within the expected for subtropical estuaries. A five-year time series (2014-2018) was used to calibrate the model, and 15 years simulations were performed until 2033, testing increase and decrease fishing effort scenarios. The scenarios with a 50% and 100% increase indicated effects on trophic indicators, corroborating the simulated relative biomass analysis that shows that species with higher trophic levels respond more visibly to fishing effort change. Otherwise, fishing effort increasing on species with intermediate trophic levels seems more sustainable.

Keywords: Trophic structure; Paranaguá estuarine complex; Ecopath with Ecosim; Pufferfish

Lista de figuras

[FIGURA 1 – TÍTULO DA FIGURA 18](#_Toc510715049)

[FIGURA 2 – TÍTULO DA FIGURA 19](#_Toc510715050)

[FIGURA 3 – TÍTULO DA FIGURA 19](#_Toc510715051)

Lista de gráficos

[GRÁFICO 1 – TÍTULO DO GRÁFICO 23](#_Toc510715118)

[GRÁFICO 2 – TÍTULO DO GRÁFICO 23](#_Toc510715119)

Lista de quadros

[QUADRO 1 – TÍTULO DO QUADRO 20](#_Toc510715130)

[QUADRO 2 – TÍTULO DO QUADRO 20](#_Toc510715131)

Lista de Tabelas

Lista de abreviaturas OU siglas

SIGLA - Nome por extenso

SIGLA - Nome por extenso

SIGLA - Nome por extenso

SIGLA - Nome por extenso

SIGLA - Nome por extenso

Lista de SÍMBOLOS

© - copyright

@ - arroba

® - marca registrada

Σ - somatório de números

Π - produtório de números

SUMÁRIO

[1 INTRODUÇÃO 16](#_Toc510714449)

[1.1 JUSTIFICATIVA 16](#_Toc510714450)

[1.2 OBJETIVOS 16](#_Toc510714451)

[1.2.1 Objetivo geral 16](#_Toc510714452)

[1.2.2 Objetivos específicos 16](#_Toc510714453)

[1.3 METODOLOGIA 17](#_Toc510714454)

[2 REVISÃO DE LITERATURA 18](#_Toc510714455)

[2.1 TÍTULO DA SEÇÃO SECUNDÁRIA 18](#_Toc510714456)

[2.2 TÍTULO DA SEÇÃO SECUNDÁRIA 18](#_Toc510714457)

[2.2.1 Título da seção terciária 19](#_Toc510714458)

[2.2.1.1 Título da seção quaternária 20](#_Toc510714459)

[3 MATERIAL E MÉTODOS 22](#_Toc510714460)

[4 APRESENTAÇÃO DOS RESULTADOS 23](#_Toc510714461)

[5 CONSIDERAÇÕES FINAIS 24](#_Toc510714462)

[5.1 RECOMENDAÇÕES PARA TRABALHOS FUTUROS 24](#_Toc510714463)

[REFERÊNCIAS 25](#_Toc510714464)

[APÊNDICE 1 – TÍTULO DO APÊNDICE 26](#_Toc510714465)

[ANEXO 1 – TÍTULO DO ANEXO 27](#_Toc510714466)

# INTRODUCTION

Estuaries are among the most productive, dynamic, and exploited ecosystems in the world. Because of their constant changes, it is difficult to distinguish between the effects of natural cycles (environmental stressors) and the anthropic impact on these environments Barbier et al. (2011 e Boerema; Meire (2017). In estuarine areas, fishing plays an important and complex role as an anthropogenic driver Barbier et al. (2011 e Blaber (2013 e Sheaves et al. (2015).

Fishing impacts both target and non-target resources, and these effects may include changes in abundance, age structure, biometrics, and the nursery functions that these ecosystems have for many species Blaber, S. (2000). Fisheries also change food webs because they remove or reduce organisms from several trophic levels (e.g., predators or prey), thereby disrupting natural interactions Blaber, S. J. M. (2000). They may also promote the increase of organic matter due to bycatch in these areas Blaber, S. (2000 e Blaber, S. J. M. (2000). Although there is a good deal of information in the marine and oceanic literature about the impact of fisheries in general, relatively little research has been conducted on fisheries within estuaries, and the existent data are sporadic Blaber; Barletta (2016).

Due to these complexities and the need to adopt integrative approaches to maintaining sustainable levels of fishing without considerable changes to ecosystem structure and functioning Garcia et al. (2003 e Larkin (1996 e Trochta et al. (2018), ecological models have become very useful tools Plagányi (2007), especially models representing fisheries’ impact on food webs Colléter et al. (2015). In this sense, the Ecopath with Ecosim (EwE) approach has been advanced recently, especially in marine environments Colléter et al. (2015).

Several Ecopath models assessed the trophic structure in estuaries and how that structure can be affected by fishing (Colléter et al., 2015; Lira et al., 2018), including subtropical estuaries (Du et al.; 2015; Duan et al., 2009; Han et al., 2016; Lin et al., 2007a). In the Southwest Atlantic, estuarine food web models were concentrated in the tropical region, but in these cases, the effects of fishing on the structure and functioning of the system were not evaluated (Lira et al., 2018; Wolff et al., 2000; Xavier, 2013). However, Lercari et al. (2015) evaluate the impact of fishing on the La Plata estuary, from a static model, and they concluded that fishing had produced low effects on the trophic structure of that estuary.

Fisheries commonly overexploit stocks reducing the trophic level in ecosystems (Pauly, 1998), accelerating natural declines in many fish stocks following environmental change and poor recruitment (Jennings and Kaiser, 1998). Fishing methods commonly impacts many other species besides the target resource.

In this work, we also used the Ecopath approach to develop a food web model of the Paranaguá Estuary Complex (PEC), a subtropical estuary in the southeast of Brazil. The PEC model was calibrated using a short landing time series (2014-2018), which contributed to an understanding of the role of fishing in the ecosystem structure. Our simulations tested several fishing scenarios in order to evaluate the impact of fishing on the main target species and the ecosystem.

## RESEARCH JUSTIFICATION

Because of the challenges faced by fisheries management, it is necessary to identify the role of fisheries in ecosystems and to develop tools that assist management processes, especially those with complex socio-ecological characteristics, such as subtropical estuaries.

The Paranaguá Estuary Complex (PEC) represents a good example of the subtropical estuary, with a complex socio-ecological system. Regarding the ecological characteristics, a wide variety of marine and brackish species, including many fishing resources (Possatto, 2015; Passos et al., 2012; Spach et al., 2004; Vendel et al., 2002), marine mammals Miranda (2017), turtles Barrera (2009) and sea birds Gomes (2010) uses the PEC as habitats, breeding and feeding areas. From the socio-economic perspective, the PEC holds an important (expanding) harbor industry that acts concurrently a small-scale fishing activity Andriguetto-Filho et al. (2006, 2009).

## OBJECTIVES

Evaluate the possible effects that fishing can have on the structure and functioning of trophic flows in a subtropical estuary, based on an ecological model.

### Specific objectives

* Build a mass balance model that represents the Paranaguá Estuarine Complex in 2014;
* Assess the performance of ecological indicators and those related to fishing;
* Calibrate time series of fishing effort and total catches.
* Simulate the short-term effects of increasing and reducing fishing effort.

# Literature review

## ECOLOGICAL MODELING AND THE ECOPATH WITH ECOSIM APPROACH

Ecological models are representations of complex systems that seek to simplify the relationship between the components present there. In the 18th century, Malthus used ecological models to explain the exponential growth of populations. Scientific advances in this area have gone through Verhulst's logistical growth models (19th century). In the 20th century, Lotka and Volterra developed predator-prey models. From the development of the ecosystem concept, models have been developed to assess the ecosystem as a whole in an integrated manner Angelini; Gomes (2008).

The Ecopath with Ecosim - EwE software allows the development of mass balance models based on the quantitative description of the functioning of ecosystems according to their trophic relationships (Christensen et al., 2008). It was initially developed by Polovina (1984) and has been continuously developed from 1990 to the present day Christensen; Pauly (1992 e Steenbeek et al. (2016).

The first task in building the models is the definition of functional groups. Such groups can be composed of one or more species that share similar population dynamics and ecological functions. When the groups correspond to a single species, there is the advantage that the parameters can be estimated directly from publications, without the need for averages. In turn, for groups composed of more than one species, the average weighted by the biomass of each species is calculated for each parameter. Once the functional groups are defined, you can enter the input parameters. The mass balance for any group (i) of a trophic network is obtained by defining that its production is equal to the sum of the consumption components, expressed through the mass balance used by Ecopath.

The following parameters are required for each group: biomass, production (PB), food consumption (QB), ecotrophic efficiency (EE), fishing catch (Y), and diet composition (DC). Parameters such as production, consumption and diet composition are already included in an electronic database specially designed for Ecopath models Froese; Pauly (2018).

After the static model, Ecopath evolved with a temporal change module (Ecosim) in 1995 Walters et al. (1997), enabling dynamic modeling to explore threats from environmental disturbances. Its development is based on a system of differential equations that expresses the flow of biomass between the components as a function of the variation in the rates of biomass and production over time (Althauser, 2003; Christensen et al., 2008). More recently, a space module - Ecospace Walters et al. (1999) has finally been implemented that allows a spatial simulation and an exploration of environmental policies to protect habitats, for example Marine Protected Areas, and an investigation of the effects of dispersion and advection, as well as species capture

## Ecosystem structure ans functioning

The ecologist Odum suggests a set of hypotheses to explain the ecological succession Odum, Eugene P (1969). In his theory, he establishes components that describe the succession stage of ecosystems based on twenty-four attributes, distributed in categories that incorporate elements of trophic links, size, habitat structure, and species community. According to the theory, with the progression of succession stages, the trophic webs become more complex, the stratification of the trophic levels more accentuated, niches become more specialized, increased information and reduced entropy. Therefore, the more developed ecosystem has a greater capacity for self-regulation (homeostasis). A mature system corresponds to a stable system, where controls by trophic interactions prevail over environmental factors, providing an increase in the complexity and stability of the ecosystem Hattab et al. (2013).

Based on Odum's theory, new approaches have been developed in an attempt to quantitatively analyze ecological succession in ecosystems, all supported by systems analysis. Ecological studies started to incorporate elements of network analysis, information theory, thermodynamics concepts and trophic indicators Angelini (2002 e Angelini; Gomes (2008 e Christensen (1995 e Dame; Christian (2008 e Vasconcellos et al. (1997). Such approaches favored the analysis of the interrelationships of the components of the ecosystem and allowed the observation of a series of emerging properties, that is, characteristics that arise when the components are integrated Angelini (2002). The use of these attributes has been used to measure and compare the state of development between different ecosystems or between different periods of the same ecosystem, as well as to identify impacts generated by fisheries or management measures applied to them Aydin et al. (2007 e Cox et al. (2002 e Geers et al. (2016 e Heymans et al. (2007 e Shannon et al. (2003).

Ecosystems can be analyzed for trophic flow and concepts of thermodynamics. Such characteristics are quantified in terms of consumption, production, breathing and flow import and export for debris. Such information may indicate stages of ecosystem development (Bundy et al., 2009; Christensen et al., 2008; Christensen and Walters, 2004b; Coll et al., 2009; Hattab et al., 2013). Following is the description of basic statistics, which characterize trophic flows and thermodynamic aspects:

* Total System Throughput - TST (t/ km2 / year), is the total sum of flows in the ecosystem. In other words, it is the sum of the entire consumption flow (QB, t / km2 / year), export (E, t / km2 / year), respiration (TR, t / km2 / year) and flows (import + export) for groups of debris (t / km2 / year). This attribute provides a general representation of the size of the ecosystem in terms of flow;
* Mean Transfer Efficiency - TE is the geometric average of the energy transfer efficiency between each trophic level, that is, it calculates the loss of efficiency between trophic levels, due to breathing, excretion and natural mortality (maintenance costs). It is usually represented by a flow chart known as the Lindman Spine;
* Total Primary Production and Total System Respiration (TPP / TR) indicates how many times the production is higher than the cost of maintaining (respiration) the ecosystem; Mature systems have low values since production tends to match respiration;
* Total Primary Production and Total Biomass (TPP / TB) indicates the capacity of the system to accumulate biomass concerning productivity, high values indicate low rate of biomass accumulation, both factors are measures of the state of maturity of the ecosystem, in the sense that high values indicate early stages of development, while low values indicate maturity;
* Total Biomass and Total System Transfer (TB / TTE) refers to the biomass that is supported by the flow of energy available in the ecosystem, increasing according to the maturity of the ecosystem;
* Net System Production is the difference between total primary production and total respiration. Production will be high in developing ecosystems and close to zero in developed systems. Values can be negative if the import rate of the systems is high.

Based on the parameters listed above, ecological indexes were developed to analyze the impacts of fishing on the ecosystemBundy (2004 e Bundy et al. (2009 e Christensen (1998 e Coll et al. (2006 e Tomczak et al. (2009), which are explained below:

* Gross Efficiency (GE) of a system is the rate of catch by fishing per unit of net system production. The systems tend to have very low values (global average 0.0002), in systems with fisheries concentrated in top predators;
* Primary production required (PPR) to sustain fisheries catches. This rate expresses the catch in terms of flows from primary production or production from detritus, calculating past flows;
* The mean trophic level of catches (mTLc) is calculated as an average of the trophic levels caught by a fishery. The analysis of mTLc allows identifying the trophic levels impacted by fisheries and evaluating in terms of fishing down food webs.

Network analysis integrates techniques to assess direct and indirect trophic effects and the flow recycling structure Bundy et al. (2009). In general, network analysis concerns the characteristics of the system's complexity and the cycling of flows within them. Such features are related to the maturity of the ecosystem Barausse et al. (2009 e Christensen; Walters (2004). Among the complexity indices we can mention the following:

* System Omnivory Index (SOI) is defined with the average of the omnivory indexes of all consumers weighted by the logarithm of each consumer's food intake. The index of omnivory of a group, in turn, calculates the variance of the trophic levels of the prey of a given consumer group. When the value of the omnivory index is zero, the consumer is more specialized, while values increase according to the scope of the trophic levels predated by a consumer. Therefore, SOI tends to present high values in developed ecosystems, given the complexity of trophic relationships;
* Connectivity Index (CI) of a trophic network is the ratio of the number of actual trophic relationships to the number of possible relationships. Links from detritivorous groups are accounted, but flows to detritus are not. The number of possible connections can be estimated with (N-1)², where N is the number of living compartments. The real number of links in a trophic network is approximately proportional to the number of compartments in the system;
* Finn’s Cycling Index (FCI) measures the energy fraction of the total system flow that is cycled in an ecosystem. The increased recycling of energy and nutrients in a system reflects its maturity, and the development of routes to store energy (nutrients). An increase in this index indicates a shorter recovery time in the face of disturbances;
* Predatory Cycling Index is the percentage of flows in an ecosystem, excluding the debris compartment;
* Mean Pathway Length (MPL) is the average number of components that a unit of energy passes through. This index is sensitive to the number of compartments in the model.

The mixed trophic impact (MTI) analysis is an approach derived from the economic sciences that were originally developed to assess the direct and indirect effects on the United States economy Heymans et al. (2005). This approach was introduced in ecology by Hannon (1973)and incorporated into Ecopath by a similar routine, enabling the assessment of trophic interactions between functional groups in the ecosystem, including fishing fleets Christensen; Walters (2004). The MTI is calculated by building a square matrix, where element *ij* represents the interaction between the impacting group *i* and the impacted group *j*, taking into account how much the j contributes to the diet of *i*. This term indicates the proportion of predation in *j* that is due to the production of *i*. This approach makes it possible to identify cascade effects on ecosystems (Christensen et al., 2008). From MTI it is possible to identify Keystone Species (KS), which have low biomass but play a structuring role in ecosystems Libralato et al. (2006).

Aspects arising from information theory take into account the size (in terms of flows) and the organization of the ecosystem (information contained). Such features has been proposed as an index to characterize the degree of development of the ecosystem Ulanowicz, Robert E. (1986). For this author, the development of the ecosystem is reflected by the increase in the information contained therein. In other words, it means that in an ecosystem in advanced stages of development, the knowledge of the path probabilities of a flow particle is greater. This degree of knowledge is measured by ascendency (A). The ascendency expresses characteristics of quantity of flows (TST) and organization of information. The concept of information, in this case, refers to the probabilities of transferring a unit of flow between the components of the system, based on the average mutual information (AMI). A = TST \* AMI. The AMI is a summation of the relations of input and output flows of each component in relation to the total flow (TST), weighted by a logarithmic curve Barausse et al. (2009 e Bundy et al. (2009). This index characterizes the organization of exchanges between components of the system Heymans (2003). The increase in this index points to an increase in flows channeled by specific paths.

The maximum potential of the ascendency of an ecosystem is defined as carrying capacity (C). And the difference between the carrying capacity and current ascendency results in what is known as system overhead (O), that is, the amount of uncertainty we have regarding the flow probabilities of a particle in the system. These uncertainties are divided between import, export and internal flows Angelini; Gomes (2008 e Bundy et al. (2009 e Ulanowicz; Abarca-Arenas (1997).

At first, the capacity of the ecosystem was related to its ascendency. However, Christensen (1995) from the analysis of 41 ecosystems, obtained negative correlation between the stage of development of the ecosystem and the ascendency, however, the overhead was positively correlated, leading to the understanding that the development of ecosystems is related to the amount of reserve energy available in the system. The development capacity of an ecosystem was ranked based on the work of Christensen (1995) and allowed the identification of important trends. For example, the upwelling ecosystem has an early stage of development, while coastal systems in tropical regions tend to further develop

## FISHING IMPACTS ON ECOSYSTEM

exto texto texto texto texto texto texto texto texto.

# Methods

## THE STUDY AREA

The PEC (Figure 1) is a subtropical and nutrient-rich ecosystem where plankton and mangrove detritus dominate the system. It covers a flooded area of 612 km2 and consists of two main embayment: i) the North-South axis, 30 km long and 13 km wide; and ii the East-West axis, 50 km long and 7 km wide Marone et al. (2005). There is a great diversity of habitats, including mangroves, salt marshes, rocky shores, islands, and shoals (both vegetated and not vegetated), providing complexity of environment and biodiversity Lana et al. (2001).

The climate is humid subtropical with hot, rainy summers and dry winters, with mean water temperature ranges of 23° to 30°C (summer) and 18° to 25°C (winter). Horizontal seawater gradient of salinity reaches a maximum range of 0 to 30 ppm in the summer. The tide cycle is semi-diurnal, with tidal amplitude at 2.7m upstream and 1.7m downstream Marone et al. (2005).

This estuary is an example of a socioecological system because it is recognized as a world heritage site due to its ecological importance and because it is where a set of protected areas were established. The PEC is an area of breeding, nursery, and feeding for a wide variety of marine and brackish species, including many fisheries’ resources Passos et al. (2012 e Possatto et al. (2017), dolphins Miranda (2017 e Sasaki (2010), turtles Barrera (2009) and seabirds Gomes (2010). At the same time, there are anthropogenic activities around the bay, including harbor/ports, tourism, and small-scale fisheries Possatto et al. (2017).

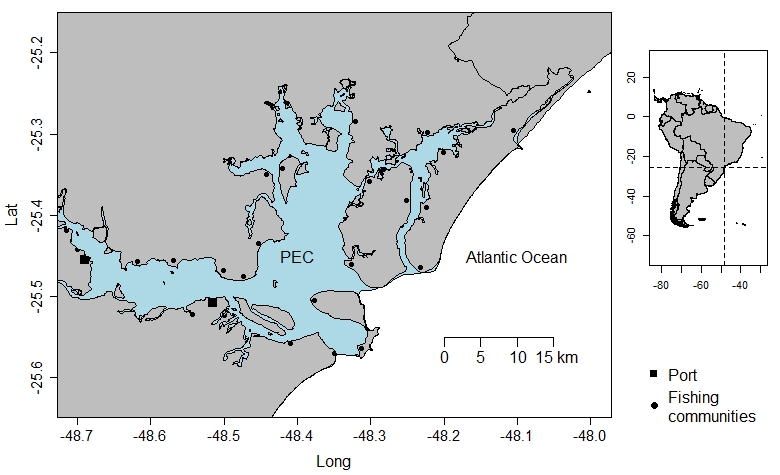


Figure 1 - Paranaguá Estuarine Complex (PEC) in the Brazilian Southeast. Blue represents the 612 km2 of the model area

The fisheries in the PEC area have high fishing gears diversity and low technological levels, and the main fishing targets are shrimp, crabs, bivalve mollusks, and several fish species Andriguetto-Filho et al. (2009). The fishing spots are close to the coast, and landings are performed in many fishing communities (at least 30, Figure 1) Andriguetto-Filho et al. (2006). The fishers use the fisheries’ resources for subsistence and they sell what is left over, either to consumers (such as tourists), local restaurants, or the fish market (Porto do Paraná, in press).

The management measures for the PEC fisheries deal with fishing licenses, fishing areas closures, gear prohibitions (e.g., motorized trawl fishery or restrictions on gear mesh size), prohibitions on catching endangered species, and biometric restrictions (such as minimum fish size) (ICMBio, 2018; Medeiros et al., 2013).

Small-scale fisheries are commonly carried out in wood or fiberglass vessels, with low load capacity (less than a ton) and motorization (less than 22HP), with the friendship and family ties dominating the work relationship Andriguetto-filho et al. (2009). In the development of our PEC model, we considered five fleets by gear type as follows: Artisanal Mollusks Fishery (AMF), Estuarine Trap Fishery (ETF), Estuarine Shrimp Fishery (ESF), Gillnets Fishery (GNF), and Longline Fishery (LLF). A brief description of these fishing fleets is in the Table 1.

Table 1 - Description and basic characteristics of the fleets considered in the Paranaguá Estuarine Complex (PEC) model. N.l (net length), n.h (net height, in meters), ø (diameter, in mm), m.s (mesh size, mm); h (height)

| **Code** | **Fleet name** | **Brief description** | **Notes** (dimensions of gear) | **Resources** |
| --- | --- | --- | --- | --- |
| **GNF** | Gillnets Fishery | Bottom drift net | n.l = 300-500 / n.h = 1.5 -3.0 / Ø = 0.4-0.6/ m.s = 60-70 | Small hake |
|  |  | Bottom fixed net | n.l = 300-400 / n.h = 2.0 -4.0 / Ø = 0.6-0.7/ m.s = 80-180 | Demersal fish |
|  |  | Bottom fixed net | n.l = 100-200 / n.h = 4.0-6.0 / Ø = 1.0-1.2 / m.s = 180-250 | Snooks, Large and Medium hake |
|  |  | Bottom fixed net | n.l = 300-400 / n.h = 1.0 -2.0/ Ø = 0.5-0.6 / m.s = 150-220 | Flatfish |
|  |  | Purse seines net |  | Mugelids, anchovy, and sardines |
| **LLF** | Longline Fishery | Bottom longlines | A set about 50 hooks, small fishes and crabs as bait | Large demersal (croaker, catfish, and the rays) |
| **ETF** | Estuarine Trap  Fishery | A set of 20-50 cages in the bottom | Cylindrical (diameter = 50 cm, h=20 cm) with funnel-shaped opening | Crabs and pufferfish |
| **AMF** | Artisanal Mollusk Fishery | Manual mollusks extraction | Rocks, sand and mud substrates | Oyster, mollusks, and other bivalves |
| **ESF** | Estuarine Shrimp Fishery | Non-motorized trawl | with small conical net attached to the boat by a cable / mouth length = 3 m/ m.s = 25 | Shrimp |

## MASS-BALANCE ECOPATH MODELING APPROACH

The Ecopath with Ecosim (EwE) (http://www.ecopath.org) approach facilitates the elaboration of mass balance models in order to understand trophic relationships and ecosystem functioning Christensen, Villy ; Walters, Carl. J.; Pauly, Daniel; Forrest (2008). The mass balance for any group (i) expresses the balance between the factors that increase its biomass (production, consumption, and immigration) and the factors that decrease its biomass (fishing, predation, and other mortality). This balance can be expressed as follows (Equation 1):

Bi and P/Bi respectively indicate the biomass (t\*km-2) and the production per unit of the biomass (t\*km-2\*year-1) of the prey i; EEi is the ecotrophic efficiency, which represents the part of the group production that is transferred to higher trophic levels and removed by fishing; Bj and Q/Bj respectively indicate the biomass and the consumption per unit of the biomass of predators (j). DCji is the fraction (%) of (i) in the diet of (j); EXi is the export of (i) and represents the fishing biomass. Functional groups may consist of a single species or a group of species which have a similar life history.

## GENERAL DESCRIPTION OF INPUT DATA

The PEC model represents the year 2014, and it has 39 functional groups, including one group of marine mammals, four seabirds, one marine turtles, 19 fish, eight benthic and two pelagic invertebrates, and four primary producer groups besides one detritus. These groups are the main trophic components of the ecosystem and they include all fishing target species in the area.

Data used to parameterize the values for the model were mainly compiled from the literature, electronic databases, and direct measurements. Inputs to the model were standardized to wet weight (t\*km-2). A detailed description of EwE groups, length-weight-growth data, estimation methods, diet matrix, and references used to build the PEC Ecopath model can be seen in the next section.

For diet matrix, priority was given to diet assessments from the study area or adjacent areas for the same species. If these categories were not available, information from similar areas and similar species was used. The landings data for the small-scale fisheries were obtained from a local monthly monitoring program (Portos do Paraná, in press) between 2014 and 2018. Some groups (such as sardines) had their catch rates adjusted from new monitoring programs FUNDEPAG (2018), and information about discards (general demersal fish), turtles, and dolphins was estimated based on the information of local fishers.

## MODEL PARAMETERIZATION

### Marine mammals

Marine mammals are represented in the PEC model by the Guiana dolphin (*Sotalia guianensis*). Several behavioral patterns, including feeding, are often observed in the PEC.

Despite the occurrence of porpoises (*Pontoporia blainvillei*), these were not considered in the parameterization, since the size of the population is unknown, and the records are sporadic.

#### Biomass

From Miranda (2017) was determined the Biomass ( = 0.22 ton km-2). In this study was estimated the population of 1811 of *S. guianensis*. From length-weight relationships, the mean body weight of *S. guianensis* estimated at 74 kg Rosas; Barreto; Monteiro-Filho, Emygdio L. A. (2003).

#### Production

We applied Hoening's equation (Equation 2) for marine mammals Araújo; Bundy (2011a) to estimate total mortality (Z):

The maximum age of 30 years for *Sotalia guianensis* was determined by Rosas et al. (2003)

#### Consumption

The daily ratio (DR) consumption of Guiana dolphins was calculated from the following empirical equation (Equation 3) Innes et al. (1987):

W = Mean body mass and both DR and W are expressed in kilograms (74 kg).

#### Diet

The studies of Cremer et al. (2012 e Daura-Jorge et al. (2011 e Zanelatto (2001) provided the diet of *S. guianensis*. These studies reinforced the importance of *Micropogonias cromis*, *Trichiurus lepturus,* and sardines in dolphin’s diet.

### Seabirds

Seabirds groups were divided in four groups: Cormorants, the most abundant one, Piscivorous seabird I, which eat on sardines, anchovy and demersal fish, Piscivorous seabird II which eats Zooplankton and Benthos Birds which prefers Gastropods, Crustaceous and Mussels. The species that are composing the groups, as well as basic parameters, are listed in Table 2, and detailed parameterization of each group are described in Table 3.

Table 2 - Species composition of Seabirds groups and basic input data for the Paranaguá Estuarine Complex (PEC) model

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **EWE group** | **Family** | **Taxon** | **Body mass (grams)** | **Reference of Body Mass** | **Density (inds/km²)** | **Reference Density** |
| 2. Cormorants | Phalacrocoracidae | *Nannopterum brasilianus* | 1300 | Wikiaves (2018) | 42.11 | Portos do Paraná, in press |
| 3. Piscivorous Seabirds I | Fregatidae | *Fregata magnifiscens* | 1400 | Wikiaves (2018) | 0.95 | Portos do Paraná, in press |
|  | Sternidae | *Sterna hirundinacea* | 199 | EOL (2018) | 10.53 | Portos do Paraná, in press |
|  |  | *Thalasseus acuflavidus* | 200 |  | 6.21 | Portos do Paraná, in press |
|  |  | *Thalasseus maximus* | 400 | Wikiaves (2018) | 7.68 | Portos do Paraná, in press |
|  | Sulidae | *Sula leucogaster* | 1.300 | EOL (2018)) | 17.47 | Portos do Paraná, in press |
| 4. Piscivorous Seabirds II | Alcedinidae | *Chloroceryle americana* | 34 | EOL (2018) | 1.05 | Portos do Paraná, in press |
|  |  | *Megaceryle torquata* | 320 | Wikiaves (2018) | 2.11 | Portos do Paraná, in press |
|  | Ardeidae | *Ardea alba* | 1200 | Wikiaves (2018) | 1.05 | Portos do Paraná, in press |
|  |  | *Ardea cocoi* | 1937 | EOL (2018) | 0.37 | Portos do Paraná, in press |
|  |  | *Butorides striatus* | 226 | EOL (2018) | 0.53 | Portos do Paraná, in press |
|  |  | *Egretta caerulea* | 396 | EOL (2018) | 2.00 | Portos do Paraná, in press |
|  |  | *Egretta thula* | 370 | EOL (2018) | 1.32 | Portos do Paraná, in press |
|  |  | *Nyctanassa violacea* | 650 | Wikiaves (2018) | 0.53 | Portos do Paraná, in press |
|  |  | *Nycticorax nycticorax* | 800 | EOL (2018)) | 0.11 | Portos do Paraná, in press |
|  | Laridae | *Chroicocephalus maculipennis* | 454 | EOL (2018) | 0.21 | Portos do Paraná, in press |
|  |  | *Larus dominicanus* | 1100 | EOL (2018) | 0.42 | Portos do Paraná, in press |
|  | Rynchopidae | *Rynchops niger* | 300 | Wikiaves (2018) | 0,06 | Portos do Paraná, in press |
| 5. Birds Benthos | Charadriidae | *Charadrius semipalmatus* | 45 | EOL (2018) | 4.21 | Portos do Paraná, in press |
|  | Haematopodidae | *Haematopus palliatus* | 600 | Wikiaves (2018) | 1.05 | Portos do Paraná, in press |
|  | Scolapacidae | *Actitis macularius* | 42 | EOL (2018) | 2.63 | Portos do Paraná, in press |
|  | Threskiornithidae | *Eudocimus ruber* | 650 | EOL (2018) | 4.21 | Field observation |
|  |  | *Platalea ajaja* | 1350 | Wikiaves (2018) | 2.11 | Portos do Paraná, in press |

#### Biomass

Monthly counts on the east-west axis of the PEC was used to estimate the biomass of the birds. Boarded transects were carried out covering a distance of 47 km length x 0,4 km width (0.2 km in each vessel edge), therefore an area of approximately 19 km2. The value was extrapolated to the whole PEC area.

#### Production

The P/B was defined as 0,25 ton km-2 year-1F for all seabirds groups Araújo; Bundy (2011a e Bergamino et al. (2012)

#### Consumption

The empirical equation (Equation 4) presented by Nilsson and Nilsson (1976) determined the daily consumption ratio.

Where the food consumption, F, is in grams of fish/day and the weight of the bird, W, in grams. The value was converted in ton\*km-2 \*year-1

#### Groups

Table 3 - Parameterization of Seabirds groups for Paranaguá Estuarine Complex (PEC) Model in 2014.

| **Functional Group** | **(Original Value) Adjust Value** | **Reference** | **Notes** |
| --- | --- | --- | --- |
| **2. Cormorants** |  |  |  |
| *Biomass* | 0.04 | (Portos do Paraná, in press) | Average Body Mass x Density |
| *Production* | 0.25 | Araújo; Bundy (2011b e Bergamino et al. (2012) |  |
| *Consumption* | 63.42 | Nilsson; Nilsson (1976) |  |
| *Diet* |  | Branco et al. (2009) | Catfish and anchovy/sardines are among the main prey, but also mugulides, crabs and general demersal fishes. In the field, it was observed the capture of estuarine shrimp |
| **3. Seabirds I** |  |  |  |
| *Biomass* | 0.03 | (Portos do Paraná, in press) | Mean body mass x Density |
| *Production* | 0.25 | Araújo; Bundy (2011b e Bergamino et al. (2012) |  |
| *Consumption* | 66.84 | Nilsson; Nilsson (1976) | The weighted average of Q/B of each species |
| *Diet* |  | Branco; Fracasso; et al. (2005 e Bugoni; Vooren (2004 e Serrano; Azevedo Júnior (2005)) | Species with pelagic habit. anchovy/sardines and general demersal fishes are mainly food items. |
| **4. Seabirds II** |  |  |  |
| *Biomass* | 0.01 | (Portos do Paraná, in press) | Mean body mass x density |
| *Production* | 0.25 | Araújo; Bundy (2011b e Bergamino et al. (2012) |  |
| *Consumption* | 73.94 | Nilsson; Nilsson (1976) | The weighted average of Q/B of each species |
| *Diet* |  | Britto (2013 e Gianuca et al. (2011, 2012 e Miotto (2015)) | They feed on the edges of the estuary, mainly juvenile fish and invertebrates. |
| **5.Benthos Birds** |  |  |  |
| *Biomass* | 0.01 | (Portos do Paraná, in press) | Mean body mass x density |
| *Production* | 0.25 | Araújo; Bundy (2011b e Bergamino et al. (2012) |  |
| *Consumption* | 125.84 | Nilsson; Nilsson (1976) | The weighted average of Q/B of each species |
| *Diet* |  | Britto (2013 e Gianuca et al. (2011, 2012)) | Invertebrates (mainly crustaceans and mollusks), and imports of insects. |

### Marine Turtles

The marine turtles are represented in the model by the Green turtle (*Chelonia mydas*). The sheltered waters and the presence of feeding sources favor the presence of juvenile green turtles.

#### Biomass

The EwE estimated the biomass at 0.17 ton km-2.

#### Catch

Gillnet fisheries accidentally catch turtles. In case of drift nets, which has a fast operation time, turtles are released alive to the sea. However, in case of fixed nets, the turtles may be released deadly to the sea. The studies of Barrera, (2009) in PEC area indicates that in 13% of the fishing events with fixed gillnets, there were records of dead turtles.

A total of 2400 fishing events were estimated in fixed gillnets fishery in 2014 (Portos do Paraná, in press). The mean body weight of 15 kg was used. Thus, the annual catch per area was equal to 0.015 ton km-2 year-1.

#### Production

For *Chelonia mydas*, P/B was defined as 0.15 ton km-2 year-1 Angelini et al. (2018 e Lira et al. (2018 e Opitz (1996)

#### Consumption

Q/B was defined as 10.2 ton km-2 year-1 Angelini et al. (2018).

### Fish Groups

The Table 4 list the species that are composing the groups, as well as basic parameters, and detailed parameterization of each group are described in Table 5

There are two hake groups (Scianidae Family) in PEC model. Small hakes is grouping species until 35 cm length (Macrodon ancylodon, Menticirrhus sp.) while Medium and Large hakes refers the biggest ones, especially Cynoscion sp..

Table 4 - Species composition of Fishes groups and basic input data for the Paranaguá Estuarine Complex (PEC) model.

| **EwE group** | **Family** | **Taxa** | **Lmax (cm)** | **K** | **Winf (g)** | **Ar** | **H** | **D** | **M** | **Q/B** | **Ref Lmax** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 7. Anchovy and Sardine | Clinidae | *Ribeiroclinus eigenmanni* | 4.4 |  | 1.1 | 0.97 | 0 | 0 |  | 25,17 | Froese (2018) |
|  | Clupeidae | *Brevoortia sp.* | 26 | 0.5 | 176.2 | 2.33 | 0 | 0 | 1.08 | 11,59 | Froese (2018) |
|  | Clupeidae | *Harengula clupeola* | 15.2 | 0.85 | 40.04 | - | 0 | 0 | 1.77 | 10,04 | Possato (2015 |
|  | Clupeidae | *Harengula jaguana* | 21.2 | 0.6 | 249.3 | 3.4 | 0 | 0 | 1.29 | 13,25 | Froese (2018) |
|  | Clupeidae | *Opistonema oglinum* | 25.9 | 0.65 | 283.3 | 1.19 | 0 | 0 | 1.28 | 8,46 | (Froese, 2018 |
|  | Clupeidae | *Platanichthys platana* | 9.7 | 1.25 | 10.3 | 2.46 | 0 | 0 | 2.58 | 21,2 | (Froese, 2018 |
|  | Clupeidae | *Sardinella brasiliensis* | 22.6 | 0.71 | 103.9 | 1.07 | 0 | 0 | 1.41 | 10,15 | Froese (2018) |
|  | Engraulidae | *Anchoa filifera* | 12 | 1 | 14.4 | 2.36 | 0 | 1 | 2.1 | 48,58 | Froese (2018) |
|  | Engraulidae | *Anchoa januaria* | 7.5 | 1.55 | 12.2 | 1.58 | 0 | 0 | 3.19 | 17,31 | Froese (2018) |
|  | Engraulidae | *Anchoa lyolepis* | 12 | 1 | 12.2 | 1.04 | 0 | 0 | 2.1 | 15,62 | Froese (2018) |
|  | Engraulidae | *Anchoa spinifer* | 16.4 | 0.53 | 29.46 | 2.39 | 0 | 0 | 1.28 | 16,88 |  |
|  | Engraulidae | *Anchoa tricolor* | 8.9 | 1.64 | 9.01 | 1.32 | 0 | 0 | 3.16 | 17,52 | Possato (2015) |
|  | Engraulidae | *Anchovia clupeoides* | 18.7 | 0.43 | 48.36 | 1.06 | 0 | 0 | 1.07 | 11,84 | Possato (2015) |
|  | Engraulidae | *Anchoviella lepidentostole* | 11.5 | 0.92 | 14.57 | 3.06 | 0 | 0 | 2.02 | 22,16 | Possato (2015) |
|  | Engraulidae | *Cetengraulis edentulus* | 15 | 0.15 | 36.54 | 1.86 | 1 | 0 | 0.58 | 49,71 | Possato (2015) |
|  | Engraulidae | *Engraulis anchoita* | 17 | 0.24 | 101.7 | 2.73 | 0 | 0 | 0.76 | 13,99 | (Froese, 2018) |
|  | Engraulidae | *Lycengraulis grossidens* | 16.2 | 0.42 | 35.97 | 1.24 | 0 | 0 | 1.1 | 13,01 | Possato (2015) |
|  | Pristigasteridae | *Chirocentrodon bleekerianus* | 8.1 | 1.25 | 3.09 | 2.3 | 0 | 0 | 2.72 | 26,29 | Possato (2015) |
|  | Pristigasteridae | *Pellona harroweri* | 11.9 | 0.81 | 16.66 | 1.41 | 0 | 0 | 1.84 | 15,73 | Possato (2015) |
| 8. Small Pelagic Fishes | Argentinidae | *Glossanodon pygmaeus* | 11.3 | 0.63 | 17.3 | 1.1 | 0 | 0 | 1.58 | 14,71 | (Froese, 2018) |
| (SPF) | Atherinopsidae | *Atherinella brasiliensis* | 16 | 0.83 | 42.4 | 1.4 | 1 | 1 | 1.72 | 37,85 | (Froese, 2018) |
|  | Atherinopsidae | *Odontesthes bonariensis* | 33.3 | 0.77 | 1056 | 1.21 | 1 | 1 | 1.34 | 18,94 | (Froese, 2018) |
|  | Carangidae | *Chloroscombrus chrysurus* | 11.3 | 0.65 | 12.74 | 3.2 | 0 | 0 | 1.62 | 23,39 | Possato (2015) |
|  | Hemirhamphidae | *Hemiramphus brasiliensis* | 35.5 | 0.58 | 230.6 | 2.34 | 1 | 0 | 1.09 | 37,41 | (Froese, 2018) |
|  | Hemirhamphidae | *Hyporhamphus robertii* | 32 | 0.77 | 150.2 |  | 0 | 0 | 1.35 | 7,67 | (Froese, 2018) |
|  | Hemirhamphidae | *Hyporhamphus unifasciatus* | 30 | 1.46 | 175.9 | 2.07 | 0 | 1 | 2.08 | 27,58 | (Froese, 2018) |
|  | Stromateidae | *Peprilus paru* | 15.3 | 0.98 | 71.53 | 2.77 | 0 | 0 | 1.94 | 15,15 | Possato (2015) |
| 9. Medium Pelagic Fishes | Belonidae | *Strongylura marina* | 111 | 0.17 | 2566 | 1.34 | 0 | 0 | 0.36 | 5,55 | (Froese, 2018) |
| (MPF) | Belonidae | *Strongylura timucu* | 61 | 0.29 | 375 | 0.48 | 0 | 0 | 0.6 | 6,98 | (Froese, 2018) |
|  | Carangidae | *Caranx crysos* | 70 | 0.38 | 1736 | 3.36 | 0 | 0 | 0.81 | 8,85 | (Froese, 2018) |
|  | Carangidae | *Caranx ruber* | 59 | 0.14 | 4136 | 4.23 | 0 | 0 | 0.38 | 8,75 | (Froese, 2018) |
|  | Carangidae | *Hemicaranx amblyrhynchus* | 35 | 0.39 | 1541 | 2.62 | 0 | 0 | 0.85 | 7,87 | (Froese, 2018) |
|  | Carangidae | *Oligoplites palometa* | 49.7 | 0.39 | 902.2 | 3 | 0 | 0 | 0.77 | 9,44 | (Froese, 2018) |
|  | Carangidae | *Oligoplites saliens* | 50 | 0.39 | 654 | 2.81 | 0 | 0 | 0.77 | 9,72 | (Froese, 2018) |
|  | Carangidae | *Oligoplites saurus* | 35 | 0.54 | 265 | 3.35 | 0 | 0 | 1.05 | 12,96 | (Froese, 2018) |
|  | Carangidae | *Selene setapinnis* | 45 | 0.63 | 905 | 3.53 | 0 | 0 | 1.08 | 10,44 | (Froese, 2018) |
|  | Carangidae | *Selene vomer* | 45 | 0.4 | 1050 | 3.71 | 0 | 0 | 0.8 | 10,48 | (Froese, 2018) |
|  | Elopidae | *Elops saurus* | 100 | 0.32 | 9668.7 | 0.9 | 0 | 0 | 0.56 | 3,9 | (Froese, 2018) |
|  | Fistulariidae | *Fistularia petimba* | 200 |  | 5846.5 | - | 0 | 0 |  | 3,63 | (Froese, 2018) |
|  | Fistulariidae | *Fistularia tabacaria* | 200 |  | 6355.8 | - | 0 | 0 |  | 3,57 | (Froese, 2018) |
|  | Pomatomidae | *Pomatomus saltatrix* | 23.8 | 0.13 | 140.65 | 2.35 | 0 | 0 | 0.46 | 12,18 | Possato (2015) |
|  | Sphyraenidae | *Sphyraena guachancho* | 70 | 0.09 | 2000 | 2.16 | 0 | 0 | 0.27 | 6,83 | (Froese, 2018) |
|  | Sphyraenidae | *Sphyraena tome* | 45 | 0.35 | 858 | 1.68 | 0 | 0 | 0.74 | 7,41 | (Froese, 2018) |
|  | Trichiuridae | *Trichiurus lepturus* | 160 | 0.25 | 2002 | - | 0 | 0 | 0.41 | 4,52 | Possato (2015) |
| 10. Large Pelagic Fishes | Carangidae | *Caranx hippos* | 124 | 0.35 | 36000 | 3.41 | 0 | 0 | 0.55 | 4,81 | (Froese, 2018) |
| (LPF) | Carangidae | *Caranx latus* | 101 | 0.18 | 22000 | 3.53 | 0 | 0 | 0.38 | 5,44 | (Froese, 2018) |
|  | Carangidae | *Seriola lalandi* | 148 | 0.13 | 43000 | 3.7 | 0 | 0 | 0.28 | 4,91 | (Froese, 2018) |
|  | Lobotidae | *Lobotes surinamensis* | 70.3 | 0.69 | 10893.3 | 1.71 | 0 | 0 | 1.01 | 4,44 | (Froese, 2018) |
|  | Rachycentridae | *Rachcentrodum canadum* | 131 | 0.43 | 16173 | 0.99 | 0 | 0 | 0.62 | 3,57 |  |
|  | Scombridae | *Scomberomorus brasiliensis* | 114.2 | 0.11 | 10796 | 3.35 | 0 | 0 | 0.27 | 6,08 | (Froese, 2018) |
| 11. Snook | Centropomidae | *Centropomus parallelus* | 29.5 | 0.19 | 215.83 | 1.32 | 0 | 0 | 0.56 | 9,17 | Possato (2015) |
|  | Centropomidae | *Centropomus undecimalis* | 119.3 | 0.3 | 17140 | 1.9 | 0 | 0 | 0.51 | 4,2 | (Froese, 2018) |
| 12. Pampo And Grunt | Carangidae | *Trachinotus carolinus* | 27.2 | 0.31 | 288.44 | 2.55 | 0 | 0 | 0.78 | 10,93 | Possato (2015) |
|  | Carangidae | *Trachinotus falcatus* | 90.1 | 0.39 | 18224 | 3.55 | 0 | 0 | 0.65 | 5,68 | (Froese, 2018) |
|  | Carangidae | *Trachinotus goodei* | 50 | 0.39 | 1406 | 2.39 | 0 | 0 | 0.77 | 7,67 | (Froese, 2018) |
|  | Carangidae | *Trachinotus marginatus* | 45 | 0.26 | 1105 | 3.23 | 0 | 0 | 0.61 | 9,46 | (Froese, 2018) |
|  | Haemulidae | *Anisotremus surinamensis* | 76 | 0.15 | 11773.7 | 2.3 | 0 | 0 | 0.37 | 4,89 | (Froese, 2018) |
|  | Haemulidae | *Genyatremus luteus* | 37 | 0.29 | 91.85 | 1.3 | 0 | 0 | 0.69 | 10,87 | (Froese, 2018) |
|  | Haemulidae | *Orthopristis ruber* | 40 | 0.35 | 961.8 | 2.1 | 0 | 0 | 0.76 | 7,85 | (Froese, 2018) |
|  | Sparidae | *Archosargus probatocephalus* | 47.8 | 0.36 | 3847.2 | 1.44 | 0 | 0 | 0.74 | 5,21 | (Froese, 2018) |
|  | Sparidae | *Archosargus rhomboidalis* | 33 | 1.78 | 1706 | 2.35 | 0 | 0 | 2.31 | 7,32 | (Froese, 2018) |
| 13. Omnivores | Ephippidae | *Chaetodipterus faber* | 12 | 0.34 | 62.13 | 3.23 | 0 | 0 | 1.04 | 17,03 | Possato (2015) |
|  | Gerreidae | *Diapterus auratus* | 34 | 0.53 | 639.3 | 1.34 | 0 | 0 | 1.04 | 7,37 | (Froese, 2018) |
|  | Gerreidae | *Diapterus rhombeus* | 40 | 2.21 | 146 | 0.82 | 0 | 0 | 2.52 | 9,02 | (Froese, 2018) |
| 14. Mugelids | Mugilidae | *Mugil curema* | 45.5 | 0.14 | 1869.4 | 1.91 | 0 | 1 | 0.4 | 16,52 | (Froese, 2018) |
|  | Mugilidae | *Mugil curvidens* | 31 | 0.31 | 343.3 | 2.32 | 0 | 1 | 0.75 | 25,24 | (Froese, 2018) |
|  | Mugilidae | *Mugil incilis* | 40 | 1.01 | 688.5 | 4.22 | 0 | 1 | 1.51 | 31,49 | (Froese, 2018) |
|  | Mugilidae | *Mugil liza* | 76.4 | 0.24 | 5315.7 | 1.7 | 0 | 1 | 0.5 | 12,82 | (Froese, 2018) |
| 15. Large Reef Fishes | Ephinephelidae | *Epinephelus itajara* | 201 | 0.13 | 143200 | 1.2 | 0 | 0 | 0.25 | 2,38 | (Froese, 2018) |
| (LRF) | Ephinephelidae | *Epinephelus marginatus* | 114 | 0.09 | 23200 | 1.48 | 0 | 0 | 0.23 | 3,64 | (Froese, 2018) |
|  | Ephinephelidae | *Hyporthodus nigritus* | 163 | 0.14 | 78600 | 1.18 | 0 | 0 | 0.28 | 2,68 | (Froese, 2018) |
|  | Ephinephelidae | *Hyporthodus niveatus* | 112 | 0.12 | 21300 | 1.4 | 0 | 0 | 0.28 | 3,65 | (Froese, 2018) |
|  | Ephinephelidae | *Mycteroperca bonaci* | 131 | 0.17 | 36500 | 1.56 | 0 | 0 | 0.34 | 3,37 | (Froese, 2018) |
|  | Ephinephelidae | *Mycteroperca rubra* | 105 | 0.33 | 13900 | 1.15 | 0 | 0 | 0.56 | 3,79 | (Froese, 2018) |
|  | Lutjanidae | *Lutjanus analis* | 86.9 | 0.16 | 12068.2 | 1.69 | 0 | 0 | 0.37 | 4,33 | (Froese, 2018) |
|  | Lutjanidae | *Lutjanus synagris* | 38 | 0.28 | 9.36 | 1.46 | 0 | 0 | 0.28 | 17,86 | Possato (2015) |
| 16. General Reef Fishes (GRF) | Albulidae | *Albula vulpes* | 104 | 0.28 | 7182.2 | 2.4 | 0 | 0 | 0.5 | 5,51 | (Froese, 2018) |
| 17. Pufferfishes | Tetraodontidae | *Lagocephalus laevigatus* | 27.5 | 0.18 | 356.48 | 1.78 | 0 | 0 | 0.55 | 9,04 | Possato (2015) |
|  | Tetraodontidae | *Sphoeroides greeleyi* | 18 | 0.89 | 169.5 | 1.32 | 0 | 0 | 1.74 | 9,63 | Possato (2015) |
|  | Tetraodontidae | *Sphoeroides spengleri* | 30 | 0.55 | 177 | 1.97 | 0 | 0 | 1.11 | 10,81 | Possato (2015) |
|  | Tetraodontidae | *Sphoeroides testudineus* | 26.1 | 0.78 | 486.49 | 1.42 | 0 | 0 | 1.44 | 7,92 | Possato (2015) |
| 18. Skate and rays | Narcinidae | *Narcine brasiliensis* | 54 |  | 1298.7 | 1.63 | 0 | 0 | 3.62 | 9,38 | (Froese, 2018) |
|  | Rhinobatidae | *Rhinobatos horkelii* | 138 | 0.14 |  | 1.62 | 0 | 0 | 0.3 | #NÚM! | (Froese, 2018) |
|  | Rhinobatidae | *Rhinobatos percellens* | 100 | 0.18 | 4050 | 1.62 | 0 | 0 | 0.38 | 5,34 | (Froese, 2018) |
| 19. Hake Fish | Sciaenidae | *Cynoscion jamaicensis* | 14.9 | 0.4 | 34.39 | 1.53 | 0 | 0 | 1.09 | 13,88 | Possato (2015) |
| Small | Sciaenidae | *Isopisthus parvipinnis* | 25 | 0.67 | 179 | 1.38 | 0 | 0 | 1.32 | 9,63 | Possato (2015) |
|  | Sciaenidae | *Macrodon ancylodon* | 43.6 | 0.27 | 877 | 1.32 | 0 | 0 | 0.63 | 6,89 | Possato (2015) |
|  | Sciaenidae | *Menticirrhus americanus* | 47.7 | 0.27 | 264.34 | 1.3 | 0 | 0 | 0.24 | 8,76 | Possato (2015) |
|  | Sciaenidae | *Menticirrhus littoralis* | 48.3 | 0.36 | 1340 | 1.06 | 0 | 0 | 0.73 | 6,01 | (Froese, 2018) |
|  | Sciaenidae | *Nebris microps* | 40 | 0.43 | 497 | 1.7 | 0 | 0 | 0.87 | 8,32 | Possato (2015) |
| 20. Hake Fish | Sciaenidae | *Cynoscion acoupa* | 100 | 0.27 | 14657 | 1.48 | 0 | 0 | 0.5 | 4 | (Froese, 2018) |
| Medium and Large | Sciaenidae | *Cynoscion guatucupa* | 50 | 0.21 | 1654.5 | 1.16 | 0 | 0 | 0.51 | 5,87 | (Froese, 2018) |
|  | Sciaenidae | *Cynoscion leiarchus* | 45.4 | 0.35 | 1461 | 0.71 | 0 | 0 | 0.73 | 5,52 | (Froese, 2018) |
|  | Sciaenidae | *Cynoscion microlepidotus* | 90 | 0.15 | 7000 | 0.96 | 0 | 0 | 0.35 | 4,21 | (Froese, 2018) |
|  | Sciaenidae | *Cynoscion striatus* | 60 | 0.23 | 1800 | 1.53 | 0 | 0 | 0.52 | 6,19 | (Froese, 2018) |
|  | Sciaenidae | *Cynoscion virescens* | 115 | 0.16 | 11914 | 0.91 | 0 | 0 | 0.34 | 3,74 | (Froese, 2018) |
| 21. Croakeres | Sciaenidae | *Micropogonias furnieri* | 15.7 | 0.5 | 39.34 | 1.7 | 0 | 0 | 1.24 | 13,95 | Possato (2015) |
|  | Sciaenidae | *Pogonias cromis* | 170 | 0.2 | 72400 | 1.25 | 0 | 0 | 0.35 | 2,76 | (Froese, 2018) |
| 22. Flatfishes | Paralichthyidae | *Paralichthys brasiliensis* | 100 | 0.12 | 17000 | 1.08 | 0 | 0 | 0.29 | 3,59 | Possato (2015) |
|  | Paralichthyidae | *Paralichthys orbignyanus* | 100 | 0.12 | 11000 | 2.04 | 0 | 0 | 0.29 | 4,72 | Possato (2015) |
| 23. Catfishes | Ariidae | *Aspistor luniscutis* | 120 | 0.09 | 18131 | 1.24 | 0 | 1 | 0.23 | 9,14 | (Froese, 2018) |
|  | Ariidae | *Bagre bagre* | 55 | 0.16 | 12191 | 3.04 | 0 | 1 | 0.42 | 13,98 | Possato (2015) |
|  | Ariidae | *Cathorops spixii* | 28.5 | 0.09 | 217.76 | 1.9 | 0 | 1 | 0.35 | 25,56 | Possato (2015) |
|  | Ariidae | *Genidens barbus* | 120 | 0.13 | 11624 | 1.9 | 0 | 1 | 0.29 | 11,36 | Possato (2015) |
|  | Ariidae | *Genidens genidens* | 42 | 0.23 | 750 | 2.04 | 0 | 1 | 0.57 | 20,4 | Possato (2015) |
|  | Ariidae | *Notarius grandicassis* | 49.1 | 0.16 | 1432.96 | 1.47 | 0 | 1 | 0.43 | 16,03 | Possato (2015) |
| 24. General Demersal Fishes | Achiridae | *Achirus declivis* | 19 | 0.49 | 158.66 | 1.15 | 0 | 0 | 1.16 | 9,45 | Possato (2015) |
| (GDF) | Achiridae | *Achirus lineatus* | 33.1 | 0.29 | 926.7 | 1.21 | 0 | 0 | 0.71 | 6,67 | Possato (2015) |
|  | Achiridae | *Catathyridium garmani* | 17 | 0.64 | 58.3 | 0.96 | 0 | 0 | 1.43 | 11,18 | Possato (2015) |
|  | Achiridae | *Trinectes paulistanus* | 18 | 0.62 | 170.5 | 1.32 | 0 | 0 | 1.38 | 9,62 | Possato (2015) |
|  | Achiridae | *Trinects microphtalmus* | 9.4 | 0.93 | 9.8 | 1.32 | 0 | 0 | 2.15 | 17,23 | Possato (2015) |
|  | Batrachoididae | *Opsanus beta* | 30 | 0.22 | 440.9 | 1.32 | 0 | 0 | 0.61 | 7,92 | Possato (2015) |
|  | Batrachoididae | *Porichthys porosissimus* | 32 | 0.34 | 438 | 0.9 | 0 | 0 | 0.79 | 7,32 | (Froese, 2018) |
|  | Batrachoididae | *Potamobatrachus trispinosus* | 5 | 0.92 | 1.6 | 0.75 | 0 | 0 | 2.55 | 22,36 | (Froese, 2018) |
|  | Cynoglossidae | *Symphurus diomedianus* | 22 | 0.46 | 124.9 | - | 0 | 0 | 1.07 | 7,96 | Possato (2015) |
|  | Cynoglossidae | *Symphurus plagusia* | 25 | 0.56 | 139.8 | 0.56 | 0 | 0 | 1.18 | 8,66 | (Froese, 2018) |
|  | Cynoglossidae | *Symphurus tessellatus* | 22 | 0.39 | 100.3 | - | 0 | 0 | 0.96 | 8,33 | Possato (2015) |
|  | Dactylopteridae | *Dactylopterus volitans* | 50 | 0.58 | 1546.4 | 1.47 | 0 | 0 | 0.99 | 6,31 | (Froese, 2018) |
|  | Diodontidae | *Cyclichthys spinosus* | 20.2 |  | 371.66 | 0.83 | 0 | 0 | 0 | 7,47 | Possato (2015) |
|  | Eleotridae | *Guavina guavina* | 30 | 0.26 | 312.6 | 0.85 | 0 | 0 | 0.68 | 7,77 | (Froese, 2018) |
| (GDF) | Eleotridae | *Eleotris pisonis* | 25 | 0.37 | 181 | 0.62 | 0 | 0 | 0.9 | 8,31 | Possato (2015) |
|  | Gadidae | *Urphycis brasiliensis* | 40 | 0.26 | 625 | 0.6 | 0 | 0 | 0.63 | 6,43 | (Froese, 2018) |
|  | Gerreidae | *Eucinostomus argenteus* | 21 | 0.37 | 43.67 | 2.35 | 0 | 0 | 0.94 | 15,46 | Possato (2015) |
|  | Gerreidae | *Eucinostomus gula* | 21.4 | 0.34 | 122 | 2.13 | 0 | 0 | 0.89 | 12,02 | (Froese, 2018) |
|  | Gerreidae | *Eucinostomus melanopterus* | 30 | 0.59 | 377.8 | 2.6 | 0 | 0 | 1.16 | 10,44 | (Froese, 2018) |
|  | Gerreidae | *Eugerres brasilianus* | 37.6 | 0.29 | 676.6 | 3.02 | 0 | 0 | 0.68 | 10,05 | (Froese, 2018) |
|  | Gerreidae | *Ulaema lefroyi* | 23 | 0.76 | 170.7 | 3.05 | 0 | 0 | 1.47 | 13,39 | (Froese, 2018) |
|  | Haemulidae | *Boridia grossidens* | 19.2 | 0.24 | 83.7 | 1.63 | 0 | 0 | 0.73 | 11,8 | (Froese, 2018) |
|  | Haemulidae | *Conodon nobilis* | 32.5 | 0.49 | 305 | 1.25 | 0 | 0 | 1 | 8,43 | Possatto (2015) |
|  | Haemulidae | *Haemulon steindachneri* | 30 | 0.3 | 446.9 | 1.95 | 0 | 0 | 0.75 | 8,91 | (Froese, 2018) |
|  | Haemulidae | *Pomadasys corvinaeformis* | 19.5 | 0.65 | 109.2 | 1.14 | 0 | 0 | 1.39 | 10,18 | Possato (2015) |
|  | Haemulidae | *Pomadasys ramosus* | 35 | 0.31 | 490.3 | 1.78 | 0 | 0 | 0.73 | 8,47 | (Froese, 2018) |
| (GDF) | Monacanthidae | *Stephanolepis hispidus* | 14.8 | 0.4 | 0.4 | 1.27 | 0 | 0 | 1.09 | 32,77 | (Froese, 2018) |
|  | Paralichthyidae | *Citharichthys arenaceus* | 20 | 0.54 | 223 | 1.32 | 0 | 0 | 1.22 | 9,11 | Possato (2015) |
|  | Paralichthyidae | *Citharichthys macrops* | 20 | 0.54 | 107.2 | 1.07 | 0 | 0 | 1.22 | 10,08 | (Froese, 2018) |
|  | Paralichthyidae | *Citharichthys spilopterus* | 20 | 0.42 | 91 | 1.28 | 0 | 0 | 1.04 | 10,85 | Possato (2015) |
|  | Paralichthyidae | *Etropus crossotus* | 20 | 0.46 | 134.9 | 1.3 | 0 | 0 | 1.1 | 10,05 | (Froese, 2018) |
|  | Paralichthyidae | *Syacium papillosum* | 30 | 0.37 | 366 | 1.45 | 0 | 0 | 0.85 | 8,44 | (Froese, 2018) |
|  | Phycidae | *Urophycis brasiliensis* | 40 | 0.26 | 325 | 0.6 | 0 | 0 | 0.63 | 7,35 | Possato (2015) |
|  | Pleuronectidae | *Oncopterus darwinii* | 30.4 | 0.21 | 373 | 0.83 | 0 | 0 | 0.59 | 7,47 | (Froese, 2018) |
|  | Poeciliidae | *Poecilia vivipara* | 5.2 | 0.84 | 3.3 | 1.32 | 0 | 0 | 2.37 | 21,51 | (Froese, 2018) |
|  | Polynemidae | *Polydactylus oligodon* | 46 | 0.51 | 1099 | 2.06 | 0 | 0 | 0.93 | 7,58 | (Froese, 2018) |
|  | Polynemidae | *Polydactylus virginicus* | 33 | 0.7 | 371 | 0.85 | 0 | 0 | 1.26 | 7,5 | Possato (2015) |
|  | Sciaenidae | *Bairdiella ronchus* | 35 | 0.49 | 415 | 1.32 | 0 | 0 | 0.98 | 8,02 | Possato (2015) |
|  | Sciaenidae | *Ctenosciaena gracilicirrhus* | 15.3 | 0.33 | 49.8 | 1.15 | 0 | 0 | 0.96 | 11,97 | Possato (2015) |
|  | Sciaenidae | *Larimus breviceps* | 25.4 | 0.55 | 171 | 1.05 | 0 | 0 | 1.16 | 9,13 | Possato (2015) |
|  | Sciaenidae | *Ophioscion punctatissimus* | 25 | 0.67 | 160.6 | 1.32 | 0 | 0 | 1.32 | 9,74 | (Froese, 2018) |
|  | Sciaenidae | *Paralonchurus brasiliensis* | 30 | 0.57 | 331 | 1.32 | 0 | 0 | 1.13 | 8,4 | (Froese, 2018) |
|  | Sciaenidae | *Stellifer brasiliensis* | 14.5 | 0.83 | 48.2 | 1.32 | 0 | 0 | 1.77 | 12,45 | Possato (2015) |
|  | Sciaenidae | *Stellifer rastrifer* | 32.1 | 0.35 | 550 | 1.32 | 0 | 0 | 0.81 | 7,57 | Possato (2015) |
|  | Sciaenidae | *Stellifer stellifer* | 21 | 0.79 | 108.2 | 1.32 | 0 | 0 | 1.54 | 10,55 | Possato (2015) |
|  | Sciaenidae | *Umbrina canosai* | 39 | 0.41 | 865.1 | 1.32 | 0 | 0 | 0.85 | 6,91 | (Froese, 2018) |
|  | Sciaenidae | *Umbrina coroides* | 23.1 | 0.36 | 158.7 | 2.18 | 0 | 0 | 0.9 | 11,5 | (Froese, 2018) |
|  | Scorpaenidae | *Scorpaena isthmensis* | 16 | 0.33 | 48.3 | 1.32 | 0 | 0 | 0.96 | 12,44 | (Froese, 2018) |
| (GDF) | Serranidae | *Diplectrum radiale* | 26 | 0.39 | 272 | 1.53 | 0 | 0 | 0.92 | 9,1 | Possato (2015) |
|  | Serranidae | *Rypticus randalli* | 20 | 0.5 | 87.1 | 1.44 | 0 | 0 | 1.16 | 11,29 | (Froese, 2018) |
|  | Serranidae | *Rypticus saponaceos* | 20 | 0.3 | 200 |  | 0 | 0 |  |  |  |
|  | Synodontidae | *Synodus foetens* | 48.3 | 0.38 | 840 | 1.88 | 0 | 0 | 0.76 | 7,73 | Possato (2015) |
|  | Triglidae | *Prionotus nudigula* | 28 | 0.13 | 755.8 | 1.32 | 0 | 0 | 0.44 | 7,1 | (Froese, 2018) |
|  | Triglidae | *Prionotus punctatus* | 42.3 | 0.13 | 108.3 | 1.13 | 0 | 0 | 0.39 | 10,18 | Possato (2015) |
|  | Uranoscopidae | *Astroscopus sexspinosus* | 31 | 0.27 | 668.8 | 1.32 | 0 | 0 | 0.69 | 7,28 | (Froese, 2018) |
|  | Uranoscopidae | *Astroscopus y-graecum* | 44 | 0.23 | 960.7 | 1.32 | 0 | 0 | 0.56 | 6,76 | (Froese, 2018) |
| 25. Sand and Mud | Blenniidae | *Parablennius pilicornis* | 12.7 | 0.45 | 24.6 | 1.4 | 0 | 0 | 1.23 | 14,5 | (Froese, 2018) |
| Criptic Fishes (SMCF) | Gobiesocidae | *Gobiesox strumosus* | 8 | 0.3 | 8.8 | 0.78 | 1 | 1 | 1.08 | 135,18 | (Froese, 2018) |
|  | Gobiidae | *Bathygobius soporator* | 15 | 0.4 | 110.8 | 0.59 | 0 | 0 | 1.09 | 9,14 | (Froese, 2018) |
|  | Gobiidae | *Ctenogobius boleosoma* | 7.5 | 0.85 | 3.4 | 0.43 | 0 | 0 | 2.16 | 18,04 | (Froese, 2018) |
|  | Gobiidae | *Ctenogobius shufeldti* | 8 | 0.8 | 6.4 | 0.43 | 1 | 1 | 2.04 | 134,92 | (Froese, 2018) |
|  | Gobiidae | *Ctenogobius smaragdus* | 15 | 0.45 | 20.1 | 0.34 | 1 | 1 | 1.18 | 105,01 | (Froese, 2018) |
|  | Gobiidae | *Ctenogobius stigmaticus* | 8 | 0.8 | 6.4 | 0.4 | 1 | 1 | 2.04 | 134,15 | (Froese, 2018) |
|  | Gobiidae | *Gobioides broussonnetii* | 55 | 0.13 | 1891.2 | 0.27 | 1 | 1 | 0.37 | 41 | (Froese, 2018) |
|  | Gobiidae | *Gobionellus oceanicus* | 17.8 | 0.36 | 21.78 | 0.24 | 0 | 0 | 0.97 | 11,91 | Possato (2015) |
|  | Gobiidae | *Microgobius meeki* | 10 | 0.54 | 5.3 | 0.55 | 0 | 0 | 1.48 | 16,86 | (Froese, 2018) |
|  | Ophichthidae | *Ophichthus gomesii* | 91.4 | 0.25 | 8332.4 | - | 0 | 0 | 3.62 | 9,21 | (Froese, 2018) |

#### Biomass

For fish, only pufferfishes and catfishes had the biomass estimated by the swept area method. This method was not applied to all groups, because in these cases the biomass estimated by trawl survey was lower than the records of capture by the artisanal fishery. In this way, we chose to estimate the biomass of top the predator group using a guesstimate of the exploitation ratio, E (or F/Z). Thus, the groups of higher trophic levels and aim of the fishery had the exploitation rate (E) estimated between 25% and 35%; lower trophic levels and aim of the fishery had the rate of exploitation between 5% and 20%. For the other fish with high mortality due to predation, the biomass was estimated by the EwE, and the exploitation rate was estimated between 1% and 2% once these groups are not fishing targets and are caught only as by-catch.

#### Catches

Landing data from 2014 assessed by the Monitoring Program of the Fishing Activity conducted by the Ports of Parana were used (Paraná, Unpublished results). This program is conducted at the main fishery landing sites in the PEC, which provides reasonable estimates of fish landings. Daily, the landings are recorded with information regarding the capture (resource, weight, location, and price of the first sale). However, due to the nature of small-scale fishing activity in the region, where landings occur in a diluted form along the coast Andriguetto-Filho (2003), some flows in the fishery production chain are not monitored. There is also no information available about the discarded catch.

#### Production

The natural mortality rates (M) was calculated by empirical equation Pauly (1980) and fishing mortality rates (F) was determined by guesstimates of exploitation rate (E). Basic inputs for the empirical equation of the natural mortality rate were taken from the FishBase Froese; Pauly (2018)

#### Consumption

To build the diet matrix was prioritized the local studies (or adjacent areas) of same or similar species of each group

#### Groups

Table 5 - Parameterization of fish groups for Paranaguá Estuarine Complex (PEC) model in 2014.

| **Functional Group** | **(Original Value) Adjust Value** | **Reference** | **Notes** |
| --- | --- | --- | --- |
| **7. Anchovy and Sardines** |  |  |  |
| *Biomass* | 3.74 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0,001) | (Paraná, Unpublished results) | Anchovy and Sardines catch possibly underestimates for 2014 (0.06 ton year-1). |
| *F/Z* | 0.05 | *Guesstimate* | So, F= 0.09 |
| *P/B* | (1.65) 2.304 | P/B= F+M | M= 1.65 (Pauly, 1980) |
| *Q/B* | 15.00 | Palomares; Pauly (1998) |  |
| *Diet* |  | Chaves; Vendel (2008 e Hofling et al. (2008 e Krumme et al. (2008 e Muto et al. (2008) | The literature consulted suggests that Anchovy and Sardines have a planktivorous feeding habitat, including ichthyoplankton. |
| **8. Small Pelagic Fishes (SPF)** |  |  |  |
| *Biomass* | 0.73 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0) 0.01 | *Guesstimate* | The Catch of this group occur incidentally in gillnet fisheries and then discarded. We guesstimate the discard of this group corresponds to 2% (1 of the total catch of the gillnets. *Chloroscombrus chrysurus* can occur in high densities in gillnets with meshes smaller than 8 cm. |
| *F/Z* | 0.01 | *Guesstimate* | So, F= 0.02 |
| *P/B* | 1.61 | P/B= F+M | M = 1.59 (Pauly, 1980) |
| *Q/B* | 14.00 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Chaves; Umbria (2003 e Chaves; Vendel (2008 e Höfling et al. (1998 e Silva; Lopes (2002) | The diet of small pelagics is dependent on the planktonic community. However, small fish, mollusks, and polychaetes have the greatest contribution to the diet when compared to Anchovy and Sardines' diet, besides the presence of organic matter. |
| **9. Medium Pelagic Fishes (MPF)** |  |  |  |
| *Biomass* | 0.31 | Guesstimate | So, F=C/B rate |
| *Catch* | (0.009) 0.01 | *Guesstimate* | The genus *Oligoplites spp*. (leather jacket) Are considered an important resource for small scale fisheries in the area, during the wet session of the year, when the landing is more accentuated. Sporadically occur landings of *Trachiurus lepturus*, and *Pomatomus saltatrix*. Discards are not identified for these species. |
| *F/Z* | 0.04 | *Guesstimate* | F= 0.03 |
| *P/B* | 0.69 | P/B= F+M | M= 0.66 Pauly, 1980) |
| *Q/B* | 7.50 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Bittar et al. (2008 e Höfling et al. (1998 e Martins et al. (2005 e Winik et al. (2007) | The literature indicates the importance of fish, especially engraulids and clupeids, in the diet of the pelagic medium. However, the contributions to diets of small crustaceans, crabs, squid, and other mollusks were recurrent in the diet of these species |
| **10. Large Pelagic Fishes (LPF)** |  |  |  |
| *Biomass* | 0.02 | *Guesstimate* | F=C/B |
| *Catch* | (0.004) | (Paraná, Unpublished results) | Total landings reported for was used (2.515 ton\* year-1). |
| *F/Z* | 0.25 | *Guesstimate* | F= 0.17 |
| *P/B* | 0.69 | P/B= F+M | M= 0.52 (Pauly, 1980) |
| *Q/B* | 4.90 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Arendt et al. (2001 e Bakhoum (2007 e Dias (2016 e Franks et al. (2003 e Silvano (2001) | It presents a voracious alimentary habit, with piscivore characteristics more striking when compared to MPF preferentially preying on sardines, anchovy, and other small pelagic fish. Shrimps also count in the diet. |
| **11. Snook** |  |  |  |
| *Biomass* | 0.04 | *Guesstimate* | F=C/B |
| *Catch* | (0.003) 0.01 | (Paraná, Unpublished results) and FUNDEPAG (2018) | The recorded values(1718) were corrected because the snooks are often marketed by routes not monitored by (Paraná, Unpublished results). Since FUNDEPAG (2018) has released better information on the capture for this group. Indicating that the catch may be close to 4 tons year-1 . Discards are not known in view of the high commercial value of the species of this group. |
| *F/Z* | 0.25 | *Guesstimate* | F= 0.18 |
| *P/B* | 0.71 | P/B= F+M | M=0.53 (Pauly, 1980) |
| *Q/B* | 6.68 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Arantes (2014 e Blewett et al. (2006 e Rabelo et al. (2009 e Tonini et al. (2007) | Both species presented piscivores characteristics. However, for *C. paralellus*, the brachyurus represent a more substantial portion of the diet. |
| **12. Pampos and Grunts** |  |  |  |
| *Biomass* | 0.085 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0.006) 0.01 | (Paraná, Unpublished results) | The group has habits associated with consolidated structures with similarity in the diet. Furthermore, they are important resources for fishing line and hook, is also captured by amateur/sportive fishing. Total landing reported (3.46 tons year-1) (Paraná, Unpublished results) had been adjusted (0.008 ton year-1) considering the catch by amateur/sport fishing and a possible bycatch of small individuals of this group. |
| *F/Z* | 0.25 | *Guesstimate* | F= 0.28 |
| *P/B* | 1.14 | P/B= F+M | M= 0.85 (Pauly, 1980) |
| *Q/B* | 7.77 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Arantes (2014 e Castillo-Rivera et al. (2007 e Niang et al. (2010 e Regina Denadai et al. (2013) | Among the preyed items are the mysids, bivalves, bryozoans, cnidarians, polychaetes, and algae |
| **13. Omnivores** |  |  |  |
| *Biomass* | 0.14 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0.011) 0.01 | (Paraná, Unpublished results) | This value corresponds to the landings of *Chaetodipterus faber*. Total landings reported for (Paraná, Unpublished results) was used (6.54 ton year-1). Fishing gears are gillnets (mesh> 10 cm between nodes) and catch mainly during the rainy season. |
| *F/Z* | 0.05 | *Guesstimate* | F= 0.08 |
| *P/B* | 1.62 | P/B= F+M | M= 1.53 (Pauly, 1980) |
| *Q/B* | 11.14 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Barros et al. (2013 e Da Gama (2017 e Vasconcelos Filho et al. (2009) | Sessile faunaS and jellyfishes were reported as prey items of this group. Ingestion of plants and algae also were reported. |
| **14. Mugelids** |  |  |  |
| *Biomass* | 1.19 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0.031) 0.03 | (Paraná, Unpublished results) | This value corresponds to the landings of *Mugil curema* and *M. liza* *M. incilis* and *M. curvidens*). Total landings reported for (Paraná, Unpublished results) was used (18.85 ton year-1). Fishing gears are gillnets (mesh> 10 cm between nodes) and catch mainly during the dry season. |
| *F/Z* | 0.1 | *Guesstimate* | F= 0.09 |
| *P/B* | (0.79) 1.60 | P/B= F+M | M= 0.79 (Pauly, 1980) |
| *Q/B* | 15.00 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Oliveira; Soares (1996 e Thompson et al. (2015 e Vasconcelos Filho et al. (2009) | Several benthic invertebrates are found in the stomachs analyzed in the studies, but organic matter and sediments predominate |
| **15. Large Reef Fishes (LRF)** |  |  |  |
| *Biomass* | 0.05 | *Guesstimate* | F=C/B |
| *Catch* | (0.001) 0.005 | (Paraná, Unpublished results); FUNDEPAG (2018) | The original value (0.38 ton year-1) was modified because we identified other production routes that are not monitored. FUNDEPAG (2018) suggests that such annual production may reach 1 ton year -1. It was determined 2.6 ton year^-1 yet because we consider a possible catch of amateur and sportive fishing. |
| *F/Z* | 0.2 | *Guesstimate* | F= 0.08 |
| *P/B* | 0.41 | P/B= F+M | M= 0.33 (Pauly, 1980) |
| *Q/B* | 5.21 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | (Arantes (2014 e Artero et al. (2015 e Brulé et al. (2011 e Ferreira; Silva (2014 e Freitas et al. (2015 e Gibran (2007 e Machado Leonardo et al. (2008) | Opportunistic species, consuming a large variety of benthic invertebrates (mostly decapods) and teleosts. Shrimp also accounts an important food item for this group. |
| **16. General Reef Fishes (GRF)** |  |  |  |
| *Biomass* | 0.22 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0) 0.0016 | *Guesstimate* | There are no official records of the landing of this group. However, we consider 1 ton year^-1 considering eventual bycatch |
| *F/Z* | 0.01 | *Guesstimate* | F= 0.01 |
| *M* | 0.5 | (Pauly, 1980) |  |
| *P/B* | 0.51 | P/B= F+M | M=0.5 (Pauly, 1980) |
| *Q/B* | 5.48 | (Palomares and Pauly, 1998) |  |
| *Diet* |  |  | This group feeds on invertebrates, mainly the fauna and algae fouling on rocky reefs |
| **17. Pufferfishes** |  |  |  |
| *Biomass* | 0,35 | Possato (2015) | swept area method |
| *Catch* | (0.064) 0.06 | (Paraná, Unpublished results) | The original total landed value (38.86 ton year-1) was used. |
| *F/Z* | 0.4 | E=F/Z | F= 0.81 |
| *P/B* | 2.02 | Z = F+M | M = 1.21 (Pauly, 1980) |
| *Q/B* | 9.35 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | (Chiaverini, 2008) | Feeding on crustaceans and mollusks |
| **18. Skate and Rays** |  |  |  |
| *Biomass* | 0.09 | *Guesstimate* | F=C/B |
| *Catch* | (0.007) 0.02 | (Paraná, Unpublished results) | The original landed value (4.04 ton year-1) was duplicate, concerning bycatch |
| *F/Z* | 0.1 | *Guesstimate* | F= 0.16 |
| *P/B* | 1.59 | P/B= F+M | M= 1.43 (Pauly, 1980) |
| *Q/B* | 6.61 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Bornatowski et al. (2010 e Jacobsen; Bennett (2013) | Opportunistic species, consuming a large variety of benthic invertebrates (mainly crustaceans and mollusks) and a considerable proportion of fish |
| **19. Hake - Small** |  |  |  |
| *Biomass* | 1.47 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0.019) 0.02 | (Paraná, Unpublished results) | The original landed value (11.55 ton year-1) was used. Only catch taken within the estuary are considered. Since this resource is highly explored on the adjacent continental shelf |
| *F/Z* | 0.2 | *Guesstimate* | F= 0.2 |
| *P/B* | 1.02 | P/B= F+M | M= 0.81 (Pauly, 1980) |
| *Q/B* | 8.92 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Castro et al. (2015 e Rondineli et al. (2007) | Feeding mainly on shrimp, and other crustaceans |
| **20. Hake - Medium and Large** |  |  |  |
| *Biomass* | 0.12 | *Guesstimate* | F=C/B |
| *Catch* | (0.026) 0.03 | (Paraná, Unpublished results) | The original landed value (16.05 ton year-1) was used |
| *F/Z* | 0.3 | *Guesstimate* | F= 0.21 |
| *P/B* | 0.7 | P/B= F+M | M= 0.49 (Pauly, 1980) |
| *Q/B* | 4.92 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Ferreira (2016) | As the smaller hake, the large and medium hake prey on invertebrates. However, the piscivorous feeding habit is more pronounced |
| **21. Croakers** |  |  |  |
| *Biomass* | 0.58 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0.022) 0.02 | (Paraná, Unpublished results) | The original landed value (13.77 ton year-1) was used. |
| *F/Z* | 0.2 | *Guesstimate* | F= 0.2 |
| *P/B* | 1 | P/B= F+M | M= 0.8 (Pauly, 1980) |
| *Q/B* | 8.36 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Arantes (2014 e Blasina et al. (2010 e Denadai et al. (2015 e Mendenhall (2015 e Mendoza-Carranza; Vieira (2008) | They are feeding on benthic invertebrates, (polychaetes, bivalves, and crustaceans), also zooplankton and detritus |
| **22. Flatfish** |  |  |  |
| *Biomass* | 0.07 | *Guesstimate* | F=C/B |
| *Catch* | (0.009) 0.01 | (Paraná, Unpublished results) | The original landed value (5.4 ton year-1) was used. |
| *F/Z* | 0.3 | *Guesstimate* | F= 0.13 |
| *P/B* | 0.42 | P/B= F+M | M= 0.29 (Pauly, 1980) |
| *Q/B* | 4.16 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Cazorla; Forte (2005) | They are feeding foraging fishes and small demersal, besides shrimps. |
| **23. Catfish** |  |  |  |
| *Biomass* | 1.38) | Possato (2015) | swept area method |
| *Catch* | (0.039) 0.04 | (Paraná, Unpublished results) | The original total landed value was used (23.92 ton year-1) |
| *F/Z* | 0.1 | E=F/Z | So, F= 0.04 |
| *P/B* | 0.5 | Z = F+M | M = 0.38 (Pauly, 1980) |
| *Q/B* | 13.00 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Denadai et al. (2012 e Possato (2010 e Rabitto; Abilhôa (1999) | In general, they are opportunistic, predating all diversity of benthic invertebrates, zooplankton, demersal fish, and organic material (detritus). *Genidens barbus*, also, to invertebrates, has a more considerable influence of fish in the diet. In turn, zooplankton (copepods) was important for *Cathorops spixii* |
| **24. General Demersal Fishes - GDF** |  |  |  |
| *Biomass* | 3.22 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0.002) 0.01 | (Paraná, Unpublished results) | The original total landed value (1.48 ton year-1) was modified considering 5000 ton year^-1 of bycatch |
| *F/Z* | 0.01 | *Guesstimate* | So, F= 0.01 |
| *P/B* | 1.05 | P/B= F+M | M= 1.03 (Pauly, 1980) |
| *Q/B* | 10.24 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Arantes (2014 e Branco; Lunardon-Branco; et al. (2005) | Diet and feeding habitats of the most abundant species of this group were used. Which in summary are benthivore, but prey on fish (foraging and other small demersal) and zooplankton |
| **25. Sand and Mud Cryptic Fishes - SMCF** |  |  |  |
| *Biomass* | 0.55 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0) 0.01 | *Guesstimate* | No official landing data but we considering 500 ton year^-1 of eventual bycatch |
| *F/Z* | 0.01 | *Guesstimate* | So, F= 0.02 |
| *P/B* | 1.58 | P/B= F+M | M= 1.57 (Pauly, 1980) |
| *Q/B* | (35.00) 15.00 | (Palomares and Pauly, 1998) |  |
| *Diet* |  | Reis-Filho; Giarrizzo (2016 e Zanlorenzi; Chaves (2011) | Small crustaceans (copepods and peracarids) |

### Plankton and Benthc Invertebrates

Between crustaceans, shrimps and crabs are important resources in the PEC. Other crustaceans including mantis shrimp and the hermit crab, were grouped separated. Mollusks bivalves are other resources than maintaining a fishery system. The gastropods and bivalves (an important resource for the fishery) are presents in the soft and hard bottom. The Echinoderms also inhabit both the soft and hard bottom and often occur as bycatch in gillnet fisheries. Sessile fauna represents barnacles, corals and sea anemones found in consolidated structures around the PEC. The infauna is a recurrent prey to many groups in the model.

#### Parameterization

The biomass of benthic invertebrates was estimated by the model. We considered 0.95 for the value of E.E. For P/B and Q/B were obtained from other estuarine or coastal models of subtropical regions. Mainly Opitz (1996) and Angelini et al. (2018). The diets were extracted from the literature

Table 6 - Parameterization of plankton and benthic invertebrates groups for Paranaguá Estuarine Complex (PEC) model in 2014.

| **Functional Group** | **(Original Value) Adjust Value** | **Reference** | **Notes** |
| --- | --- | --- | --- |
| **26. Blue Crabs** |  |  |  |
| *Biomass* | 3.60 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0.12) | (Paraná, Unpublished results) | The monitoring program has registered 13.776 kg of crab’s meat and 199.476 units of *Callinectes sp*. In this case of crab’s meat, an average of 40 units of large-size blue crabs are used to obtain 1 kg of meat. Alternatively, by units (mean body mass considered was 100 grams). |
| *P/B* | 3 | Shinozaki-Mendes; Lessa (2017) | exploitation area of Blue Crabs. |
| *Q/B* | 10 |  | $ Q/B = 3P/B $ |
| *Diet* |  | Branco et al. (2002) | Generalized dietary strategy comprising all invertebrates groups and detritus |
| **27. Shrimp** |  |  |  |
| *Biomass* | 2.59 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0.02) 0.02 | (Paraná, Unpublished results) |  |
| *P/B* | 6 | Arreguín-Sánches et al. (2002 e Carvalho (2013 e Villela et al. (1997) | high exploitation of shrimps |
| *Q/B* | 26.9 | Angelini et al. (2018) |  |
| *Diet* |  | Branco (2005) | The Infauna, Zooplankton, besides organic matter (detritus), are the main components of the diet of shrimps. |
| **28. Other Crustaceans** |  |  |  |
| *Biomass* | 1.77 | EwE Estimation | E.E = 0.95 |
| *Catch* | - |  |  |
| *P/B* | 3.3 | Opitz (1996) |  |
| *Q/B* | 31 | Opitz (1996) |  |
| *Diet* |  | Opitz (1996) | Generalized dietary strategy comprising all invertebrates groups and detritus |
| **29. Infauna** |  |  |  |
| *Biomass* | 0.17 | EwE Estimation | E.E = 0.95 |
| *Catch* | - |  |  |
| *P/B* | 60 | Angelini et al. (2018 e Opitz (1996) | ) |
| *Q/B* | 350 | Angelini et al. (2018 e Opitz (1996) |  |
| *Diet* |  | Angelini et al. (2018 e Opitz (1996) |  |
| **30. Gastropods** |  |  |  |
| *Biomass* | 0.85 | EwE Estimation | E.E = 0.95 |
| *Catch* | - |  |  |
| *P/B* | 12 | (Angelini et al., 2018) | (Angelini et al., 2018; Opitz, 1996) |
| *Q/B* | 65 | (Angelini et al., 2018) |  |
| *Diet* |  | (Angelini et al., 2018; Lira et al., 2018) | Algae grazing |
| **31. Bivalves** |  |  |  |
| *Biomass* | 0.25 | EwE Estimation | E.E = 0.95 |
| *Catch* | (0.073) | (Paraná, Unpublished results) | Bivalves are among the most exploited by fishing in the CEP. Oysters, the vongole, and mollusks represent them. The values recorded in the monitoring program represent the resource in the product benefited (without the shells). In this way, the value was adjusted to consider the resource in its natural form. Thus we adopted a rate of 0.5 for shells in nature form/product benefited. |
| *P/B* | 55 | Angelini et al. (2018) |  |
| *Q/B* | 400 | Angelini et al. (2018) |  |
| *Diet* |  | Angelini et al. (2018 e Lira et al. (2018) |  |
| **32. Echinoderms** |  |  |  |
| *Biomass* | 0.77 | EwE Estimation | E.E = 0.95 |
| *Catch* | - |  |  |
| *P/B* | 0.7 |  | (Angelini et al., 2018) |
| *Q/B* | 5 | Angelini et al. (2018) |  |
| *Diet* |  | Guilherme; Rosa (2014) | The small crustaceans and mollusks as the most frequent items |
|  |  |  |  |
| **33. Sessile Fauna** |  |  |  |
| *Biomass* | 2.47 | EwE Estimation | E.E = 0.95 |
| *Catch* | - |  |  |
| *P/B* | 5.0 |  | (Opitz, 1996) |
| *Q/B* | 25 | Opitz (1996) |  |
| *Diet* |  | Opitz (1996) | Feeding on plankton and detritus |
|  |  |  |  |
| **34. Jellyfish** |  |  |  |
| *Biomass* | 0.27 | EwE Estimation | E.E = 0.95 |
| *Catch* | - |  |  |
| *P/B* | 5 | Pauly et al. (2009) | inshore tropical waters |
| *Q/B* | 25 | Pauly et al. (2009) | inshore tropical waters |
| *Diet* |  | Júnior; Haddad (2008 e Pauly et al. (2009) | Feeding on the zooplankton, |
|  |  |  |  |
| **36. Zooplankton** |  |  |  |
| *Biomass* | 3 | Souza (2013) | We assumed the zooplankton biomass is equal to Babitonga Bay, an estuary less than 50 km away. |
| *Catch* | - |  |  |
| *P/B* | 90 | (Adapted from Angelini et al., 2018; Opitz, 1996) |  |
| *Q/B* | 200 | (Opitz, 1996) |  |
| *Diet* |  | (Opitz, 1996) | Feeding on mainly on phytoplankton and Zooplankton |

### Primary Producers

Three groups are identified in the PEC area: Seagrass can be found on estuary margin (*Spartina alterniflora*) or in shallow areas (*Halodule wrightii*). Macroalgaes are observed in reefs and shallow areas (in this case: *Ulva* sp.). Diatom dominates phytoplankton.

#### Biomass

Phytoplankton biomass was calculate multiplying the number of cell/liter by average biovolume Leblanc et al. (2012), using this method, we obtained the annual mean value of 28.5 ton km--2. This value was compared to the estimates obtained by Brandini et al., (2007) in adjacents coastal waters (in this case, an oscillation between 0.05 ton km2 and 25.00 ton km2). The value estimated by the biovolume of diatomaceous cells was consistent with the other estimates mentioned and suitable for the modeled area. The ratios used for conversion were: to mg C = 30 (Strickland, 1960) and mg C to mg wet weight =16 (Walsh, 1981). Macroalgae and Seagrass had their biomasses estimated by the model.

#### Production

The P/B of phytoplankton was estimated based on the biomass estimate described above, and an estimate of primary productivity reported by Kampel (2003)) for adjacent coastal waters was utilized for P/B. For another primary producer, the P/B was derived from other models: seagrass Walters; Martell; Christensen; et al. (2008)) and macroalgae . (Freire 2005).

## Model analyses and ecosystem indicators

### Assessing the quality of model input estimates and balancing the model

Input data quality was assessed using the Ecopath Pedigree routine. In this routine, the user classifies the data by choosing values between 0 (low quality) and 1 (high quality) for each input parameter (B, P/B, Q/B, and diet data) according to the information source. The average value for all parameters and groups provides a general and concise index of the model input data quality Christensen, Villy ; Walters, Carl. J.; Pauly, Daniel; Forrest (2008 e Morissette (2007).

In order to calibrate and trust the model, we also utilized the following best practices in Ecopath modeling (Heymans et al., 2016): i) before running the model, we increased the non-assimilated consumption ratio for zooplankton from 20% to 40% and for benthos groups and other groups feeding on phytoplankton from 20% to 30% (which is physiologically realistic); (ii) the model was balanced to Ecotropic Efficiency (E.E) values lower than 1.0 changing diet composition matrix firstly, and then the other basic input parameters; iii) we also confirmed if GE (Gross Efficiency or P/Q) values were between 0.1 and 0.3; iv) the Respiration/Assimilation ratio (R/A) must be < 1.0; v) the Respiration/Biomass (R/B) rate values must be between 1 and 10 for fish compartments and higher for groups with higher metabolic rates; and vi) Net Efficiency must be higher than GE. The Pre-Balanced (PREBAL) diagnosis Link (2010) was used to assess issues related to the model structure, including the order of magnitude that the biomass reaches and whether or not B, P/B, and Q/B decrease with the increase of trophic levels.

### Ecosystem structure, maturity, flows, and fishing impact

Input data quality was assessed using the Ecopath Pedigree routine. In this routine, the user classifies the data by choosing values between 0 (low quality) and 1 (high quality) for each input parameter (B, P/B, Q/B, and diet data) according to the information source. The average value for all parameters and groups provides a general and concise index of the model input data quality (Christensen et al., 2008; Morissette, 2007).

In order to calibrate and trust the model, we also utilized the following best practices in Ecopath modeling (Heymans et al., 2016): i) before running the model, we increased the non-assimilated consumption ratio for zooplankton from 20% to 40% and for benthos groups and other groups feeding on phytoplankton from 20% to 30% (which is physiologically realistic); (ii) the model was balanced to Ecotropic Efficiency (E.E) values lower than 1.0 changing diet composition matrix firstly, and then the other basic input parameters; iii) we also confirmed if GE (Gross Efficiency or P/Q) values were between 0.1 and 0.3; iv) the Respiration/Assimilation ratio (R/A) must be < 1.0; v) the Respiration/Biomass (R/B) rate values must be between 1 and 10 for fish compartments and higher for groups with higher metabolic rates; and vi) Net Efficiency must be higher than GE. The Pre-Balanced (PREBAL) diagnosis (Link, 2010) was used to assess issues related to the model structure, including the order of magnitude that the biomass reaches and whether or not B, P/B, and Q/B decrease with the increase of trophic levels.

### Ecosystem structure, maturity, flows, and fishing impact

Functional groups of the PEC model were aggregated at a discrete trophic level and represented by the Lindeman spine analysis Corrales et al. (2015 e Libralato et al. (2010 e Lindeman (1942). This analysis also allows us to calculate the Transfer Efficiency (TE%) of the flows between trophic levels, representing the fraction of the total flow of a trophic level that is consumed by the immediately superior TL. The mTE is the geometric mean of transfer efficiencies for trophic levels II to IV. Ecosystem structure, functioning, and stage of development were analyzed in terms of trophic flows, thermodynamics, information theory, and trophodynamic indicators Christensen (1995 e Ulanowicz, Robert E (1986).

The mixed trophic impact analysis MTIij identifies the relative impact (direct or indirect) that a hypothetical increase in the biomass of one group (i), including fishing fleets, would produce on the biomass of other groups (j) Christensen, Villy ; Walters, Carl. J.; Pauly, Daniel; Forrest (2008 e Ulanowicz; Puccia (1987). From MTIi analysis it is possible to obtain the overall effect, ɛi (Equation 5), which can be shown as related to the maximum effect measured in the food web, excluding the effect on itself.

The low biomass groups with a structuring role in the food web are defined as keystone species. The Keystoneness (KSi) of a functional group is defined as follows (Equation 6):

In this equation, pi is the contribution of each functional group i to the total biomass of the food web.

In order to consider fishing effects in the PEC, a series of fishing-related indicators were reviewed to assess exploitation status, including the relative primary production required to sustain the fisheries -PPR% Pauly; Villy (1995), the mean trophic level of the catches (TLc), and the gross efficiency of the fishery (GE, catch/NetPP).

The Lindex (Equation 7) takes into account ecosystem properties to quantify the loss of total secondary production due to fishing. A meta-analysis of 51 ecological models’ ecosystems previously classified as overexploited or sustainably exploited allows the association of the L-index with the probability that the ecosystem has a sustainable fishery (Psust) Libralato et al. (2008).

Where: PPR is the absolute value of primary production required for sustain the fisheries, TE is the overall energy transfer ratio, The TLc is the mean trophic level of catches, Primary Production of ecosystem

Functional groups of the PEC model were aggregated at a discrete trophic level and represented by the Lindeman spine analysis Corrales et al. (2015 e Libralato et al. (2010 e Lindeman (1942). This analysis also allows us to calculate the Transfer Efficiency (TE%) of the flows between trophic levels, representing the fraction of the total flow of a trophic level that is consumed by the immediately superior TL. The mTE is the geometric mean of transfer efficiencies for trophic levels II to IV. Ecosystem structure, functioning, and stage of development were analyzed in terms of trophic flows, thermodynamics, information theory, and trophodynamic indicators Christensen (1995 e Ulanowicz, Robert E (1986).

The mixed trophic impact analysis MTIij identifies the relative impact (direct or indirect) that a hypothetical increase in the biomass of one group (i), including fishing fleets, would produce on the biomass of other groups (j) Christensen, Villy ; Walters, Carl. J.; Pauly, Daniel; Forrest (2008 e Ulanowicz; Puccia (1987). From MTIi analysis it is possible to obtain the overall effect, ɛi (Equation 5), which can be shown as related to the maximum effect measured in the food web, excluding the effect on itself.

The low biomass groups with a structuring role in the food web are defined as keystone species. The Keystoneness (KSi) of a functional group is defined as follows (Equation 6):

In this equation, pi is the contribution of each functional group i to the total biomass of the food web.

In order to consider fishing effects in the PEC, a series of fishing-related indicators were reviewed to assess exploitation status, including the relative primary production required to sustain the fisheries -PPR% Pauly; Villy (1995), the mean trophic level of the catches (TLc), and the gross efficiency of the fishery (GE, catch/NetPP).

The Lindex (Equation 7) takes into account ecosystem properties to quantify the loss of total secondary production due to fishing. A meta-analysis of 51 ecological models’ ecosystems previously classified as overexploited or sustainably exploited allows the association of the L-index with the probability that the ecosystem has a sustainable fishery (Psust) Libralato et al. (2008).

Where: PPR is the absolute value of primary production required for sustain the fisheries, TE is the overall energy transfer ratio, The TLc is the mean trophic level of catches, Primary Production of ecosystem

### Simulating temporal dynamics

Ecopath had been developed by adopting a time simulation (Ecosim, Walters et al., 1997), enabling dynamics modeling to explore the impact of environmental disturbances. The dynamic module of EwE uses settings from the mass-balance module to estimate temporal biomass flows Walters et al. (1997 e Walters; Martell; Villy; et al. (2008). Ecosim works with a set of differential equations to estimate biomass flows for each functional group, as Equation 8:

In this equation, dBi/dt is the biomass growth rate of group (i) during the interval dt; gi is the net growth efficiency (P/Q ratio); Ii is the immigration rate; Mi and Fi are the natural and fishing mortality rates of group (i); ei is the emigration rate; and Bi is the biomass.

The consumption rates Qij (Equation 9) are calculated based on the foraging arena concept Ahrens et al. (2012), in which prey biomasses are divided into vulnerable and invulnerable states, setting the maximum increase in predation mortality a given predator can cause on a given prey. This determines whether the flow control is top-down (vij > 2), bottom-up (vij < 2), or mixed (vij = 2; the default value in EwE).

The variable aij is the effective search rate (time of search by the area or volume of the foraging arena) of predator j feeding on prey I; Bi is the biomass of the prey; Pj is the biomass of predator; and vij is the vulnerability of prey i to predator j.

### Calibration

Before being used to make predictions, the Ecosim model was calibrated with landing times series from 2014 to 2018 (Portos do Paraná, in press). The fitting time series was carried out using an integrated plug-in: the Stepwise Fitting Procedure Scott et al. (2016). This tool automatically searches for the best model to observed data by testing a set of hypotheses to assess the impact of fishing (through fishing mortality/effort time series), changes in predator-prey dynamics (vulnerability settings), and changes in primary production Philippsen et al. (2019), with the Akaike Information Criterion (AIC) choosing the best fit. We used fishing effort data (number of landing operations) for each fleet as the driving factor to fit the observed catch data from 2014 to 2018 (Portos do Paraná, in press).

### Simulating Future Scenarios

After the model was fitted to the data, we developed several temporal simulations covering 2019 through 2033 (15 total years) to assess any possible changes in ecosystem characteristics due to changes in fishing effort. We adopted the fishing effort from 2018 as a baseline (S1) and then simulated scenarios that increased fishing effort by 25% (S2), 50% (S3), and 100% (S4) as well as a scenario that reduced fishing effort by 50% (S5). The changes were simultaneous and in the same proportion for all fishing fleets; they were kept constant between 2019 and 2033.

A test of the significance of ecological indicators trends (Total biomass, the TLco – trophic level of entire community, and Kempton's Q, which shows the biomass diversity for TL > 3) and of fishing indicators (TL of catches and Lindex) was conducted for the adjustment periods (2014-2018) and simulation (2019-2033). Due to the relatively short period (n = 4 years for the fitting period and n = 15 years for the simulation period), a linear trend in the high autocorrelation model was fit to each one of the simulations using a generalized least squares regression framework Coll et al. (2008 e Philippsen et al. (2019).

We addressed the uncertainty of simulations with the Monte Carlo routine, where 250 iterations were developed, modifying the input parameters as from a normal distribution centered on the base value of Ecopath and using a 10% coefficient of variation (EwE default) Piroddi et al. (2017). The range of outputs (5% and 95%) was plotted for both outputs of the simulations (biomasses).

# 

# RESULTS

## Functional groups, parameterization, and data quality

The initial input values for the PEC model (Table 7) were modified in order to balance the model and to regard physiological restrictions (using several rates and PREBAL analyses)

Table 7 - Input parameter values to model trophic functioning of Paranaguá Estuarine Complex (PEC model). B (Biomass, t\*km-2); P/B (Production/Biomass ratio, t\*km-2\*year-); Q/B (Consumption/Biomass ratio, t\*km-2\*year-1); E.E (ecotrophic efficiency). Bold values were estimated by the model

| **ID** | **Group name** | **TL** | **Biomass** | **P/B** | **Q/B** | **EE** | **P/Q** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | Guiana Dolphins | **3.61** | 0.22 | 0.13 | 15.36 | **0.05** | 0.01 |
| 2 | Cormorants | **3.69** | 0.04 | 0.25 | 65 | **0** | 0 |
| 3 | Piscivorous seabird I | **3.79** | 0.04 | 0.25 | 72 | **0** | 0 |
| 4 | Piscivorous seabird II | **3.28** | 0.004 | 0.25 | 67 | **0** | 0 |
| 5 | Benthos Birds | **3.18** | 0.002 | 0.25 | 69 | **0** | 0 |
| 6 | Turtles | **2.14** | **0.17** | 0.15 | 2.54 | **0.3** | 0.06 |
| 7 | Anchovies and Sardines | **2.67** | **3.74** | 2.3 | 15 | 0.95 | 0.15 |
| 8 | Small Pelagic Fish (SPF) | **2.66** | **0.73** | 1.61 | 14 | 0.95 | 0.12 |
| 9 | Medium Pelagic Fish (MPF) | **3.47** | 0.31 | 0.69 | 7.5 | **0.98** | 0.09 |
| 10 | Large Pelagic Fish (LPF) | **3.73** | 0.02 | 0.69 | 4.9 | **0.3** | 0.14 |
| 11 | Snooks | **3.67** | 0.04 | 0.71 | 6.68 | **0.33** | 0.11 |
| 12 | Pampo and Grunt | **3.07** | **0.09** | 1.14 | 7.7 | 0.95 | 0.15 |
| 13 | Omnivores | **2.37** | **0.14** | 1.62 | 11.14 | 0.95 | 0.15 |
| 14 | Mugelids | **2.24** | **1.19** | 1.6 | 15 | 0.95 | 0.11 |
| 15 | Large Reef Fish (LRF) | **3.57** | 0.05 | 0.41 | 5 | **0.09** | 0.08 |
| 16 | General Reef Fish (GRF) | **3.12** | **0.22** | 0.51 | 5.48 | 0.95 | 0.09 |
| 17 | Pufferfish | **3.03** | 0.35 | 2.02 | 9.35 | **0.23** | 0.22 |
| 18 | Skate and Rays | **3.42** | 0.09 | 1.59 | 6.61 | **0.32** | 0.24 |
| 19 | Hake - Small | **3.37** | **1.47** | 1.02 | 8.92 | 0.95 | 0.11 |
| 20 | Hake- Medium and Large | **3.58** | 0.12 | 0.7 | 4.92 | **0.27** | 0.14 |
| 21 | Croakers | **3.2** | **0.58** | 1 | 8.36 | 0.95 | 0.12 |
| 22 | Flatfish | **3.72** | 0.07 | 0.42 | 4.16 | **0.99** | 0.1 |
| 23 | Catfish | **2.86** | 1.38 | 0.5 | 13 | **0.92** | 0.04 |
| 24 | General Demersal Fish (GDF) | **3.17** | **3.22** | 1.05 | 10.24 | 0.95 | 0.1 |
| 25 | Cryptic Fish (CF) | **2.7** | **0.55** | 1.58 | 14 | 0.95 | 0.11 |
| 26 | Crabs | **2.46** | **3.6** | 3 | 10 | 0.95 | 0.3 |
| 27 | Shrimp | **2.3** | **2.59** | 6 | 26.9 | 0.95 | 0.22 |
| 28 | Other Crustaceans | **2.26** | **1.77** | 3.3 | 31 | 0.95 | 0.11 |
| 29 | Infauna | **2.25** | **0.17** | 60 | 350 | 0.95 | 0.17 |
| 30 | Gastropods | **2.19** | **0.85** | 12 | 65 | 0.95 | 0.18 |
| 31 | Molusks | **2.05** | **0.25** | 55 | 400 | 0.95 | 0.14 |
| 32 | Equinoderms | **2.01** | **0.77** | 0.7 | 5 | 0.95 | 0.14 |
| 33 | Sessile Fauna | **2.06** | **2.47** | 2.3 | 22 | 0.95 | 0.1 |
| 34 | Jellyfish | **3.11** | **0.27** | 5 | 25 | 0.95 | 0.2 |
| 35 | Zooplankton | **2.17** | 3 | 90 | 200 | **0.77** | 0.45 |
| 36 | Macroalgae | **1** | **1.50** | 15 |  | 0.95 |  |
| 37 | Seagrass | **1** | **0.09** | 8 |  | 0.95 |  |
| 38 | Phytoplankton | **1** | 12 | 300 |  | **0.16** |  |
| 39 | Detritus | **1** | 16 |  |  | **0.11** |  |

For some groups, P/B and P/Q were adjusted to achieve a better balance of the PQ ratios and ensure physiologically realistic values for GE (0.1 <PQ <0.3), the exceptions were Guiana dolphins and the seabird’s , and zooplankton groups (GE < 0.01). Other metabolism rates were assured: Net Efficiency> GE, respiration/ assimilation < 1, and respiration/biomass are within expected (close to 10 years1 for fish and higher for others groups, like the zooplankton, seabirds and dolphins) (Table 8 and Figure 2). When biomass was omitted for a group, the value of E.E = 0.95 was assumed, when EE was estimated by EwE values were lower than 1.

Table 8 - Physiological parameters to validate the Paranaguá Estuarine Complex (PEC) model. Resp. /Ass.: Respiration/Assimilation rate (values need to be lower than 1.0); Resp./Biom.: Respiration/Biomass rate (values need to be from 1 to 10 for fish and from 50 to 100 for groups with higher turnovers rates).

|  | **Group name** | **Respiration / assimilation** | **Respiration / biomass (year-1)** |
| --- | --- | --- | --- |
| 1 | Guiana Dolphin | 0,989 | 12,158 |
| 2 | Cormorants | 0,995 | 51,750 |
| 3 | Piscivorous seabirds | 0,996 | 57,350 |
| 4 | Piscivorous seabirds II | 0,995 | 53,350 |
| 5 | Benthos Birds | 0,995 | 54,950 |
| 6 | Turtle | 0,926 | 1,882 |
| 7 | Anchovy and Sardines | 0,781 | 8,200 |
| 8 | SPF | 0,856 | 9,590 |
| 9 | MPF | 0,885 | 5,310 |
| 10 | LFP | 0,824 | 3,230 |
| 11 | Snooks | 0,867 | 4,634 |
| 12 | Pampo and Grunt | 0,815 | 5,020 |
| 13 | Omnivores | 0,818 | 7,292 |
| 14 | Mugelids | 0,867 | 10,400 |
| 15 | LRF | 0,898 | 3,590 |
| 16 | GRF | 0,884 | 3,874 |
| 17 | Pufferfishes | 0,730 | 5,460 |
| 18 | Skate and Rays | 0,699 | 3,698 |
| 19 | Hake - Small | 0,857 | 6,116 |
| 20 | Hake- Medium and Large | 0,822 | 3,236 |
| 21 | Croakers | 0,850 | 5,688 |
| 22 | Flatfishes | 0,874 | 2,908 |
| 23 | Catfishes | 0,952 | 9,900 |
| 24 | GDF | 0,872 | 7,142 |
| 25 | SMCF | 0,859 | 9,620 |
| 26 | Crabs | 0,625 | 5,000 |
| 27 | Shrimp | 0,721 | 15,520 |
| 28 | Others Crustaceans | 0,867 | 21,500 |
| 29 | Infauna | 0,786 | 220,000 |
| 30 | Gastropods | 0,769 | 40,000 |
| 31 | Mussel | 0,804 | 225,000 |
| 32 | Equinoderms | 0,800 | 2,800 |
| 33 | Sessile Fauna | 0,851 | 13,100 |
| 34 | Jellyfish | 0,714 | 12,500 |
| 35 | Zooplankton | 0,250 | 30,000 |

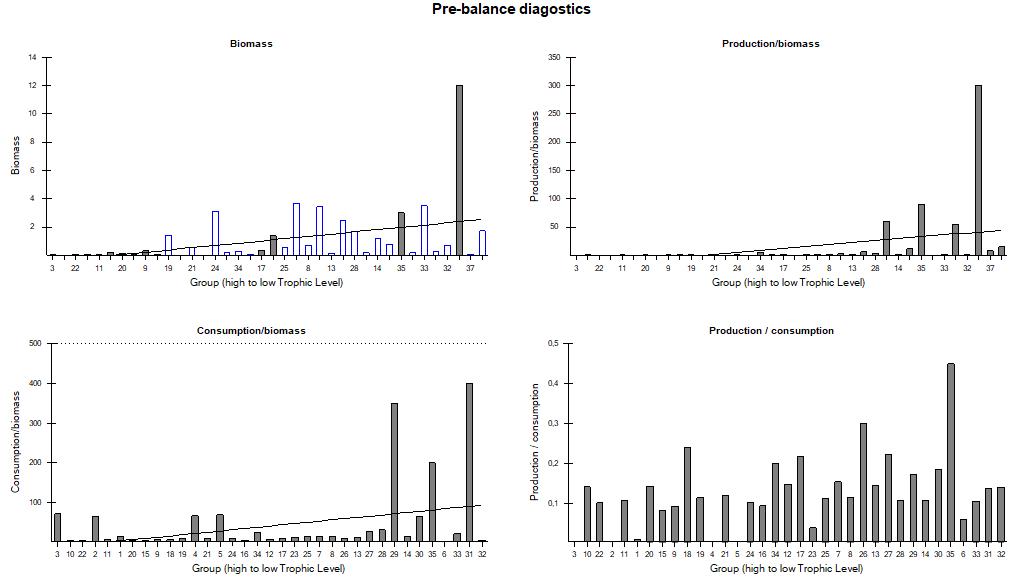


Figure 2 – Pre-balance (PREBAL) diagnostics. Relation of Trophic Level (inverted axes) to P/B: Production/Biomass; Q/B: Consumption/Biomass; R/B: Respiration/Biomass; and P/Q: Production/Consumption

## Trophic Structure and Flows

The highest trophic level value was 3.79 for the piscivorous seabird I group and the total biomass, excluding detritus, was 44.66 ton\*km-2. Invertebrates accounted for about 35.6% of total biomass, with emphasis on zooplankton, crabs, sessile fauna, and shrimp. Fish represented 32.5% and primary producers 30.8% of the total biomass. Mammals, seabirds, and turtles are collectively about 1%, (Table 7 and Figure 3).

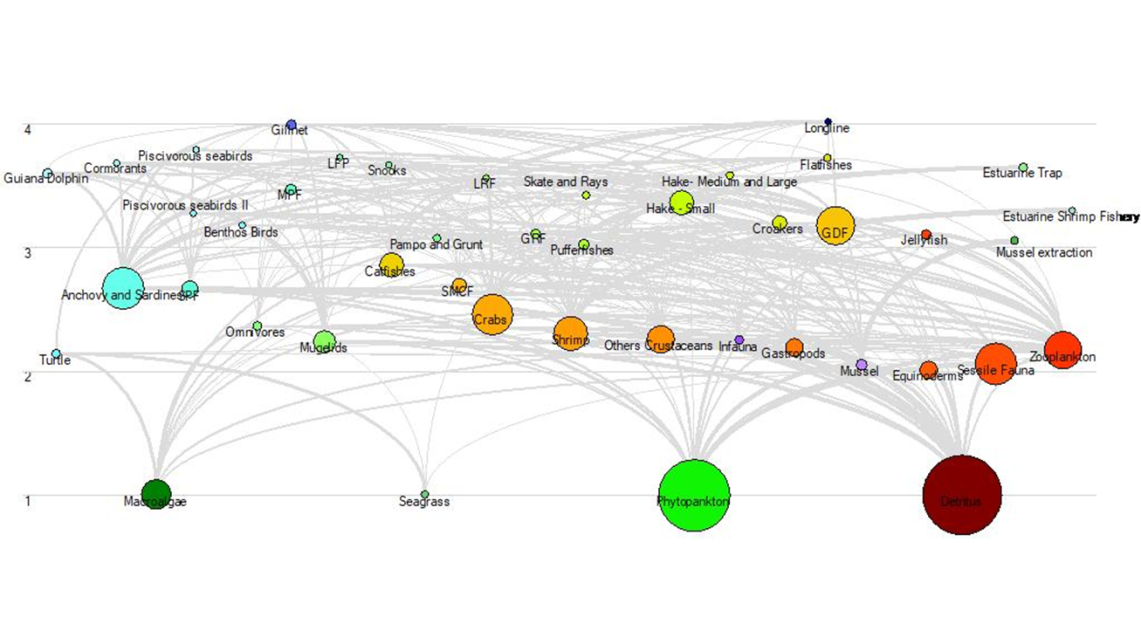


Figure 3 - Biomass flows in the Paranaguá Estuarine Complex (PEC) ecosystem, including the fisheries harvest

The most prominent flow was between the primary producers and TL II, mainly due to zooplankton grazing on phytoplankton. Furthermore, sessile fauna and bivalves, both with high biomass groups and high levels of phytoplankton consumption, contributed to a lower detritivory/herbivory ratio (0.62) (Figure 2). Flow that originated in detritus was important for other invertebrates and some fishes, such as mugelids and catfish. The overall mean transfer efficiency was 12.6%, with similar values for the grazing chain and the detritus chain (12.9% and 12.0%, respectively) (Figure 4).

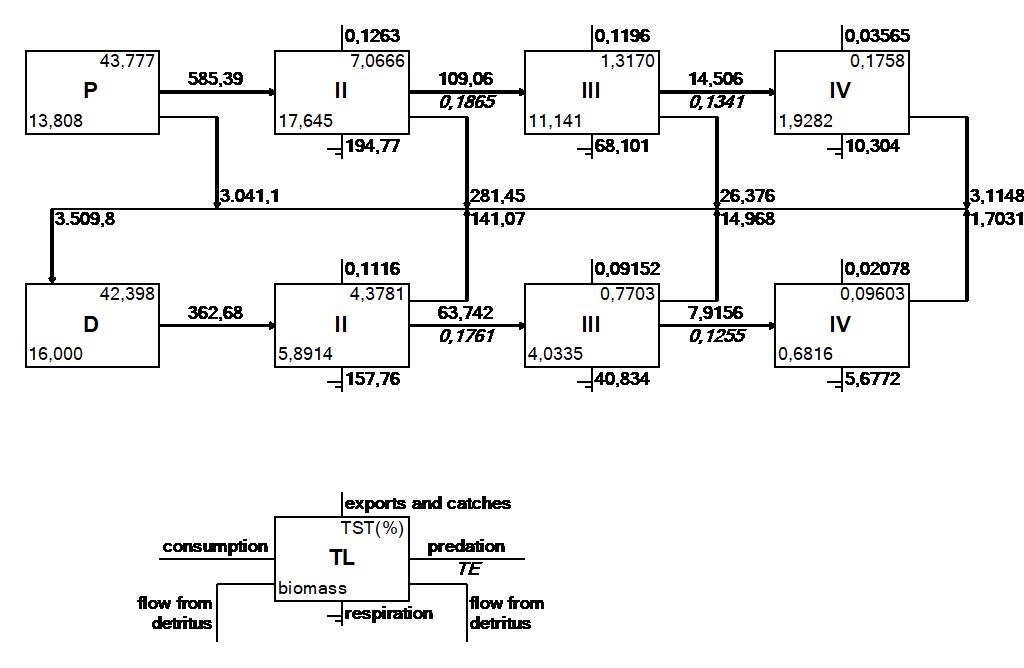


Figure 4 - Detritus-based and grazing-based flow diagram of the Paranaguá Estuarine Complex- PEC ecosystem (Brazil) organized by four trophic levels (TL) in the form of a modified Lindeman spine.

The TL I (PP and detritus) generated 76% of TST (t\*km-2\*year-1) with high flow to detritus from primary producers and high exports by detritus pathways. Proportionally, the consumption was higher in grazing-based chains, although their importance along with trophic levels similarly decreased in both. From TL II, flows by respiration became the largest, followed by flow into detritus (Figure 5).

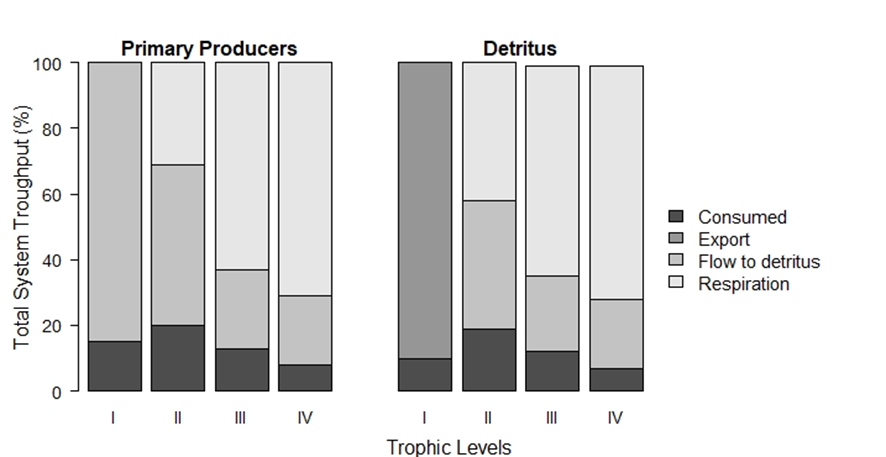


Figure 5 - The proportion of main energy flow in the total system throughput for each trophic level in the PEC model (Brazil).

Ecosystem attributes (Table 9) show that the PEC is a developing ecosystem. Zooplankton (7.1%), catfish (4%), and cormorants (3.1%) have the highest values in terms of PPR to sustain their consumption of functional groups.

Table 9 - Ecosystem attributes of the Paranaguá Estuarine Complex (PEC) model, Southwest- Atlantic (Brazil)

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Units** |
| Sum of all consumption | 1235.62 | ton\*km-²\*year-1 |
| Sum of all exports | 3149.07 | ton\*km-²\*year-1 |
| Sum of all respiratory flows | 478.74 | ton\*km-²\*year-1 |
| Sum of all flows into detritus | 3511.24 | ton\*km-²\*year-1 |
| Total system throughput | 8374.68 | ton\*km-²\*year-1 |
| Sum of all production | 3991.46 | ton\*km-²\*year-1 |
| Mean trophic level of the catch | 2.73 |  |
| Gross efficiency (catch/net p.p.) | 0.0001 |  |
| Calculated total net primary production | 3624.53 | ton\*km-²\*year-1 |
| Total primary production/total respiration | 7.57 |  |
| Net system production | 3147.78 | ton\*km-²\*year-1 |
| Total primary production/total biomass | 81.2 |  |
| Total biomass/total throughput | 0.005 | ton\*km-²\*year-1 |
| Total biomass (excluding detritus) | 44.66 | ton\*km-² |
| Total catch | 0.51 | ton\*km-²\*year-1 |
| Connectance Index | 0.24 |  |
| System Omnivory Index | 0.21 |  |
| Ecopath pedigree | 0.48 |  |

## Mixed Trophic Impacts and the Keystoneness Index

The analysis of MTI (Figure 4) revealed the competitive interactions between functional groups with a similar trophic level. In general, primary producers had positive impacts on all groups, and this may reveal a bottom-up control mechanism on the PEC. The Keystoneness analysis showed that the Guiana dolphins, cormorants, and GDF have an essential role in the ecosystem's trophic structure.

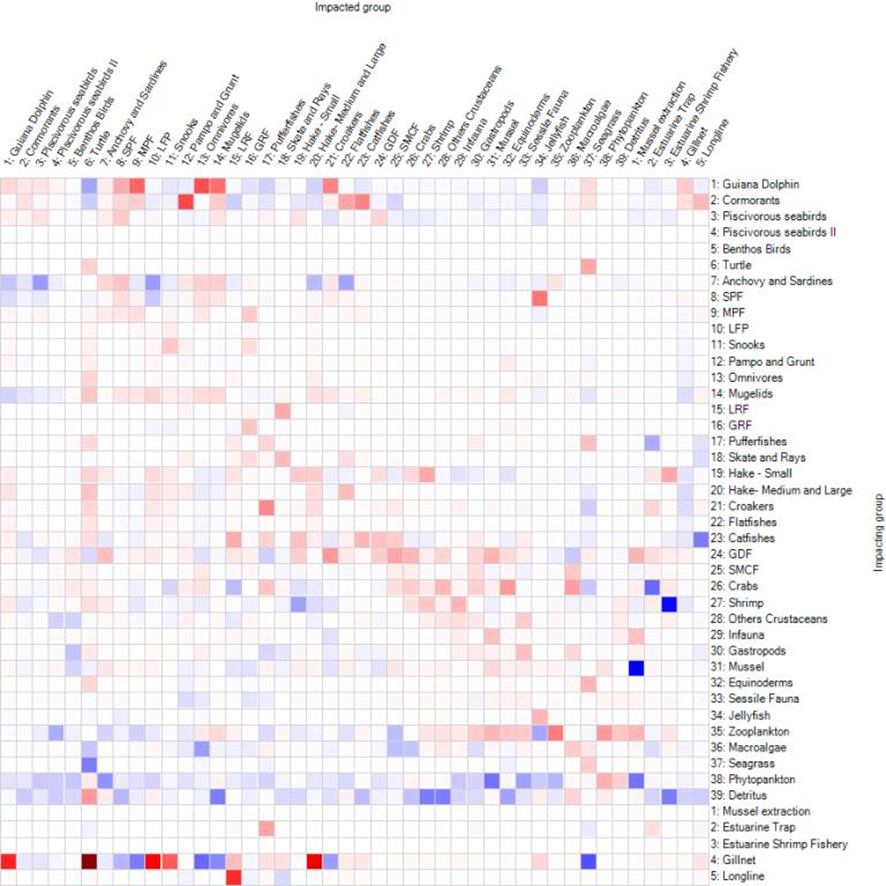


Figure 6 - Mixed Trophic Impact (MTI) analysis of the Paranaguá Estuarine Complex - PEC food web (Brazil). The intensity of the color indicates the intensity of the trophic impact of the functional groups (blue squares indicate positive impact, while red squares show negative impact). The five fishing fleets included in the model are represented at the bottom.

## The fisheries’ impact

The total catch of the model was 0.51 ton\*km-2\*year-1,with commercial landings representing 92.2% and bycatch at 0.05 ton\*km-2\*year-1. The mean trophic level of catches (TLc) was 2.73. The Gillnet Fisheries Fleet (GLF) accounted for 41% of the biomass landed and the most heterogeneous gear to catch target species. The Estuarine Trap Fishery (ETF) accounted for 35% of total landings, shared between blue crabs (66%) and the remaining puffer fishes (34%). The Artisanal Mollusks Fishery (AMF) and the Estuarine Shrimp Fishery (ESF) exploited only one group each and accounted for 14% and 4%, respectively, while the Longline Fishery (LLF) contributed 5% of the total landing. Discards were identified only in the GLF fleet and represented 27% of this fleet’s total catch, the most significant fractions of which were turtles, GDF, and rays (Table 10).

Table 10 - Fisheries landings and bycatch rates (D) for each fleet. AMF (Artisanal Mollusks Fishery), ETF (Estuarine Trap Fishery), ESF (Estuarine Shrimp Fishery), GLF (Gillnets Fishery), LLF (Longline Fishery), and Primary Production Required (PPR%) for resource harvesting in Paranaguá Estuarine Complex PEC food web (Brazil)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **EwE Groups** | **AMF** | **ETF** | **ESF** | **GLF** | **LLF** | **Total** | **PPR(%)** |
| Guiana Dolphins |  |  |  | 0.001 (D) |  |  | 0.082 |
| Turtles |  |  |  | 0.008 (D) |  | 0.01 | 0.0036 |
| Anchovies and Sardines |  |  |  | 0.0003 |  |  | 0.00005 |
| Small Pelagic Fish (SPF) |  |  |  | 0.007 (D) |  | 0.01 | 0.003 |
| Medium Pelagic Fish (MPF) |  |  |  | 0.009 |  | 0.01 | 0.02971 |
| Large Pelagic Fish (LPF) |  |  |  | 0.004 |  | 0 | 0.020 |
| Snooks |  |  |  | 0.007 |  | 0.01 | 0.042 |
| Pampos and Grunts |  |  |  | 0.006 |  | 0.01 | 0.005 |
| Omnivores |  |  |  | 0.011 | 0.001 | 0.01 | 0.003 |
| Mugelids |  |  |  | 0.031 |  | 0.03 | 0.008 |
| Large Reef Fish (LRF) |  |  |  | 0.001 | 0.001 |  | 0.027 |
| General Reef Fish (GRF) |  |  |  | 0.002 |  |  | 0.002 |
| Puffer fish |  | 0.058 |  | 0.002 | 0.003 | 0.06 | 0.028 |
| Skate and Rays |  |  |  | 0.01 | 0.005 | 0.02 | 0.040 |
| Hake - Small |  |  |  | 0.018 |  | 0.02 | 0.025 |
| Hake- Medium and Large |  |  |  | 0.022 |  | 0.02 | 0.064 |
| Croakers |  |  |  | 0.022 |  | 0.02 | 0.036 |
| Flatfish |  |  |  | 0.009 |  | 0.01 | 0.043 |
| Catfish |  |  |  | 0.026 | 0.017 | 0.04 | 0.208 |
| General Demersal Fish (GDF) |  |  |  | 0.011 |  | 0.01 | 0.014 |
| Cryptic Fish (CF) |  |  |  | 0.001 (D) |  |  | 0.0003 |
| Crabs |  | 0.118 |  | 0.001 (D) |  | 0.12 | 0.018 |
| Shrimp |  |  | 0.02 |  |  | 0.02 | 0.002 |
| Mussel | 0.073 |  |  |  |  | 0.07 | 0.007974 |
| Total | 0.073 | 0.176 | 0.02 | 0.207 | 0.028 | 0.5 | 0.7137 |
| **Trophic level (TLc)** | **2.055** | **2.65** | **2.302** | **3** | **3.02** | **2.72** |  |

The primary production required (PPR) to sustain the fisheries in the PEC was 50.9 ton\*km2\*year-1, which is equivalent to 0.71% of total primary production, taking into account the primary producers together with detritus. The highest PPR values were shown by catfish (0.20%), Guiana dolphins (0.08%), medium and large hakes (0.06%), and flatfishes (0.04%) (Table 10). The gross efficiency value was low (GE = 0.0001). Two fishing fleets, ESF and AMF, did not present any relevant impact on any functional group, not even in the target species of those fisheries (Figure 6). The Lindex (0.004) resulted in a probability of 95% that this activity on the ecosystem was sustainable (PSust).

3.5. Fitting time series

The stepwise fitting routine found the best fit for the Ecosim model when only the fishing effort was considered, maintaining the mixed (default values) effect vulnerabilities (v = 2) for all interactions. This fitting produced minimum values of sums of squares deviation (SS = 11.45) and the lowest AICs (-185.52).

Using the “best” fitted model, Ecosim reproduced the biomass trends for commercial groups with available landing data (Figure 7). Specifically, croakers, General Demersal Fish (GDF), and bivalves showed a good fit. There was no clear trend for the ecological (biomass, Kempton's Q index, and TLco) and fishing (biomass of fishing groups, TLc, and L-index) indicators between 2014 and 2018 (Figure 6).

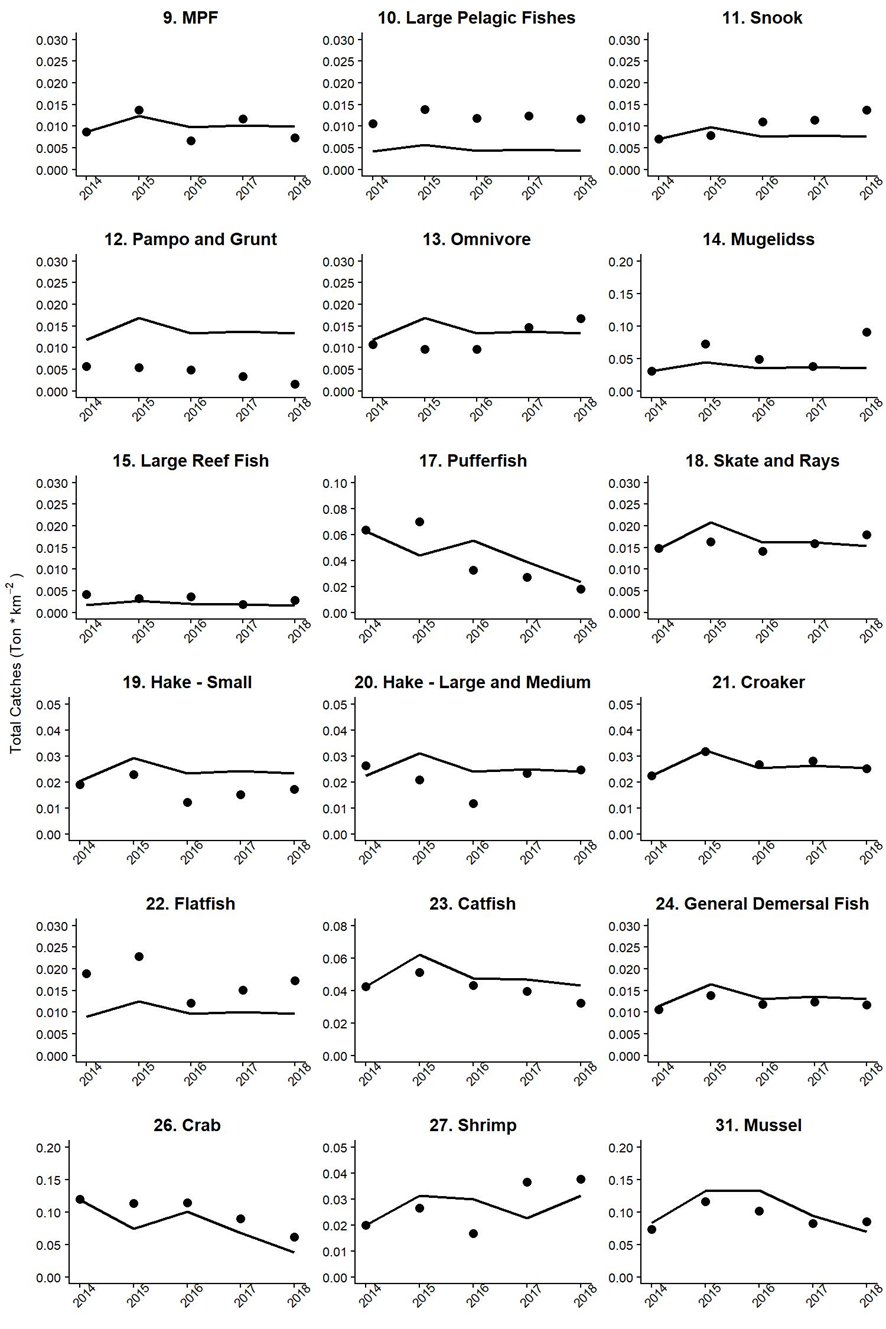


Figure 7 - Fitting time series for commercial groups in the Paranaguá Estuarine Complex (PEC) model. Catch observed (points) and predicted (line) by EwE model. The catch is in tons\*km-2

## Simulation of fishing scenarios

The simulations performed under scenarios with increases and decrease of fishing effort resulted in some changes in ecological indicators. The scenario with an increase of 25% fishing effort did not show significant trends of change for any index analyzed. The total biomass and biomass of commercial species did not present significant differences in any scenarios (Figure 6 A and B). The scenarios with 50% and 100% fishing effort increases showed negative trends in TLc, Kempton’s Q index, and TLco > 3.25 (Figure 8 C, D, and F). The 50% reduction of fishing effort scenario showed significant trends only with respect to an increase in the trophic level of the community with TL > 2 (Figure 8E).

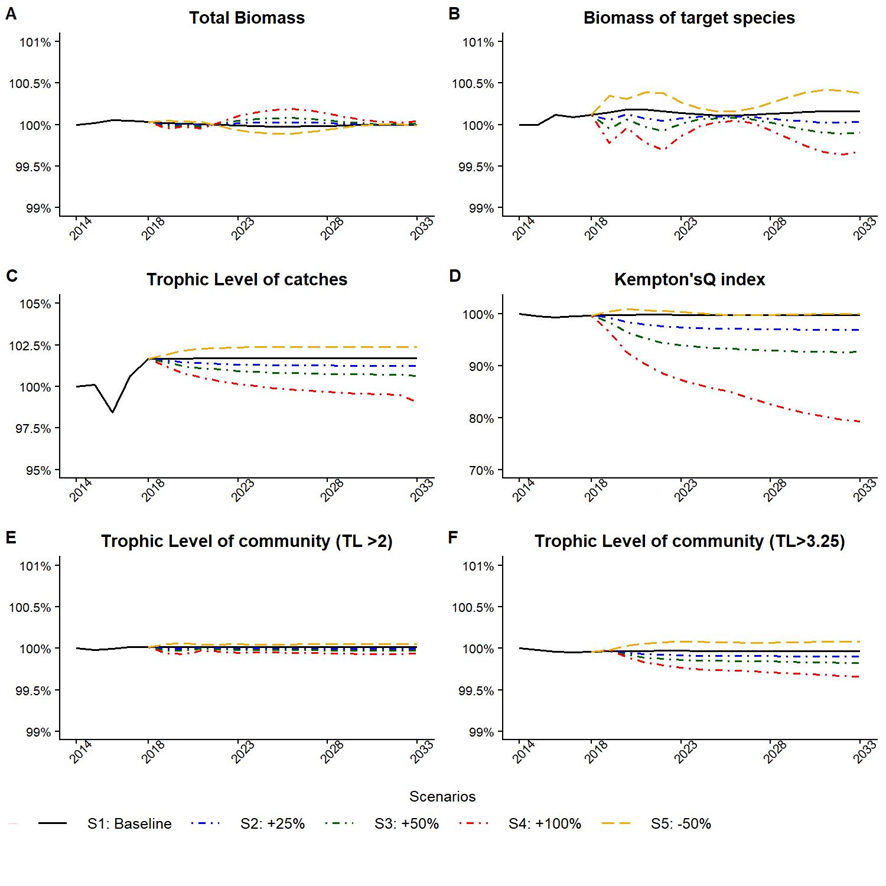
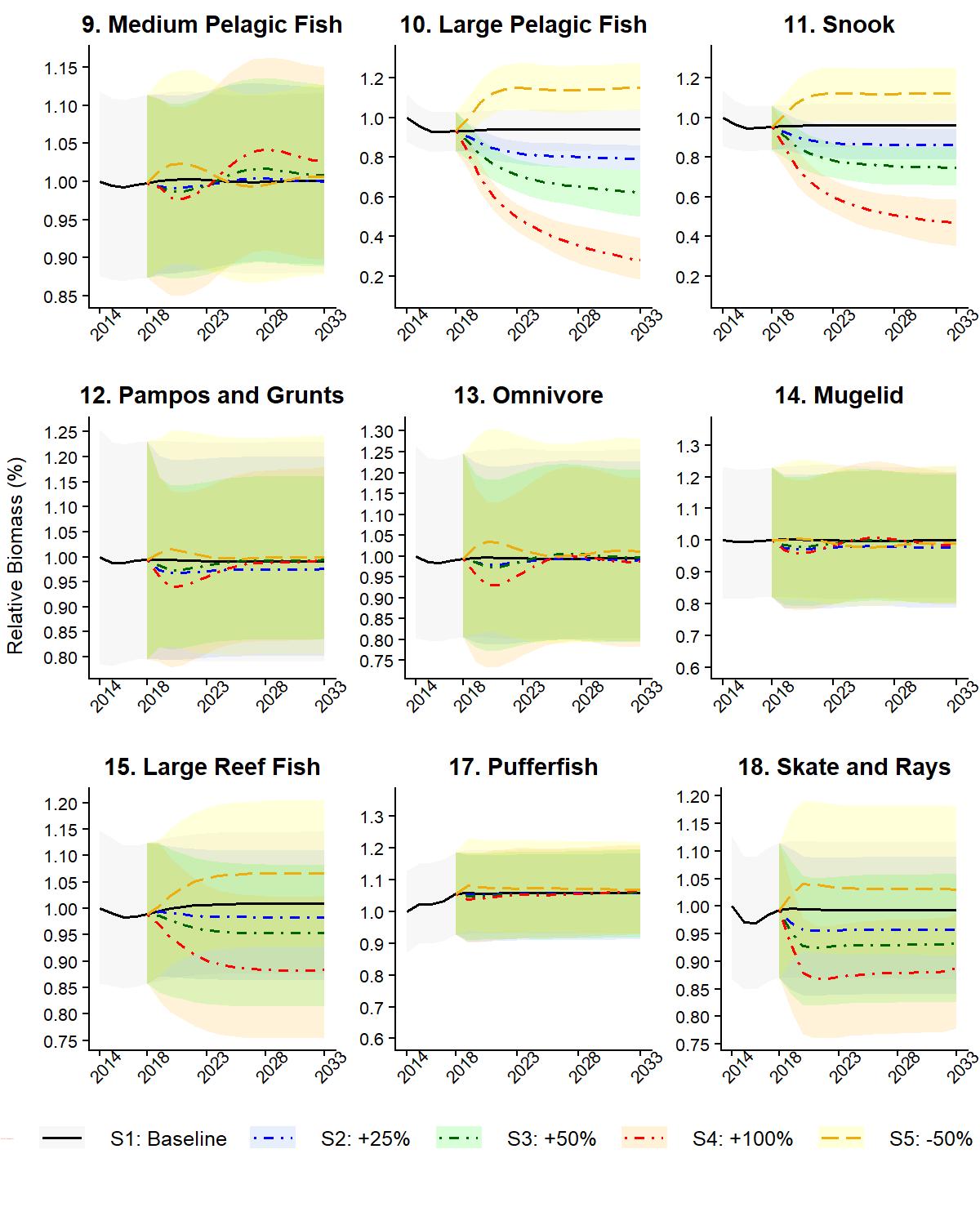


Figure 8 – Simulation of relative values of ecological indicators for the fitted (2014 -2018) and simulated (2019-2033) period in the Paranaguá Estuarine Complex (PEC) model (Brazil).

In the simulated scenarios, the functional groups with higher trophic levels responded directly to the increase or reduction of fishing effort (Figure 9). The catfish group was also sensitive to the changes in fishing effort, even with lower trophic level in comparison to the others. Other groups, such as croakers and pampo and grunts, also presented a similar pattern but with less sensitivity to fishing effort (Figure 9**).**

Otherwise, some groups responded inversely to the fishing effort. In these cases, the scenario with a 100% increase of fishing effort reported the highest biomass increase; this group included omnivores and mugelids.

For the other functional groups, particularly the invertebrates and some demersal groups, the biomass across all simulated scenarios was relatively constant. In these cases, the values predicted by the simulations were very close to one another, and there was high overlapping of the variations of the scenarios as determined by the Monte Carlo simulations. The simulation for all groups can be found in Figure 9.



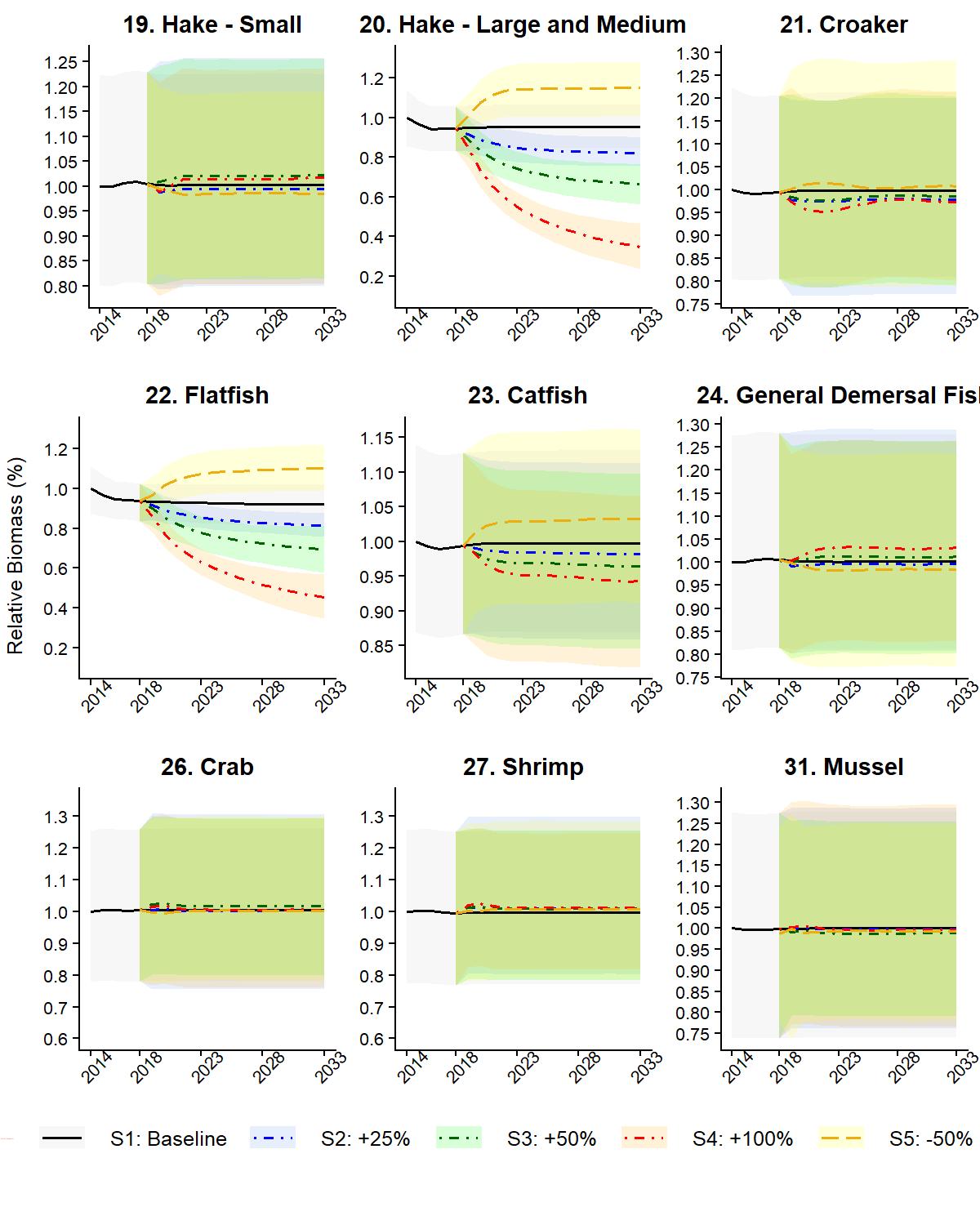


Figure 9 - Relative values of biomasses simulated by the Ecosim model for commercially grops in the Paranaguá Estuarine Complex (PEC) model (Brazil). The lines describe the values predicted by the scenarios, and the shaded areas represent the 95% and 5% obtained through the 250 Monte Carlo simulation (coefficient of variation = 0.1). Values in Ton\*km²

Scenarios were also simulated for megafauna groups (often captured as bycatch), although there were no adjusted time series. Turtles responded linearly to changes in fishing effort. This response was not very obvious for *Sotalia guianensis* (Figure 8).

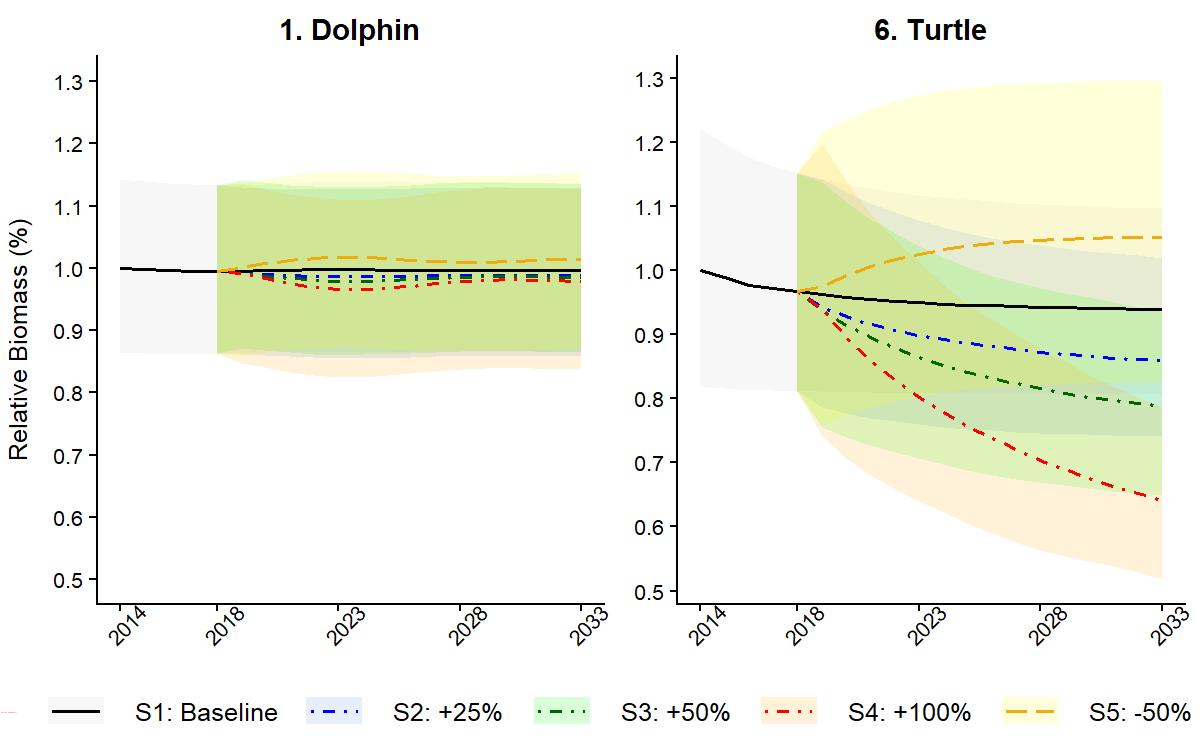


Figure 10 - Relative values of biomasses simulated by the Ecosim model for megafauna captured as bycatch in the Paranaguá Estuarine Complex (PEC) model (Brazil). The lines describe the values predicted by the scenarios, and the shaded areas represent the 95% and 5% obtained through the 250 Monte Carlo simulation (coefficient of variation = 0.1). Values in ton\*km²

# Discussion

Our results indicate that the Paranaguá Estuarine Complex (PEC) model has a high primary production, which supports a grazing-based food web with low connectivity between functional groups, a high value (for estuarine systems) of the omnivory index, and a recycling rate in the ecosystem lower than 10%, classifying it as a subtropical estuary (Lira et al., 2018) in the early stages of ecosystem development Christensen (1995 e Odum, E.P. (1969 e Ulanowicz, Robert E (1986). Fishing has a low impact on the structure and functioning of the food webs in the steady-state perspective (Ecopath). However, fishing simulations with modifications in fleet effort (Ecosim) showed that high trophic level groups are more sensitive and respond more directly to the increase or reduction of fishing effort.

## Parameterization and Confidence

Regarding parameterization, the PEC model has half of the biomass values estimated by the Ecopath. However, for high trophic level groups (dolphins, seabirds, and some fish groups), the biomass values were determined by local assessments or estimated using an exploitation rate (E). In the PEC area, the ichthyological surveys are conducted mainly by trawl technique Barletta et al. (2008 e Possatto et al. (2017) and are therefore restricted to regions with suitable depth and habitat Spach, Henry L et al. (2004). Many commercial species captured locally (FUNDEPAG, 2018; Portos do Paraná, in press) have not been sampled by scientific surveys, which reduces the capacity of the application of the catchability coefficient Lauretta et al. (2013). This challenge in the survey of quantitative data is known in estuaries Blaber (2002) and may be related to the diversity of habitats therein.

The biomass values and the trophic level position of the functional groups in the PEC model (even those estimated indirectly) are nonetheless consistent with similar functional groups observed in other coastal marine models Angelini et al. (2018 e Duan et al. (2009 e Han et al. (2016 e Lercari et al. (2015a e Xavier (2013). Moreover, to make estimates based on fisher’s knowledge is useful in areas with scarce information Bevilacqua et al. (2016 e Strieder Philippsen et al. (2017). The Pedigree value was considered acceptable (0.48), since it was within the range of observed values in other models and close to the global average Morissette (2007).

The PREBAL routine Heymans et al. (2016b e Link (2010) and the estimate of several rates indicate that the PEC model has coherent ecological and physiological aspects and we can trust its outputs.

## Ecosystem structure and flows of the PEC food web

The presence of seabirds and marine mammals increased TL value to reach a higher range than observed in other estuarine models in the tropical region Lira et al. (2018 e Xavier (2013) but lower than others in subtropical estuaries Dutta et al. (2017b e Han et al. (2016 e Lercari et al. (2015a e Wolff et al. (2000) due to the presence of sharks, rays, and marine mammal groups.

Moreover, the biomass of the ecosystem is dominated by benthic fauna (~40%) with high dependence on detritus. It is therefore expected that the flow from this source would prevail over the grazing pathway, a natural characteristic in estuaries Rybarczyk; Elkaim (2003 e Xu et al. (2011). Instead the model revealed a low detritivore to herbivore ratio, because of strong phyto-zooplankton coupling. The high biomass (and production) of plankton filter feeders (bivalve and sessile fauna; barnacles, corals, and anemones) also contributed to the herbivory pathway. This feature was also observed in the Yangtse estuary (0.71) Han et al. (2016), the Rio de La Plata estuary (0.60) Lercari et al. (2015a), the Gulf of Nicoya (0.33), and the Caeté estuary (0.53) Wolff (2006). The mean Transfer Efficiency of PEC was close to the overall average (10%; Pauly and Christensen, 1995).

The Mixed Trophic Impact analysis allowed us to identify multiple effects (mixing control) described by Cury et al. (1995) within the estuary; food chain base groups (phytoplankton, detritus, zooplankton, and benthic invertebrates) triggered positive impacts on the upper TLs, indicating a possible bottom-up control. Moreover, top-down effects from Guiana dolphins, cormorants, and the piscivorous seabird I groups negatively disturbed intermediate TLs with indirect positive impact on invertebrates. The Keystoneness analysis reinforces the role of phytoplankton for bottom-up control and Guiana dolphins and cormorants for top-down control Libralato et al. (2006). According, the analysis of pairwise species perturbation has proved that the impact human on these groups needs to be reduced in order to avoid negative effect on the ecosystem Móréh et al. (2018).

## Fisheries’ impact

The mean trophic level of the catch (mTLc; 2.71) of all fisheries in the PEC system is similar to that obtained from the La Plata estuary Lercari et al. (2015a), Bay of Benguela Dutta et al. (2017a), and Sirinhaém River Lira et al. (2018). This indicator reflects the composition of catches, where benthic invertebrates predominate (mainly crabs, shrimp, and mollusks).

Fleets such as Gillnet Fisheries Fleet (GLF) and Longline Fishery (LLF) had TLc values (3.00 and 3.02, respectively) above the general mTLc (2.72). The ESF (2.30) and AMF (2.05) gears showed lower values because they explored just one single compartment. The ETF fleet exploited two resources (crabs and puffer fish) and presented mTLc = 2.65, near the overall mean. Comparing with other estuaries, the mTLc was close to Sirinhaém River (2.68) Lira et al. (2018), lower than Yangtse (3.24) Han et al. (2016), La Plata (2.95) Lercari et al. (2015a), Nicoya Gulf (4.01) Wolff (2006), and higher than Danshuei estuary (2.17) Lin et al. (2007b).

Regarding total catch, the PEC shows the lowest value when compared to other estuaries. The La Plata and Yangtse estuaries had the closest values (0.980 ton km²/ year and 1.16 ton km²/ year, respectively, but other Brazilian estuaries in the North and Northeast presented much higher values, including the Caeté estuary (18.3 ton km²/ year), the Mamanguape estuary (7.37 ton km²/ year), and the Sirinhaém River estuary (9.57 ton km²/ year) Lira et al. (2018).

The low upgrading of the fishing gears may explain the low total catches Andriguetto-filho et al. (2009 e Andriguetto-Filho et al. (2006) with other factors relating to the size and presence of specific fishing grounds (AMF, ESF, and ETF occur only in the shallow areas of the estuary) as well as fishing exclusion areas due to ship traffic and harbor activity. The fisheries have low bycatch rates, occurring only in the GLF fleet, whereas incidental catches of Guiana dolphins and turtles occur (e.g., SPF and GDF).

Indicators related to primary production (PPR% and GE) and loss of secondary production (L-index) were much lower than the overall averages Libralato et al. (2008 e Pauly; Villy (1995), suggesting that fisheries might have a low impact on the trophic structure of this ecosystem. As a comparison, the PPR% to maintain the consumption of cormorants was five times higher than all estuarine fisheries. The landings from Paranaguá estuary are divided likewise between pelagic and demersal species. However, the pelagic food chain has, in general, higher transfer efficiency because of the size ratio between predator and prey Sommer et al. (2018) an output that may raise new hypotheses for the subsequent studies in this environment.

## Times Series analysis

The PEC model calibration resulted in a good fit despite the short time series. The landing data without changes in vulnerability (v = 2) was the best fit found by the automated procedure to calibrate the model, corroborating the mixed flow control identified by the mixed impact analyses. The model was able to predict the decreasing trend in landings of crabs, puffer fish, and mollusks in addition to the oscillations of shrimp. Ecosystems attributes (Lindex, TLco, TLc, Kempton's Q) showed that the ecosystem has no pronounced changes in the fitting period of the model (2014-2018).

The simulations’ outputs of fishing effort scenarios showed that high TL groups are more sensible to effort changes. The biomass increase for intermediate groups was identified in the scenarios with increased fishing effort after 2023 (indirect effect of predator reduction). On the other hand, groups with lower trophic levels (mainly invertebrates) were apparently not impacted even in scenarios with fishing increases. It seems that an intermediate catch TL value is based and sustainable because the high resilience of low TL groups in Paranaguá Estuarine Complex.

The impact on the upper trophic levels reflected on ecological indicators trends (TLco, TLc, Kempton's Q), which show important decreases in scenarios with increased fishing effort. This change was not identified in the fisheries reduction scenario (Scenario 5), even though the functional groups of the higher TL groups showed biomass increase.

## Ecopath approach limitations

The PEC model was able to reproduce the fishery catch on a short time scale, which is essential to increase our confidence on the model’s output. Besides that, Prebal diagnostics confirmed the biological reality and plausibility of the PEC model. However, it is needed to stress some weaknesses of the PEC model, which was built using high-quality information about landings, but scarce local data for fish biomass and diet composition. Moreover, abiotic variables and issues with species, which spent part of their life cycle outside estuary, were not considered. Thus, it is vital to bear in mind that stakeholders need to be careful to use the PEC model outputs to define management rules. Despite these issues, the PEC model can be used to develop a model-oriented research project and to organize high-quality sampling from local data, especially about the main paucity of data which are: fish biomass (using hydroacoustic surveys), local diet composition (including non-target fish species), plankton biomass, and abiotic variables (temperature, nutrients, and salinity). Therefore, the PEC model could be the first step of an interdisciplinary research project able to support the Ecosystem-Based Fishery Management approach to be applied to the Paranaguá Estuarine Complex.

# final considerations

Our Ecopath model described the Paranaguá Estuary Complex as a subtropical estuary and therefore add to an understanding of these relationships in these specific kinds of ecosystems. The fisheries activities in the PEC model seems sustainable especially to be concentrated in groups with low trophic levels

## Recommendations for FUTURE WORKS

For the next steps, besides a better variables monitoring, we suggested a further development of spatial simulations, using the Ecospace module, and an economic analysis, using Value Chain module, could help to establish better spatial zoning (close areas) and the importance of PEC conservation for food security. For diet matrix, eDNA-based approaches could mark future directions.

1. BIBLIOGRAPHY

AHRENS, R. N. M.; WALTERS, C. J.; CHRISTENSEN, V. Foraging arena theory. **Fish and Fisheries**, v. 13, p. 41–59, 2012.

ALTHAUSER, L. L. **AN ECOPATH/ECOSIM ANALYSIS OF AN ESTUARINE FOOD WEB: SEASONAL ENERGY FLOW AND RESPONSE TO RIVER-FLOW RELATED PERTURBATIONS**, 2003. Graduate Faculty of the Louisiana State University.

ANDRIGUETTO-FILHO, J. M. A mudança técnica e o processo de diferenciação dos sistemas de produção pesqueira do Litoral do Paraná , Brasil Technical change and differentiation of small-scale fisheries production systems in the coast of Paraná , Brazil. **Desenvolvimento e Meio Ambiente**, v. 8, p. 43–58, 2003.

ANDRIGUETTO-FILHO, J. M.; CHAVES, P. DE T. DA C.; SANTOS, C.; LIBERATI, S. A. Diagnóstico da pesca no litoral do estado do Paraná. In: V. J. Isaac; A. S. Martins; M. Haimovici; J. M. Andriguetto Filho (Orgs.); **Pesca marinha e estuarina do Brasil no início do século XXI**. p.117–140, 2006. Belém: Editora Universitária UFPA.

ANDRIGUETTO-FILHO, J. M.; KRUL, R.; FEITOSA, S. Analysis of natural and social dynamics of fishery production systems in Parana Brazil : implications for management and sustainability. **Journal Appl. Ichthyol.**, v. 25, p. 277–286, 2009.

ANDRIGUETTO-FILHO, J. M.; KRUL, R.; FEITOSA, S. Analysis of natural and social dynamics of fishery production systems in Parana Brazil : implications for management and sustainability. **Journal Appl. Ichthyol.**, v. 25, p. 277–286, 2009.

ANGELINI, R. Bases para a aplicação da teoria da informação em ecossistemas , com ênfase na ascendência. **Acta Scientiarum. Biological Sciences**, v. 24, n. 2, p. 275–283, 2002.

ANGELINI, R.; CONTENTE, R. F.; ROSSI-WONGTSCHOWSKI, C. L. D. B.; et al. Ecosystem modeling as a framework to convert a multi-disciplinary research approach into a useful model for the Araçá Bay (Brazil). **Ocean & Coastal Management**, v. 164, n. July 2017, p. 92–103, 2018. Disponível em: <https://linkinghub.elsevier.com/retrieve/pii/S0964569117306543>. .

ANGELINI, R.; GOMES, L. C. **O Artesão de ecossistemas**. Maringá: EDUEM, 2008.

ARANTES, P. L. **Relações alimentares de peixes da Enseada do Araçá (SP), Sudeste do Brasil**, 2014. Universidade de São Paulo.

ARAÚJO, J. N.; BUNDY, A. Description of three Ecopath with Ecosim ecosystem models developed for the Bay of Fundy, Western Scotian Shelf and NAFO Division 4X. **Can. Tech. Rep. Fish. Aquat. Sci**, v. 2952, p. 189, 2011a.

ARAÚJO, J. N.; BUNDY, A. Description of three Ecopath with Ecosim ecosystem models developed for the Bay of Fundy, Western Scotian Shelf and NAFO Division 4X. **Can. Tech. Rep. Fish. Aquat. Sci.**, v. 2952, p. 189, 2011b.

ARENDT, M. D.; LUCY, J. A.; OLNEY, J. E. Stomach content analysis of cobia, Rachycentron canadum, from lower Chesapeake Bay. **Fishery Bulletin**, v. 99, n. 4, p. 665–670, 2001.

ARREGUÍN-SÁNCHES, F.; ARCOS, E.; CHÁVES, E. A. Flows of biomass and structure in an exploited benthic ecosystem in the gulf of California , Mexico. **Ecological Modelling**, v. 156, p. 167–183, 2002.

ARTERO, C.; KOENIG, C. C.; RICHARD, P.; et al. Ontogenetic dietary and habitat shifts in goliath grouper Epinephelus itajara from French Guiana. **Endangered Species Research**, v. 27, n. 2, p. 155–168, 2015. Disponível em: <http://www.int-res.com/abstracts/esr/v27/n2/p155-168/>. .

AYDIN, K.; GAICHAS, S.; ORTIZ, I.; KINZEY, D.; FRIDAY, N. **A Comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands Large Marine Ecosystems Through Food Web Modeling**. Springfield, USA, 2007.

BAKHOUM, S. A. Diet overlap of immigrant narrow – barred Spanish mackerel Scomberomorus commerson ( Lac ., 1802 ) and the largehead hairtail ribbonfish Trichiurus lepturus ( L ., 1758 ) in the Egyptian Mediterranean coast. **Animal Biodiversity and Conservation**, v. 30, n. 2, p. 147–160, 2007.

BARAUSSE, A.; DUCI, A.; MAZZOLDI, C.; ARTIOLI, Y.; PALMERI, L. Trophic network model of the Northern Adriatic Sea: Analysis of an exploited and eutrophic ecosystem. **Estuarine, Coastal and Shelf Science**, v. 83, n. 4, p. 577–590, 2009. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0272771409002406>. .

BARBIER, E. B.; HACKER, S. D.; KENNEDY, C.; et al. The value of estuarine and coastal ecosystem services. **Ecological Monographs**, v. 81, n. 2, p. 169–193, 2011. Disponível em: <http://www.esajournals.org/doi/abs/10.1890/10-1510.1>. .

BARLETTA, M.; AMARAL, C. S.; CORRÊA, M. F. M.; et al. Factors affecting seasonal variations in demersal fish assemblages at an ecocline in a tropical-subtropical estuary. **Journal of Fish Biology**, v. 73, n. 6, p. 1314–1336, 2008.

BARRERA, E. A. L. **Análise da captura acidental de tartarugas marinhas em artes de pesca artesanal na desembocadura sul da Baía de Paranaguá, litoral do Paraná**, 2009. Universdidade Federal do Paraná.

BARROS, B.; SAKAI, Y.; ABRUNHOSA, F. A.; VALLINOTO, M. Trophic adaptability of late juvenile Atlantic spadefish Chaetodipterus faber (Teleostei: Ephippidae) related to habitat preferences in an estuary in northeastern Brazil. **Hydrobiologia**, v. 717, n. 1, p. 161–167, 2013. Disponível em: <http://link.springer.com/10.1007/s10750-013-1574-x>. .

BERGAMINO, L.; SZTEREN, D.; LERCARI, D. Trophic Impacts of Marine Mammals and Seabirds in the Río de la Plata Estuary and the Nearshore Oceanic Ecosystem. **Estuaries and Coasts**, v. 35, n. 6, p. 1571–1582, 2012. Disponível em: <http://link.springer.com/10.1007/s12237-012-9545-4>. .

BEVILACQUA, A. H. V.; CARVALHO, A. R.; ANGELINI, R.; CHRISTENSEN, V. More than anecdotes: Fishers’ ecological knowledge can fill gaps for ecosystem modeling. **PLoS ONE**, v. 11, n. 5, p. 1–18, 2016.

BITTAR, V. T.; FIGUEIREDO, B. DE; CASTELLO, L.; PAULA, A.; DI, M. Hábito alimentar do peixe-espada adulto, Trichiurus lepturus, na costa norte do Rio de Janeiro, sudeste do Brasil. **Biotemas**, v. 21, n. 2, p. 83–90, 2008.

BLABER, S. Effects of fishing on the structure and functioning of estuarine and nearshore ecosystems. **ICES Journal of Marine Science**, v. 57, n. 3, p. 590–602, 2000. Disponível em: <https://academic.oup.com/icesjms/article-lookup/doi/10.1006/jmsc.2000.0723>. .

BLABER, S. J. M. **Tropical Estuarine Fishes**. Wiley, 2000.

BLABER, S. J. M. ?Fish in hot water?: the challenges facing fish and fisheries research in tropical estuaries. **Journal of Fish Biology**, v. 61, n. SUPPL. A, p. 1–20, 2002. Disponível em: <http://doi.wiley.com/10.1006/jfbi.2002.2063>. .

BLABER, S. J. M. Fishes and fisheries in tropical estuaries: The last 10 years. **Estuarine, Coastal and Shelf Science**, v. 135, p. 57–65, 2013. Elsevier Ltd. Disponível em: <http://dx.doi.org/10.1016/j.ecss.2012.11.002>. .

BLABER, S. J. M.; BARLETTA, M. A review of estuarine fish research in South America: what has been achieved and what is the future for sustainability and conservation? **Journal of fish biology**, v. 89, n. 1, p. 537–568, 2016.

BLASINA, G. E.; BARBINI, S. A.; DÍAZ DE ASTARLOA, J. M. Trophic ecology of the black drum, Pogonias cromis (Sciaenidae), in Mar Chiquita coastal lagoon (Argentina). **Journal of Applied Ichthyology**, v. 26, n. 4, p. 528–534, 2010. Disponível em: <http://doi.wiley.com/10.1111/j.1439-0426.2010.01459.x>. .

BLEWETT, D. A.; HENSLEY, R. A.; STEVENS, P. W. Feeding Habits of Common Snook, Centropomus undecimalis, in Charlotte Harbor, Florida. **Gulf and Caribbean Research**, v. 18, n. 1, p. 1–14, 2006. Disponível em: <http://aquila.usm.edu/gcr/vol18/iss1/1>. .

BOEREMA, A.; MEIRE, P. Management for estuarine ecosystem services: A review. **Ecological Engineering**, v. 98, p. 172–182, 2017. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecoleng.2016.10.051>. .

BORNATOWSKI, H.; ROBERT, M. DE C.; COSTA, L. Feeding of guitarfish Rhinobatos percellens (Walbaum , 1972) (Elasmobranchii, Rhinobatidae), the target of artisanal fishery in Southern Brazil. **Brazilian Journal of Oceanography**, v. 58, n. 1, p. 45–52, 2010.

BRANCO, J. O. Biologia e pesca do camarão sete-barbas Xiphopenaeus kr eri ( Heller ) ( Cr ustacea , Penaeidae ), na Ar mação do Ita pocor o y , Penha , Santa Catar ina , Br asil Brasil Armação Itapocor pocoro. **Revista Brasileira de Zoologia**, v. 22, n. 4, p. 1050–1062, 2005.

BRANCO, J. O.; FRACASSO, H. A. A.; MACHADO, I. F.; BOVENDORP, M. S.; VERANI, J. R. Dieta de Sula leucogaster Boddaert (Sulidae, Aves), nas Ilhas Moleques do Sul, Florianópolis, Santa Catarina, Brasil. **Revista Brasileira de Zoologia**, v. 22, n. 4, p. 1044–1049, 2005.

BRANCO, J. O.; LUNARDON-BRANCO, M. J.; EVANGELISTA, C. L.; AZEVEDO-JUNIOR, S. M.; LARRAZÁBAL, M. E. Atividade diária de Phalacrocorax brasilianus (Aves, Phalacrocoracidae), na região do Saco da Fazenda, Itajaí, SC, Brasil. **Ornithologia**, v. 3, n. 2, p. 73–82, 2009.

BRANCO, J. O.; LUNARDON-BRANCO, M. J.; VERANI, J. R. Aspectos biológicos e pesqueiros de Paralonchurus brasiliensis Steindachner, (Pisces, Sciaenidae), na Armação do Itapocoroy, Penha, Santa Catarina, Brasil. **Revista Brasileira de Zoologia**, v. 22, n. 4, p. 1063–1071, 2005. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S0101-81752005000400035&lng=pt&tlng=pt>. .

BRANCO, J. O.; LUNARDON-BRANCO, M. J.; VERANI, J. R.; SOUTO, F. X.; VALE, W. G. Natural Diet of Callinectes ornatus Ordway , 1863 (Decapoda , Portunidae) in the Itapocoroy Inlet , Penha , SC , Brazil. , v. 45, n. 1974, p. 35–40, 2002.

BRANDINI, F. P.; SCHEFFER DA SILVA, A.; TEIXEIRA DA SILVA, E.; KOLM, H. Sources of Nutrients and Seasonal Dynamics of Chlorophyll in the Inner Shelf off Paraná State—South Brazil Bight. **Journal of Coastal Research**, v. 235, p. 1131–1140, 2007. Disponível em: <http://www.bioone.org/doi/abs/10.2112/04-0360.1>. .

BRITTO, V. O. **Ecologia alimentar do colhereiro (Platalea ajaja) e da garça-branca-grande (Ardea alba) em ambiente límnico e estuarino no sul do Brasil**, 2013. Universidade Federal do Paraná.

BRULÉ, T.; MENA-LORÍA, A.; PÉREZ-DÍAZ, E.; RENÁN, X. Diet of juvenile gag Mycteroperca microlepis from a non-estuarine seagrass bed habitat in the southern Gulf of Mexico. **Bulletin of Marine Science**, v. 87, n. 1, p. 31–43, 2011. Disponível em: <http://openurl.ingenta.com/content/xref?genre=article&issn=0007-4977&volume=87&issue=1&spage=31>. .

BUGONI, L.; VOOREN, C. M. Feeding ecology of the Common Tern Sterna hirundo in a wintering area in southern Brazil. **Ibis**, v. 146, n. 3, p. 438–453, 2004. Disponível em: <http://doi.wiley.com/10.1111/j.1474-919X.2004.00277.x>. .

BUNDY, A. The Ecological Effects of Fishing and Implications for Coastal Management in San Miguel Bay, the Philippines. , , n. August 2003, p. 25–38, 2004.

BUNDY, A.; HEYMANS, J. J.; MORISSETTE, L.; SAVENKOFF, C. Seals, cod and forage fish: A comparative exploration of variations in the theme of stock collapse and ecosystem change in four Northwest Atlantic ecosystems. **Progress in Oceanography**, v. 81, p. 188–206, 2009.

CARVALHO, C. DE. **Crescimento e Mortalidade do camarão branco Litopenaeus schmitti (Burkenroad, 1936) (Crustacea: Decapoda: Penaeidae) em ambiente natural e emconfinamento**, 2013. Universidade Federal Rural do Rio de Janeiro.

CASTILLO-RIVERA, M.; ZARATE-HERNANDEZ, R.; SALGADO-UGARTE, I. H. Juvenile and adult food habits of Archosargus probatocephalus (Teloostei: Sparidae) in a tropical estuary of Veracruz. **Hidrobiologica**, v. 17, n. 2, p. 119–126, 2007.

CASTRO, D. N.; LIMA, W. M. G.; MENDES, N. C. B.; et al. Dieta Natural de Macrodon ancylodon (Bloch & Schneider, 1801) Capturada por Embarcações Pesqueiras Industriais Sediadas no Estado do Pará. **Biota Amazônia**, v. 5, n. 3, p. 50–54, 2015. Disponível em: <http://www.bibliotekevirtual.org/index.php/2013-02-07-03-02-35/2013-02-07-03-03-11/1292-biota/v05n03/13673-dieta-natural-de-macrodon-ancylodon-bloch-schneider-1801-capturada-por-embarcacoes-pesqueiras-industriais-sediadas-no-estado-do-para.html>. .

CAZORLA, A. L.; FORTE, S. Food and Feeding Habits of Flounder Paralichthys Orbignyanus (Jenyns, 1842) in Bahía Blanca Estuary, Argentina. **Hydrobiologia**, v. 549, n. 1, p. 251–257, 2005. Disponível em: <http://link.springer.com/10.1007/s10750-005-5446-x>. .

CHAVES, P. D. T. D. C.; UMBRIA, S. C. Changes in the diet composition of transitoty fishes in costal systems, estuary and continental shelf. **Brazilian Archives of Biology and Technology**, v. 46, n. 1, p. 41–46, 2003.

CHAVES, P. D. T.; VENDEL, A. L. Análise comparativa da alimentação de peixes (Teleostei) entre ambientes de marisma e de manguezal num estuário do sul do Brasil (Baía de Guaratuba, Paraná). **Revista Brasileira de Zoologia**, v. 25, n. 1, p. 10–15, 2008. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S0101-81752008000100002&lng=pt&tlng=pt>. .

CHRISTENSEN, VILLY ; WALTERS, CARL. J.; PAULY, DANIEL; FORREST, R. **Ecopath with Ecosim version 6 - Guide, User**. Lenfest Ocean Futures Project 2008, 2008.

CHRISTENSEN, V. Ecosystem maturity - towards quantification. **Ecological modelling**, v. 77, p. 3–32, 1995.

CHRISTENSEN, V. Fishery-induced changes in a marine ecosystem: insight from models of the Gulf of Thailand. **Journal of Fish Biology**, v. 53, p. 128–142, 1998.

CHRISTENSEN, V.; PAULY, D. ECOPATH II - a software for balancing steady-state ecosystem models and calculating network characteristics \*. **Ecological Modelling**, v. 61, p. 169–185, 1992.

CHRISTENSEN, V.; WALTERS, C. J. Ecopath with Ecosim: methods, capabilities and limitations. , v. 172, p. 109–139, 2004.

COLL, M.; BUNDY, A.; SHANNON, L. J. Ecosystem Modelling Using the Ecopath with Ecosim Approach. In: B. Megrey; E. Moksness (Orgs.); **Computers in Fisheries Research**. 2o ed, p.225–291, 2009. Springer.

COLL, M.; PALOMERA, I.; TUDELA, S.; DOWD, M. Food-web dynamics in the South Catalan Sea ecosystem (NW Mediterranean) for 1978–2003. **Ecological Modelling**, v. 217, n. 1–2, p. 95–116, 2008. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0304380008002925>. .

COLL, M.; PALOMERA, I.; TUDELA, S.; SARDA, F. Trophic flows, ecosystem structure and fishing impacts in the South Catalan Sea, Northwestern Mediterranean. **Journal of Marine Systems**, v. 59, p. 63–96, 2006.

COLLÉTER, M.; VALLS, A.; GUITTON, J.; et al. Global overview of the applications of the Ecopath with Ecosim modeling approach using the EcoBase models repository. **Ecological Modelling**, v. 302, p. 42–53, 2015. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecolmodel.2015.01.025>. .

CORRALES, X.; COLL, M.; TECCHIO, S.; et al. Ecosystem structure and fishing impacts in the northwestern Mediterranean Sea using a food web model within a comparative approach. **Journal of Marine Systems**, v. 148, p. 183–199, 2015. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.jmarsys.2015.03.006>. .

COX, S. P.; ESSINGTON, T. E.; KITCHELL, J. F.; et al. Reconstructing ecosystem dynamics in the central Pacific Ocean, 1952&#150;1998. II. A preliminary assessment of the trophic impacts of fishing and effects on tuna dynamics. **Canadian Journal of Fisheries and Aquatic Sciences**, v. 59, n. 11, p. 1736–1747, 2002. Disponível em: <http://www.nrcresearchpress.com/doi/10.1139/f02-138>. .

CREMER, M. J.; PINHEIRO, P. C.; SIMÕES-LOPES, P. C. Prey consumed by Guiana dolphin Sotalia guianensis (Cetacea, Delphinidae) and franciscana dolphin Pontoporia blainvillei (Cetacea, Pontoporiidae) in an estuarine environment in southern Brazil. **Iheringia. Série Zoologia**, v. 102, n. 2, p. 131–137, 2012. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S0073-47212012000200003&lng=en&tlng=en>. .

CURY, P.; SHANNON, L.; SHIN, Y. The functioning of marine ecosystems: a fisheries perspective. **Responsible fisheries in the marine ecosystem**. p.103–123, 1995. Wallingford: CABI. Disponível em: <http://www.cabi.org/cabebooks/ebook/20103194519>. .

DAME, J. K.; CHRISTIAN, R. R. Evaluation of ecological network analysis: Validation of output. **Ecological Modelling**, v. 210, n. 3, p. 327–338, 2008. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0304380007004115>. .

DAURA-JORGE, F. G.; WEDEKIN, L. L.; SIMÕES-LOPES, P. C. Feeding habits of the Guiana dolphin, Sotalia guianensis (Cetacea: Delphinidae), in Norte Bay, southern Brazil. **Scientia Marina**, v. 75, n. 1, p. 163–169, 2011. Disponível em: <http://scientiamarina.revistas.csic.es/index.php/scientiamarina/article/view/1240/1308>. .

DENADAI, M. R.; BESSA, E.; SANTOS, F. B.; et al. Life history of three catfish species (Siluriformes: Ariidae) from southeastern Brazil. **Biota Neotropica**, v. 12, n. 4, p. 74–83, 2012. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S1676-06032012000400008&lng=en&tlng=en>. .

DENADAI, M. R.; SANTOS, F. B.; BESSA, E.; et al. Feeding habits of whitemouth croaker Micropogonias furnieri (Perciformes: Sciaenidae) in Caraguatatuba Bay, southeastern Brazil. **Brazilian Journal of Oceanography**, v. 63, n. 2, p. 125–134, 2015. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S1679-87592015000200125&lng=en&tlng=en>. .

DIAS, E. **Caracterização da Comunidade de Pequenos Peixes Pelágicos e da Dieta do Predador , Caranx hippos , no Parque Nacional Marinho João Vieira Poilão ,** 2016. Universidade de Lisboa.

DU, J.; CHEUNG, W. W. L.; ZHENG, X.; et al. Comparing trophic structure of a subtropical bay as estimated from mass-balance food web model and stable isotope analysis. **Ecological Modelling**, v. 312, p. 175–181, 2015. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecolmodel.2015.05.027>. .

DUAN, L. J.; LI, S. Y.; LIU, Y.; JIANG, T.; FAILLER, P. A trophic model of the Pearl River Delta coastal ecosystem. **Ocean & Coastal Management**, v. 52, n. 7, p. 359–367, 2009. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0964569109000222>. .

DUTTA, S.; CHAKRABORTY, K.; HAZRA, S. Ecosystem structure and trophic dynamics of an exploited ecosystem of Bay of Bengal , Sundarban Estuary , India. **Fisheries Science**, v. 83, n. 2, p. 145–159, 2017a. Springer Japan.

DUTTA, S.; CHAKRABORTY, K.; HAZRA, S. Ecosystem structure and trophic dynamics of an exploited ecosystem of Bay of Bengal, Sundarban Estuary, India. **Fisheries Science**, v. 83, n. 2, p. 145–159, 2017b. Springer Japan. Disponível em: <http://link.springer.com/10.1007/s12562-016-1060-2>. .

EOL. Encyclopedia of Life. .

FERREIRA, A.; SILVA, D. A. **Variações temporais de curta escala da estrutura e dieta da ictiofauna em uma planície de maré em um estuário tropical**, 2014. Universidade Estadual da Paraíba.

FERREIRA, G. V. B. **Ecologia alimentar e distribuição espaço-temporal das diferentes fases ontogenéticas da espécie Cynoscion acoupa no estuário do Rio Goiana (PE/PB)**, 2016. Universidade Fedeal de Pernambuco.

FRANKS, J. S.; VANDERKOOY, K. E.; GARBER, N. M. Diet of Tripletail, Lobotes surinamensis, from Mississippi Coastal Waters. **Gulf and Caribbean Research**, v. 15, n. 1, p. 27–32, 2003. Disponível em: <http://aquila.usm.edu/gcr/vol15/iss1/5>. .

FREIRE, K. DE M. F. **Fishing impacts on marine ecosystems off Brazil, with emphasis on the Northeastern Region**, 2005. THE UNIVERSITY OF BRITISH COLUMBIA.

FREITAS, M. O.; ABILHÔA, V.; GIGLIO, V. J.; et al. Diet and reproduction of the goliath grouper, Epinephelus itajara (Actinopterygii: Perciformes: Serranidae), in eastern Brazil. **Acta Ichthyologica et Piscatoria**, v. 45, n. 1, p. 1–11, 2015. Disponível em: <http://www.aiep.pl/volumes/2010/6\_1/txt/txt\_01.php>. .

FROESE, R. Fishbase. **http://www.fishbase.org**, 2018.

FROESE, R.; PAULY, D. Fishbase. Disponível em: <www.fishbase.org>. Acesso em: 1/6/2018.

FUNDEPAG. http://propesq-pr.fundepag.br/usuarioexterno/. .

DA GAMA, L. M. **Ecologia trófica da ictiofauna da zona de arrrebentação da Baía de Santos - SP**, 2017. Universidade Santa Cecília.

GARCIA, S. M.; ZERBI, A.; ALIAUME, C.; DO CHI, T.; LASSERRE, G. **The Ecosystem Approach to Fisheries**. 2003.

GEERS, T. M.; PIKITCH, E. K.; FRISK, M. G. An original model of the northern Gulf of Mexico using Ecopath with Ecosim and its implications for the effects of fishing on ecosystem structure and maturity. **Deep Sea Research Part II: Topical Studies in Oceanography**, v. 129, p. 319–331, 2016. Elsevier. Disponível em: <http://dx.doi.org/10.1016/j.dsr2.2014.01.009>. .

GIANUCA, D.; BRANCO, J. O.; VOOREN, C. M. Notes on breeding by Yellow-crowned Night Heron Nyctanassa violacea in southern Brazil. **Cotinga**, v. 33, n. 1, p. 61–70, 2011.

GIANUCA, D.; GIANUCA, A. T.; VOOREN, C. M. Abundance , breeding and food of the Little Blue Heron Egretta caerulea ( Aves , Ardeidae ) in the Patos Lagoon estuary , a recently colonized area in southern Brazil. **Iheringia - Serie Zoologia**, v. 102, n. 1, p. 19–25, 2012.

GIBRAN, F. Z. Activity, habitat use, feeding behavior, and diet of four sympatric species of Serranidae (Actinopterygii: Perciformes) in southeastern Brazil. **Neotropical Ichthyology**, v. 5, n. 3, p. 387–398, 2007. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S1679-62252007000300018&lng=en&tlng=en>. .

GOMES, A. L. M. **Padrões de uso e ocorrência de aves associadas ao ambiente aquático no Complexo Estuarino de Paranaguá, Paraná, Brasil**, 2010. Universdidade Federal do Paraná.

GUILHERME, P. D. B.; ROSA, L. C. Seasonal variation in body size and diet of the sea star Astropecten marginatus ( Paxillosida , Astropectinidae ) off coast of Paraná , Southern Brazil. **Revista de Biologia Tropical**, v. 62, n. March, p. 1–10, 2014.

HAN, R.; CHEN, Q.; WANG, L.; TANG, X. Preliminary investigation on the changes in trophic structure and energy flow in the Yangtze estuary and adjacent coastal ecosystem due to the Three Gorges Reservoir. **Ecological Informatics**, v. 36, p. 152–161, 2016. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecoinf.2016.03.002>. .

HANNON, B. The structure of ecosystems. **Journal of Theoretical Biology**, v. 41, p. 535–546, 1973.

HATTAB, T.; LASRAM, F. B. R.; ALBOUY, C.; et al. An ecosystem model of an exploited southern {Mediterranean} shelf region ({Gulf} of {Gabes}, {Tunisia}) and a comparison with other {Mediterranean} ecosystem model properties. **Journal of Marine Systems**, v. 128, p. 159–174, 2013.

HEYMANS, J. J. **Ecosystem Models of Southeastern Labrador: Newfoundland and Additional information and analyses for ‘Back to the Future’**. Vancouver, Canadá, 2003.

HEYMANS, J. J.; COLL, M.; LINK, J. S.; et al. Best practice in Ecopath with Ecosim food-web models for ecosystem-based management. **Ecological Modelling**, v. 331, p. 173–184, 2016a. Elsevier B.V.

HEYMANS, J. J.; COLL, M.; LINK, J. S.; et al. Best practice in Ecopath with Ecosim food-web models for ecosystem-based management. **Ecological Modelling**, v. 331, p. 173–184, 2016b. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecolmodel.2015.12.007>. .

HEYMANS, J. J.; GUÉNETTE, S.; CHRISTENSEN, V. Evaluating Network Analysis Indicators of Ecosystem Status in the Gulf of Alaska. **Ecosystems**, v. 10, n. 3, p. 488–502, 2007. Disponível em: <http://link.springer.com/10.1007/s10021-007-9034-y>. .

HEYMANS, S. J. J.; CHRISTENSEN, V.; TRITES, A. W. Ecosystem Models of the Aleutian Islands and Southeast Alaska Show that Steller Sea Lions are Impacted by Killer Whale Predation when Sea Lion Numbers are Low. , p. 2000–2004, 2005.

HÖFLING, J. C.; FERREIRA, L.; RIBEIRO NETO, F. N.; PAIVA FILHO, A. M.; DA SILVA, M. S. R. Fish alimentation of the Carangidae family of the estuarine lagoon complex in Cananéia, São Paulo, Brazil. **Bioikos**, v. 12, n. 2, p. 7–18, 1998.

HOFLING, J.; FERREIRA, L.; RIBEIRO NETO, F.; et al. Fish alimentation of the Clupeidae family of the estuarine lagoon complex in Cananeia, Sao Paulo, Brazil. **NOTAS TÉC. FACIMAR**, v. 14, n. 2, p. 12–20, 2008. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S0101-81752008000100002&lng=pt&tlng=pt>. .

ICMBIO. Áreas de exclusão da pesca. .

INNES, B. Y. S.; LAVIGNE, D. M.; EARLE, W. M.; KOVACS, K. M. Feeding Rates of Seals and Whales. **Journal of Animal Ecology**, v. 56, n. 1, p. 115–130, 1987.

JACOBSEN, I. P.; BENNETT, M. B. A Comparative Analysis of Feeding and Trophic Level Ecology in Stingrays (Rajiformes ; Myliobatoidei) and Electric Rays (Rajiformes : Torpedinoidei). **plos one**, v. 8, n. 8, 2013.

JENNINGS, S.; KAISER, M. J. The Effects of Fishing on Marine Ecosystems. **Advances in Marine Biology**. v. 34, p.201–352, 1998. Elsevier Masson SAS. Disponível em: <http://dx.doi.org/10.1016/S0065-2881(08)60212-6>. .

JÚNIOR, M. N.; HADDAD, M. A. The diet of cubomedusae (cnidaria, cubozoa) in southern Brazil. **Brazilian Journal of Oceanography**, v. 56, n. 3, p. 157–164, 2008.

KAMPEL, M. **Estimativa da produção primária e biomassa fitoplanctônica através de sensoriamento remoto da cor do oceano e dados in situ na costa sudeste Brasileira**, 2003. Universidade de São Paulo.

KRUMME, U.; KEUTHEN, H.; BARLETTA, M.; SAINT-PAUL, U.; VILLWOCK, W. Resuspended Intertidal Microphytobenthos As Major Diet Component of Planktivorous Atlantic Anchoveta Cetengraulis Edentulus (Engraulidae) From Equatorial Mangrove Creeks. **Ecotropica**, v. 14, p. 121–128, 2008.

LANA, P. C.; MARONE, E.; LOPES, R. M.; MACHADO, E. C. The Subtropical Estuarine Complex of Paranaguá Bay, Brazil. In: U. Seeliger; B. Kjerfve (Orgs.); **Coastal Marine Ecosystems of Latin America**. p.131–145, 2001. Berlin, Heidelberg: Springer Berlin Heidelberg. Disponível em: <http://dx.doi.org/10.1007/978-3-662-04482-7\_11>. .

LARKIN, P. A. Larkin 1996. Concepts and issues in marine ecosystem management.pdf. **Reviews in Fish Biology and Fisheries**, v. 164, n. 6, p. 139–164, 1996.

LAURETTA, M. V.; CAMP, E. V.; EARL, W.; III, P.; FRAZER, T. K. Catchability model selection for estimating the composition of fishes and invertebrates within dynamic aquatic ecosystems. **Canadian Journal of Fisheries Aquatic Science**, v. 392, n. January, p. 381–392, 2013.

LEBLANC, K.; AR, J.; ARMAND, L.; et al. A global diatom database - abundance , biovolume and biomass in the world ocean To cite this version : A global diatom database – abundance , biovolume and. , 2012.

LERCARI, D.; HORTA, S.; MARTÍNEZ, G.; CALLIARI, D.; BERGAMINO, L. A food web analysis of the Río de la Plata estuary and adjacent shelf ecosystem: trophic structure, biomass flows, and the role of fisheries. **Hydrobiologia**, v. 742, n. 1, p. 39–58, 2015a. Disponível em: <http://link.springer.com/10.1007/s10750-014-1964-8>. .

LERCARI, D.; HORTA, S.; MARTÍNEZ, G.; CALLIARI, D.; BERGAMINO, L. A food web analysis of the Río de la Plata estuary and adjacent shelf ecosystem: trophic structure, biomass flows, and the role of fisheries. **Hydrobiologia**, v. 742, n. 1, p. 39–58, 2015b. Disponível em: <http://link.springer.com/10.1007/s10750-014-1964-8>. .

LIBRALATO, S.; CHRISTENSEN, V.; PAULY, D. A method for identifying keystone species in food web models. **Ecological Modelling**, v. 195, n. 3–4, p. 153–171, 2006. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0304380005006149>. .

LIBRALATO, S.; COLL, M.; TEMPESTA, M.; et al. Food-web traits of protected and exploited areas of the Adriatic Sea. **Biological Conservation**, v. 143, n. 9, p. 2182–2194, 2010. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0006320710002685>. .

LIBRALATO, S.; COLL, M.; TUDELA, S.; PALOMERA, I.; PRANOVI, F. Novel index for quantification of ecosystem effects of fishing as removal of secondary production. , v. 355, p. 107–129, 2008.

LIN, H. J.; SHAO, K. T.; JAN, R. Q.; et al. A trophic model for the Danshuei River Estuary, a hypoxic estuary in northern Taiwan. **Marine Pollution Bulletin**, v. 54, n. 11, p. 1789–1800, 2007a.

LIN, H. J.; SHAO, K. T.; JAN, R. Q.; et al. A trophic model for the Danshuei River Estuary, a hypoxic estuary in northern Taiwan. **Marine Pollution Bulletin**, v. 54, n. 11, p. 1789–1800, 2007b.

LINDEMAN, R. L. The trophic-dynamic aspect of ecology. **Ecology**, v. 4, n. 1–2, p. 399–417, 1942. Disponível em: <http://link.springer.com/10.1007/BF02464428>. .

LINK, J. S. Adding rigor to ecological network models by evaluating a set of pre-balance diagnostics: A plea for PREBAL. **Ecological Modelling**, v. 221, n. 12, p. 1580–1591, 2010. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecolmodel.2010.03.012>. .

LIRA, A.; ANGELINI, R.; LE LOC’H, F.; et al. Trophic flow structure of a neotropical estuary in northeastern Brazil and the comparison of ecosystem model indicators of estuaries. **Journal of Marine Systems**, v. 182, n. August 2017, p. 31–45, 2018. Elsevier. Disponível em: <https://doi.org/10.1016/j.jmarsys.2018.02.007>. .

MACHADO LEONARDO, F.; FELIPPE A M L, D.; ATHILA ANDRADE, B.; MAURICIO, H.-SI.; JOÃO PEDRO, B. Feeding strategy and trophic ontogeny in Epinephelus marginatus (Serranidae) from Southern Brazil. **Cybium**, v. 32, n. 1, p. 9, 2008.

MARONE, E.; MACHADO, E. C.; LOPES, R. M.; DA SILVA, E. T. Land-ocean fluxes in the Paranaguá Bay estuarine system, southern Brazil. **Brazilian Journal of Oceanography**, v. 53, n. 3–4, p. 169–181, 2005. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S1679-87592005000200007&lng=en&tlng=en>. .

MARSHALL, C. Encyclopedia of Life. .

MARTINS, A. S.; HAIMOVICI, M.; PALACIOS, R. Diet and feeding habitat of the cutlassfish Trichiurus lepturus in the Subtropical Convergence Ecosystem of southern Brazil. **J. Mar. Biol. Ass. U.K.**, v. 85, p. 1223–1229, 2005.

MEDEIROS, R. P.; GUANAIS, J. H. D. G.; SANTOS, L. DE O.; et al. Estratégias para a redução da fauna acompanhante na frota artesanal de arrasto do camarão sete-barbas: Perspectivas para a gestão pesqueira. **Boletim do Instituto de Pesca**, v. 39, n. 3, p. 339–358, 2013.

MENDENHALL, K. S. **Diet of black drum (Pogonias cromis) based on stable isotope and stomach content analyses**, 2015. TEXAS A&M UNIVERSITY-CORPHUS CHRISTI.

MENDOZA-CARRANZA, M.; VIEIRA, J. Whitemouth croaker Micropogonias furnieri (Desmarest, 1823) feeding strategies across four southern Brazilian estuaries. **Aquatic Ecology**, v. 42, n. 1, p. 83–93, 2008. Disponível em: <http://link.springer.com/10.1007/s10452-007-9084-4>. .

MIOTTO, M. L. **ASPECTOS ALIMENTARES DA GAIVOTA, Larus dominicanus: VARIAÇÃO SAZONAL E INFLUÊNCIA DO DEFESO**, 2015. Universidade Federal do Paraná.

MIRANDA, A. V. DE. **Estimativa de densidade e tamanho populacional de botos- cinza, Sotalia guianensis (van Bénéden, 1864), no complexo estuarino de Paranaguá, Paraná**, 2017. Universidade Federal do Paraná.

MÓRÉH, Á.; ENDRÉDI, A.; JORDÁN, F. Additivity of pairwise perturbations in food webs: Topological effects. **Journal of Theoretical Biology**, v. 448, p. 112–121, 2018. Disponível em: <https://linkinghub.elsevier.com/retrieve/pii/S0022519318301693>. .

MORISSETTE, L. **Complexity, cost and quality of ecosystem models and their impacts on resilience: A comparative analysis, with emphasis on marine mammals and the Gulf of St. Lawrence**, 2007. University of British Columbia.

MUTO, E. Y.; MALFARA, D. T.; COELHO, L. I.; SOARES, L. S. H. Alimentação das sardinhas Pelloona harroweri (Fowler, 1919) e Chirocentrodon bleekerianus (Poey, 1867), região costeira de santos, Estado de SãPaulo. **Oceanografia e Mudanças Globais**. p.287–302, 2008.

NIANG, T. M. S.; PESSANHA, A. L. M.; ARAÚJO, F. G. Dieta de juvenis de Trachinotus carolinus (Actinopterygii, Carangidae) em praias arenosas na costa do Rio de Janeiro. **Iheringia. Série Zoologia**, v. 100, n. 1, p. 35–42, 2010. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S0073-47212010000100005&lng=pt&tlng=pt>. .

NILSSON, S. G.; NILSSON, I. N. food consumption , and fish Numbers , by birds predation in Lake Mdckeln , southern Sweden. **Ornis Scandinavica**, v. 7, n. 1, p. 61–70, 1976.

ODUM, EUGENE P. The Strategy of Ecosystem Development. **Science**, v. 164ODUM, E, p. 262–270, 1969.

ODUM, E.P. Strategy of Ecosystem Development. **Science**, v. 164, n. 3877, p. 262–270, 1969.

OLIVEIRA, I. DA R.; SOARES, L. S. H. Alimentação da Tainha Mugil platanus Günther, 1880 (Pisces: Mugilidae) da região estuarino-lagunar de Cananéia, São Paulo, Brazil. **Boletim do Instituto de Pesca**, v. 23, n. único, p. 95–104, 1996.

OPITZ, S. **Trophic Interactions in Caribbean Coral Reefs**. ICKARM Tec ed. Manila, Phillippines: ICLARM Tech., 1996.

PALOMARES, M. L. D.; PAULY, D. Predicting food consumption of fish populations. **Marine Freshwater Resource**, v. 49, p. 447–453, 1998.

PARANÁ, P. DO. **Relatório Semestral dos Programas Ambientais**. 2019.

PASSOS, A. C. DOS; CONTENTE, R. F.; COLODETTI, C. V. DE A.; et al. Fishes of Paranaguá Estuarine Complex , South West Atlantic Fishes of Paranaguá Estuarine Complex , South West Atlantic. , v. 12, n. 3, p. 226–238, 2012.

PAULY, D. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. **ICES Journal of Marine Science**, v. 39, n. 2, p. 175–192, 1980. Disponível em: <https://academic.oup.com/icesjms/article-lookup/doi/10.1093/icesjms/39.2.175>. .

PAULY, D. Fishing Down Marine Food Webs. **Science**, v. 279, n. 5352, p. 860–863, 1998. Disponível em: <https://www.sciencemag.org/lookup/doi/10.1126/science.279.5352.860>. .

PAULY, D.; GRAHAM, W.; LIBRALATO, S.; MORISSETTE, L.; DENG PALOMARES, M. L. Jellyfish in ecosystems, online databases, and ecosystem models. **Hydrobiologia**, v. 616, n. 1, p. 67–85, 2009. Disponível em: <http://link.springer.com/10.1007/s10750-008-9583-x>. .

PAULY, D.; VILLY, C. Primary production required to sustain global fisheries. **Nature**, v. 376, p. 255–257, 1995.

PHILIPPSEN, J. S.; MINTE-VERA, C. V.; COLL, M.; ANGELINI, R. Assessing fishing impacts in a tropical reservoir through an ecosystem modeling approach. **Reviews in Fish Biology and Fisheries**, v. 29, n. 1, p. 125–146, 2019. Springer International Publishing. Disponível em: <https://doi.org/10.1007/s11160-018-9539-9>. .

PIRODDI, C.; COLL, M.; LIQUETE, C.; et al. Historical changes of the Mediterranean Sea ecosystem: modelling the role and impact of primary productivity and fisheries changes over time. **Scientific Reports**, v. 7, n. 1, p. 44491, 2017. Nature Publishing Group. Disponível em: <http://dx.doi.org/10.1038/srep44491>. .

PLAGÁNYI, É. E. **Models for an ecosystem approach to fisheries**. Rome, 2007.

POLOVINA, J. J. Coral Reefs Model of a Coral Reef Ecosystem. **Coral Reefs**, v. 3, p. 1–11, 1984.

POSSATO, F. E. **Ecologia alimentar nas diferentes fases ontogenéticas de**, 2010. Universidade Federal de Pernambuco.

POSSATO, F. E. **Composição, estrutura e abundância da ictiofauna capturada com redes de arrasto de portas na plataforma continental interna do Litoral do Paraná**, 2015. Universidade Federal do Paraná.

POSSATTO, F. E.; BROADHURST, M. K.; GRAY, C. A.; SPACH, H. L.; LAMOUR, M. R. Spatiotemporal variation among demersal ichthyofauna in a subtropical estuary bordering World Heritage-listed and marine protected areas: Implications for resource management. **Marine and Freshwater Research**, v. 68, n. 4, p. 703–717, 2017.

RABELO, L. B.; MUTO, E. Y.; SATIKO, L.; SOARES, H. Observações preliminares sobre o hábito alimentar do robalo-flecha Centropomus undecimalis ( BLOCH , 1792 ) E ROBALO-PEBA Centropomus parallelus POEY , 1860 , no Estuário de Caravelas ( Bahia , Brasil ). **Boletim Técnico Científico Cepene**, v. 17, n. 1, p. 89–96, 2009.

RABITTO, I. DA S.; ABILHÔA, V. A alimentação do bagre Genidens genidens Valenciennes, 1839 em um banco areno-lodoso da Ilha do Mel, Paraná, Brasil. **Arq. ciên. vet. zool. UNIPAR**, 1999.

REGINA DENADAI, M.; BORGES SANTOS, F.; BESSA, E.; SILVA FERNANDEZ, W.; TURRA, A. Population Biology and Diet of the Pompano Trachinotus carolinus (Perciformes: Carangidae) in Caraguatatuba Bay, Southeastern Brazil. **Journal of Marine Biology & Oceanography**, v. 02, n. 02, p. 1947–1954, 2013. Disponível em: <http://www.scitechnol.com/2324-8661/2324-8661-2-108.php>. .

REIS-FILHO, J. A.; GIARRIZZO, T. Microgobius meeki as a potential bio-indicator of habitat disturbance in shallow estuarine areas: a useful tool for the assessment of estuarine quality. **Journal of Fish Biology**, v. 89, n. 1, p. 713–734, 2016. Disponível em: <http://doi.wiley.com/10.1111/jfb.13007>. .

RONDINELI, G. R.; BRAGA, F. M. DE S.; TUTUI, S. L. DOS S.; BASTOS, G. C. C. Dieta de Menticirrhus americanus (Linnaeus, 1758) e Cynoscion jamaicensis (Vaillant e Bocourt, 1883)(Pisces, Sciaenidae) no sudeste do Brasil, Estado de São Paulo. **Bol. Inst. Pesca**, v. 33, n. 2, p. 221–228, 2007.

ROSAS, F. C. W.; BARRETO, A. S.; MONTEIRO-FILHO, EMYGDIO L. A. Age and growth of the estuarine dolphin (Sotalia guianensis) (Cetacea, Delphinidae) on the Parana coast, southern Brazil. **Fishery Bulletin**, v. 101, n. 2, p. 377–383, 2003.

ROSAS, F. C. W.; BARRETO, A. S.; MONTEIRO-FILHO, EMYGDIO L A. Age and growth of the estuarine dolphin (Sotalia guianensis) (Cetacea, Delphinidae) on the Parana coast, southern Brazil. **Fishery Bulletin**, v. 101, n. 2, p. 377–383, 2003.

RYBARCZYK, H.; ELKAIM, B. An analysis of the trophic network of a macrotidal estuary: the Seine Estuary (Eastern Channel, Normandy, France). **Estuarine, Coastal and Shelf Science**, v. 58, n. 4, p. 775–791, 2003. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0272771403001847>. .

SASAKI, G. **Uso de habitat pelo boto-cinza, Sotalia guianensis) (Van bénéden, 1864), na região próxima à desembocadura sul da Baía de Paranaguá, Litoral do Estado do Paraná**, 2010. Universidade Federal do Paraná.

SCOTT, E.; SERPETTI, N.; STEENBEEK, J.; HEYMANS, J. J. A Stepwise Fitting Procedure for automated fitting of Ecopath with Ecosim models. **SoftwareX**, v. 5, p. 25–30, 2016. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.softx.2016.02.002>. .

SERRANO, I. D. L.; AZEVEDO JÚNIOR, S. M. DE. Dietas das aves marinhas no Parque Nacional dos Abrolhos, Bahia, Brasil. **Ornithologia**, v. 1, n. 1, p. 75–92, 2005.

SHANNON, L. J.; MOLONEY, C. L.; JARRE, A.; FIELD, J. G. Trophic flows in the southern Benguela during the 1980s and 1990s. **Journal of Marine Systems**, v. 39, n. 1–2, p. 83–116, 2003.

SHEAVES, M.; BAKER, R.; NAGELKERKEN, I.; CONNOLLY, R. M. True Value of Estuarine and Coastal Nurseries for Fish: Incorporating Complexity and Dynamics. **Estuaries and Coasts**, v. 38, n. 2, p. 401–414, 2015. Disponível em: <http://link.springer.com/10.1007/s12237-014-9846-x>. .

SHINOZAKI-MENDES, R. A.; LESSA, R. Population dynamics of Callinectes danae Smith, 1869 (Brachyura: Portunidae) in a tropical estuary. **Journal of Crustacean Biology**, v. 37, n. 6, p. 683–692, 2017. Disponível em: <http://academic.oup.com/jcb/article/37/6/683/4210263>. .

SILVA, J. T. O.; LOPES, P. R. D. Notas sobre a alimentação e morfologia do aparelho digestivo de Chloroscombrus chrysurus ( Linnaeus , 1766 ) ( Actinopterygii , Carangidae ) na Praia de Ponta da Ilha ( Ilha de Itaparica , Bahia ). **Revista brasileira de Zoociências, Juiz de Fora**, v. 4, n. 2, p. 179–192, 2002.

SILVANO, R. A. M. Feeding habits and interspecific feeding associations of Caranx latus (Carangidae) in a subtropical reef. **Environmental Biology of Fishes**, v. 60, n. 4, p. 465–470, 2001.

SOMMER, U.; CHARALAMPOUS, E.; SCOTTI, M.; MOUSTAKA-GOUNI, M. Big fish eat small fish: Implications for food chain length? **Community Ecology**, v. 19, n. 2, p. 107–115, 2018.

SPACH, HENRY L.; GODEFROID, R. S.; SANTOS, C.; SCHWARZ JR., R.; QUEIROZ, G. M. L. DE. Temporal variation in fish assemblage composition on a tidal flat. **Brazilian Journal of Oceanography**, v. 52, n. 1, p. 47–58, 2004.

SPACH, HENRY L; GODEFROID, R. S.; SANTOS, C.; SCHWARZ JR., R.; QUEIROZ, G. M. L. DE. Temporal variation in fish assemblage composition on a tidal flat. **Brazilian Journal of Oceanography**, v. 52, n. 1, p. 47–58, 2004.

STEENBEEK, J.; BUSZOWSKI, J.; CHRISTENSEN, V.; et al. Ecopath with Ecosim as a model-building toolbox: Source code capabilities, extensions, and variations. **Ecological Modelling**, v. 319, p. 178–189, 2016. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecolmodel.2015.06.031>. .

STRICKLAND, J. D. H. **Measuring the Production of Marine Phytoplankton**. 1960.

STRIEDER PHILIPPSEN, J.; MINTE-VERA, C. V.; OKADA, E. K.; CARVALHO, A. R.; ANGELINI, R. Fishers’ and scientific histories: an example of consensus from an inland fishery. **Marine and Freshwater Research**, v. 68, n. 5, p. 980, 2017. Disponível em: <http://www.publish.csiro.au/?paper=MF16053>. .

THOMPSON, G.; FORTUNATO, R. C.; CHIESA, I.; VOLPEDO, A. Trophic ecology of Mugil liza at the southern limit of its distribution (Buenos Aires, Argentina). **Brazilian Journal of Oceanography**, v. 63, n. 3, p. 271–277, 2015. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S1679-87592015000300271&lng=en&tlng=en>. .

TOMCZAK, M. T.; MÜLLER-KARULIS, B.; JÄRV, L.; et al. Analysis of trophic networks and carbon flows in south-eastern Baltic coastal ecosystems. **Progress in Oceanography**, v. 81, n. 1–4, p. 111–131, 2009. Elsevier Ltd. Disponível em: <http://dx.doi.org/10.1016/j.pocean.2009.04.017>. .

TONINI, W. C. T.; BRAGA, L. G. T.; VILA NOVA, D. L. D. Dieta de juvenis de robalo Centropomus parallelus Poey, 1860 no sul da Bahia, Brasil. **Boletim do Instituto de Pesca**, v. 33, n. 1, p. 85–91, 2007.

TROCHTA, J. T.; PONS, M.; RUDD, M. B.; et al. Ecosystem-based fisheries management: Perception on definitions, implementations, and aspirations. **PLoS ONE**, v. 13, n. 1, p. 1–9, 2018.

ULANOWICZ, ROBERT E. **Growth and Development**. New York, NY: Springer New York, 1986.

ULANOWICZ, ROBERT E. **Growth and Development**. New York, NY: Springer New York, 1986.

ULANOWICZ, R. E.; ABARCA-ARENAS, L. G. An informational synthesis of ecosystem structure and function. **Ecological Modelling**, v. 95, p. 1–10, 1997.

ULANOWICZ, R. E.; PUCCIA, C. J. Mixed Trophic Impacts in Ecosystems. **Coenoses**, v. 5, n. I, p. 7–16, 1987.

VASCONCELLOS, M.; MACKINSON, S.; SLOMAN, K.; PAULY, D. The stability of troophic mass-balance models of marine ecosystems: a comparative analys. **Ecological Modelling**, v. 100, p. 125–134, 1997.

VASCONCELOS FILHO, A. DE L.; NEUMANN-LEITÃO, S.; ESKINAZI-LEÇA, E.; OLIVEIRA, A. M. E. DE; PORTO-NETO, F. DE F. Hábitos alimentares de consumidores primários da ictiofauna do sistema estuarino de Itamaracá (Pernambuco - Brasil). **Revista Brasileira de Engenharia de Pesca**, v. 4, n. 1, p. 21–31, 2009.

VENDEL, A. L.; SPACH, H. L.; LOPES, S. G.; SANTOS, C. Structure and dynamics of fish assemblages in a tidal creek environment. **Brazilian Archives of Biology and Technology**, v. 45, n. 3, p. 365–373, 2002.

VILLELA, M. J.; COSTA, P. A. S.; VALETINI, J. L. Crescimento e mortalidade de juvenis do camarão-rosa (Penaeus brasiliensis Latreille, 1817) na Lagoa de Araruama, Rio de Janeiro. **Revista Brasileira de Biologia**, v. 57, n. 3, p. 487–499, 1997.

WALSH, J. J. Shelf-sea ecosystems. In: A. R. Longhurst (Org.); **Analysis of Marine Ecosystems**. p.159–196, 1981. London: Academic Press.

WALTERS, C.; CHRISTENSEN, V.; PAULY, D. Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. **Reviews in Fish Biology and Fisheries**, v. 7, p. 139–172, 1997.

WALTERS, C.; MARTELL, S. J. D.; CHRISTENSEN, V.; MAHMOUDI, B. An ecosim model for exploring gulf of mexico ecosystem management options: implications of including multistanza life- history models for policy predictions. **Bulletin of Marine Science**, v. 83, n. 1, p. 251–271, 2008.

WALTERS, C.; MARTELL, S. J. D.; VILLY, C.; MAHMOUDI, B. An Ecosim model for exploring Gulf of Mexico ecosystem management options: Implications of including multistanza life-history models for policy predictions. **Bulletin of Marine Science**, v. 83, n. 1, p. 251–271, 2008.

WALTERS, C.; PAULY, D.; CHRISTENSEN, V. Ecospace : Prediction of Mesoscale Spatial Patterns in Trophic Relationships of Exploited Ecosystems , with Emphasis on the Impacts of Marine Protected Areas. , p. 539–554, 1999.

WIKIAVES. WikiAves, a Enciclopédia das Aves do Brasil. .

WINIK, S.; CARNEIRO, M. H.; MENDONCA, J. T. Alimentação da guaivira Oligoplites saliens (Bloch, 1793) (Perciformes: Carangidae) Proveniente da pesca na Região de Cananéia-SP. **Série Relatórios Técnicos**, v. 27, p. 1–13, 2007.

WOLFF, M. Biomass flow structure and resource potential of two mangrove estuaries : insights from comparative modelling in Costa Rica and Brazil. , v. 54, n. September, p. 69–86, 2006.

WOLFF, M.; KOCH, V.; ISAAC, V. A Trophic Flow Model of the Caeté Mangrove Estuary (North Brazil) with Considerations for the Sustainable Use of its Resources. **Estuarine, Coastal and Shelf Science**, v. 50, n. 6, p. 789–803, 2000. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0272771400906115>. .

XAVIER, J. H. DE A. **Teia trófica e fluxo de energia no Estuário do Rio Mamanguape, Paraíba, Brasil**, 2013. Universidade Federal da Paraíba.

XU, S.; CHEN, Z.; LI, S.; HE, P. Modeling Trophic Structure and Energy Flows in a Coastal Artificial Ecosystem Using Mass-Balance Ecopath Model. **Estuaries and Coasts**, v. 34, n. 2, p. 351–363, 2011. Disponível em: <http://link.springer.com/10.1007/s12237-010-9323-0>. .

ZANELATTO, R. C. **Dieta do boto-cinza, Sotalia fluviatilis (Cetacea, Delphinidae), no Complexo Estuarino de Paranaguá e sua relação com a ictiofauna estuarina**, 2001. Universidade Federal do Paraná.

ZANLORENZI, D.; CHAVES, P. D. T. Alimentação de Ctenogobius shufeldti (Jordan e Eigenmann, 1887) (Teleostei, Gobiidae) na Baía de Guaratuba, Atlântico oeste subtropical doi:10.5007/2175-7925.2011v24n1p37. **Biotemas**, v. 24, n. 1, p. 37–46, 2011. Disponível em: <http://www.periodicos.ufsc.br/index.php/biotemas/article/view/18109>. .

AHRENS, R. N. M.; WALTERS, C. J.; CHRISTENSEN, V. Foraging arena theory. **Fish and Fisheries**, v. 13, p. 41–59, 2012.

ALTHAUSER, L. L. **AN ECOPATH/ECOSIM ANALYSIS OF AN ESTUARINE FOOD WEB: SEASONAL ENERGY FLOW AND RESPONSE TO RIVER-FLOW RELATED PERTURBATIONS**, 2003. Graduate Faculty of the Louisiana State University.

ANDRIGUETTO-FILHO, J. M. A mudança técnica e o processo de diferenciação dos sistemas de produção pesqueira do Litoral do Paraná , Brasil Technical change and differentiation of small-scale fisheries production systems in the coast of Paraná , Brazil. **Desenvolvimento e Meio Ambiente**, v. 8, p. 43–58, 2003.

ANDRIGUETTO-FILHO, J. M.; CHAVES, P. DE T. DA C.; SANTOS, C.; LIBERATI, S. A. Diagnóstico da pesca no litoral do estado do Paraná. In: V. J. Isaac; A. S. Martins; M. Haimovici; J. M. Andriguetto Filho (Orgs.); **Pesca marinha e estuarina do Brasil no início do século XXI**. p.117–140, 2006. Belém: Editora Universitária UFPA.

ANDRIGUETTO-FILHO, J. M.; KRUL, R.; FEITOSA, S. Analysis of natural and social dynamics of fishery production systems in Parana Brazil : implications for management and sustainability. **Journal Appl. Ichthyol.**, v. 25, p. 277–286, 2009.

ANDRIGUETTO-FILHO, J. M.; KRUL, R.; FEITOSA, S. Analysis of natural and social dynamics of fishery production systems in Parana Brazil : implications for management and sustainability. **Journal Appl. Ichthyol.**, v. 25, p. 277–286, 2009.

ANGELINI, R. Bases para a aplicação da teoria da informação em ecossistemas , com ênfase na ascendência. **Acta Scientiarum. Biological Sciences**, v. 24, n. 2, p. 275–283, 2002.

ANGELINI, R.; CONTENTE, R. F.; ROSSI-WONGTSCHOWSKI, C. L. D. B.; et al. Ecosystem modeling as a framework to convert a multi-disciplinary research approach into a useful model for the Araçá Bay (Brazil). **Ocean & Coastal Management**, v. 164, n. July 2017, p. 92–103, 2018. Disponível em: <https://linkinghub.elsevier.com/retrieve/pii/S0964569117306543>. .

ANGELINI, R.; GOMES, L. C. **O Artesão de ecossistemas**. Maringá: EDUEM, 2008.

ARANTES, P. L. **Relações alimentares de peixes da Enseada do Araçá (SP), Sudeste do Brasil**, 2014. Universidade de São Paulo.

ARAÚJO, J. N.; BUNDY, A. Description of three Ecopath with Ecosim ecosystem models developed for the Bay of Fundy, Western Scotian Shelf and NAFO Division 4X. **Can. Tech. Rep. Fish. Aquat. Sci**, v. 2952, p. 189, 2011a.

ARAÚJO, J. N.; BUNDY, A. Description of three Ecopath with Ecosim ecosystem models developed for the Bay of Fundy, Western Scotian Shelf and NAFO Division 4X. **Can. Tech. Rep. Fish. Aquat. Sci.**, v. 2952, p. 189, 2011b.

ARENDT, M. D.; LUCY, J. A.; OLNEY, J. E. Stomach content analysis of cobia, Rachycentron canadum, from lower Chesapeake Bay. **Fishery Bulletin**, v. 99, n. 4, p. 665–670, 2001.

ARREGUÍN-SÁNCHES, F.; ARCOS, E.; CHÁVES, E. A. Flows of biomass and structure in an exploited benthic ecosystem in the gulf of California , Mexico. **Ecological Modelling**, v. 156, p. 167–183, 2002.

ARTERO, C.; KOENIG, C. C.; RICHARD, P.; et al. Ontogenetic dietary and habitat shifts in goliath grouper Epinephelus itajara from French Guiana. **Endangered Species Research**, v. 27, n. 2, p. 155–168, 2015. Disponível em: <http://www.int-res.com/abstracts/esr/v27/n2/p155-168/>. .

AYDIN, K.; GAICHAS, S.; ORTIZ, I.; KINZEY, D.; FRIDAY, N. **A Comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands Large Marine Ecosystems Through Food Web Modeling**. Springfield, USA, 2007.

BAKHOUM, S. A. Diet overlap of immigrant narrow – barred Spanish mackerel Scomberomorus commerson ( Lac ., 1802 ) and the largehead hairtail ribbonfish Trichiurus lepturus ( L ., 1758 ) in the Egyptian Mediterranean coast. **Animal Biodiversity and Conservation**, v. 30, n. 2, p. 147–160, 2007.

BARAUSSE, A.; DUCI, A.; MAZZOLDI, C.; ARTIOLI, Y.; PALMERI, L. Trophic network model of the Northern Adriatic Sea: Analysis of an exploited and eutrophic ecosystem. **Estuarine, Coastal and Shelf Science**, v. 83, n. 4, p. 577–590, 2009. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0272771409002406>. .

BARBIER, E. B.; HACKER, S. D.; KENNEDY, C.; et al. The value of estuarine and coastal ecosystem services. **Ecological Monographs**, v. 81, n. 2, p. 169–193, 2011. Disponível em: <http://www.esajournals.org/doi/abs/10.1890/10-1510.1>. .

BARLETTA, M.; AMARAL, C. S.; CORRÊA, M. F. M.; et al. Factors affecting seasonal variations in demersal fish assemblages at an ecocline in a tropical-subtropical estuary. **Journal of Fish Biology**, v. 73, n. 6, p. 1314–1336, 2008.

BARRERA, E. A. L. **Análise da captura acidental de tartarugas marinhas em artes de pesca artesanal na desembocadura sul da Baía de Paranaguá, litoral do Paraná**, 2009. Universdidade Federal do Paraná.

BARROS, B.; SAKAI, Y.; ABRUNHOSA, F. A.; VALLINOTO, M. Trophic adaptability of late juvenile Atlantic spadefish Chaetodipterus faber (Teleostei: Ephippidae) related to habitat preferences in an estuary in northeastern Brazil. **Hydrobiologia**, v. 717, n. 1, p. 161–167, 2013. Disponível em: <http://link.springer.com/10.1007/s10750-013-1574-x>. .

BERGAMINO, L.; SZTEREN, D.; LERCARI, D. Trophic Impacts of Marine Mammals and Seabirds in the Río de la Plata Estuary and the Nearshore Oceanic Ecosystem. **Estuaries and Coasts**, v. 35, n. 6, p. 1571–1582, 2012. Disponível em: <http://link.springer.com/10.1007/s12237-012-9545-4>. .

BEVILACQUA, A. H. V.; CARVALHO, A. R.; ANGELINI, R.; CHRISTENSEN, V. More than anecdotes: Fishers’ ecological knowledge can fill gaps for ecosystem modeling. **PLoS ONE**, v. 11, n. 5, p. 1–18, 2016.

BITTAR, V. T.; FIGUEIREDO, B. DE; CASTELLO, L.; PAULA, A.; DI, M. Hábito alimentar do peixe-espada adulto, Trichiurus lepturus, na costa norte do Rio de Janeiro, sudeste do Brasil. **Biotemas**, v. 21, n. 2, p. 83–90, 2008.

BLABER, S. Effects of fishing on the structure and functioning of estuarine and nearshore ecosystems. **ICES Journal of Marine Science**, v. 57, n. 3, p. 590–602, 2000. Disponível em: <https://academic.oup.com/icesjms/article-lookup/doi/10.1006/jmsc.2000.0723>. .

BLABER, S. J. M. **Tropical Estuarine Fishes**. Wiley, 2000.

BLABER, S. J. M. ?Fish in hot water?: the challenges facing fish and fisheries research in tropical estuaries. **Journal of Fish Biology**, v. 61, n. SUPPL. A, p. 1–20, 2002. Disponível em: <http://doi.wiley.com/10.1006/jfbi.2002.2063>. .

BLABER, S. J. M. Fishes and fisheries in tropical estuaries: The last 10 years. **Estuarine, Coastal and Shelf Science**, v. 135, p. 57–65, 2013. Elsevier Ltd. Disponível em: <http://dx.doi.org/10.1016/j.ecss.2012.11.002>. .

BLABER, S. J. M.; BARLETTA, M. A review of estuarine fish research in South America: what has been achieved and what is the future for sustainability and conservation? **Journal of fish biology**, v. 89, n. 1, p. 537–568, 2016.

BLASINA, G. E.; BARBINI, S. A.; DÍAZ DE ASTARLOA, J. M. Trophic ecology of the black drum, Pogonias cromis (Sciaenidae), in Mar Chiquita coastal lagoon (Argentina). **Journal of Applied Ichthyology**, v. 26, n. 4, p. 528–534, 2010. Disponível em: <http://doi.wiley.com/10.1111/j.1439-0426.2010.01459.x>. .

BLEWETT, D. A.; HENSLEY, R. A.; STEVENS, P. W. Feeding Habits of Common Snook, Centropomus undecimalis, in Charlotte Harbor, Florida. **Gulf and Caribbean Research**, v. 18, n. 1, p. 1–14, 2006. Disponível em: <http://aquila.usm.edu/gcr/vol18/iss1/1>. .

BOEREMA, A.; MEIRE, P. Management for estuarine ecosystem services: A review. **Ecological Engineering**, v. 98, p. 172–182, 2017. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecoleng.2016.10.051>. .

BORNATOWSKI, H.; ROBERT, M. DE C.; COSTA, L. Feeding of guitarfish Rhinobatos percellens (Walbaum , 1972) (Elasmobranchii, Rhinobatidae), the target of artisanal fishery in Southern Brazil. **Brazilian Journal of Oceanography**, v. 58, n. 1, p. 45–52, 2010.

BRANCO, J. O. Biologia e pesca do camarão sete-barbas Xiphopenaeus kr eri ( Heller ) ( Cr ustacea , Penaeidae ), na Ar mação do Ita pocor o y , Penha , Santa Catar ina , Br asil Brasil Armação Itapocor pocoro. **Revista Brasileira de Zoologia**, v. 22, n. 4, p. 1050–1062, 2005.

BRANCO, J. O.; FRACASSO, H. A. A.; MACHADO, I. F.; BOVENDORP, M. S.; VERANI, J. R. Dieta de Sula leucogaster Boddaert (Sulidae, Aves), nas Ilhas Moleques do Sul, Florianópolis, Santa Catarina, Brasil. **Revista Brasileira de Zoologia**, v. 22, n. 4, p. 1044–1049, 2005.

BRANCO, J. O.; LUNARDON-BRANCO, M. J.; EVANGELISTA, C. L.; AZEVEDO-JUNIOR, S. M.; LARRAZÁBAL, M. E. Atividade diária de Phalacrocorax brasilianus (Aves, Phalacrocoracidae), na região do Saco da Fazenda, Itajaí, SC, Brasil. **Ornithologia**, v. 3, n. 2, p. 73–82, 2009.

BRANCO, J. O.; LUNARDON-BRANCO, M. J.; VERANI, J. R. Aspectos biológicos e pesqueiros de Paralonchurus brasiliensis Steindachner, (Pisces, Sciaenidae), na Armação do Itapocoroy, Penha, Santa Catarina, Brasil. **Revista Brasileira de Zoologia**, v. 22, n. 4, p. 1063–1071, 2005. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S0101-81752005000400035&lng=pt&tlng=pt>. .

BRANCO, J. O.; LUNARDON-BRANCO, M. J.; VERANI, J. R.; SOUTO, F. X.; VALE, W. G. Natural Diet of Callinectes ornatus Ordway , 1863 (Decapoda , Portunidae) in the Itapocoroy Inlet , Penha , SC , Brazil. , v. 45, n. 1974, p. 35–40, 2002.

BRANDINI, F. P.; SCHEFFER DA SILVA, A.; TEIXEIRA DA SILVA, E.; KOLM, H. Sources of Nutrients and Seasonal Dynamics of Chlorophyll in the Inner Shelf off Paraná State—South Brazil Bight. **Journal of Coastal Research**, v. 235, p. 1131–1140, 2007. Disponível em: <http://www.bioone.org/doi/abs/10.2112/04-0360.1>. .

BRITTO, V. O. **Ecologia alimentar do colhereiro (Platalea ajaja) e da garça-branca-grande (Ardea alba) em ambiente límnico e estuarino no sul do Brasil**, 2013. Universidade Federal do Paraná.

BRULÉ, T.; MENA-LORÍA, A.; PÉREZ-DÍAZ, E.; RENÁN, X. Diet of juvenile gag Mycteroperca microlepis from a non-estuarine seagrass bed habitat in the southern Gulf of Mexico. **Bulletin of Marine Science**, v. 87, n. 1, p. 31–43, 2011. Disponível em: <http://openurl.ingenta.com/content/xref?genre=article&issn=0007-4977&volume=87&issue=1&spage=31>. .

BUGONI, L.; VOOREN, C. M. Feeding ecology of the Common Tern Sterna hirundo in a wintering area in southern Brazil. **Ibis**, v. 146, n. 3, p. 438–453, 2004. Disponível em: <http://doi.wiley.com/10.1111/j.1474-919X.2004.00277.x>. .

BUNDY, A. The Ecological Effects of Fishing and Implications for Coastal Management in San Miguel Bay, the Philippines. , , n. August 2003, p. 25–38, 2004.

BUNDY, A.; HEYMANS, J. J.; MORISSETTE, L.; SAVENKOFF, C. Seals, cod and forage fish: A comparative exploration of variations in the theme of stock collapse and ecosystem change in four Northwest Atlantic ecosystems. **Progress in Oceanography**, v. 81, p. 188–206, 2009.

CARVALHO, C. DE. **Crescimento e Mortalidade do camarão branco Litopenaeus schmitti (Burkenroad, 1936) (Crustacea: Decapoda: Penaeidae) em ambiente natural e emconfinamento**, 2013. Universidade Federal Rural do Rio de Janeiro.

CASTILLO-RIVERA, M.; ZARATE-HERNANDEZ, R.; SALGADO-UGARTE, I. H. Juvenile and adult food habits of Archosargus probatocephalus (Teloostei: Sparidae) in a tropical estuary of Veracruz. **Hidrobiologica**, v. 17, n. 2, p. 119–126, 2007.

CASTRO, D. N.; LIMA, W. M. G.; MENDES, N. C. B.; et al. Dieta Natural de Macrodon ancylodon (Bloch & Schneider, 1801) Capturada por Embarcações Pesqueiras Industriais Sediadas no Estado do Pará. **Biota Amazônia**, v. 5, n. 3, p. 50–54, 2015. Disponível em: <http://www.bibliotekevirtual.org/index.php/2013-02-07-03-02-35/2013-02-07-03-03-11/1292-biota/v05n03/13673-dieta-natural-de-macrodon-ancylodon-bloch-schneider-1801-capturada-por-embarcacoes-pesqueiras-industriais-sediadas-no-estado-do-para.html>. .

CAZORLA, A. L.; FORTE, S. Food and Feeding Habits of Flounder Paralichthys Orbignyanus (Jenyns, 1842) in Bahía Blanca Estuary, Argentina. **Hydrobiologia**, v. 549, n. 1, p. 251–257, 2005. Disponível em: <http://link.springer.com/10.1007/s10750-005-5446-x>. .

CHAVES, P. D. T. D. C.; UMBRIA, S. C. Changes in the diet composition of transitoty fishes in costal systems, estuary and continental shelf. **Brazilian Archives of Biology and Technology**, v. 46, n. 1, p. 41–46, 2003.

CHAVES, P. D. T.; VENDEL, A. L. Análise comparativa da alimentação de peixes (Teleostei) entre ambientes de marisma e de manguezal num estuário do sul do Brasil (Baía de Guaratuba, Paraná). **Revista Brasileira de Zoologia**, v. 25, n. 1, p. 10–15, 2008. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S0101-81752008000100002&lng=pt&tlng=pt>. .

CHRISTENSEN, VILLY ; WALTERS, CARL. J.; PAULY, DANIEL; FORREST, R. **Ecopath with Ecosim version 6 - Guide, User**. Lenfest Ocean Futures Project 2008, 2008.

CHRISTENSEN, V. Ecosystem maturity - towards quantification. **Ecological modelling**, v. 77, p. 3–32, 1995.

CHRISTENSEN, V. Fishery-induced changes in a marine ecosystem: insight from models of the Gulf of Thailand. **Journal of Fish Biology**, v. 53, p. 128–142, 1998.

CHRISTENSEN, V.; PAULY, D. ECOPATH II - a software for balancing steady-state ecosystem models and calculating network characteristics \*. **Ecological Modelling**, v. 61, p. 169–185, 1992.

CHRISTENSEN, V.; WALTERS, C. J. Ecopath with Ecosim: methods, capabilities and limitations. , v. 172, p. 109–139, 2004.

COLL, M.; BUNDY, A.; SHANNON, L. J. Ecosystem Modelling Using the Ecopath with Ecosim Approach. In: B. Megrey; E. Moksness (Orgs.); **Computers in Fisheries Research**. 2o ed, p.225–291, 2009. Springer.

COLL, M.; PALOMERA, I.; TUDELA, S.; DOWD, M. Food-web dynamics in the South Catalan Sea ecosystem (NW Mediterranean) for 1978–2003. **Ecological Modelling**, v. 217, n. 1–2, p. 95–116, 2008. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0304380008002925>. .

COLL, M.; PALOMERA, I.; TUDELA, S.; SARDA, F. Trophic flows, ecosystem structure and fishing impacts in the South Catalan Sea, Northwestern Mediterranean. **Journal of Marine Systems**, v. 59, p. 63–96, 2006.

COLLÉTER, M.; VALLS, A.; GUITTON, J.; et al. Global overview of the applications of the Ecopath with Ecosim modeling approach using the EcoBase models repository. **Ecological Modelling**, v. 302, p. 42–53, 2015. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecolmodel.2015.01.025>. .

CORRALES, X.; COLL, M.; TECCHIO, S.; et al. Ecosystem structure and fishing impacts in the northwestern Mediterranean Sea using a food web model within a comparative approach. **Journal of Marine Systems**, v. 148, p. 183–199, 2015. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.jmarsys.2015.03.006>. .

COX, S. P.; ESSINGTON, T. E.; KITCHELL, J. F.; et al. Reconstructing ecosystem dynamics in the central Pacific Ocean, 1952&#150;1998. II. A preliminary assessment of the trophic impacts of fishing and effects on tuna dynamics. **Canadian Journal of Fisheries and Aquatic Sciences**, v. 59, n. 11, p. 1736–1747, 2002. Disponível em: <http://www.nrcresearchpress.com/doi/10.1139/f02-138>. .

CREMER, M. J.; PINHEIRO, P. C.; SIMÕES-LOPES, P. C. Prey consumed by Guiana dolphin Sotalia guianensis (Cetacea, Delphinidae) and franciscana dolphin Pontoporia blainvillei (Cetacea, Pontoporiidae) in an estuarine environment in southern Brazil. **Iheringia. Série Zoologia**, v. 102, n. 2, p. 131–137, 2012. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S0073-47212012000200003&lng=en&tlng=en>. .

CURY, P.; SHANNON, L.; SHIN, Y. The functioning of marine ecosystems: a fisheries perspective. **Responsible fisheries in the marine ecosystem**. p.103–123, 1995. Wallingford: CABI. Disponível em: <http://www.cabi.org/cabebooks/ebook/20103194519>. .

DAME, J. K.; CHRISTIAN, R. R. Evaluation of ecological network analysis: Validation of output. **Ecological Modelling**, v. 210, n. 3, p. 327–338, 2008. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0304380007004115>. .

DAURA-JORGE, F. G.; WEDEKIN, L. L.; SIMÕES-LOPES, P. C. Feeding habits of the Guiana dolphin, Sotalia guianensis (Cetacea: Delphinidae), in Norte Bay, southern Brazil. **Scientia Marina**, v. 75, n. 1, p. 163–169, 2011. Disponível em: <http://scientiamarina.revistas.csic.es/index.php/scientiamarina/article/view/1240/1308>. .

DENADAI, M. R.; BESSA, E.; SANTOS, F. B.; et al. Life history of three catfish species (Siluriformes: Ariidae) from southeastern Brazil. **Biota Neotropica**, v. 12, n. 4, p. 74–83, 2012. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S1676-06032012000400008&lng=en&tlng=en>. .

DENADAI, M. R.; SANTOS, F. B.; BESSA, E.; et al. Feeding habits of whitemouth croaker Micropogonias furnieri (Perciformes: Sciaenidae) in Caraguatatuba Bay, southeastern Brazil. **Brazilian Journal of Oceanography**, v. 63, n. 2, p. 125–134, 2015. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S1679-87592015000200125&lng=en&tlng=en>. .

DIAS, E. **Caracterização da Comunidade de Pequenos Peixes Pelágicos e da Dieta do Predador , Caranx hippos , no Parque Nacional Marinho João Vieira Poilão ,** 2016. Universidade de Lisboa.

DU, J.; CHEUNG, W. W. L.; ZHENG, X.; et al. Comparing trophic structure of a subtropical bay as estimated from mass-balance food web model and stable isotope analysis. **Ecological Modelling**, v. 312, p. 175–181, 2015. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecolmodel.2015.05.027>. .

DUAN, L. J.; LI, S. Y.; LIU, Y.; JIANG, T.; FAILLER, P. A trophic model of the Pearl River Delta coastal ecosystem. **Ocean & Coastal Management**, v. 52, n. 7, p. 359–367, 2009. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0964569109000222>. .

DUTTA, S.; CHAKRABORTY, K.; HAZRA, S. Ecosystem structure and trophic dynamics of an exploited ecosystem of Bay of Bengal , Sundarban Estuary , India. **Fisheries Science**, v. 83, n. 2, p. 145–159, 2017a. Springer Japan.

DUTTA, S.; CHAKRABORTY, K.; HAZRA, S. Ecosystem structure and trophic dynamics of an exploited ecosystem of Bay of Bengal, Sundarban Estuary, India. **Fisheries Science**, v. 83, n. 2, p. 145–159, 2017b. Springer Japan. Disponível em: <http://link.springer.com/10.1007/s12562-016-1060-2>. .

EOL. Encyclopedia of Life. .

FERREIRA, A.; SILVA, D. A. **Variações temporais de curta escala da estrutura e dieta da ictiofauna em uma planície de maré em um estuário tropical**, 2014. Universidade Estadual da Paraíba.

FERREIRA, G. V. B. **Ecologia alimentar e distribuição espaço-temporal das diferentes fases ontogenéticas da espécie Cynoscion acoupa no estuário do Rio Goiana (PE/PB)**, 2016. Universidade Fedeal de Pernambuco.

FRANKS, J. S.; VANDERKOOY, K. E.; GARBER, N. M. Diet of Tripletail, Lobotes surinamensis, from Mississippi Coastal Waters. **Gulf and Caribbean Research**, v. 15, n. 1, p. 27–32, 2003. Disponível em: <http://aquila.usm.edu/gcr/vol15/iss1/5>. .

FREIRE, K. DE M. F. **Fishing impacts on marine ecosystems off Brazil, with emphasis on the Northeastern Region**, 2005. THE UNIVERSITY OF BRITISH COLUMBIA.

FREITAS, M. O.; ABILHÔA, V.; GIGLIO, V. J.; et al. Diet and reproduction of the goliath grouper, Epinephelus itajara (Actinopterygii: Perciformes: Serranidae), in eastern Brazil. **Acta Ichthyologica et Piscatoria**, v. 45, n. 1, p. 1–11, 2015. Disponível em: <http://www.aiep.pl/volumes/2010/6\_1/txt/txt\_01.php>. .

FROESE, R. Fishbase. **http://www.fishbase.org**, 2018.

FROESE, R.; PAULY, D. Fishbase. Disponível em: <www.fishbase.org>. Acesso em: 1/6/2018.

FUNDEPAG. http://propesq-pr.fundepag.br/usuarioexterno/. .

DA GAMA, L. M. **Ecologia trófica da ictiofauna da zona de arrrebentação da Baía de Santos - SP**, 2017. Universidade Santa Cecília.

GARCIA, S. M.; ZERBI, A.; ALIAUME, C.; DO CHI, T.; LASSERRE, G. **The Ecosystem Approach to Fisheries**. 2003.

GEERS, T. M.; PIKITCH, E. K.; FRISK, M. G. An original model of the northern Gulf of Mexico using Ecopath with Ecosim and its implications for the effects of fishing on ecosystem structure and maturity. **Deep Sea Research Part II: Topical Studies in Oceanography**, v. 129, p. 319–331, 2016. Elsevier. Disponível em: <http://dx.doi.org/10.1016/j.dsr2.2014.01.009>. .

GIANUCA, D.; BRANCO, J. O.; VOOREN, C. M. Notes on breeding by Yellow-crowned Night Heron Nyctanassa violacea in southern Brazil. **Cotinga**, v. 33, n. 1, p. 61–70, 2011.

GIANUCA, D.; GIANUCA, A. T.; VOOREN, C. M. Abundance , breeding and food of the Little Blue Heron Egretta caerulea ( Aves , Ardeidae ) in the Patos Lagoon estuary , a recently colonized area in southern Brazil. **Iheringia - Serie Zoologia**, v. 102, n. 1, p. 19–25, 2012.

GIBRAN, F. Z. Activity, habitat use, feeding behavior, and diet of four sympatric species of Serranidae (Actinopterygii: Perciformes) in southeastern Brazil. **Neotropical Ichthyology**, v. 5, n. 3, p. 387–398, 2007. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S1679-62252007000300018&lng=en&tlng=en>. .

GOMES, A. L. M. **Padrões de uso e ocorrência de aves associadas ao ambiente aquático no Complexo Estuarino de Paranaguá, Paraná, Brasil**, 2010. Universdidade Federal do Paraná.

GUILHERME, P. D. B.; ROSA, L. C. Seasonal variation in body size and diet of the sea star Astropecten marginatus ( Paxillosida , Astropectinidae ) off coast of Paraná , Southern Brazil. **Revista de Biologia Tropical**, v. 62, n. March, p. 1–10, 2014.

HAN, R.; CHEN, Q.; WANG, L.; TANG, X. Preliminary investigation on the changes in trophic structure and energy flow in the Yangtze estuary and adjacent coastal ecosystem due to the Three Gorges Reservoir. **Ecological Informatics**, v. 36, p. 152–161, 2016. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecoinf.2016.03.002>. .

HANNON, B. The structure of ecosystems. **Journal of Theoretical Biology**, v. 41, p. 535–546, 1973.

HATTAB, T.; LASRAM, F. B. R.; ALBOUY, C.; et al. An ecosystem model of an exploited southern Mediterranean shelf region (Gulf of Gabes, Tunisia) and a comparison with other Mediterranean ecosystem model properties. **Journal of Marine Systems**, v. 128, p. 159–174, 2013.

HEYMANS, J. J. **Ecosystem Models of Southeastern Labrador: Newfoundland and Additional information and analyses for ‘Back to the Future’**. Vancouver, Canadá, 2003.

HEYMANS, J. J.; COLL, M.; LINK, J. S.; et al. Best practice in Ecopath with Ecosim food-web models for ecosystem-based management. **Ecological Modelling**, v. 331, p. 173–184, 2016a. Elsevier B.V.

HEYMANS, J. J.; COLL, M.; LINK, J. S.; et al. Best practice in Ecopath with Ecosim food-web models for ecosystem-based management. **Ecological Modelling**, v. 331, p. 173–184, 2016b. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecolmodel.2015.12.007>. .

HEYMANS, J. J.; GUÉNETTE, S.; CHRISTENSEN, V. Evaluating Network Analysis Indicators of Ecosystem Status in the Gulf of Alaska. **Ecosystems**, v. 10, n. 3, p. 488–502, 2007. Disponível em: <http://link.springer.com/10.1007/s10021-007-9034-y>. .

HEYMANS, S. J. J.; CHRISTENSEN, V.; TRITES, A. W. Ecosystem Models of the Aleutian Islands and Southeast Alaska Show that Steller Sea Lions are Impacted by Killer Whale Predation when Sea Lion Numbers are Low. , p. 2000–2004, 2005.

HÖFLING, J. C.; FERREIRA, L.; RIBEIRO NETO, F. N.; PAIVA FILHO, A. M.; DA SILVA, M. S. R. Fish alimentation of the Carangidae family of the estuarine lagoon complex in Cananéia, São Paulo, Brazil. **Bioikos**, v. 12, n. 2, p. 7–18, 1998.

HOFLING, J.; FERREIRA, L.; RIBEIRO NETO, F.; et al. Fish alimentation of the Clupeidae family of the estuarine lagoon complex in Cananeia, Sao Paulo, Brazil. **NOTAS TÉC. FACIMAR**, v. 14, n. 2, p. 12–20, 2008. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S0101-81752008000100002&lng=pt&tlng=pt>. .

ICMBIO. Áreas de exclusão da pesca. <http://www.icmbio.gov.br/cepsul/areas-protegidas/area-de-exclusao-a-pesca.html>, acessado em 14/01/2017.

INNES, B. Y. S.; LAVIGNE, D. M.; EARLE, W. M.; KOVACS, K. M. Feeding Rates of Seals and Whales. **Journal of Animal Ecology**, v. 56, n. 1, p. 115–130, 1987.

JACOBSEN, I. P.; BENNETT, M. B. A Comparative Analysis of Feeding and Trophic Level Ecology in Stingrays (Rajiformes ; Myliobatoidei) and Electric Rays (Rajiformes : Torpedinoidei). **plos one**, v. 8, n. 8, 2013.

JENNINGS, S.; KAISER, M. J. The Effects of Fishing on Marine Ecosystems. **Advances in Marine Biology**. v. 34, p.201–352, 1998. Elsevier Masson SAS. Disponível em: <http://dx.doi.org/10.1016/S0065-2881(08)60212-6>. .

JÚNIOR, M. N.; HADDAD, M. A. The diet of cubomedusae (cnidaria, cubozoa) in southern Brazil. **Brazilian Journal of Oceanography**, v. 56, n. 3, p. 157–164, 2008.

KAMPEL, M. **Estimativa da produção primária e biomassa fitoplanctônica através de sensoriamento remoto da cor do oceano e dados in situ na costa sudeste Brasileira**, 2003. Universidade de São Paulo.

KRUMME, U.; KEUTHEN, H.; BARLETTA, M.; SAINT-PAUL, U.; VILLWOCK, W. Resuspended Intertidal Microphytobenthos As Major Diet Component of Planktivorous Atlantic Anchoveta Cetengraulis Edentulus (Engraulidae) From Equatorial Mangrove Creeks. **Ecotropica**, v. 14, p. 121–128, 2008.

LANA, P. C.; MARONE, E.; LOPES, R. M.; MACHADO, E. C. The Subtropical Estuarine Complex of Paranaguá Bay, Brazil. In: U. Seeliger; B. Kjerfve (Orgs.); **Coastal Marine Ecosystems of Latin America**. p.131–145, 2001. Berlin, Heidelberg: Springer Berlin Heidelberg. Disponível em: <http://dx.doi.org/10.1007/978-3-662-04482-7\_11>. .

LARKIN, P. A. Larkin 1996. Concepts and issues in marine ecosystem management.pdf. **Reviews in Fish Biology and Fisheries**, v. 164, n. 6, p. 139–164, 1996.

LAURETTA, M. V.; CAMP, E. V.; EARL, W.; III, P.; FRAZER, T. K. Catchability model selection for estimating the composition of fishes and invertebrates within dynamic aquatic ecosystems. **Canadian Journal of Fisheries Aquatic Science**, v. 392, n. January, p. 381–392, 2013.

LEBLANC, K.; AR, J.; ARMAND, L.; et al. A global diatom database - abundance , biovolume and biomass in the world ocean To cite this version : A global diatom database – abundance , biovolume and. , 2012.

LERCARI, D.; HORTA, S.; MARTÍNEZ, G.; CALLIARI, D.; BERGAMINO, L. A food web analysis of the Río de la Plata estuary and adjacent shelf ecosystem: trophic structure, biomass flows, and the role of fisheries. **Hydrobiologia**, v. 742, n. 1, p. 39–58, 2015a. Disponível em: <http://link.springer.com/10.1007/s10750-014-1964-8>. .

LERCARI, D.; HORTA, S.; MARTÍNEZ, G.; CALLIARI, D.; BERGAMINO, L. A food web analysis of the Río de la Plata estuary and adjacent shelf ecosystem: trophic structure, biomass flows, and the role of fisheries. **Hydrobiologia**, v. 742, n. 1, p. 39–58, 2015b. Disponível em: <http://link.springer.com/10.1007/s10750-014-1964-8>. .

LIBRALATO, S.; CHRISTENSEN, V.; PAULY, D. A method for identifying keystone species in food web models. **Ecological Modelling**, v. 195, n. 3–4, p. 153–171, 2006. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0304380005006149>. .

LIBRALATO, S.; COLL, M.; TEMPESTA, M.; et al. Food-web traits of protected and exploited areas of the Adriatic Sea. **Biological Conservation**, v. 143, n. 9, p. 2182–2194, 2010. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0006320710002685>. .

LIBRALATO, S.; COLL, M.; TUDELA, S.; PALOMERA, I.; PRANOVI, F. Novel index for quantification of ecosystem effects of fishing as removal of secondary production. , v. 355, p. 107–129, 2008.

LIN, H. J.; SHAO, K. T.; JAN, R. Q.; et al. A trophic model for the Danshuei River Estuary, a hypoxic estuary in northern Taiwan. **Marine Pollution Bulletin**, v. 54, n. 11, p. 1789–1800, 2007a.

LIN, H. J.; SHAO, K. T.; JAN, R. Q.; et al. A trophic model for the Danshuei River Estuary, a hypoxic estuary in northern Taiwan. **Marine Pollution Bulletin**, v. 54, n. 11, p. 1789–1800, 2007b.

LINDEMAN, R. L. The trophic-dynamic aspect of ecology. **Ecology**, v. 4, n. 1–2, p. 399–417, 1942. Disponível em: <http://link.springer.com/10.1007/BF02464428>. .

LINK, J. S. Adding rigor to ecological network models by evaluating a set of pre-balance diagnostics: A plea for PREBAL. **Ecological Modelling**, v. 221, n. 12, p. 1580–1591, 2010. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecolmodel.2010.03.012>. .

LIRA, A.; ANGELINI, R.; LE LOC’H, F.; et al. Trophic flow structure of a neotropical estuary in northeastern Brazil and the comparison of ecosystem model indicators of estuaries. **Journal of Marine Systems**, v. 182, n. August 2017, p. 31–45, 2018. Elsevier. Disponível em: <https://doi.org/10.1016/j.jmarsys.2018.02.007>. .

MACHADO LEONARDO, F.; FELIPPE A M L, D.; ATHILA ANDRADE, B.; MAURICIO, H.-SI.; JOÃO PEDRO, B. Feeding strategy and trophic ontogeny in Epinephelus marginatus (Serranidae) from Southern Brazil. **Cybium**, v. 32, n. 1, p. 9, 2008.

MARONE, E.; MACHADO, E. C.; LOPES, R. M.; DA SILVA, E. T. Land-ocean fluxes in the Paranaguá Bay estuarine system, southern Brazil. **Brazilian Journal of Oceanography**, v. 53, n. 3–4, p. 169–181, 2005. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S1679-87592005000200007&lng=en&tlng=en>. .

MARSHALL, C. Encyclopedia of Life. .

MARTINS, A. S.; HAIMOVICI, M.; PALACIOS, R. Diet and feeding habitat of the cutlassfish Trichiurus lepturus in the Subtropical Convergence Ecosystem of southern Brazil. **J. Mar. Biol. Ass. U.K.**, v. 85, p. 1223–1229, 2005.

MEDEIROS, R. P.; GUANAIS, J. H. D. G.; SANTOS, L. DE O.; et al. Estratégias para a redução da fauna acompanhante na frota artesanal de arrasto do camarão sete-barbas: Perspectivas para a gestão pesqueira. **Boletim do Instituto de Pesca**, v. 39, n. 3, p. 339–358, 2013.

MENDENHALL, K. S. **Diet of black drum (Pogonias cromis) based on stable isotope and stomach content analyses**, 2015. TEXAS A&M UNIVERSITY-CORPHUS CHRISTI.

MENDOZA-CARRANZA, M.; VIEIRA, J. Whitemouth croaker Micropogonias furnieri (Desmarest, 1823) feeding strategies across four southern Brazilian estuaries. **Aquatic Ecology**, v. 42, n. 1, p. 83–93, 2008. Disponível em: <http://link.springer.com/10.1007/s10452-007-9084-4>. .

MIOTTO, M. L. **ASPECTOS ALIMENTARES DA GAIVOTA, Larus dominicanus: VARIAÇÃO SAZONAL E INFLUÊNCIA DO DEFESO**, 2015. Universidade Federal do Paraná.

MIRANDA, A. V. DE. **Estimativa de densidade e tamanho populacional de botos- cinza, Sotalia guianensis (van Bénéden, 1864), no complexo estuarino de Paranaguá, Paraná**, 2017. Universidade Federal do Paraná.

MÓRÉH, Á.; ENDRÉDI, A.; JORDÁN, F. Additivity of pairwise perturbations in food webs: Topological effects. **Journal of Theoretical Biology**, v. 448, p. 112–121, 2018. Disponível em: <https://linkinghub.elsevier.com/retrieve/pii/S0022519318301693>. .

MORISSETTE, L. **Complexity, cost and quality of ecosystem models and their impacts on resilience: A comparative analysis, with emphasis on marine mammals and the Gulf of St. Lawrence**, 2007. University of British Columbia.

MUTO, E. Y.; MALFARA, D. T.; COELHO, L. I.; SOARES, L. S. H. Alimentação das sardinhas Pelloona harroweri (Fowler, 1919) e Chirocentrodon bleekerianus (Poey, 1867), região costeira de santos, Estado de SãPaulo. **Oceanografia e Mudanças Globais**. p.287–302, 2008.

NIANG, T. M. S.; PESSANHA, A. L. M.; ARAÚJO, F. G. Dieta de juvenis de Trachinotus carolinus (Actinopterygii, Carangidae) em praias arenosas na costa do Rio de Janeiro. **Iheringia. Série Zoologia**, v. 100, n. 1, p. 35–42, 2010. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S0073-47212010000100005&lng=pt&tlng=pt>. .

NILSSON, S. G.; NILSSON, I. N. food consumption , and fish Numbers , by birds predation in Lake Mdckeln , southern Sweden. **Ornis Scandinavica**, v. 7, n. 1, p. 61–70, 1976.

ODUM, EUGENE P. The Strategy of Ecosystem Development. **Science**, v. 164ODUM, E, p. 262–270, 1969.

ODUM, E.P. Strategy of Ecosystem Development. **Science**, v. 164, n. 3877, p. 262–270, 1969.

OLIVEIRA, I. DA R.; SOARES, L. S. H. Alimentação da Tainha Mugil platanus Günther, 1880 (Pisces: Mugilidae) da região estuarino-lagunar de Cananéia, São Paulo, Brazil. **Boletim do Instituto de Pesca**, v. 23, n. único, p. 95–104, 1996.

OPITZ, S. **Trophic Interactions in Caribbean Coral Reefs**. ICKARM Tec ed. Manila, Phillippines: ICLARM Tech., 1996.

PALOMARES, M. L. D.; PAULY, D. Predicting food consumption of fish populations. **Marine Freshwater Resource**, v. 49, p. 447–453, 1998.

PARANÁ, P. DO. **Relatório Semestral dos Programas Ambientais**. 2019.

PASSOS, A. C. DOS; CONTENTE, R. F.; COLODETTI, C. V. DE A.; et al. Fishes of Paranaguá Estuarine Complex , South West Atlantic Fishes of Paranaguá Estuarine Complex , South West Atlantic. , v. 12, n. 3, p. 226–238, 2012.

PAULY, D. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. **ICES Journal of Marine Science**, v. 39, n. 2, p. 175–192, 1980. Disponível em: <https://academic.oup.com/icesjms/article-lookup/doi/10.1093/icesjms/39.2.175>. .

PAULY, D. Fishing Down Marine Food Webs. **Science**, v. 279, n. 5352, p. 860–863, 1998. Disponível em: <https://www.sciencemag.org/lookup/doi/10.1126/science.279.5352.860>. .

PAULY, D.; GRAHAM, W.; LIBRALATO, S.; MORISSETTE, L.; DENG PALOMARES, M. L. Jellyfish in ecosystems, online databases, and ecosystem models. **Hydrobiologia**, v. 616, n. 1, p. 67–85, 2009. Disponível em: <http://link.springer.com/10.1007/s10750-008-9583-x>. .

PAULY, D.; VILLY, C. Primary production required to sustain global fisheries. **Nature**, v. 376, p. 255–257, 1995.

PHILIPPSEN, J. S.; MINTE-VERA, C. V.; COLL, M.; ANGELINI, R. Assessing fishing impacts in a tropical reservoir through an ecosystem modeling approach. **Reviews in Fish Biology and Fisheries**, v. 29, n. 1, p. 125–146, 2019. Springer International Publishing. Disponível em: <https://doi.org/10.1007/s11160-018-9539-9>. .

PIRODDI, C.; COLL, M.; LIQUETE, C.; et al. Historical changes of the Mediterranean Sea ecosystem: modelling the role and impact of primary productivity and fisheries changes over time. **Scientific Reports**, v. 7, n. 1, p. 44491, 2017. Nature Publishing Group. Disponível em: <http://dx.doi.org/10.1038/srep44491>. .

PLAGÁNYI, É. E. **Models for an ecosystem approach to fisheries**. Rome, 2007.

POLOVINA, J. J. Coral Reefs Model of a Coral Reef Ecosystem. **Coral Reefs**, v. 3, p. 1–11, 1984.

POSSATO, F. E. **Ecologia alimentar nas diferentes fases ontogenéticas de**, 2010. Universidade Federal de Pernambuco.

POSSATO, F. E. **Composição, estrutura e abundância da ictiofauna capturada com redes de arrasto de portas na plataforma continental interna do Litoral do Paraná**, 2015. Universidade Federal do Paraná.

POSSATTO, F. E.; BROADHURST, M. K.; GRAY, C. A.; SPACH, H. L.; LAMOUR, M. R. Spatiotemporal variation among demersal ichthyofauna in a subtropical estuary bordering World Heritage-listed and marine protected areas: Implications for resource management. **Marine and Freshwater Research**, v. 68, n. 4, p. 703–717, 2017.

RABELO, L. B.; MUTO, E. Y.; SATIKO, L.; SOARES, H. Observações preliminares sobre o hábito alimentar do robalo-flecha Centropomus undecimalis ( BLOCH , 1792 ) E ROBALO-PEBA Centropomus parallelus POEY , 1860 , no Estuário de Caravelas ( Bahia , Brasil ). **Boletim Técnico Científico Cepene**, v. 17, n. 1, p. 89–96, 2009.

RABITTO, I. DA S.; ABILHÔA, V. A alimentação do bagre Genidens genidens Valenciennes, 1839 em um banco areno-lodoso da Ilha do Mel, Paraná, Brasil. **Arq. ciên. vet. zool. UNIPAR**, 1999.

REGINA DENADAI, M.; BORGES SANTOS, F.; BESSA, E.; SILVA FERNANDEZ, W.; TURRA, A. Population Biology and Diet of the Pompano Trachinotus carolinus (Perciformes: Carangidae) in Caraguatatuba Bay, Southeastern Brazil. **Journal of Marine Biology & Oceanography**, v. 02, n. 02, p. 1947–1954, 2013. Disponível em: <http://www.scitechnol.com/2324-8661/2324-8661-2-108.php>. .

REIS-FILHO, J. A.; GIARRIZZO, T. Microgobius meeki as a potential bio-indicator of habitat disturbance in shallow estuarine areas: a useful tool for the assessment of estuarine quality. **Journal of Fish Biology**, v. 89, n. 1, p. 713–734, 2016. Disponível em: <http://doi.wiley.com/10.1111/jfb.13007>. .

RONDINELI, G. R.; BRAGA, F. M. DE S.; TUTUI, S. L. DOS S.; BASTOS, G. C. C. Dieta de Menticirrhus americanus (Linnaeus, 1758) e Cynoscion jamaicensis (Vaillant e Bocourt, 1883)(Pisces, Sciaenidae) no sudeste do Brasil, Estado de São Paulo. **Bol. Inst. Pesca**, v. 33, n. 2, p. 221–228, 2007.

ROSAS, F. C. W.; BARRETO, A. S.; MONTEIRO-FILHO, EMYGDIO L. A. Age and growth of the estuarine dolphin (Sotalia guianensis) (Cetacea, Delphinidae) on the Parana coast, southern Brazil. **Fishery Bulletin**, v. 101, n. 2, p. 377–383, 2003.

ROSAS, F. C. W.; BARRETO, A. S.; MONTEIRO-FILHO, EMYGDIO L A. Age and growth of the estuarine dolphin (Sotalia guianensis) (Cetacea, Delphinidae) on the Parana coast, southern Brazil. **Fishery Bulletin**, v. 101, n. 2, p. 377–383, 2003.

RYBARCZYK, H.; ELKAIM, B. An analysis of the trophic network of a macrotidal estuary: the Seine Estuary (Eastern Channel, Normandy, France). **Estuarine, Coastal and Shelf Science**, v. 58, n. 4, p. 775–791, 2003. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0272771403001847>. .

SASAKI, G. **Uso de habitat pelo boto-cinza, Sotalia guianensis) (Van bénéden, 1864), na região próxima à desembocadura sul da Baía de Paranaguá, Litoral do Estado do Paraná**, 2010. Universidade Federal do Paraná.

SCOTT, E.; SERPETTI, N.; STEENBEEK, J.; HEYMANS, J. J. A Stepwise Fitting Procedure for automated fitting of Ecopath with Ecosim models. **SoftwareX**, v. 5, p. 25–30, 2016. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.softx.2016.02.002>. .

SERRANO, I. D. L.; AZEVEDO JÚNIOR, S. M. DE. Dietas das aves marinhas no Parque Nacional dos Abrolhos, Bahia, Brasil. **Ornithologia**, v. 1, n. 1, p. 75–92, 2005.

SHANNON, L. J.; MOLONEY, C. L.; JARRE, A.; FIELD, J. G. Trophic flows in the southern Benguela during the 1980s and 1990s. **Journal of Marine Systems**, v. 39, n. 1–2, p. 83–116, 2003.

SHEAVES, M.; BAKER, R.; NAGELKERKEN, I.; CONNOLLY, R. M. True Value of Estuarine and Coastal Nurseries for Fish: Incorporating Complexity and Dynamics. **Estuaries and Coasts**, v. 38, n. 2, p. 401–414, 2015. Disponível em: <http://link.springer.com/10.1007/s12237-014-9846-x>. .

SHINOZAKI-MENDES, R. A.; LESSA, R. Population dynamics of Callinectes danae Smith, 1869 (Brachyura: Portunidae) in a tropical estuary. **Journal of Crustacean Biology**, v. 37, n. 6, p. 683–692, 2017. Disponível em: <http://academic.oup.com/jcb/article/37/6/683/4210263>. .

SILVA, J. T. O.; LOPES, P. R. D. Notas sobre a alimentação e morfologia do aparelho digestivo de Chloroscombrus chrysurus ( Linnaeus , 1766 ) ( Actinopterygii , Carangidae ) na Praia de Ponta da Ilha ( Ilha de Itaparica , Bahia ). **Revista brasileira de Zoociências, Juiz de Fora**, v. 4, n. 2, p. 179–192, 2002.

SILVANO, R. A. M. Feeding habits and interspecific feeding associations of Caranx latus (Carangidae) in a subtropical reef. **Environmental Biology of Fishes**, v. 60, n. 4, p. 465–470, 2001.

SOMMER, U.; CHARALAMPOUS, E.; SCOTTI, M.; MOUSTAKA-GOUNI, M. Big fish eat small fish: Implications for food chain length? **Community Ecology**, v. 19, n. 2, p. 107–115, 2018.

SPACH, HENRY L.; GODEFROID, R. S.; SANTOS, C.; SCHWARZ JR., R.; QUEIROZ, G. M. L. DE. Temporal variation in fish assemblage composition on a tidal flat. **Brazilian Journal of Oceanography**, v. 52, n. 1, p. 47–58, 2004.

SPACH, HENRY L; GODEFROID, R. S.; SANTOS, C.; SCHWARZ JR., R.; QUEIROZ, G. M. L. DE. Temporal variation in fish assemblage composition on a tidal flat. **Brazilian Journal of Oceanography**, v. 52, n. 1, p. 47–58, 2004.

STEENBEEK, J.; BUSZOWSKI, J.; CHRISTENSEN, V.; et al. Ecopath with Ecosim as a model-building toolbox: Source code capabilities, extensions, and variations. **Ecological Modelling**, v. 319, p. 178–189, 2016. Elsevier B.V. Disponível em: <http://dx.doi.org/10.1016/j.ecolmodel.2015.06.031>. .

STRICKLAND, J. D. H. **Measuring the Production of Marine Phytoplankton**. 1960.

STRIEDER PHILIPPSEN, J.; MINTE-VERA, C. V.; OKADA, E. K.; CARVALHO, A. R.; ANGELINI, R. Fishers’ and scientific histories: an example of consensus from an inland fishery. **Marine and Freshwater Research**, v. 68, n. 5, p. 980, 2017. Disponível em: <http://www.publish.csiro.au/?paper=MF16053>. .

THOMPSON, G.; FORTUNATO, R. C.; CHIESA, I.; VOLPEDO, A. Trophic ecology of Mugil liza at the southern limit of its distribution (Buenos Aires, Argentina). **Brazilian Journal of Oceanography**, v. 63, n. 3, p. 271–277, 2015. Disponível em: <http://www.scielo.br/scielo.php?script=sci\_arttext&pid=S1679-87592015000300271&lng=en&tlng=en>. .

TOMCZAK, M. T.; MÜLLER-KARULIS, B.; JÄRV, L.; et al. Analysis of trophic networks and carbon flows in south-eastern Baltic coastal ecosystems. **Progress in Oceanography**, v. 81, n. 1–4, p. 111–131, 2009. Elsevier Ltd. Disponível em: <http://dx.doi.org/10.1016/j.pocean.2009.04.017>. .

TONINI, W. C. T.; BRAGA, L. G. T.; VILA NOVA, D. L. D. Dieta de juvenis de robalo Centropomus parallelus Poey, 1860 no sul da Bahia, Brasil. **Boletim do Instituto de Pesca**, v. 33, n. 1, p. 85–91, 2007.

TROCHTA, J. T.; PONS, M.; RUDD, M. B.; et al. Ecosystem-based fisheries management: Perception on definitions, implementations, and aspirations. **PLoS ONE**, v. 13, n. 1, p. 1–9, 2018.

ULANOWICZ, ROBERT E. **Growth and Development**. New York, NY: Springer New York, 1986.

ULANOWICZ, ROBERT E. **Growth and Development**. New York, NY: Springer New York, 1986.

ULANOWICZ, R. E.; ABARCA-ARENAS, L. G. An informational synthesis of ecosystem structure and function. **Ecological Modelling**, v. 95, p. 1–10, 1997.

ULANOWICZ, R. E.; PUCCIA, C. J. Mixed Trophic Impacts in Ecosystems. **Coenoses**, v. 5, n. I, p. 7–16, 1987.

VASCONCELLOS, M.; MACKINSON, S.; SLOMAN, K.; PAULY, D. The stability of troophic mass-balance models of marine ecosystems: a comparative analys. **Ecological Modelling**, v. 100, p. 125–134, 1997.

VASCONCELOS FILHO, A. DE L.; NEUMANN-LEITÃO, S.; ESKINAZI-LEÇA, E.; OLIVEIRA, A. M. E. DE; PORTO-NETO, F. DE F. Hábitos alimentares de consumidores primários da ictiofauna do sistema estuarino de Itamaracá (Pernambuco - Brasil). **Revista Brasileira de Engenharia de Pesca**, v. 4, n. 1, p. 21–31, 2009.

VENDEL, A. L.; SPACH, H. L.; LOPES, S. G.; SANTOS, C. Structure and dynamics of fish assemblages in a tidal creek environment. **Brazilian Archives of Biology and Technology**, v. 45, n. 3, p. 365–373, 2002.

VILLELA, M. J.; COSTA, P. A. S.; VALETINI, J. L. Crescimento e mortalidade de juvenis do camarão-rosa (Penaeus brasiliensis Latreille, 1817) na Lagoa de Araruama, Rio de Janeiro. **Revista Brasileira de Biologia**, v. 57, n. 3, p. 487–499, 1997.

WALSH, J. J. Shelf-sea ecosystems. In: A. R. Longhurst (Org.); **Analysis of Marine Ecosystems**. p.159–196, 1981. London: Academic Press.

WALTERS, C.; CHRISTENSEN, V.; PAULY, D. Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. **Reviews in Fish Biology and Fisheries**, v. 7, p. 139–172, 1997.

WALTERS, C.; MARTELL, S. J. D.; CHRISTENSEN, V.; MAHMOUDI, B. An ecosim model for exploring gulf of mexico ecosystem management options: implications of including multistanza life- history models for policy predictions. **Bulletin of Marine Science**, v. 83, n. 1, p. 251–271, 2008.

WALTERS, C.; MARTELL, S. J. D.; VILLY, C.; MAHMOUDI, B. An Ecosim model for exploring Gulf of Mexico ecosystem management options: Implications of including multistanza life-history models for policy predictions. **Bulletin of Marine Science**, v. 83, n. 1, p. 251–271, 2008.

WALTERS, C.; PAULY, D.; CHRISTENSEN, V. Ecospace : Prediction of Mesoscale Spatial Patterns in Trophic Relationships of Exploited Ecosystems , with Emphasis on the Impacts of Marine Protected Areas. , p. 539–554, 1999.

WIKIAVES. WikiAves, a Enciclopédia das Aves do Brasil. .

WINIK, S.; CARNEIRO, M. H.; MENDONCA, J. T. Alimentação da guaivira Oligoplites saliens (Bloch, 1793) (Perciformes: Carangidae) Proveniente da pesca na Região de Cananéia-SP. **Série Relatórios Técnicos**, v. 27, p. 1–13, 2007.

WOLFF, M. Biomass flow structure and resource potential of two mangrove estuaries : insights from comparative modelling in Costa Rica and Brazil. , v. 54, n. September, p. 69–86, 2006.

WOLFF, M.; KOCH, V.; ISAAC, V. A Trophic Flow Model of the Caeté Mangrove Estuary (North Brazil) with Considerations for the Sustainable Use of its Resources. **Estuarine, Coastal and Shelf Science**, v. 50, n. 6, p. 789–803, 2000. Disponível em: <http://linkinghub.elsevier.com/retrieve/pii/S0272771400906115>. .

XAVIER, J. H. DE A. **Teia trófica e fluxo de energia no Estuário do Rio Mamanguape, Paraíba, Brasil**, 2013. Universidade Federal da Paraíba.

XU, S.; CHEN, Z.; LI, S.; HE, P. Modeling Trophic Structure and Energy Flows in a Coastal Artificial Ecosystem Using Mass-Balance Ecopath Model. **Estuaries and Coasts**, v. 34, n. 2, p. 351–363, 2011. Disponível em: <http://link.springer.com/10.1007/s12237-010-9323-0>. .

ZANELATTO, R. C. **Dieta do boto-cinza, Sotalia fluviatilis (Cetacea, Delphinidae), no Complexo Estuarino de Paranaguá e sua relação com a ictiofauna estuarina**, 2001. Universidade Federal do Paraná.

ZANLORENZI, D.; CHAVES, P. D. T. Alimentação de Ctenogobius shufeldti (Jordan e Eigenmann, 1887) (Teleostei, Gobiidae) na Baía de Guaratuba, Atlântico oeste subtropical doi:10.5007/2175-7925.2011v24n1p37. **Biotemas**, v. 24, n. 1, p. 37–46, 2011. Disponível em: <http://www.periodicos.ufsc.br/index.php/biotemas/article/view/18109>. .