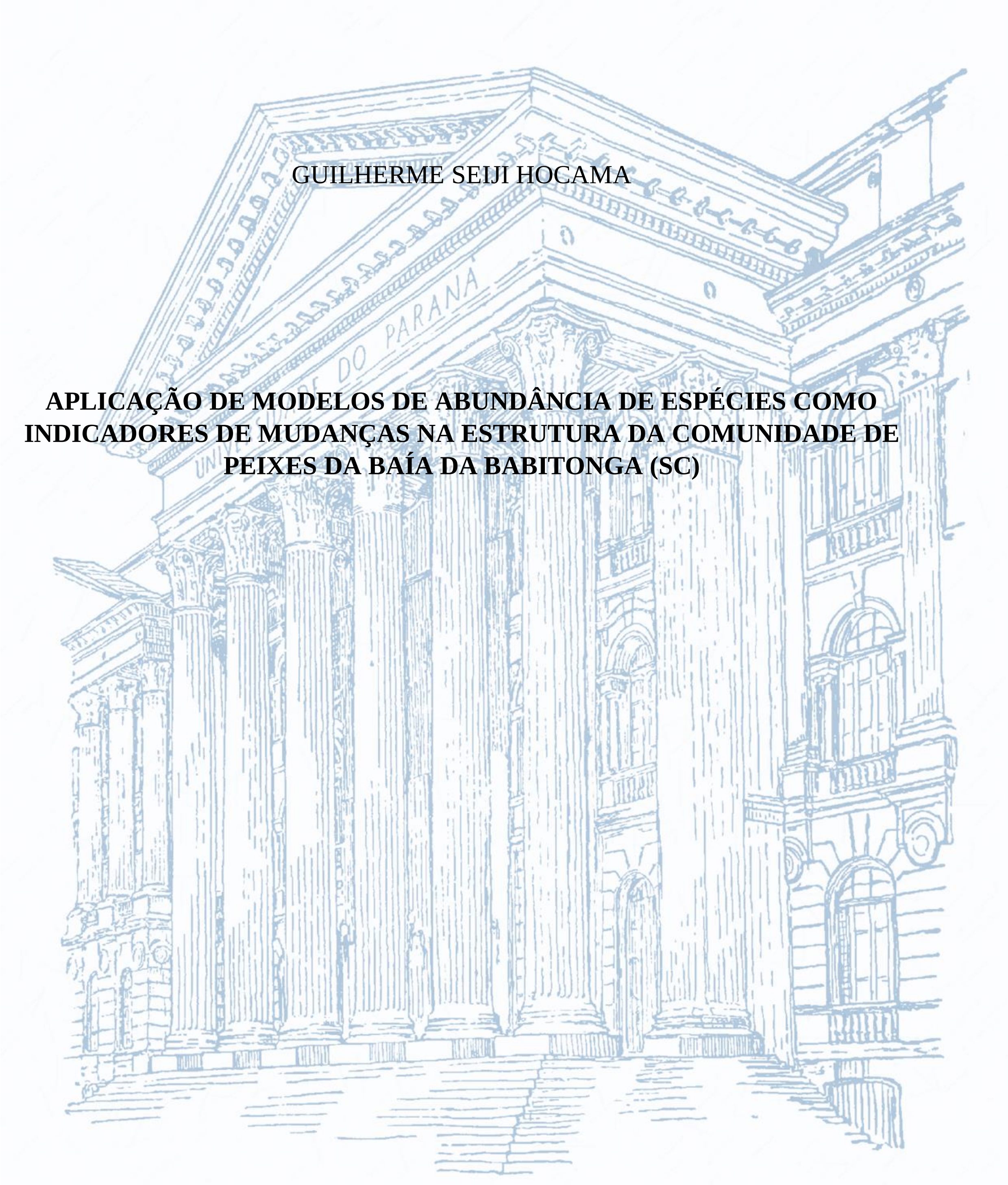
UNIVERSIDADE FEDERAL DO PARANÁ
CENTRO DE ESTUDOS DO MAR
PÓS-GRADUAÇÃO EM SISTEMAS COSTEIROS E OCEÂNICOS



GUILHERME SEIJI HOCAMA

APLICAÇÃO DE MODELOS DE ABUNDÂNCIA DE ESPÉCIES COMO INDICADORES DE MUDANÇAS NA ESTRUTURA DA COMUNIDADE DE PEIXES DA BAÍA DA BABITONGA (SC)

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Dissertação apresentada como requisito parcial à obtenção do grau de Mestre em Sistemas Costeiros e Oceânicos, do Centro de Estudos do Mar, Universidade Federal do Paraná.
Orientador: Maurício G. de Camargo.

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TERMO DE APROVAÇÃO

Guilherme Seiji Hocama

Aplicação de modelos de abundância de espécies como indicadores de mudanças na estrutura da comunidade de peixes da Baía da Babitonga (SC)

Dissertação aprovada como requisito parcial para a obtenção do grau de Mestre(a) em Sistemas Costeiros e Oceânicos, da Universidade Federal do Paraná, pela Comissão formada pelos professores:

Dr. Maurício Garcia de Camargo (UFPR/CEM)
Orientador e Presidente

Dr. Henry Louis Spach (UFPR/CEM)
Membro Examinador

Dr. Alexandre Miranda Garcia (FURG)
Membro Examinador

Pontal do Paraná,23/03/2015.

Most people say that it is the intellect which makes a great scientist.
They are wrong: it is character.
Albert Einstein

Words, in my humble opinion, are the most inexhaustible source of magic we have.

J.K. Rowling

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Aos meus pais.

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Aos *Amiégos* e os *Bando de à toas.*

#pgsiscolifestyle

RESUMO

Um dos principais objetivos da ecologia é entender como as espécies se distribuem, tanto espacialmente quanto temporalmente. Descobrir os padrões de distribuição da riqueza e abundância é um passo essencial para esse entendimento. A observação de espécies raras e comuns dentro de um mesmo ambiente é um dos padrões mais recorrente encontrado na ecologia. Conhecê-las e entender o porquê desse padrão é um passo fundamental para a proteção ambiental. Os modelos de Distribuição de Abundância de Espécies aparecem como ferramenta indispensável, uma vez que são capazes de descrever matematicamente a maioria das nuances intrínsecas das comunidades, demonstradas numa curva. A tentativa de explicar essas curvas tem sido um tema central em ecologia teórica, mas ainda sem consenso formal entre pesquisadores. Coletas foram realizadas entre os anos de 2005 a 2008 ao longo de todo o gradiente ambiental da Baia da Babitonga, litoral norte de Santa Catarina, Sul do Brasil. Foram utilizadas seis tipos de rede que foram capazes de amostrar com sucesso a ictiofauna da Baia, como mostrado pela curva de rarefação. Para a modelagem, foram utilizados quatro diferentes modelos, buscando encontrar qual seria o responsável por ilustrar a distribuição da comunidade de peixes de forma mais eficaz. Foram eles: o modelo normal-logarítmico, a série-logarítmica, o de metacomunidade e o de vara-quebrada. Foram realizadas análises de agrupamento e discriminantes para auxiliar nas inferências. Todas as análises foram realizadas no *ambiente R*, com os pacotes *sads* e *vegan*. Para as análises espaciais, o modelo normal-logarítmico foi o elencado, para todas as áreas. Para a análise temporal, novamente o modelo normal-logarítmico foi o elencado, porém, em 2006, o modelo de série-logarítmica e o de metacomunidade também foram escolhidos. Para as análises de guildas, os estuarinos residentes e zooplanctívoros mostraram distribuição metacomunidade e séries-logarítmica; migrantes marinhos, piscívoros e zoobentívoros apresentaram distribuição normal-logarítmica e os marinhos-visitantes distribuição normal-logarítmica, série-logarítmica e metacomunidade. O resultado mostrou que a Baía da Babitonga possui uma comunidade em equilíbrio e pouco impactada, com grande abundância de espécies marinhas, quase igual ao número de espécies estuarinas. O resultado das guildas indica que processos diferentes atuam dentro de escalas menores, como corroborado pelas análises multivariadas, onde os índices ecológicos estavam relacionadas às guildas mais abundantes e com mais espécies. Estudos que avaliem a variação da biomassa são necessários, assim como analises dos parâmetros dos modelos elencados.

Palavras-chave: Estuário subtropical, ictiofauna, normal-logarítmico, ecologia estuarina

ABSTRACT

One of the main goal on ecology is to understand how species are distributed, both spatially and temporally. Unveil the distribution patterns of richness and abundances are essential steps to achieve it. Observation of rare and common species within an ecosystem is one of the most recurrent pattern found on natural communities, and understand why this pattern occurs, is essential for preservation. Species Abundance Distributions (SAD) models are a fundamental tool, once they are able to describe mathematically almost all nuances of each community, showed on a distribution curve. Attempts to explain these curves has been a central theme of theoretical ecology, but with no formal agreement between researcher ecologists. Surveys occurred between years 2005 and 2008, along an environmental gradient of Babitonga Bay, north littoral of Santa Catarina state, South of Brazil. Six different seine nets were utilized, being able to success capture the Bay's diversity, as showed on rarefaction curve. Four different models get tested, trying to identify which is the responsible for accurate representation of fish community distribution, following: lognormal, logseries, matacommunity and broken-stick models. Cluster and discriminant analysis were used to help on inferences. All analyzes were performed on *R Program* with packages *sads* and *vegan*. For spatial analysis, the lognormal model was the chose for all areas. For temporal analysis, lognormal model was also the chosen one, however for year 2006, logseries and metacommunity models were also chosen. For the analysis of guilds, residents, estuarine and zooplanktivore showed metacommunity and logseries distribution; marine-migrants, piscivore and zoobenthivore had lognormal distribution and marine-stragglers lognormal, logseries and metacommunity distribution. The results showed that Babitonga Bay has a balanced community and little anthropogenic affected, with large numbers of marine species, almost equal to the number of estuarine ones. The result of guilds indicates that different processes act in smaller scales, as evidenced by the multivariate analysis, where the ecological indices were related to more abundant and richer guilds. Studies assessing the change in biomass are required, as well as analysis of the parameters of chose guilds models.

Key-worlds: Babitonga Bay, ichtyofauna, lognormal

SUMÁRIO

PREFÁCIO

Esta dissertação é requisito parcial para a obtenção do Título de Mestre em Sistemas Costeiros e Oceânicos, conforme modelo proposto pela coordenação. Ela está dividida em três partes: A primeira parte é composta por uma introdução geral, com justificativa, hipótese e objetivos, abordando parte teórica sobre os modelos de distribuição de abundância de espécies; A segunda parte, é um capítulo completo, em inglês (ainda sem revisão) sobre a aplicação dos modelos de distribuição de espécies nos dados espaciais e temporais da ictiofauna da Baía da Babitonga (SC), com submissão pretendida à revista *Ecological Modelling* (estrato Qualis: A1, JCR: 2.326). A terceira parte é um capítulo completo, em inglês (sem revisão), sobre a aplicação dos modelos de distribuição de espécies em diferentes guildas ecológicas e o uso de análises multivariadas para o entendimento de padrões ecológicos da ictiofauna da Baía da Babitonga (SC), com submissão pretendida ao periódico *Oecologia* (Qualis: A1, JCR: 3.248)

INTRODUÇÃO GERAL

Um dos objetivos centrais da ecologia é entender as regras que governam as assembleias ecológicas, tanto em escala global quanto regional (ZHOU; ZHANG, 2008). Compreender como a diversidade, distribuição e abundâncias das espécies alocam-se no ambiente é um passo essência para tal entendimento, porém ainda há muito a ser elucidado (RICKLEFS; SCHLUTER, 1993).

Os processos determinantes por alocar as espécies criam diferentes nichos e, consequentemente, resultam na observação de espécies raras ou comuns, especialistas ou generalistas (BELL, 2001). Esses processos que geram e mantêm a diversidade biológica são complexos e variados – desde processos genéticos, a geológicos globais - tornando inviável sua mensuração e análise direta. Consequentemente, sumarizá-los facilita o entendimento da diversidade (MAURER; MCGILL, 2004) e sua observação permite compreender e predizer a natureza dos padrões, respeitando as peculiaridades de cada ambiente (CASSEMIRO; PADIAL, 2008; DEVAUR; GRASS, 2011). Conhecer os reais padrões de distribuição e de abundância das espécies (ARAÚJO; WILLIAMS, 2000; GASTON; BLACKBURN, 2000) e como e por que elas variam no tempo e no espaço (MacARTHUR, 1965; PURVIS; HECTOR, 2000) são ferramentas indispensáveis para ações de preservação. No entanto, frequentemente as informações disponíveis são imprecisas e fragmentadas (JIMENEZ-VALVERDE *et al.*, 2008).

Um dos principais teoremas da macroecologia é a relação entre a distribuição e a abundância das espécies, que prega que as espécies comuns e abundantes possuem maior dispersão espacial, enquanto espécies raras são restritas espacialmente (VERBERK, 2012), apesar de ambos os grupos serem encontrados em todos os ambientes (MACE *et al.*, 2008). Além disso, identificar as espécies raras – predominantes na maioria das comunidades (FISHER; CORBET; WILLIAMS, 1943; PRESTON, 1948) – é de especial interesse, pois elas requerem maiores cuidados (devido ao maior risco de extinção; GASTON, 1994) - e sua inclusão ou exclusão no ambiente pode diminuir a capacidade de detectar e medir as mudanças ecológicas (CAO; WILLIANS; WILLIANS, 1998; HESSEN; WALSENG, 2008).

A diversidade biológica pode ser analisada de diversas formas, a partir dos índices de univariados, modelos de distribuição de espécies ou analises multivariadas. A utilização dos índices univariados - como diversidade (α – entre locais, β – entre comunidades e γ – entre ecossistemas), riqueza (número de espécies numa determinada região ou período) ou a equitabilidade (relação entre a abundância e o número de espécies) – são os mais recorrentes na literatura (HUBÁLEK, 2000), no entanto foram propostos para medir um dos parâmetros por vez, o que pode acarretar em viesses consideráveis das inferências a partir deles (PURVIS; HECTOR, 2000) devido à alta perda de informações, frequentemente não fornecendo respostas ecológicas plausíveis depois de calculados (DIAS, 2004). As análises multivariadas são mais complexas e servem para encontrar a principal direção de variação dos dados, efetuar correlações entre matrizes ou ainda encontrar diferenças entre grupos (BORCARD; GILLET; LEGENDRE, 2011).

Já os modelos de distribuição de abundância das espécies (DAE – ou SAD, do inglês "*species abundance distribution*") buscam predizer matematicamente o comportamento das comunidades a partir do número de indivíduos de cada espécies do ambiente, dado facilmente obtido(GREEN; PLOTKIN, 2007), representados por um gráfico de dispersão que apresenta uma curva côncava (ou "*hollow curve*", Figura 1), mostrando que poucas espécies são muito abundantes, e muitas espécies são raras. A tentativa de explicar o formato dessa curva tem sido um tema central da ecologia teórica desde a década de 30 (MOTOMURA, 1932; FISHER; CORBET; WILLIAMS, 1943) e tem gerado diversas propostas (ver MARQUET *et al.*, 2004; McGILL *et al.*, 2007 para detalhes).

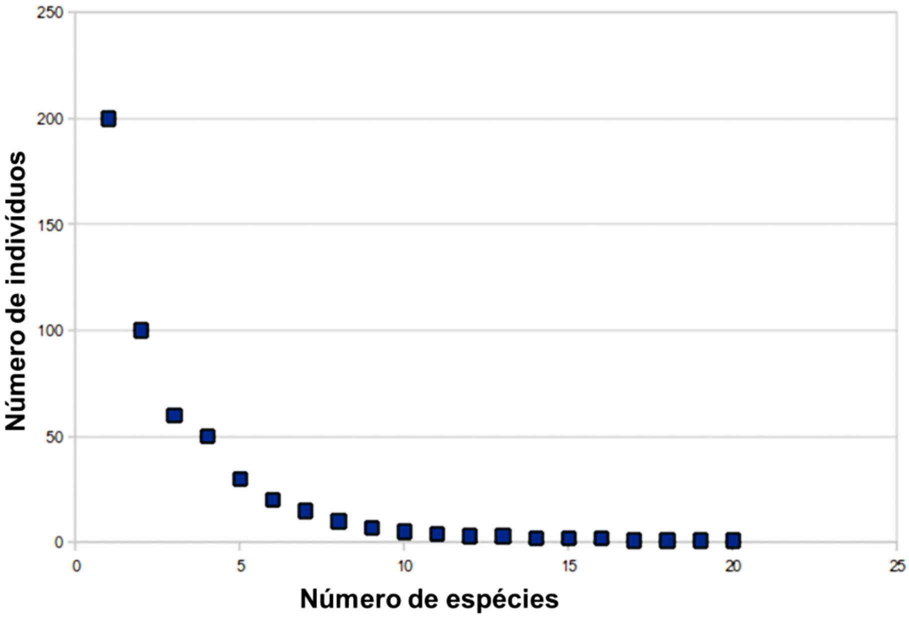

Figura 1: Distribuição de abundância de espécies, mostrando o padrão geral encontrado em comunidades ecológicas, onde é perceptível a dominância numérica de poucas espécies ("espécies comuns") e a grande frequência de espécies raras, com baixas abundâncias. Modificado de Zachary, 2013.

Mesmo possuindo um formato geral semelhante, estas curvas apresentam diferentes nuances para cada comunidade – como respostas às alterações bióticas e abióticas (BELLIER *et al.*, 2013) – tornando a modelagem estatística delas importante (LIMA *et al.*, 2012), uma vez que algumas teorias estatísticas podem ser convertidas em suposições ecológicas (McGILL, 2010). Isso representa uma inestimável, porém negligenciada, ferramenta de gestão, uma vez que as alterações podem ser detectadas na comunidade como um todo, tornando o método independente da identificação de espécies indicadoras ou sensíveis a impactos, tornando as comparações independentes da composição taxonômica das comunidades (GRAY *et al.*, 2006).

Tradicionalmente, duas famílias de modelos têm sido utilizados para a modelagem das abundâncias: biológicos e estatísticos. Enquanto os biológicos manipulam a curva a partir do ambiente, os estatísticos inferem conclusões a partir da curva (MAGURRAN, 2004). Modelos estatísticos, inicialmente criados para outras áreas, vêm se tornando cada vez mais comuns devido a capacidade de prever padrões macroecologicos (NEKOLA; BROWN, 2007), teorias de distribuição (McGILL; NEKOLA, 2010) e por sua capacidade de transformação em pressupostos ecológicos

(McGILL, 2010), permitindo que as inferências das DAE não sejam divergentes da biologia (GASTON; BLACKBURN, 2008).

A partir desses modelos, é possível identificar alterações na estruturação das populações comparando diferentes guildas e faixas etárias (MAGURRAN; HENDERSON, 2012), taxas de natalidade e mortalidade (BOWLER, KELLY, 2012), relações como predação e competição (VERBECK, 2012) relacionando as distribuições com variáveis abióticas (RODRIGUES, 2011), comparando as distribuições com diferentes esforços de amostragem (GREEN; PLOTKIN, 2007), permitindo fazer inferências sobre processos de perturbação antrópico (HILL; HAMER, 1998) e variações climáticas (MAC NALLY, 2007), analisando as respostas das distribuições ao longo de gradiente ambiental (PIELOU, 1977).

Apesar de existirem mais de 40 diferentes modelos propostos na literatura (McGILL *et al.*, 2007), ainda não há consenso sobre qual o modelo ideal para explicar um mesmo padrão ecológico (TOKESHI, 1999; MAGURRAN, 2004). A utilização de mais de um modelo concorrente é essencial para a adequada identificação do modelo correto (MAGURRAN, 2004). Neste estudo foram testados quatro modelos concorrentes: normal-logarítmico, série-logarítmica, vara quebrada e de metacomunidade (Figura 2). Para o modelo série logarítmica, a probabilidade de a espécie ocorrer dentro da amostra será dada por:

$$f(r|\propto) = \frac{N^r}{r\ (N+\propto)^r\ \log(\frac{N+\propto}{N})}$$

Onde, f (r|α) é a probabilidade da espécie ocorrer na comunidade, dado o parâmetro α (que é proporcional ao número de indivíduos da espécie na amostra e o total de indivíduos *N* (PRADO, 2010), sendo frequentemente elencado em ambientes de baixa equitatividade, com dominância de espécies raras.

Para o modelo normal-logarítmico, a função de probabilidade de abundância da amostra será dado por:

$$f(r|\mu,\sigma) = \frac{1}{r\sigma\sqrt{2\pi}} e^{\frac{(-\ln(r)-\mu)^2}{2\sigma^2}}$$

Onde, f (r|μ,σ) é a probabilidade de uma espécie ter abundância *r* na comunidade, dados os valores μ e σ, que são parâmetros de escala e forma, respectivamente (MANDAI, 2010). Esse modelo baseia-se no teorema do limite central, onde a maioria das espécies possuem distribuições intermediárias, com maior equitabilidade.

Outros modelos, como o de vara quebrada não utiliza parâmetros (MACARTHUR, 1957), com a modelagem feita a partir da riqueza e da abundância direta das espécies. A probabilidade deste modelo é dada por:

$$S(n) = \frac{S\ (S-1)}{N}\left(\frac{1-n}{N}\right)^{S-2}$$

Onde, S(n) é o número de espécies na classe de abundância com *n* indivíduos; S é o número total de espécies dentro da comunidade e; N é o número total de indivíduos (MARTINS; SANTOS, 1999). Para este modelo, as abundâncias são distribuídas aleatoriamente e de modo desigual, com a comunidade respondendo a um fator principal.

O modelo de metacomunidade considera que as espécies possuem iguais capacidades de ocupação de nichos, tornando-as todas competitivas pelos recursos dispostos no meio ambientes (HUBBEL, 2001; modificado por ALONSO; MCKANE, 2004). Para esse modelo, a probabilidade de distribuição é dado por:

$$S(n) = \ \theta \int_0^1 P_S\ (n; J, m, x) \frac{(1-x)^{\theta-1}}{x}\ dx$$

Onde: S(n) é o número de espécies com *n* indivíduos; θ é o número fundamental da biodiversidade e P_s *(n; J, m, x)* é a probabilidade de encontrar uma espécie com *n* indivíduos numa assembleia de tamanho *J* com abundancia relativa *x* com taxas de imigração *m*, onde a distribuição apresenta relação tanto com a heterogeneidade ambiental quanto com a capacidade de movimentação das espécies.

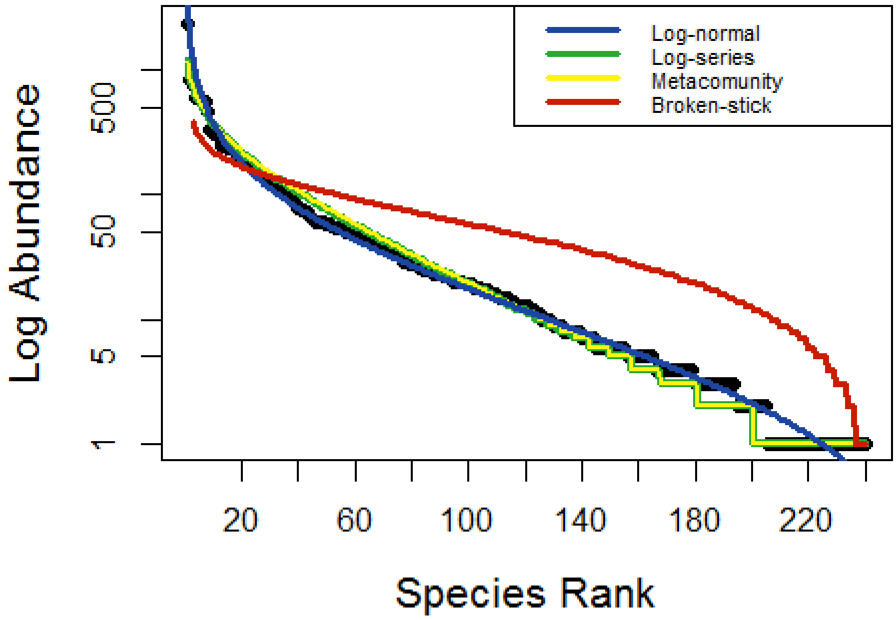

Figura 2: Simulação realizada com os dados de abundância de espécies de mariposas (Fisher et al., 1943; pontos pretos) para os modelos de distribuição de espécies normal logarítmico, série-logarítmica, metacomunidade e de vara-quebrada.

Inicialmente, é realizada a escolha dos parâmetros responsáveis por determinar a aderência do modelos em relação aos dados amostrados, feita a partir dos estimadores de verossimilhança (MANDAI, 2010). Os parâmetros passam a ser responsáveis pela escolha de modelos concorrentes, indicação dos padrões das comunidades e comparações entre áreas (PIELOU, 1977).

Dentre os modelos concorrentes, aquele mais plausível será escolhido através do Critério de Informação Akaike (AIC). Os parâmetros de cada modelo são utilizados para melhor ajustar os dados à curva. Uma vez testados os modelos, o AIC calcula o peso dos parâmetros, resultando no melhor ajuste das abundâncias a cada modelo, através da fórmula:

$$AIC = 2k - 2L$$

Onde: k é o número de parâmetros do modelo e L é o valor da Log-verossimilhança (log da probabilidade) (PRADO, 2010).

JUSTIFICATIVA

A utilização de novos métodos para a análise de dados são de importância fundamental para a identificação de padrões e entendimento dos diversos fatores responsáveis pela alocação das espécies no meio ambiente. Trabalhos de modelagem estatística de comunidades marinhas aparecem como ferramentas indispensáveis e possuem aplicação prática para a gestão dos recursos marinhos.

HIPÓTESE

- Se a distribuição de abundância de espécies responde diretamente às diferenças de abundâncias, então haverá diferentes modelos elencados quando: maior equitabilidade (lognormal), menor equitabilidade (logseries), dominância de processos ecológicos (metacomunidade/vara-quebrada), apresentados de acordo com os conjuntos de dados testados (espacial/temporal/guildas)

OBJETIVOS

Objetivo geral

- Aplicar os modelos de distribuição de abundância em dados ictiológicos da da Baia da Babitonga.

Objetivos específicos

- Testar a eficiência dos modelos de distribuição de abundância em dados ictiológicos marinhos;
- Comparar as respostas dos modelos de distribuição de abundância contra análises multivariadas;
- Identificar alteração do padrão de distribuição de abundância das espécies entre ambientes da Baía da Babitonga;

REFERÊNCIAS

ARAÚJO, M. B.; WILLIAMS, P. H. Selecting areas for species persistence using occurrence data. Biological Conservation, v. 96, p. 331 -345, 2000.

ALONSO, D.; MCKANE, A. J. Sampling Hubbell's neutral theory of biodiversity. Ecology Letters, v. 7, p. 901–910, 2004.

BELL, G. Neutral macroecology. *Science*, v. 293, p. 2413–2418, 2001.

BELLIER, E., GRØTAN, V., ENGEN, S., SCHARTAU, A. K., DISERUD, O. H., & FINSTAD, A. G. Combining counts and incidence data: an efficient approach for estimating the log-normal species abundance distribution and diversity indices. *Oecologia*, v. 170, n. 2, p. 477–88, 2012. doi:10.1007/s00442-012-2311-2

BORCARD, D., GILLET, F., & LEGENDRE, P. Numerical ecology with R. Springer, 2011, 318p.

BOWLER, M. G.; KELLY, C. K. On the statistical mechanics of species abundance distributions. *Theoretical Population Biology*, v. 82, n. 2, p. 85-91, 2012.

CAO Y.; WILLIAMS D. D.; WILLIAMS N. E. How important are rare species in aquatic community ecology and bioassessment? *Limnology and Oceanography*, v. 43, n. 1403–1409, 1998.

CASSEMIRO, F. A. S.; PADIAL, A. A. Teoria neutra da biodiversidade e biogeografia : aspectos teóricos, impactos na literatura e perspectivas. *Oecologia Brasileira*, v. 12, n. 4, p.706–719, 2008.

DEVAURS, D.; GRAS, R. Species abundance patterns in an ecosystem simulation studied through Fisher's logseries. *Simulation Modelling Practice and Theory*, v. 18, n. 1, p. 100–123, 2010. doi:10.1016/j.simpat.2009.09.012

DIAS, S. C. Planejando estudos de diversidade e riqueza: uma abordagem para estudantes de graduação. *Acta Scientiarum*, v. 26, n. 4, p. 373-379, 2004.

FISHER, R. A.; CORBET, A. S.; WILLIAMS, C. B. The relation between the number of species and the number of individuals in a random sample of an animal population. *The Journal of Animal Ecology*, v. 12, n. 1, p. 42-58, 1943.

GASTON, K. *Rarity*. Chapman and Hall, London, 1994, 205p.

GASTON, K. J.; BLACKBURN, T. M. *Macroecology*. Blackwell Science, Oxford, 2000, 378p.

GREEN, J. L.; PLOTKIN, J. B. A statistical theory for sampling species abundances. *Ecology Letters*, v. 10, n. 11, p. 1037–45, 2007. doi:10.1111/j.1461-0248.2007.01101.x

GRAY, J. S.; BJØRGESÆTER A.; UGLAND, K. I.; FRANK, K. Are there differences in structure between marine and terrestrial assemblages? *Journal of Marine Biology and Ecology*, v. 330, p. 19-26, 2006.

HILL, J. K.; HAMER, K. C. Using species abundance models as indicators of habitat disturbance in tropical forests. *Journal of Applied Ecology*, v. 35, n. 3, p. 458-460, 1998.

HESSEN, D. O.; WALSENG, B. The rarity concept and the common-ness of rarity in freshwater zooplankton. *Freshwater Biology*, v. 53, p. 2026–2035, 2008.

HUBÁLEK, Z. Measures of species diversity in ecology: an evaluation. *Folia Zoologica*, Brno: Institute of Vertebrate Biology AS CR, v. 49, n. 4, p. 241-260, 2000, ISSN 0139-7893.

HUBBELL, S. P. *The Unified Neutral Theory of Biodiversity and Biogeography*. Princeton University Press, Princeton, NJ, 2001, 378

JAMES, F. C.; MCCULLOCH, C. E. Multivariate analysis in ecology and systematics: panacea or Pandora's box? *Annual Review of Ecology and Systematics*, v. 21, p. 129-166, 1990.

JIMÉNEZ-VALVERDE, A.; HORTAL, J.; LOBO, J. M.; BORGES, P. A. V.; ABREU, C. AGUIAR, A. M. F.; AZEVEDO, E. B.; BOIEIRO, M.; FONTINHA, S.; JARDIM, R.; OLIVEIRA, P.; SÉRGIO, C.; SERRANO, A. R. M.; SIM-SIM, M.; NUNES, D. Using predictive models of species distribution to validate biodiversity data: case studies for Madeira Island. In: P. A. V. BORGES; C. ABREU; A. M. F. AGUIAR; P. CARVALHO; R. JARDIM; I. MELO; P. OLIVEIRA; C. SÉRGIO; A. R. M. SERRANO; P. VIEIRA (Eds.) *A list of the terrestrial fungi, flora and fauna of Madeira and Selvagens archipelagos*. Funchal and Angra do Heroísmo, Direcção Regional do Ambiente da Madeira and Universidade dos Açores: p. 27-56, 2008.

DE LIMA, R. A. F., PRADO, P. I., MARTINI, A. M. Z., FONSECA, L. J., GANDOLFI, S., & RODRIGUES, R. R. Improving methods in gap ecology: revisiting size and shape distributions using a model selection approach. (S. Güsewell, Ed.) *Journal of Vegetation Science*, v. 24, n. 3, p. 484–495, 2012. doi:10.1111/j.1654-1103.2012.01483.x

MacArthur, R. On the relative abundance of bird species. – Proc. Natl Acad. Sci. 43: 293–295, 1957

MacARTHUR, R. H. Patterns of species diversity. *Biological Reviews*, v. 40, p. 510–533, 1965.

MACE, G. M.; COLLAR, N. J.; GASTON, K. J.; HILTON-TAYLOR, C.; AKCAKAYA, H. R.; LEADER-WILLIAMS, N.; MILNER-GULLAND, E. J.; STUART, S. N. Quantification of extinction risk: IUCN's system for classifying threatened species. *Conservation Biology*, v. 22, p. 1424–1442, 2008. doi:10.1111/j.1523-1739.2008.01044.x

MAGURRAN, A. E. *Measuring Biological Diversity,* 2. ed. Blackwell: Oxford. 2004, 256p.

MAGURRAN, A. E.; HENDERSON, P. A. How selection structures species abundance distributions. *Proceedings of the Royal Society B*, v. 279, p. 3722–3726, 2012.

MANDAI, C. Y. Aplicação de modelos teóricos de distribuição de abundância das espécies na avaliação de efeitos de fragmentação sobre as comunidades de aves da Mata Atlântica. Universidade de São Paulo, 2010.

MARQUET, P. A.; FERNANDEZ, M.; NAVARRETE, S. A., VALDIVINOS, C. Diversity emerging: towards a deconstruction of bio- diversity patterns. In: *Frontiers of Biogeography: New Directions in the Geography of Nature* (ed HEANEY, M. L. A. L. R.). Cambridge University Press, Cambridge, pp. 192–209, 2004.

MARTINS, F. R., & SANTOS, F. A. M. Técnicas usuais de estimativa da biodiversidade. Revista Holos, Edição especial, 236–267, 1999.

MAURER, B. A.; McGILL, B. J. Neutral and non-neutral macroecology. *Basic and Applied Ecology*, v. 5, p. 413-422, 2004.

MCGILL, B. J. Towards a unification of unified theories of biodiversity. *Ecology Letters*, v. 13, p. 627–642, 2010.

MCGILL, B. J.; ETIENNE, R. S.; GRAY, J. S.; ALONSO, D.; ANDERSON, M. J.; BENECHA, H. K.; DORNELAS, M.; ENQUIST, B. J.; GREEN, J. L.; HE, F.; HURLBERT, A. H.; MAGURRAN, A. E.; MARQUET, P. A.; MAURER, B. A.; OSTLING, A.; SOYKAN, C. U.; UGLAND, K.; WHITE, E. P. Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework. *Ecology Letters*, v. 10, p. 995-1015, 2007.

MCGILL, B. J., & NEKOLA, J. C. Mechanisms in macroecology: AWOL or purloined letter? Towards a pragmatic view of mechanism. *Oikos*, v. 119, n.4, p. 591–603, 2010.

MAC NALLY, R. Use of the abundance spectrum and relative-abundance distributions to analyze assemblage change in massively altered landscapes. *The American Naturalist*, v. 170, p. 319-330, 2007.

MOTOMURA, I. On the statistical treatment of communities. *Zoological Magazine,* Tokyo (in Japanese) v. 44, p. 379–383, 1932.

NEKOLA, J. C., BROWN, J. H. The wealth of species: ecological communities, complex systems and the legacy of Frank Preston. *Ecology Letters*, v. 10, n. 3, p. 188–96, 2007.

PIELOU, E. C. *Mathematical Ecology*. New York: John Wiley and Sons, 1977, 385p.

PRADO, P. I. K. L. Distribuições de abundâncias de espécies: avanços analíticos para entender um padrão básico em ecologia. *Ciência e Ambiente*, v. 39, p. 121–136, 2010.

PRESTON, F. W. The commonness and rarity of species. *Ecology*, v. 29, n. 3, p. 254-283, 1948.

PURVIS, A.; HECTOR, A. Getting the measure of biodiversity. *Nature*, v. 405, n. 6783, p. 212-219, 2000.

RICKLEFS, R. E.; SCHLUTER, D. Species diversity: regional and historical influences, pp 350-363. In: R. E. Ricklefs; Schluter, D. (eds.), *Species diversity in ecological communities: historical and geographical perspectives.* University of Chicago Press, Chicago, 1993, 432p.

RODRIGUES, R. C. *Uso de modelos de distribuição de abundância na análise da relação entre diversidade de aves e variáveis ambientais e antrópicas*. Dissertação (Mestrado) - Instituto de Biociências, USP, São Paulo, 2011, 105p.

TOKESHI M. Species Coexistence: Ecological and Evolutionary Perspectives. Blackwell Science: Oxford, 1999, 454p.

VERBERK, W. Explaining General Patterns in Species Abundance and Distributions. *Nature Education Knowledge*, v. 3, n.10, p. 38, 2012.

ZACHARY, L. *The hollow curve, lumpers versus splitters, and arbitrary (yet useful) ranks*, publicado em 03 de janeiro de 2012. Disponível em: <http://trichopterology.blogspot.com.br/2012/01/hollow-curve-lumpers-versus-splitters.html>. Acesso em: 10.abr.2013.

ZHOU, S. & ZHANG, D. Neutral theory in community ecology. *Frontiers of Biology in China*, v. 3, p. 1-8, 2008.

CAPÍTULO 1: HOW IS GIVEN THE ABUNDANCE DISTRIBUTION OF FISHES IN A SOUTHWESTERN ATLANTIC ESTUARY?

Introduction

Abundances of species within ecological communities are not uniformly distributed and usually presents numerical dominance of few species (Fisher *et al.* 1943; Verbeck 2011). This is one of the most common pattern in ecology: the hollow curve (McGill *et al.* 2007). Attempts to discover the process underlying this pattern, some theories were proposed – such as the niche partitioning (complaining that each species occupies the environment with available resources), neutral theory (assuming that each species have equally capacity of occupying the environment) or the maximum entropy (where each specie is uniformly distributed) (McGill 2010).

Some models were created to explain this pattern, trying to undercover the the process responsible for differences in abundances os species in each ecological community, the so called Species Ambundance Distribution (SAD). Since the first model proposed from Motomura (Doi & Mori 2013), more than 30 different distribution were elaborated, still without accordance about their accuracy (McGill et al., 2007, for details). Despite mathematically containing most of ecological information, the existence of this amount of models makes clear that identify all dynamics responsible for community structure are manyfold and hardly measurable (Magurran 2004; Bowler & Kelly 2010).

Even identifying a recurrent pattern and their self-informative feature (Yen *et al.* 2013), few attention has been given to these models (McGill *et al.* 2007), due tolack of tests with empirical data and, being necessary studies capable to define precisely the inferences from each model (Ulrich *et al.* 2010).

Babitonga Bay is located in South Brazil, in a transitional zone between tropical and temperate Southern Atlantic (Spalding *et al.* 2007). It is a homogeneous estuary, with well demarcated seasons and semi-diurnal tide with 6 m maximum amplitude (Cremer *et al.* 2006). Directly influenced by continental drainage and from Atlantic

Ocean, having mangrove and rain forest fringe. Reaching 28 m maximum depth on main channel and exhibits large sandbanks on low-tide (Mazzer & Gonçalves 2011). Shelter two harbors (São Francisco do Sul and Itapóa – suffering extent anthropic pressure from six cities surrounding (Ibama & Cepsul 1998), being considered priority area for conservation (MMA 2007).

Utilization of both univariate and multivariate analyzes are broadly utilized for ecological studies in estuaries, but SADs are neglected. Thereby, this work aimed to identify the best fitted SAD model for ichtyofauna in a Brazilian estuary and its inferences, testing the hypothesis: if there is significant alteration in species abundance through areas, then different SAD models will be chosen.

METHODS

Data Collection

Abundance data were btained from three different surveys. On north margin, thirteen sand beachs along the estuarine gradient was sampled in eight months (October and November / 2007, January, February, April, May, July and August / 2008) totaling 208 samples. Every months, two hauls per site were made. For the first haul, a beach seine net with 6 m long, 21.6 m height and 1.0mm mesh size was dragged along 10m parallel to the coast. The second haul, the beach seine net had dimensions of 15 m long, 2 m height and 2.5 mm mesh, dragged 30 m along the coast.

To south margin, three hauls were made through seven sites of polihaline sector of the bay, between August 2005 to July 2006., totaling 252 samples. First haul was made with a beach seine net with 15 m long, 1.6 m height and 5 mm mesh. For second haul, the seine net had 15 m long, 1.6 m height and 2.5 mm mesh, both over 20 m path parallel to the coast. The third haul, the beach seine net used was 6 m long, 1.6 m high and 1 mm mesh over 6 m parallel to the coast, to minimize net clogging.

For channel, the collections were performed on eight months (October and November / 2007, January, February, April, May, July and August / 2008) in 9 sites along the main channel of Babitonga Bay. In each sampling site, two bottom trawls were dragged for minimum of 5 minutes, in a total of 144 samples (Figure 1).

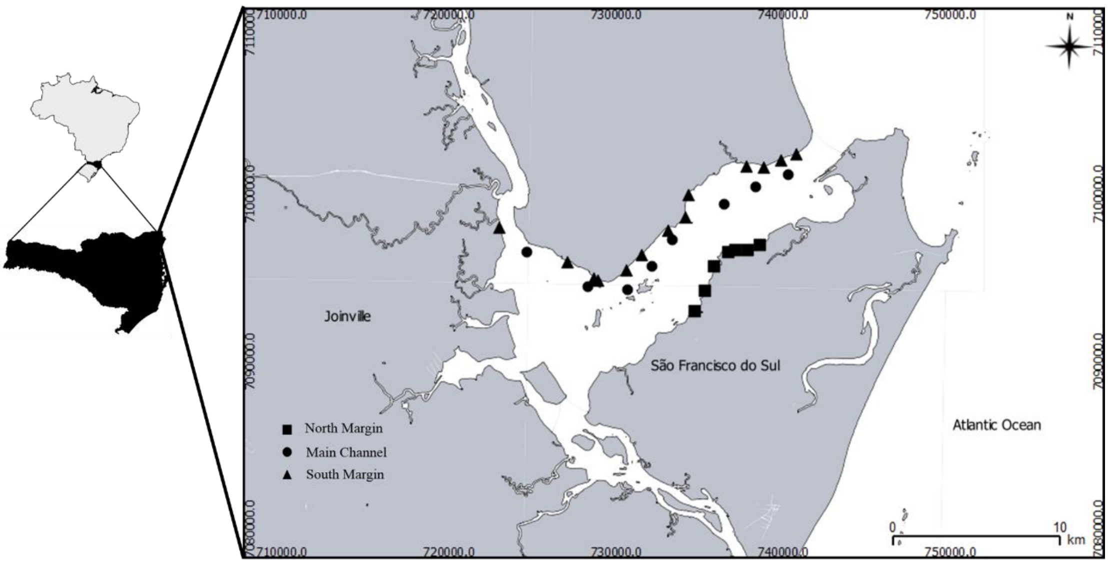

Figure 1: Babitonga Bay, north littoral of Santa Catarina, Brazil. Indications of three surveys made through years 2006 to 2008.

All fishes captures were frozenand carried to the laboratory, where they were identified (following the (Figueiredo & Menezes 1978, 1980, 2000; Menezes & Figueiredo 1980, 1985; Barletta & Corrêa 1992).

Modelling

The abundance data of the estuary was categorized in three conjuntos analysis: General – considering all species abundance sampled within the Babitonga Bay; Channel – considering all abundances sampled through the main channel of the bay; and Margins – where abundance of both north and south margins were summed up. As for temporal analyses, the collected data was divided accordingly years (2005, 2006, 2007 and 2008).

Incomplete sampling areas can cause serious problems in identifying the best fitted model, leading to biases in modeling due to sampling method (Dewdney 2000). The nd out if the samples were sufficient for accurate inferences from the models, we calculated the rarefaction of species (Hurlbert 1971) based on the abundances found and tested using the non-parametric Mann-Whitney (considering the significance level of 0.05). The rarefaction curve (Hurlbert 1971) demonstrates the efficiency of capture, considering the 29 sites analyzed in this study.

Four different models were tested: the logseries (Fisher *et al.* 1943), lognormal (Preston 1948), broken-stick (MacArthur 1960) and metacommunity (Hubbell, 2001, modified by Alonso & Mckane, 2004). Both logseries and lognormal models are the most utilized and elected for heterogeneous communities, when logseries normally elected where there is incomplete sampling and many singletons. The broken-stick model is based on sequential partitioning of resources and high evenness (Baczkowski 2000) and the metacommunity says that species has equally distribution, occupying pre-determined niches and resources available distributed equally between them (Magurran 2005). The lognormal model was 0.05 truncated to model only the real abundances.

Model selection was through Akaike Information Criteria – AIC (Akaike 1973), that calculates the best adjustment of model, where the best fitted model has the lowest values (Johnson & Omland 2004). All analysis were performance in R (R Core Team 2014), with available packages sads (Prado & Miranda 2014) and vegan (Oksanen *et al.* 2013).

RESULTS

Richness

Rarefaction curve showed that the richness of all spatial categories and years analyzed was successfully represented in surveys.

Abundance

For Babitonga Bay as a whole, 253.189 individuals were sampled, distributed among 141 taxon. Only one specie – *Steliffer rastrifer* – was responsible for numerical dominance, accounting for 34.23 % of total captures. Opposite to that, there were 17 singletons collected (Figure 2).

Figure 2: Dispersion of abundances of species found in three surveys performance on Babitonga Bay (SC)

As for margins of the Bay, 130.265 individuals were sampled, distributed among 111 taxon. The numerical dominance was accounted for *Mugil sp* (17.29%), Engraulidae sp. (16.45%) and *Atherinella brasiliensis* (16.45%) that accounted for 50.20% of total abundance. Despite having the lowest abundance of only one specie (*Mugil* sp. - 22.529 individuals), was the area that showed the higher richness and the higher number species with one individual (14 singletons).

The channel presented 122.924 individuals, distributed among 73 species. *Stellifer rastrifer* was responsible for numerical dominance, accounting for 70.21% of individuals sampled. This area presented a higher abundance of one specie, but presented the smaller richness (73 species) and lowesr number of singletons (10 species).

Model Selection

Both for the general abundance and for spatial categories, lognormal model had the best fir for all scenarios studied (ΔAIC = 0), and had at minimum 9.6 of different for the second best model (Table 1). The lognormal is the only tested model that has two parameters (σ and μ), meaning that, even with punishment of AIC, it is the strongest explaining the collected data, opposed to the broken-stick model, that don't have parameters but showed the worst fit to the data.

Table 1: Model selection to the three surveyed areas in Babitonga Bay. AIC - Akaike Information Criteria results; ΔAIC - the difference between AICs.

MODELO	GENERAL		CHANNEL		MARGINS	
	AIC	ΔAIC	AIC	ΔAIC	AIC	ΔAIC
LOGNORMAL	1717.48	0.00	812.92	0.00	1270.59	0.00
LOGSERIES	1731.79	14.31	830.58	17.66	1279.76	9.17
METACOMUNITY	1733.38	15.9	835.29	22.37	1280.2	9.61
BROKEN-STICK	2420.47	702.99	1304.21	491.29	1789.26	518.67

The graphical selection shows clearly the lognormal adherence to the data collected, with all three other models showing a weak explanation of data. The lognormal had best fit specially for intermediate abundance, which comprised most of species abundances (Figure 3)

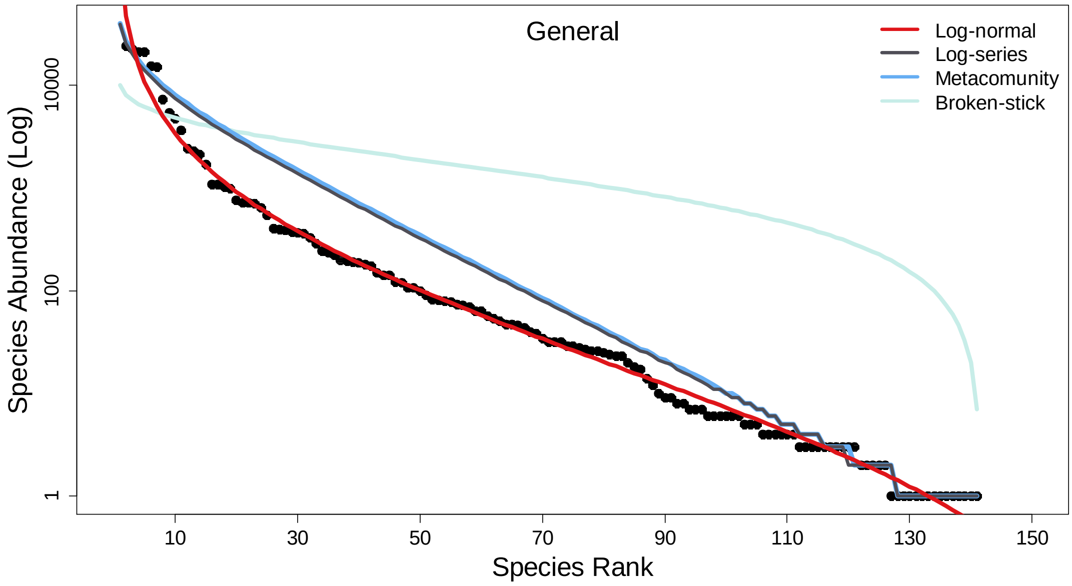

Figure 3: Graphical selection of the four tested models over Babitonga Bay fish fauna.

Graphical analysis shows that the channel had the worst fit of models, what might be correlated to the smaller abundance found in this area. However, the lognormal still is the best model explaining the data collected. For margins, the visual selection makes clear that, among the studied models, only the lognormal had adherence to the data (Figure 4).

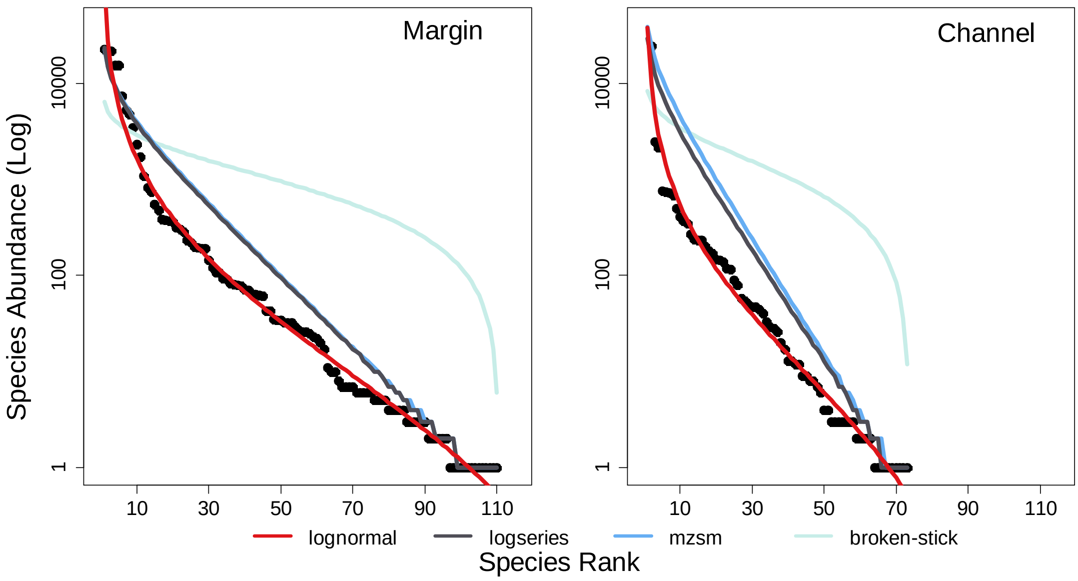

Figure 4: Graphical selection of two sampled areas - Margins and Channel - over Babitonga Bay fish fauna

Comparing the variation trough years, the abundances varied substantially, probably reflecting the sampling effort among the years. Years that presented higher abundances also showed the best AIC values, indicating that the models are better represented when the abundances increases. Instead of this, the lognormal was the best explaining all years, despite other two models had significantly ΔAIC for 2006 (logseries and metacommunity) (Table 2).

Table 2: Model selection to the four years analyzed to Babitonga Bay fish fauna. Results of Akaike Criteria Information (AIC), and the values of ΔAIC.

MODELO	**2005**		**2006**		**2007**		**2008**	
	AIC	ΔAIC	AIC	ΔAIC	AIC	ΔAIC	AIC	ΔAIC
LOGNORMAL	533.9	0.00*	611.51	0.00*	822.13	0.00*	1331.35	0.00*
LOGSERIES	545.41	11.51	612.67	1.16*	834.32	12.19	1341.03	9.68
METACOMUNITY	546.2	12.3	613.32	1.81*	836.07	13.94	1342.99	11.64
BROKEN-STICK	816.37	282.47	830.29	218.78	1212.77	390.64	1865.98	534.63

Graphical selection makes clear the variation in richness found between the years anlyzed, where 2005 showed the lower values and 2008 the higher values. The lognormal curve is adjusted to the to all years, but to 2006, the other curves (logseries and metacommunity) also showed fit, specially in the extreme values of abundance (Figure 5).

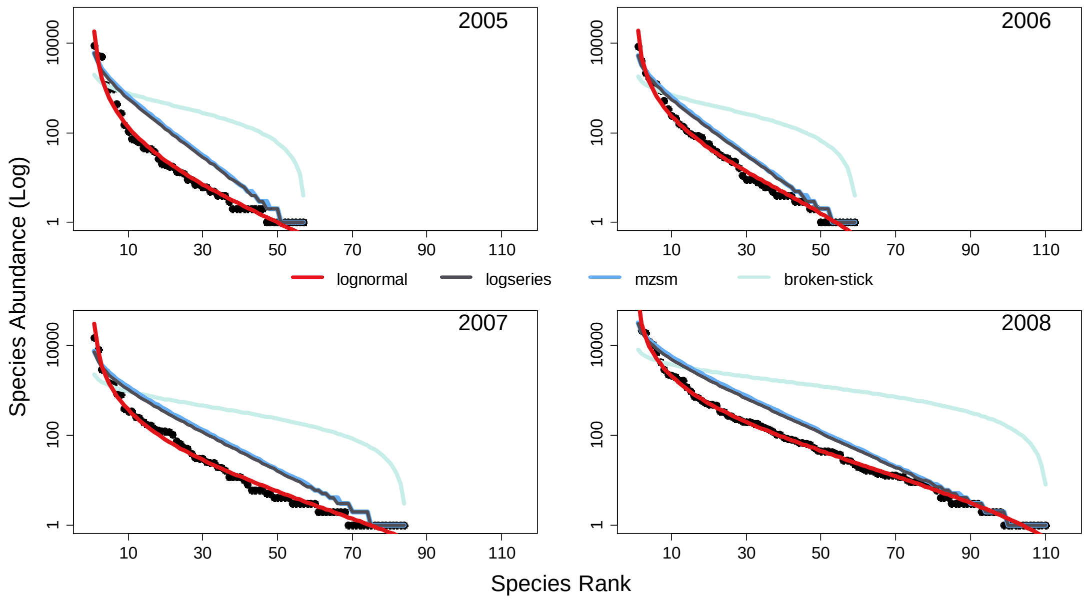

Figure 5: Graphical selection showing the fit of four curve models adjusted to the fish fauna abundance of Babitonga Bay (SC).

DISCUSSION

This study tested four different species abundance distribution models on ichtyofauna of Babitonga Bay attempting to find a pattern capable to explain the dynamics and structure of abundance and richness within the estuary, along the spatial gradient and years.

Studies related to abundance of species have shown that the success of predictions is related to the success on sampling the community analyzed, that depends on sampling effort and techniques utilized (Ulrich *et al.* 2010). Use of different nets and techniques is the most adequate to catch fish fauna (Clement *et al.* 2014) as did in this study, where six different nets were utilized, with different seize nets, length and time of sampling, besides the long time – 20 months – allowing the accurate estimate of species of Babitonga Bay, confirmed by rarefaction test.

Within the Bay, 141 species were collected. Accordingly with a recent bibliographic study, the estuary shelters 152 fish species (Vilar *et al.* 2011a), but in our study, some specific habitats wasn’t sampled – such as oyster farming and the Canal do Linguado. Accordingly with Reis-Filho *et al.* (2010) all East Atlantic estuaries presents a very similar fish fauna, wich is also similar to the one found here, with specific composition of temperate and tropical species, related to the oceanographic conditions (Blaber 2008; Vilar *et al.* 2011a) and harbor activity (Freitas & Velastin 2010).

Our study found the lognormal model as the best one on explaining the abundances distributions within the bay. Despite of being a statistical model, current literature cites it as the best for heterogeneous, but ecologically equilibrated areas that were adequate surveyed (Preston 1948; Magurran 1988; Unterseher *et al.* 2011). Connolly et al., (2005) and Hercos et al., (2013) also elected the same model for fish fauna modeling, but the fist author only found this pattern over large scales (above of km). The Babitonga Bay presents elevated levels of organic and metal contaminants (Cremer *et al.* 2006), especially nearby of the emissary (Martins *et al.* 2010) but, apparently, not directly influencing ichtyofauna abundance, maintaining this population in a equilibrated status.

Such as the estuary studied here, lognormal model has also showed success describing the abundances distribution on locations with both rare and common species (Connolly *et al.* 2009). Abundance of common species had a greater abundance than the rare ones (accounting for over 132 thousand individuals). The presence of these species being numeric significant and biologically associated to estuaries might camouflage a recurrent pattern on smaller areas: the logseries pattern of rare species (Correa *et al.* 2006; Magurran & Henderson 2012), where few species have a dominance competitively (Martins & Santos 1999), sharing the resources in distinguished ways (Henderson & Magurran 2010). Such higher abundances might be determined by resources partitioning (Magurran & Henderson 2003), once they are responsible for dominance of area use (Gotelli & Graves 1996), but not on a sequential recruitment normal on some environments, as proposed by broken-stick (Magurran 1988).

Lognormal choice suggests yet the dispersion of species as result of ecological process – such as random niche portioning (Fesl 2002), biological characteristics (Gaston & Blackburn 2008) and that the central limit theorem is important of community dynamics, when mostly of species presents the intermediate abundances (Connolly *et al.* 2005; Ulrich *et al.* 2010; Locey & White 2013). The lack of fit of metacommunity model indicates yet that the neutral theory might not have important influence on these data, corroborating that the niche partitioning of resources is prevailing, being drove by random events, therefore being important on understanding for community structure (Arakaki & Tokeshi 2011).

Another significant side revealed for the chosen models is the residency of mostly of individuals (Magurran & Henderson 2003; Ulrich & Ollik 2004). Our study found higher abundances in estuarine species – e.g. *Stellifer, Cathorops* and *Atherinella* (Barletta *et al.* 2008; Reis-Filho *et al.* 2010), that might indicate that the estuary is also an important ecosystem for development e reproduction of species, and not just for larvae and juveniles of marine species, with predominance of core species (Henderson & Magurran 2014). For instance, if the abundances of stranglers species were dominant, the model selected should be the logseries (Ulrich *et al.* 2010)./

On tropical and temperate estuaries, authors assigns the fish communities dynamics to abiotic variability, mainly salinity, but also to temperature, tides and dissolved oxygen and substratum (Andrade-Tubino *et al.* 2008; Blaber 2008; Paiva *et al.* 2008; Xavier *et al.* 2012). Our study did not find significant differences between the areas (channel and margin), what might indicate that the structure of community also respond to biotic interactions, such as feeding, migration and competition inter and intra specifics. This patters was also found by (Maes *et al.* 2004) that discuss the lack of explanation by abiotic factors, that might be attributed to migration patterns (Thiel & Potter 2001).

Due to high number of factors responsible for temporal variation of fish fauna, there is no agreement of howthe patterns of variance in structure od community occurs within years (Shimadzu *et al.* 2013), needing extra regard (Rosenzweig 1995). In our study, there was no variation in total abundance between years, but there was variation of species composition entre years, but it might be attributed to the samples surveys. This lack of variation might be due to the time, not pointed as determinant to fish structure (Villarroel 1994; Barletta *et al.* 2003).

CONCLUSION

Our study did not find differences of model chosen between the areas studied, despite of specific composition considerable different. Through the models, that might indicate that community studied are in balance, with alternation only in diversity, not in abundances (Shimadzu *et al.* 2013). It mean that, even with spatial and temporal alteration of species, the ichtyofauna is capable to respond of these alterations and maintain the dynamics within the bay.

All results found in these work are compatible to the scales analyzed. Others scales, such as samples or guilds might respond to specific factors (such as inter-specific relation or abiotic attributes) and presenting different distributions. Despite of not presenting losses on fish fauna or alteration on community structure, the protection of Babitonga bay is necessary due to high levels of contaminants described to the water, leading to structural modification of community and, the surveys being done before the implementation of Itapoá harbor that has great chances of impact the subjacent area.

REFERENCES

Akaike H (1973) Information theory and an extension of the maximum likelihood principle. In: Petrow BN, Csaki F (eds) 2nd Int. Symp. Inf. Theory. 2nd International Symposium on Information Theory., Budapeste, pp 267–281

Alonso D, Mckane AJ (2004) Sampling Hubbell's neutral theory of biodiversity. Ecol Lett 7:901–910. doi: 10.1111/j.1461-0248.2004.00640.x

Andrade-Tubino MF, Ribeiro ALR, Vianna M (2008) Organização espaço-temporal das ictiocenoses demersais nos ecossistemas estuarinos brasileiros: uma síntese. Oecologia Bras 12:640–661.

Arakaki S, Tokeshi M (2011) Analysis of spatial niche structure in coexisting tidepool fishes: null models based on multi-scale experiments. J Anim Ecol 80:137–47. doi: 10.1111/j.1365-2656.2010.01749.x

Baczkowski AJ (2000) The broken-stick model for species abundances: An initial investigation. 28.

Barletta M, Amaral CS, Corrêa MFM, et al (2008) Factors affecting seasonal variations in demersal fish assemblages at an ecocline in a tropical-subtropical estuary. J Fish Biol 73:1314–1336. doi: 10.1111/j.1095-8649.2008.02005.x

Barletta M, Barletta-Bergan a, Saint-Paul U, Hubold G (2003) Seasonal changes in density, biomass, and diversity of estuarine fishes in tidal mangrove creeks of the lower Caeté Estuary (northern Brazilian coast, east Amazon). Mar Ecol Prog Ser 256:217–228. doi: 10.3354/meps256217

Barletta M, Corrêa MFM (1992) Guia para identificação de peixes da costa do Brasil. UFPR, Curitiba

Blaber SJMJ (2008) Tropical Estuarine Fishes: Ecology, Exploitation and Conservation. 00384:384.

Bowler MG, Kelly CK (2010) The general theory of species abundance distributions. arXiv Prepr arXiv10025008 1–15.

Clement TA, Pangle K, Uzarski DG, Murry BA (2014) Effectiveness of fishing gears to assess fish assemblage size structure in small lake ecosystems. Fish Manag Ecol 21:211–219. doi: 10.1111/fme.12069

Connolly SR, Dornelas M, Bellwood DR, Hughes TP (2009) Testing species abundance models: a new bootstrap approach applied to Indo-Pacific coral reefs. Ecology 90:3138–49. doi: 10.1890/08-1832.1

Connolly SR, Hughes TP, Bellwood DR, Karlson RH (2005) Community structure of corals and reef fishes at multiple scales. Science 309:1363–5. doi: 10.1126/science.1113281

Correa MFM, Pinheiro PC, Almeida HK, et al (2006) Diagnóstico Ambiental da Ictiofauna. Diagnóstico Ambient. da Baía da Babitonga

Cremer MJ, Morales PRD, Oliveira T (2006) Diagnóstico Ambiental da Baía da Babitonga. UNIVILLE

Dewdney AK (2000) A dynamical model of communities and a new species-abundance distribution. Biol Bull 198:152–65.

Doi H, Mori T (2013) The discovery of species-abundance distribution in an ecological community. Oikos 122:179–182. doi: 10.1111/j.1600-0706.2012.00068.x

Fesl C (2002) Niche-oriented species-abundance models: different approaches of their application to larval chironomid (Diptera) assemblages in a large river. J Anim Ecol 71:1085–1094. doi: 10.1046/j.1365-2656.2002.00671.x

Figueiredo JL, Menezes NA (1978) Manual de peixes marinhos do sudeste do Brasil. II. Teleostei (1). 110.

Figueiredo JL, Menezes NA (1980) Manual de peixes marinhos do sudeste do Brasil. III. Teleostei (2). 90.

Figueiredo JL, Menezes NA (2000) Manual de peixes marinhos do sudeste do Brasil. VI. Teleostei (5). 116.

Fisher RA, Corbet AS, Williams CB (1943) The relation between the number of species and the number of individuals in a random sample of an animal population. J Anim Ecol 12:42–58.

Freitas MO, Velastin R (2010) Ictiofauna associada a um cultivo de mexilhão Perna perna (Linnaeus, 1758) Norte Catarinense, Sul do Brasil. Acta Sci Biol Sci 32:31–37. doi: 10.4025/actascibiolsci.v32i1.2515

Gaston KJ, Blackburn T (2008) Pattern and process in macroecology. 377.

Gotelli NJ, Graves G (1996) Null Models In Ecology. 384.

Henderson P a, Magurran AE (2014) Direct evidence that density-dependent regulation underpins the temporal stability of abundant species in a diverse animal community. Proc Biol Sci 281:20141336. doi: 10.1098/rspb.2014.1336

Henderson PA, Magurran AE (2010) Linking species abundance distributions in numerical abundance and biomass through simple assumptions about community structure. Proc R Soc Biol Sci 277:1561–70. doi: 10.1098/rspb.2009.2189

Hercos AP, Sobansky M, Queiroz HL, Magurran AE (2013) Local and regional rarity in a diverse tropical fish assemblage. Proc R Soc Biol Sci 280:20122076. doi: dx.doi.org/10.1098/rspb.2012.2076

Hubbell S (2001) The unified neutral theory of biodiversity and biogeography (MPB-32).

Hurlbert AH (1971) The nonconcept of species diversity: a critique and alternative parameters. Ecology 52:577–586.

Ibama, Cepsul (1998) Proteção e Controle de Ecossistemas Costeiros: Manguezal da Baía de Babitonga, Itajaí (SC). 146.

Johnson JB, Omland KS (2004) Model selection in ecology and evolution. Trends Ecol Evol 19:101–8. doi: 10.1016/j.tree.2003.10.013

Locey KJ, White EP (2013) How species richness and total abundance constrain the distribution of abundance. Ecol Lett 16:1177–85. doi: 10.1111/ele.12154

MacArthur R (1960) On the relative abundance of species. Am Nat 94:25–36.

Maes J, Damme S, Meire P, Ollevier F (2004) Statistical modeling of seasonal and environmental influences on the population dynamics of an estuarine fish community. Mar Biol 145:1033–1042. doi: 10.1007/s00227-004-1394-7

Magurran A (1988) Ecological diversity and its measurement, 168th edn. Princeton University Press, Princeton

Magurran AE (2005) Species abundance distributions: pattern or process? Funct Ecol 19:177–181. doi: 10.1111/j.0269-8463.2005.00930.x

Magurran AE (2004) Measuring biological diversity. 264.

Magurran AE, Henderson P a (2003) Explaining the excess of rare species in natural species abundance distributions. Nature 422:714–6. doi: 10.1038/nature01547

Magurran AE, Henderson PA (2012) How selection structures species abundance distributions. Proc R Soc Biol Sci 279:3722–6. doi: 10.1098/rspb.2012.1379

Martins CC, Braun JAF, Seyffert BH, et al (2010) Anthropogenic organic matter inputs indicated by sedimentary fecal steroids in a large South American tropical estuary (Paranaguá estuarine system, Brazil). Mar Pollut Bull 60:2137–2143. doi: 10.1016/j.marpolbul.2010.07.027

Martins F, Santos F (1999) Técnicas usuais de estimativa da biodiversidade. Rev. Holos

Mazzer A, Gonçalves M (2011) Aspectos geomorfológicos da Baía da Babitonga, Santa Catarina, Brasil: Caracterização morfométrica. Rev Bras Geomorfol 12:115–120.

McGill BJ (2010) Towards a unification of unified theories of biodiversity. Ecol Lett 13:627–42. doi: 10.1111/j.1461-0248.2010.01449.x

McGill BJ, Etienne RS, Gray JS, et al (2007) Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework. Ecol Lett 10:995–1015. doi: 10.1111/j.1461-0248.2007.01094.x

McGill BJ, Nekola JC (2010) Mechanisms in macroecology: AWOL or purloined letter? Towards a pragmatic view of mechanism. Oikos 119:591–603. doi: 10.1111/j.1600-0706.2009.17771.x

Menezes NA, Figueiredo JL (1980) Manual de peixes marinhos do sudeste do Brasil. IV. Teleostei (3). 94.

Menezes NA, Figueiredo JL (1985) Manual de peixes marinhos do sudeste do Brasil. V. Teleostei (4). 105.

MMA (2007) Atualização das Áreas e Ações Prioritárias para Conservação, Utilização Sustentável e Repartição de Benefícios da Biodiversidade Brasileira., Portaria M. Ministério do Meio Ambiente, Brasília, DF

Nekola JC, Brown JH (2007) The wealth of species: ecological communities, complex systems and the legacy of Frank Preston. Ecol Lett 10:188–96. doi: 10.1111/j.1461-0248.2006.01003.x

Oksanen J, Blanchet FG, Kindt R, et al (2013) vegan: Community Ecology Package. 12 December 2013

Paiva ACG De, Tarso P De, Chaves C, Araújo ME De (2008) Estruturutura e organização trófica da ictiofauna de águas rasas em um estuário tropical. Rev Bras Zool 25:647–661.

Prado PIKL, Miranda MD (2014) sads: Maximum Likelihood Models for Species Abundance Distributions. 01 July 2014

Preston F (1948) The commonness, and rarity, of species. Ecology 29:254–283.

R Core Team (2014) R: A language and environment for statistical computing.

Reis-Filho JA, Nunes JAC, Ferreira A (2010) Estuarine ichthyofauna of the Paraguaçu River, Todos os Santos Bay, Bahia, Brazil José. Biota Neotrop 10:301–312.

Rosenzweig ML (1995) Species diversity in space and time. Cambridge University Press, 1995. 436.

Shimadzu H, Dornelas M, Henderson PA, Magurran AE (2013) Diversity is maintained by seasonal variation in species abundance. BMC Biol 11:98. doi: 10.1186/1741-7007-11-98

Spalding MD, Fox HE, Allen ND, et al (2007) Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. Bioscience 57:573–583.

Thiel R, Potter IC (2001) The ichthyofaunal composition of the Elbe Estuary: an analysis in space and time. Mar Biol 138:603–616. doi: 10.1007/s002270000491

Ulrich W, Ollik M (2004) Frequent and occasional species and the shape of relative-abundance distributions. Divers Distrib 10:263–269. doi: 10.1111/j.1366-9516.2004.00082.x

Ulrich W, Ollik M, Ugland KI (2010) A meta-analysis of species-abundance distributions. Oikos 119:1149–1155. doi: 10.1111/j.1600-0706.2009.18236.x

Unterseher M, Jumpponen A, Opik M, et al (2011) Species abundance distributions and richness estimations in fungal metagenomics--lessons learned from community ecology. Mol Ecol 20:275–85. doi: 10.1111/j.1365-294X.2010.04948.x

Verbeck W (2011) Explaining General Patterns in Species Abundance and Distributions. Nat Educ Knowl 3:38.

Vilar C, Spach H, Santos L (2011) Fish fauna of Baía da Babitonga (southern Brazil), with remarks on species abundance, ontogenic stage and conservation status. Zootaxa 2734:40–52.

Villarroel PR (1994) Estructura de la comunidad de peces de la Laguna de Punta de Mangle, Isla de Margarita, Venezuela. Ecotrópicos 7:13–29.

Xavier JHA, Cordeiro CAMM, Tenório GD, et al (2012) Fish assemblage of the Mamanguape Environmental Protection Area, NE Brazil: abundance, composition and microhabitat availability along the mangrove-. Neotrop Ichthyol 10:109–122.

Yen JDL, Thomson JR, Mac Nally R (2013) Is there an ecological basis for species abundance distributions? Oecologia 171:517–25. doi: 10.1007/s00442-012-2438-1

CAPÍTULO 2: DOES SADS DISTINGUISHED OVER DIFFERENT FISH GUILDS? A STUDY CASE FROM SOUTHWESTERN ATLANTIC ESTUARY

INTRODUCTION

A abundance distribution tries to describes all abundances of species recorded within an ecological community, which is an universal law that, generally, have many species with few individuals and few species have greater abundances (Magurran 1988; Matthews & Whittaker 2014). This general law is responsible to create the so called hollow curve, which is the most common ecological pattern (McGill *et al.* 2007). Several attempts where proposed to explain it, started in 1932 with Motomura proposing a mathematical solution – the geometric distribution (Doi & Mori 2013).

Were created models to predict how the abundances are distributed between species through mathematical equations: the species abundance distributions – SAD. These equations are transformed in a distribution, with parameters responsible for the adjustment of the model on the empirical community curve. Although the similarity between them, each curve has nuances responsible to predict the biotic and abiotic influences on the distribution (Bellier *et al.* 2012).

The statistical modelling of these models are important since some statistical theories may be converted in ecological assumptions (McGill 2010; de Lima *et al.* 2012) allowing the inferences from statistical modelling not being divergent from ecology (Gaston & Blackburn 2008). The modelling is capable of identify patterns in a community such as born/death rates; predation and competition interaction, sampling effort and different guilds (Green & Plotkin 2007; Bowler & Kelly 2012; Magurran & Henderson 2012).

The use of guilds of estuarine fish have been identified groups and dynamics, providing understanding of relations, patterns and similarities (Barletta & Blaber 2007; Elliott *et al.* 2007). Different species make use of the estuary accordingly with individual tolerance to disturbance of abiotic factors and the resources availability. This differences may directly influence the way each species use the estuary (Henderson & Magurran 2010), therefore modifying the abundance distribution. Understanding how and why this alteration occurs is an essential step for comprising the ecological biogeography (McGill *et al.* 2007; Matthews & Whittaker 2014).

The Babitonga Bay is located on north coast of Santa Catarina state, South of Brazil. Having approximated 23 km of extent, seasons well defined and semi-diurnal tide (Cremer *et al.* 2006). Presents a 6 m of mean depth, with major areas with less than 2 m (Mazzer & Gonçalves 2011), being directly influenced by continental drainage and hydrodynamic from adjacent sea currents (Barros Grace *et al.* 2008). Holds two harbors (São Francisco and Itapoá Harbors), being directly impacted from all 6 cities it is surrounded (IBAMA 1998), therefore regarded as proprietary area for conservation (MMA 2007).

The aim of this study was identify if the separation of fish fauna in different estuarine use and food guilds are capable of influencing the abundance curve and, therefore, the chosen SAD model. Further multivariate analysis performed to understand the relation of the guilds with some ecological descriptors. The hypothesis tested is if there are different number of species within each guild, different SAD models will be choosen.

METHODS

Data collection

Samples taken by Laboratório de Ecologia de Peixes (CEM/UFPR) in three different occasions. At south margin, from August/2005 to July/2006, three monthly single tows parallel to the coast carried out in the margin of seven sites. First tow had 15m x 1.6m (5mm mesh size); second tow had 15m x 1.6m (2.5mm mesh size), both dragged over 20m; third tow had 6m x 1.6 (1mm mesh size) carried by 6 meters to minimize mesh clogging, totalizing 252 samples.

At north margin, samples taken over eight months (October and November/2007, January, February, April, May, July and August 2008) at thirteen different sites throughout the estuarine gradient, totalizing 208 samples. At each survey, three seine nets were used. One net with 6m x 1.6m (1.0mm mesh size) thought 10m parallel to the coast, and one net with 15m x 2m (2,5mm mesh size) thought 30m parallel to the coast.

At the main channel, sampling were collected at same eight months of north margin, but at nine different sites within estuarine gradient. At each sampling occasion, two bottom trawling with Wing Trawl nets over 5 minutes, totaling 144 samples (Figure 6).

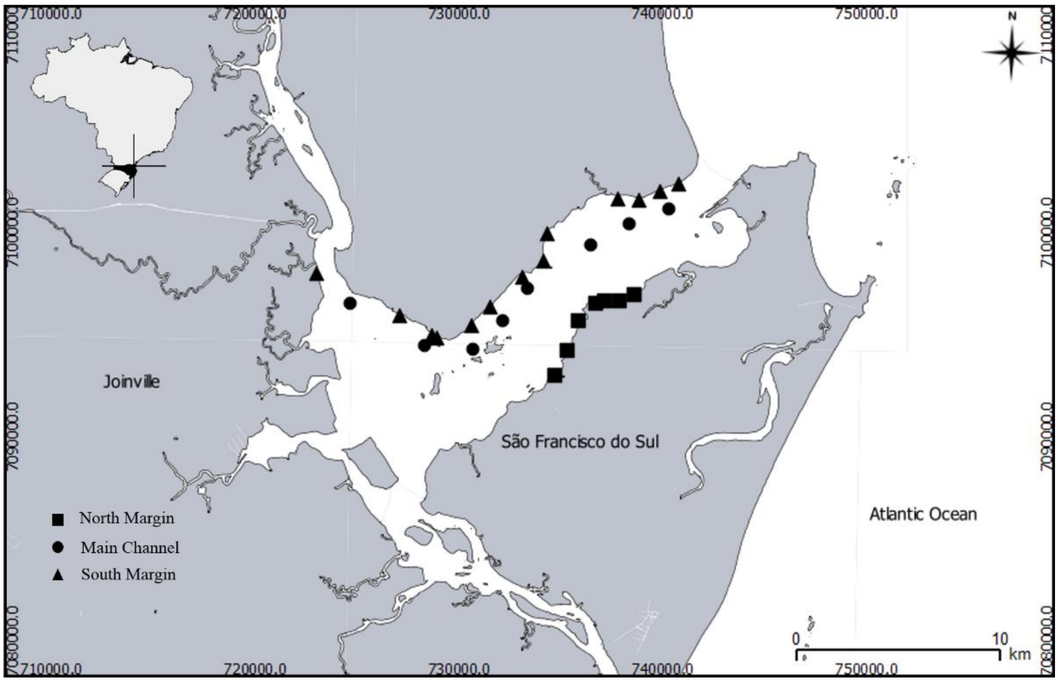

Figure 6: Babitonga Bay (SC), Brazil

All specimens were frozen and taken to the laboratory, identified to the least taxonomic level possible, accordingly with specialized keys (Figueiredo & Menezes 1978, 1980, 2000; Menezes & Figueiredo 1980, 1985; Barletta & Corrêa 1992). All taxons identified, were classified following the proposed guilds by (Elliott *et al.* 2007), based on previously literature (Kawakami & Amaral 983; Bergesen 1982; Juras & Yamaguti 1985; Vasconcelos Filho & Oliveira 1999; Chaves & Vendel 2001; Santos & Castro 2003; Spach *et al.* 2004; Chaves & Bouchereau 2004; Fischer *et al.* 2004; Barletta & Blaber 2007; Barletta *et al.* 2008; Morais 2008; Silva *et al.* 2008; Reis-Filho *et al.* 2010; Bornatowski & Costa 2010; Espinosa *et al.* 2010; Hackradt *et al.* 2011; Medeiros 2011; Derisio *et al.* 2011; Moraes *et al.* 2012; Denadai *et al.* 2012; Koenig & Coleman 2013; Muto *et al.* 2014; Froese & Pauly 2015). The use of estuary guilds: marine stragglers (MS), marine migrants (MM), estuarine species (ES), anadromous (AN), catradomous (CA), amphidromous (AM) and freshwater migrants (FM). The feeding guilds are: zooplanktivore (ZP), detritivore (DV;), herbivore (HV), omnivore (OV), piscivore (PV), zoobenthivore (ZB) and opportunist (OP).

Modelling

Incomplete surveyed areas may lead to infamous problems over choice of correct model, taking biases over inferences based only due incorrect sampling (Dewdney 2000). Testing the success of sampling, was calculated from rarefaction curve, and based on richness found in all sampling together.

For SADs analyses, were used only the guilds with more than twenty species, due to inefficiency of choosing correct SAD model from lower richness, being used only in multivariate analysis. Four different models were utilized in this study: Logseries (Fisher *et al.* 1943); Lognormal (Preston 1948), Broken-stick (MacArthur 1960) and Metacommunity (Hubbell 2001; modified by Alonso & Mckane 2004). Logseries and Lognormal are both the most used models explaining heterogeneous communities, often with proper sampling and higher singletons. Broken-stick is based on sequential partitioned of available resources, where the occupied niche is determined by resources availability (Baczkowski 2000). Metacommunity proposes the equality of species, where they occupy pre-determined niches (Magurran 2005). The lognormal model where truncated at 0.05 to exclude species under sampled.

Selection model were based on Akaike Information Criteria – AIC (Akaike 1973), which calculates the best fit of collected data on tested models, given the ∆AIC, where the minimum values represents the best predictions (Johnson & Omland 2004). Multivariate analyses based on Bray-Curtis dissimilarity matrix, made from untransformed data, both for nMDS (Nonmetric Multidimensional Scaling) and RDA (Redundancy Analysis). Ecological indicators used were: richness, Shannon Index (H), Simpson Index (D) and Inverse Simpson (D.inv). All statistics analyses were performance with R (R Core Team 2014), and available packages sads (Prado & Miranda 2014) and vegan (Oksanen *et al.* 2013)

RESULTS

Sampling of ichthyofauna on Babitonga Bay collected 253.189 individuals, classified within 140 taxon, belonging to 49 different families. The sampling effort was considered successfully, since the calculated asymptote of rarefaction curve were stabilized through the sites sampled (Figure 7).

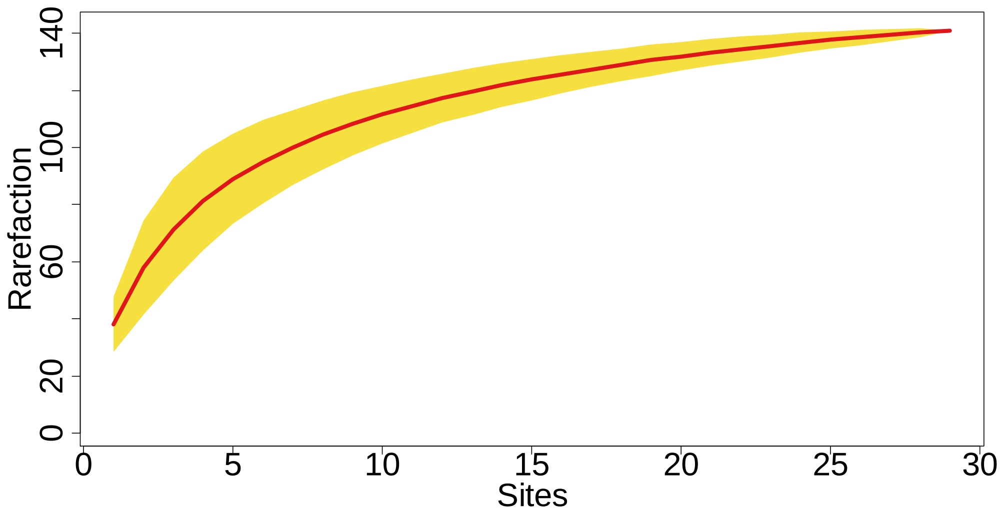

Figure 7: Rarefaction curve with 95% confidence interval (shaded area)

Estuary Use

Classification of species accordingly with estuarine use found eight different classes. The higher number of species was within marine stragglers (MS – 40 species), followed by estuarine residents (ES - 43 species) and marine migrants (MM – 38 species). As expected, the abundances were consistently with the number of species, presenting higher abundance on guilds with higher richness.

The AIC from model selection pointed different models to each of guilds (Table 3). For estuarine residents and marine stranglers three of tested models were choose as efficient on explaining the distribution, all of them with ΔAIC under 2. Concerning marine migrants, only one model – lognormal – was selected as efficient on describing the abundance distribution.

Table 3: Model selection to the three estuarine use guilds with higher abundances in Babitonga Bay. AIC - Akaike Information Criteria results; ΔAIC the difference between AICs.

MODEL	**ER**		**MM**		**MS**	
	AIC	ΔAIC	AIC	ΔAIC	AIC	ΔAIC
LOGNORMAL	582.61	1.72	484.25	0*	411.78	0.04*
LOGSERIES	581.52	0.63*	486.38	2.13	411.74	0*
METACOMMUNITY	580.89	0*	487.78	3.53	412.44	0.7*
BROKEN-STICK	817.39	236.5	591.46	107.21	545.09	133.35

Graphical selection showed that matacommunity and logseries models best fitted the extreme abundances, meanwhile the lognormal explained better the intermediated ones. Despite the graphics showing that are three models explaining the distribution for marine migrants, the ΔAIC value should overlap the decision of model selection (Figure 8).

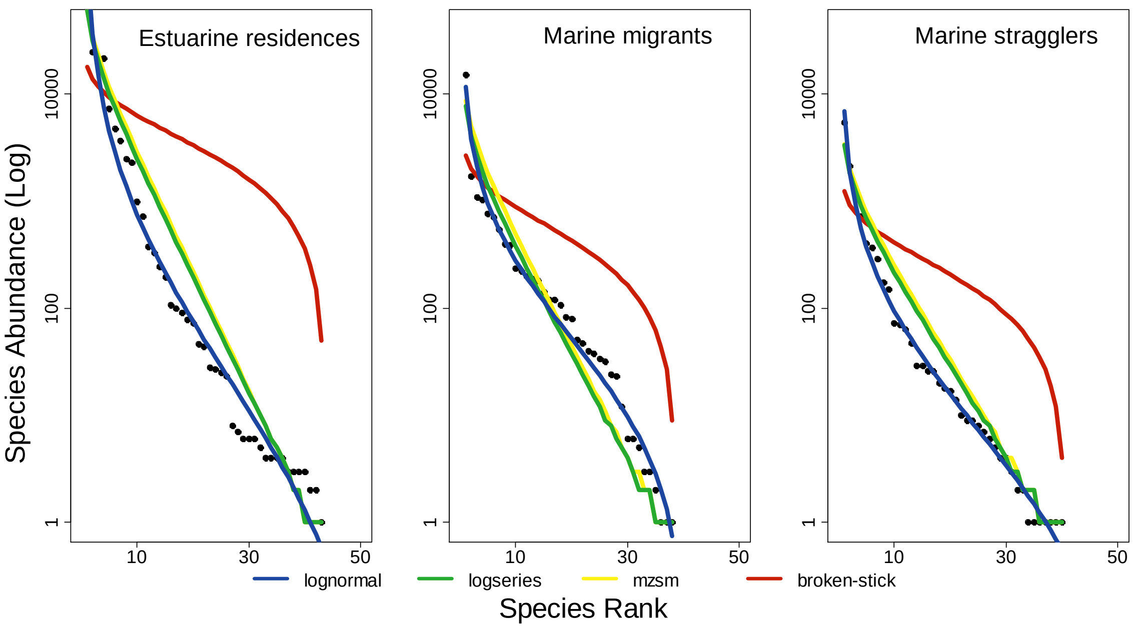

Figure 8: Graphical selection of the four tested models over fish guilds of Babitonga Bay

The nMDS for estuarine use successfully separated all guilds, gathering all three richest guilds. RDA showed that, the dominance parameters (evenness and diversity) were grouped and positively correlated with the guilds studied, due to the higher number of richness and abundance of these guilds (Figure 9). Marine stranglers was the principal guild showed on RDA, probably due to dynamics of all species. The opposite was also observed, with gathered of less representative guilds, because that minimum record of species difficulties ecological calculates (Figure 10).

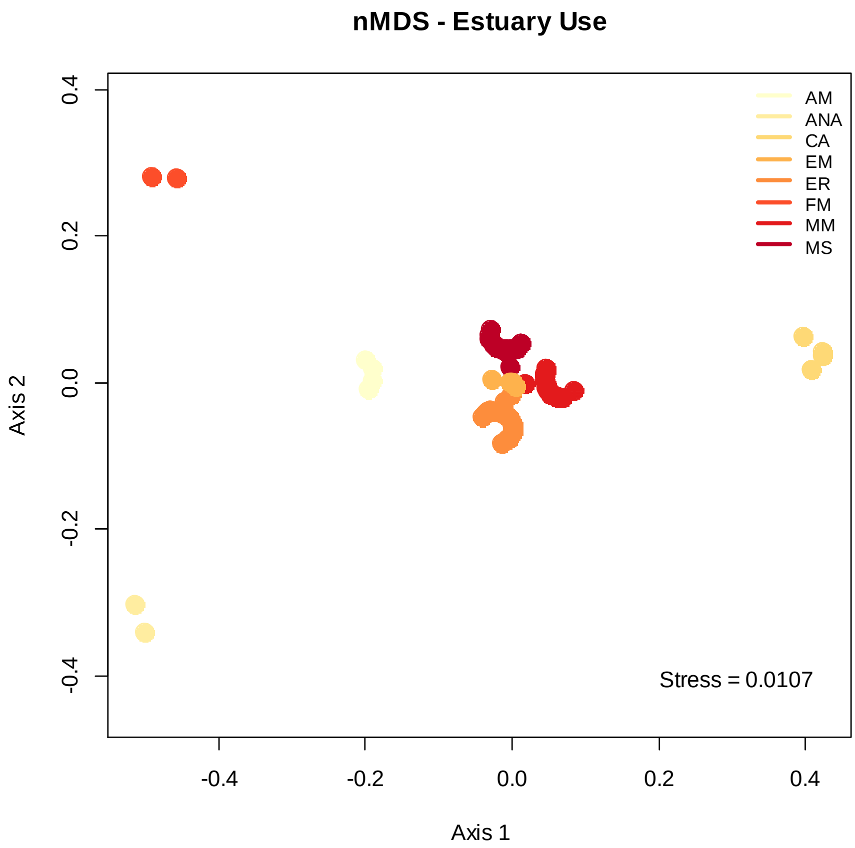

Figure 9: nMDS for estuarine use guilds within Babitonga Bay. For legend abbreviations see the Methods

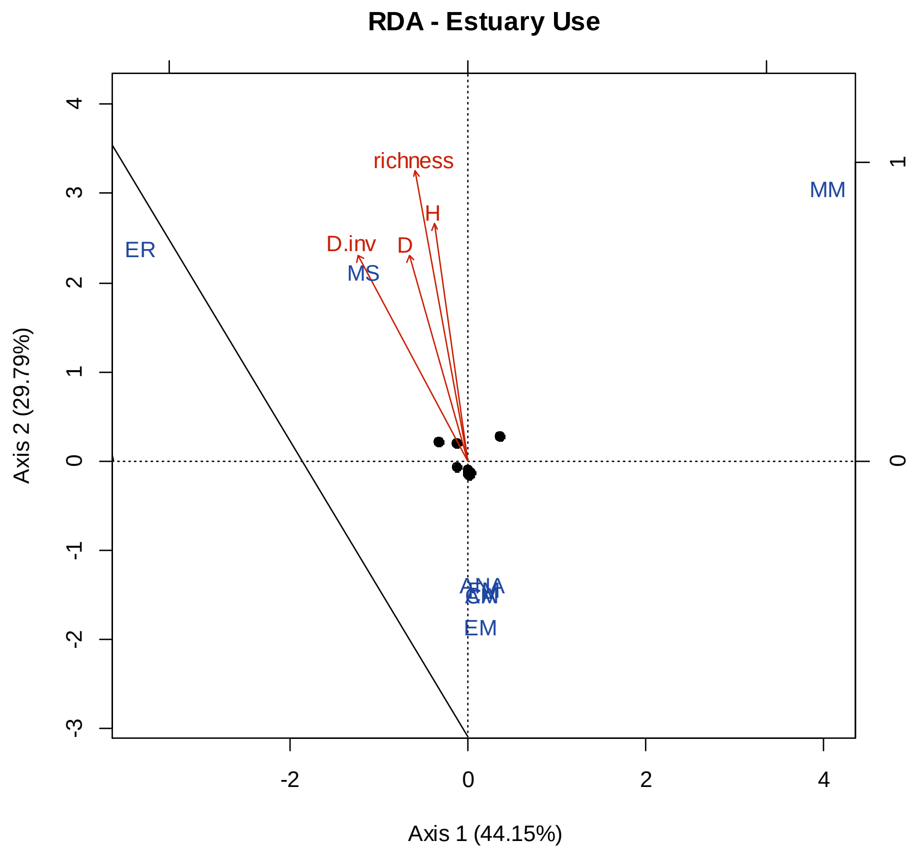

Figure 10: RDA for esturine use guilds of fishes within Babitonga Bay. For abbreviations, see the methods

Trophic Guilds

Guilds classification accordingly the feeding habits has also found eight categories. The ones that presented the bigger number of species were: zoobenthivore (ZB – 78 species), piscivorous (PV - 22 species) and zooplanktivore (ZP – 21 species). In the analysis of the competing models tested, both piscivorous and zoobenthivore, the chosen model that showed the best fit was the lognormal. For zooplanctivore species were chosen two models, the logseries and the metacommunity (Table 4).

Table 4: Model selection to the three trophic guilds with higher abundances Babitonga Bay. AIC - Akaike Information Criteria results; ΔAIC the difference between AICs.

MODEL	PV		ZB		ZP	
	AIC	ΔAIC	AIC	ΔAIC	AIC	ΔAIC
LOGNORMAL	233.47	0.00*	954.94	0.00*	303.64	4.64
LOGSERIES	236.06	2.59	961.38	6.44	299.58	0.58*

METACOMMUNITY	235.56	2.09	964.12	9.18	299	0.00*
BROKEN-STICK	237.93	4.46	1380.54	425.6	377.16	78.16

The graphics of model selection makes clear the difference in richness between the categories analyzed, which apparently did not influence directly in the listed models. Thought the graphics, it is clear the lognormal selection for piscivore and zoobenthivores categories, and the logseries and metacommunity to Zooplanktivores (Figure 11).

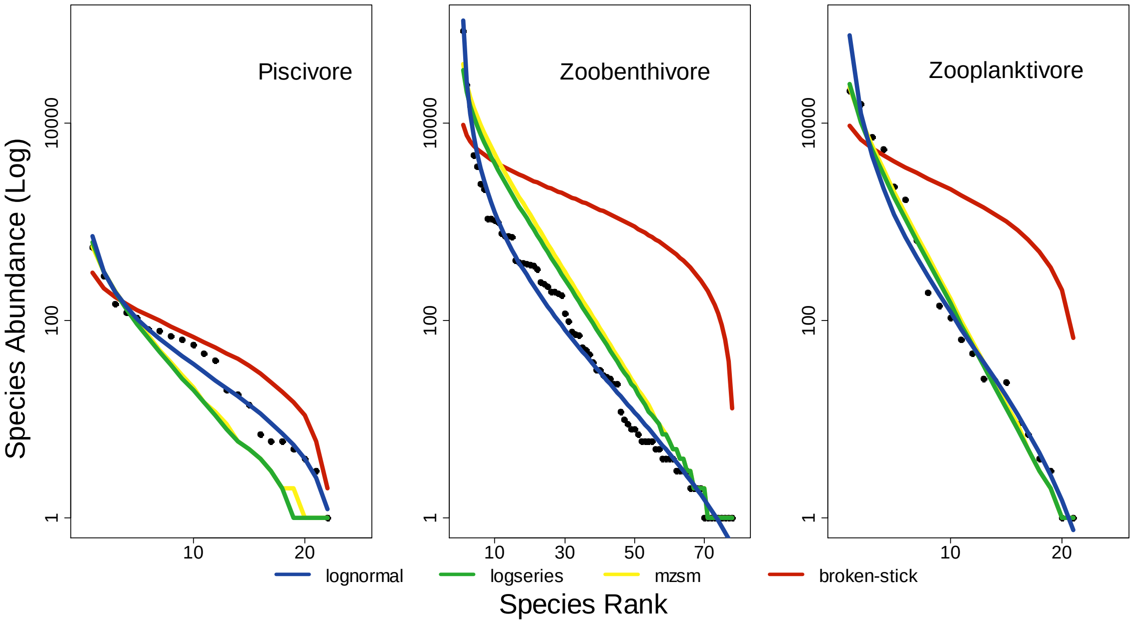

Figure 11: Graphical selection of the four tested models over trophic fish guilds of Babitonga Bay

Concerning trophic categories, nMDS was not efficient over species separation, as long mostly of them were overlapped, except by omnivorous, herbivorous and opportunist ones (Figure 12). As for RDA, piscivorous guild were positively correlated with Dinv, while zoobenthivorous with richness. All others guilds were inversely correlated with the ecological descriptors (Figure 13).

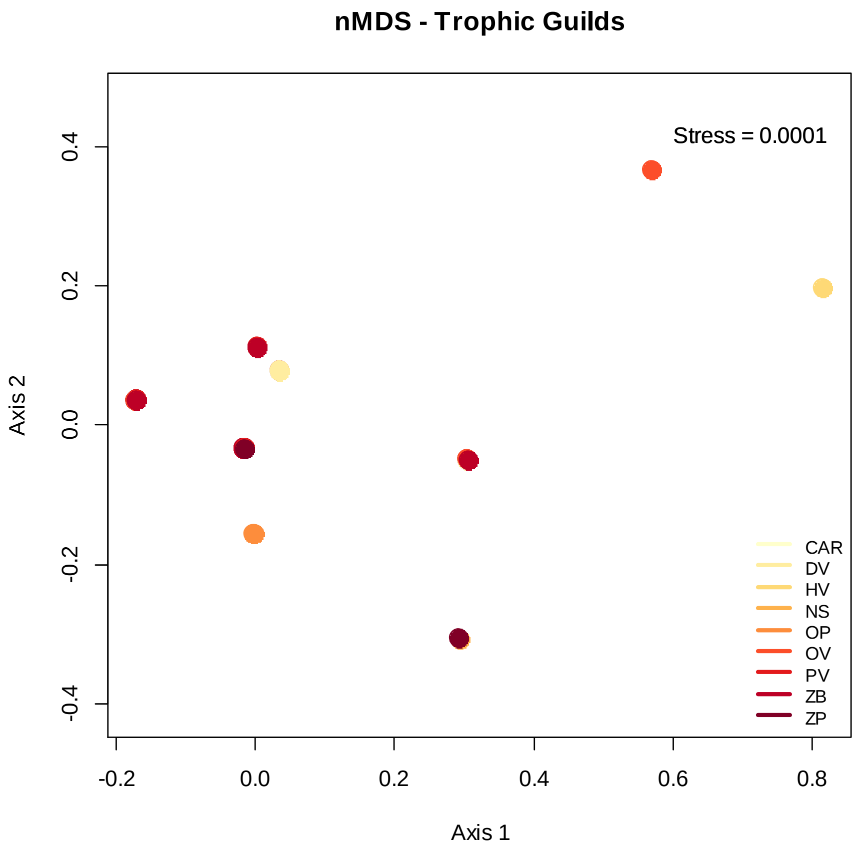

Figure 12: nMDS for trophic guilds within Babitonga Bay. For legend abbreviations see the Methods

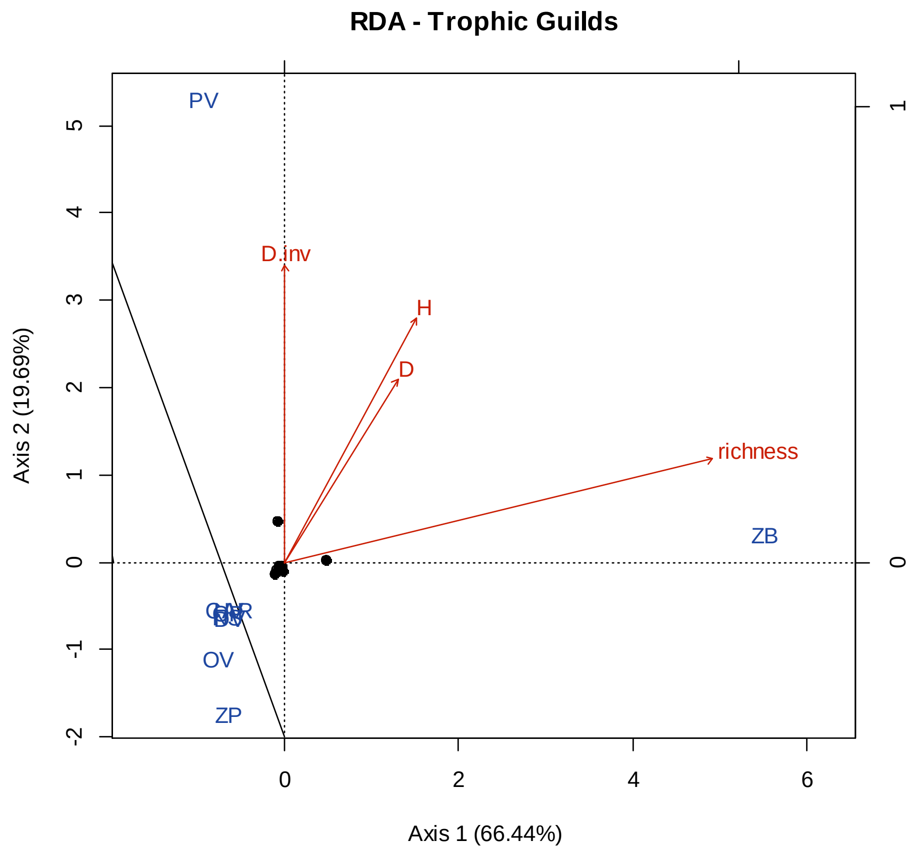

Figure 13: RDA for trophic guilds of fishes within Babitonga Bay. For abbreviations, see the methods

DISCUSSION

Correctly sampling on ichtyofauna community are essential for inferences about the ecology (Clement *et al.* 2014). On this study, we used six different mesh and two sampling methods, which were effective to sample the richness of community, as shown on rarefaction curve. Although VILAR *et al.* (2011) had found more species on his literature review about Babitonga's fish fauna (153 species total), this study didn't sampled specific environments (such as bivalve farming and headlands), making all analysis trustable.

All guilds classified – both of estuarine guild and feeding habits – were similar to others Brazilian estuarine systems (Barletta & Blaber 2007; Xavier *et al.* 2012; Passos *et al.* 2013). The guilds used on ecological modelling showed that, in some scales, each species might utilize the resources available in a specific way, since that more than one model was selected.

Accordingly with Andrade-Tubino *et al.* (2008), most of species that use Brazilian estuaries are estuarine-opportunistic, represented by marine stranglers and marine-migrants in this paper, which present mostly of species classified. They use highly developed capability of osmoregulation to get in the estuaries and use it as feeding areas, protection and reproduction habitats (Whitfield 1999; Barletta-Bergan *et al.* 2002; Barletta *et al.* 2005). All canivorous species were dominating in this study, which is a regular pattern found on estuarine systems, where predators (mainly over invertebrates) is documented (Chaves & Bouchereau 2004; Blaber 2008; Paiva *et al.* 2008).

In species abundance distributions analysis, different models were elected. For estuarine resident and zooplanctivorae species, two models were selected: metacommunity and logseries. Accordingly with these models, the use of available resources – such as food or space – are used in a specific way for each specie (Henderson & Magurran 2010), belonging to a heterogeneous community (Dornelas *et al.* 2009; Ulrich *et al.* 2010) and dominance of singletons, mostly related to alternation of species along of time (Thiel & Potter 2001; Ulrich *et al.* 2010).

For marine stragglers, three of the tested models were selected by AIC explaining the distribution. Choosing three models are frequently related to heterogeneity of guild, what means that are lots of factors operating within it (such as environmental responses and biological drivers) (Shimadzu *et al.* 2013). As shown by RDA, all ecological descriptors are positively correlated with this guild, indicating that, within it, there is a highly dynamics driving the community interactions, but not influencing significantly the trophic dynamics of estuary (Correa *et al.* 2006; Magurran & Henderson 2012). The species turnover may be another factor influencing the choose of multimodal, once they use of the estuary may not be enough to change these dynamics (Henderson & Magurran 2014).

Elliott *et al.* (2007) states that the use of estuary by species might differ significantly within the estuary, where some species are allocated accordingly with the physical characteristics of environment (Andrade-Tubino *et al.* 2008; Parsons *et al.* 2014). This characteristics might influenced the choose of models, since them implies the resource split on abundances distributions (Henderson & Magurran 2010).

For marine migrants, piscivorous and zoobenthivorous, the elected model was lognormal. The input of marine species inside estuaries is frequently registered, despite that mostly of the literature cites it as seasonal (Whitfield 1999; Barletta *et al.* 2003; Spach *et al.* 2003), this study did not find variation of abundances, mainly due to entrance of the species along all year. The variations of these guilds were low, due to the available food resources in Bay (Elliott *et al.* 2007). We might believe that, this species are very well adapted to estuaries, due to the model selection (Unterseher *et al.* 2011)

Chapter 1 showed that the model for the Babitonga Bay as all, is the lognormal. The fact that different models were selected for the specific guilds analysis can be due to biases caused for modelling a minor number of species, that might decrease the accuracy, or by the fact that they use of resources occurs differently (McGill *et al.* 2007). However, the community dynamics in different scales are capable to reveal different patterns within the community, affecting smaller scales (Henderson & Magurran 2010), but not disrupt the community as a whole (Sheaves *et al.* 2014). This general pattern was also found on the coast of Australia, where the smaller scales presented a logseries standard and larger scales (kilometer) showed a lognormal distribution (Connolly *et al.* 2005).

An another side that should be considered is that there is no identification of species, only abundances, what means, the turnover of species does not influences the community, since there’s other species that can be used as food resource available on trophic dynamics (Magurran & Henderson 2012). According to (Vance *et al.* 1996), estuaries are important areas of recruitment of species, where larvae and juveniles may use this ecotone for ontogenetic development. This way, changes of abundance are not the best choice for conducting studies about ecological changes, should being used biomass or age of individuals (Vance *et al.* 1996; Ulrich *et al.* 2010).

This study revealed that, despite having a equilibrated ichtyofauna, Babitonga Bay presents couple of other sectors with dissimilarities concerning the space use and, therefore, on structure for each classification (guild). The use of empiric data for model validation of SADs are very necessary and scarce. This work comes to complement the understanding of environment from theories that explain abundance variation successes in categorize the knowledge of space and enable effective acts of environment preservation.

REFERENCES

1.

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. In: *2nd Int. Symp. Inf. Theory.* (eds. Petrow, B.N. & Csaki, F.). 2nd International Symposium on Information Theory., Budapeste, pp. 267–281.

2.

Alonso, D. & Mckane, A.J. (2004). Sampling Hubbell's neutral theory of biodiversity. *Ecol. Lett.*, 7, 901–910.

3.

Andrade-Tubino, M.F., Ribeiro, A.L.R. & Vianna, M. (2008). Organização espaço-temporal das ictiocenoses demersais nos ecossistemas estuarinos brasileiros: uma síntese. *Oecologia Bras.*, 12, 640–661.

4.

Baczkowski, A.J. (2000). *The broken-stick model for species abundances: An initial investigation*. University Of Leeds, Leeds UK.

5.

Barletta, M., Amaral, C.S., Corrêa, M.F.M., Guebert, F., Dantas, D. V, Lorenzi, L., *et al.* (2008). Factors affecting seasonal variations in demersal fish assemblages at an ecocline in a tropical-subtropical estuary. *J. Fish Biol.*, 73, 1314–1336.

6.

Barletta, M., Barletta-Bergan, a, Saint-Paul, U. & Hubold, G. (2003). Seasonal changes in density, biomass, and diversity of estuarine fishes in tidal mangrove creeks of the lower Caeté Estuary (northern Brazilian coast, east Amazon). *Mar. Ecol. Prog. Ser.*, 256, 217–228.

7.

Barletta, M., Barletta-Bergan, A., Saint-Paul, U. & Hubold, G. (2005). The role of salinity in structuring the fish assemblages in a tropical estuary. *J. Fish Biol.*, 66, 45–72.

8.

Barletta, M. & Blaber, S. (2007). Comparison of fish assemblages and guilds in tropical habitats of the Embley (Indo-West Pacific) and Caeté (Western Atlantic) estuaries. *Bull. Mar. Sci.*, 80, 647–680.

9.

Barletta, M. & Corrêa, M.F.M. (1992). *Guia para identificação de peixes da costa do Brasil*. UFPR, Curitiba.

10.

Barletta-Bergan, A., Barletta, M. & Saint-Paul, U. (2002). Structure and Seasonal Dynamics of Larval Fish in the Caeté River Estuary in North Brazil. *Estuar. Coast. Shelf Sci.*, 54, 193–206.

11.

Barros Grace, V., Mas-Pla, J., Oliveira Novais, T., Sacchi, E. & Zuppi, G.M. (2008). Hydrological mixing and geochemical processes characterization in an estuarine/mangrove system using environmental tracers in Babitonga Bay (Santa Catarina, Brazil). *Cont. Shelf Res.*, 28, 682–695.

12.

Bellier, E., Grøtan, V., Engen, S., Schartau, A.K., Diserud, O.H. & Finstad, A.G. (2012). Combining counts and incidence data: an efficient approach for estimating the log-normal species abundance distribution and diversity indices. *Oecologia*, 170, 477–488.

13.

Bergesen, C.A.E. (1982). Aquarium Maintenance of the Skilletfish [WWW Document]. *North Am. Fish Assoc.* URL http://www.nanfa.org/articles/acskilletfish.shtml.

14.

Blaber, S.J.M.J. (2008). *Tropical Estuarine Fishes: Ecology, Exploitation and Conservation*. Wiley-Blackwell.

15.

Bornatowski, H. & Costa, L. (2010). Feeding of guiterfish Rhinobastos percellen (Walbaum, 1972) (Elamobranchii, Rhinobatidae), the target of artisanal fishery in Southern Brasil. *Brazilian J. Oceanogr.*, 58, 45–52.

16.

Bowler, M.G. & Kelly, C.K. (2012). On the statistical mechanics of species abundance distributions. *Theor. Popul. Biol.*, 82, 85–91.

17.

Chaves, P.T. & Bouchereau, J.L. (2004). Trophic organization and functioning of fish populations in the Bay of Guaratuba, Brazil, on the basis of a trophic contribution factor. *Acta Adriat*, 45, 83–94.

18.

Chaves, P.T. & Vendel, A.L. (2001). Nota complementar sobre a composição ictiofaunística da Baía de Guaratuba, Paraná, Brasil. *Rev. Bras. Zool.*, 18, 349–352.

19.

Clement, T.A., Pangle, K., Uzarski, D.G. & Murry, B.A. (2014). Effectiveness of fishing gears to assess fish assemblage size structure in small lake ecosystems. *Fish. Manag. Ecol.*, 21, 211–219.

20.

Connolly, S.R., Hughes, T.P., Bellwood, D.R. & Karlson, R.H. (2005). Community structure of corals and reef fishes at multiple scales. *Science*, 309, 1363–5.

21.

Correa, M.F.M., Pinheiro, P.C., Almeida, H.K., Kersten, M., Lienstadt, J. & Vollrath, F. (2006). Diagnóstico Ambiental da Ictiofauna. In: *Diagnóstico Ambient. da Baía da Babitonga* (eds. Cremer, M.J., Morales, P.R.D. & Oliveira, T.M.N.). UNIVILLE, Joinville.

22.

Cremer, M.J., Morales, P.R.D. & Oliveira, T. (2006). *Diagnóstico Ambiental da Baía da Babitonga*. UNIVILLE.

23.

Denadai, M.R., Bessa, E., Santos, F.B., Fernandez, W.S., Santos, F.M. da C., Feijó, M.M., *et al.* (2012). Life history of three catfish species (Siluriformes: Ariidae) from southeastern Brazil. *Biota Neotrop.*, 12, 74–83.

24.

Derisio, C., Betti, P., Martin Diaz de Astarloa, J. & Machinandiarena, L. (2011). Larval development of *Etropus longimanus* (Paralichthyidae) and *Symphurus trewavasae* (Cynoglossidae) off the Buenos Aires coast, Argentina. *Sci. Mar.*, 76, 29–37.

25.

Dewdney, A.K. (2000). A dynamical model of communities and a new species-abundance distribution. *Biol. Bull.*, 198, 152–65.

26.

Doi, H. & Mori, T. (2013). The discovery of species-abundance distribution in an ecological community. *Oikos*, 122, 179–182.

27.

Dornelas, M., Moonen, A.C., Magurran, A.E. & Barberi, P. (2009). Species abundance distributions reveal environmental heterogeneity in modified landscapes. *J. Appl. Ecol.*, 46, 666–672.

28.

Elliott, M., Whitfield, A.K., Potter, I.C., Blaber, S.J.M., Cyrus, D.P., Nordlie, F.G., *et al.* (2007). The guild approach to categorizing estuarine fish assemblages: a global review. *Fish Fish.*, 8, 241–268.

29.

Espinosa, H., Findley, L., Collette, B., Cotto, A. & Rojas, P. (2010). Atherinella nepenthe [WWW Document]. . *IUCN Red List Threat. Species.*

30.

Figueiredo, J.L. & Menezes, N.A. (1978). *Manual de peixes marinhos do sudeste do Brasil. II. Teleostei (1)*. Museu de Zoologia da Universidade de São Paulo, São Paulo.

31.

Figueiredo, J.L. & Menezes, N.A. (1980). *Manual de peixes marinhos do sudeste do Brasil. III. Teleostei (2)*. Museu de Zoologia da Universidade de São Paulo, São Paulo.

32.

Figueiredo, J.L. & Menezes, N.A. (2000). *Manual de peixes marinhos do sudeste do Brasil. VI. Teleostei (5)*. Museu de Zoologia da Universidade de São Paulo, São Paulo.

33.

Fischer, L.G., Pereira, L.E.D. & Vieira, J.P. (2004). *Peixes estuarinos e costeiros*. Gráfica Pallott.

34.

Fisher, R.A., Corbet, A.S. & Williams, C.B. (1943). The relation between the number of species and the number of individuals in a random sample of an animal population. *J. Anim. Ecol.*, 12, 42–58.

35.

Froese, R. & Pauly, D. (2015). FishBase [WWW Document]. URL www.fishbase.com.

36.

Gaston, K.J. & Blackburn, T. (2008). *Pattern and process in macroecology*. Wiley-Blackwelll Publishing.

37.

Green, J.L. & Plotkin, J.B. (2007). A statistical theory for sampling species abundances. *Ecol. Lett.*, 10, 1037–45.

38.

Hackradt, C.W., Félix-Hackradt, F.C., Pichler, H.A., Spach, H.L. & Santos, L. de O. (2011). Factors influencing spatial patterns of the ichthyofauna of low energy estuarine beaches in southern Brazil. *J. Mar. Biol. Assoc. United Kingdom*, 91, 1345–1357.

39.

Henderson, P.A. & Magurran, A.E. (2010). Linking species abundance distributions in numerical abundance and biomass through simple assumptions about community structure. *Proc. R. Soc. Biol. Sci.*, 277, 1561–70.

40.

Henderson, P.A. & Magurran, A.E. (2014). Direct evidence that density-dependent regulation underpins the temporal stability of abundant species in a diverse animal community. *Proc. R. Soc. Biol. Sci.*, 281, 20141336.

41.

Hubbell, S. (2001). *The unified neutral theory of biodiversity and biogeography (MPB-32)*.

42.

IBAMA. (1998). *Proteção e Controle de Ecossistemas Costeiros: Manguezal da Baía de Babitonga, Itajaí (SC)*. Coleção Meio Ambiente. Série Estudos – Pesca, nº 25, Brasília, DF.

43.

Johnson, J.B. & Omland, K.S. (2004). Model selection in ecology and evolution. *Trends Ecol. Evol.*, 19, 101–108.

44.

Juras, A.A. & Yamaguti, N. (1985). Food and feeding habits of king weakfish, Macrodon ancylodon (Bloch & Schneider, 1801) caught in the Southern Coast of Brazil (lat 29 to 32). *Bol. Inst. Ocean.*, 33, 149–157.

45.

Kawakami, E. & Amaral, C.S. (983). Importância de analídeos poliquetas no regime alimentas de Etropus longimanus (Norman, 1933) e Symphurus jenynsi (Evermann Kendall, 1907)(Pisces, Pleuronectiformes). *Iheringia. Série Zool.*, 62, 47–54.

46.

Koenig, C.C. & Coleman, F.C. (2013). *Protection of Grouper and Red Snapper Spawning in Shelf-Edge Marine Reserves of the Northeastern Gulf of Mexico: Demographics, Movements, Survival and Spillover Effects*. *SEDAR33-DW02. SEDAR*. North Charleston, SC.

47.

De Lima, R.A.F., Prado, P.I., Martini, A.M.Z., Fonseca, L.J., Gandolfi, S. & Rodrigues, R.R. (2012). Improving methods in gap ecology: revisiting size and shape distributions using a model selection approach. *J. Veg. Sci.*, 24, 484–495.

48.

MacArthur, R. (1960). On the relative abundance of species. *Am. Nat.*, 94, 25–36.

49.

Magurran, A.E. (1988). *Ecological diversity and its measurement*. Princeton University Press.

50.

Magurran, A.E. (2005). Species abundance distributions: pattern or process? *Funct. Ecol.*, 19, 177–181.

51.

Magurran, A.E. & Henderson, P.A. (2012). How selection structures species abundance distributions. *Proc. R. Soc. Biol. Sci.*, 279, 3722–6.

52.

Matthews, T.J. & Whittaker, R.J. (2014). Fitting and comparing competing models of the species abundance distribution: assessment and prospect. *Front. Biogeogr.*, 6, 67–82.

53.

Mazzer, A. & Gonçalves, M. (2011). Aspectos geomorfológicos da Baía da Babitonga, Santa Catarina, Brasil: Caracterização morfométrica. *Rev. Bras. Geomorfol.*, 12, 115–120.

54.

McGill, B.J. (2010). Towards a unification of unified theories of biodiversity. *Ecol. Lett.*, 13, 627–642.

55.

McGill, B.J., Etienne, R.S., Gray, J.S., Alonso, D., Anderson, M.J., Benecha, H.K., *et al.* (2007). Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework. *Ecol. Lett.*, 10, 995–1015.

56.

Medeiros, N.I. (2011). Ecologia trófica das assembléias de peixes em duas praias com diferentes graus de exposição no estuário do rio Mamanguape , Paraíba – Brasil Ecologia trófica das assembléias de peixes em duas praias com diferentes graus de exposição no estuário do rio Mam. UFPB.

57.

Menezes, N.A. & Figueiredo, J.L. (1980). *Manual de peixes marinhos do sudeste do Brasil. IV. Teleostei (3)*. Museu de Zoologia da Universidade de São Paulo, São Paulo.

58.

Menezes, N.A. & Figueiredo, J.L. (1985). *Manual de peixes marinhos do sudeste do Brasil. V. Teleostei (4)*. Museu de Zoologia da Universidade de São Paulo, São Paulo.

59.

MMA. (2007). *Atualização das Áreas e Ações Prioritárias para Conservação, Utilização Sustentável e Repartição de Benefícios da Biodiversidade Brasileira.* Portaria M. Ministério do Meio Ambiente, Brasília, DF.

60.

Moraes, L.E.D.S., Gherardi, D.F.M., Katsuragawa, M. & Paes, E.T. (2012). Brazilian sardine (Sardinella brasiliensis Steindachner, 1879) spawning and nursery habitats: spatial-scale partitioning and multiscale relationships with thermohaline descriptors. *ICES J. Mar. Sci.*, 69, 939–952.

61.

Morais, G.C. (2008). VARIAÇÃO NA DIETA NATURAL DE Cynoscion REGIÃO PORTUÁRIA DA BAÍA DE SÃO MARCOS-MA . UEMA.

62.

Muto, E.Y., Corbisier, T.N., Coelho, L.I., Arantes, L.P.L., Chalon, A. & Soares, L.S.H. (2014). Trophic Groups Of Demersal Fish Of Santos Bay And Adjacent Continental Shelf, São Paulo State, Brazil: Temporal And Spatial Comparisons. *Brazilian J. Oceanogr.*, 62, 89–102.

63.

Oksanen, J., Blanchet, F.G., Kindt, R., Legendre, P., Minchin, P.R., O'Hara, R.B., *et al.* (2013). vegan: Community Ecology Package. *12 December 2013*.

64.

Paiva, A.C.G. De, Tarso, P. De, Chaves, C. & Araújo, M.E. De. (2008). Estrutura e organização trófica da ictiofauna de águas rasas em um estuário tropical. *Rev. Bras. Zool.*, 25, 647–661.

65.

Parsons, D.M., Middleton, C., Smith, M.D. & Cole, R.G. (2014). The influence of habitat availability on juvenile fish abundance in a northeastern New Zealand estuary. *New Zeal. J. Mar. Freshw. Res.*, 48, 216–228.

66.

Passos, A.C., Contente, R.F., Abbatepaulo, F. V, Spach, H.L., Vilar, C.C., Joyeux, J.C., *et al.* (2013). Analysis of fish assemblages in sectors along a salinity gradient based on species, families and functional groups. *Brazilian J. Oceanogr.*, 61, 251–264.

67.

Prado, P.I.K.L. & Miranda, M.D. (2014). sads: Maximum Likelihood Models for Species Abundance Distributions. *01 July 2014*.

68.

Preston, F. (1948). The commonness, and rarity, of species. *Ecology*, 29, 254–283.

69.

R Core Team. (2014). R: A language and environment for statistical computing.

70.

Reis-Filho, J.A., Nunes, J.A.C. & Ferreira, A. (2010). Estuarine ichthyofauna of the Paraguaçu River, Todos os Santos Bay, Bahia, Brazil José. *Biota Neotrop.*, 10, 301–312.

71.

Santos, F.B. & Castro, R.M.C. (2003). Activity, Habitat utilization, feeding behaviour and diet of sand moray Gymnothoras ocellatus (Anguiliformes, Muraenidae) in the South Western Atlantic. *Biota Neotrop.*, 3, 1–7.

72.

Sheaves, M., Baker, R., Nagelkerken, I. & Connolly, R.M. (2014). True value of estuarine and coastal nurseries for fish: Incorporating complexity and dynamics. *Estuaries and Coasts*, 38, 401 – 414.

73.

Shimadzu, H., Dornelas, M., Henderson, P.A. & Magurran, A.E. (2013). Diversity is maintained by seasonal variation in species abundance. *BMC Biol.*, 11, 98.

74.

Silva, L.F.B., Tavares, M. & Soares-gomes, A. (2008). Population structure of the lancelet Branchiostoma caribaeum (Cephalochordata: Branchiostomidae) in the Baía de Guanabara, Rio de Janeiro, southeastern Brazil. *Rev. Bras. Zool.*, 1853, 617–623.

75.

Spach, H.L., Godefroid, R.S., Santos, C., Schwarz Jr, R. & Queiroz, G.M.L.N. de. (2004). Temporal variation in fish assemblage composition on a tidal flat. *Brazilian J. Oceanogr.*, 52, 47–58.

76.

Spach, H.L., Santos, C. & Godefroid, R.S. (2003). Padrões temporais na assembléia de peixes na gamboa do Sucuriú, Baía de Paranaguá, Brasil. *Rev. Bras. Zool.*, 20, 591–600.

77.

Thiel, R. & Potter, I.C. (2001). The ichthyofaunal composition of the Elbe Estuary: an analysis in space and time. *Mar. Biol.*, 138, 603–616.

78.

Ulrich, W., Ollik, M. & Ugland, K.I. (2010). A meta-analysis of species-abundance distributions. *Oikos*, 119, 1149–1155.

79.

Unterseher, M., Jumpponen, A., Opik, M., Tedersoo, L., Moora, M., Dormann, C.F., *et al.* (2011). Species abundance distributions and richness estimations in fungal metagenomics--lessons learned from community ecology. *Mol. Ecol.*, 20, 275–285.

80.

Vance, D.J., Haywood, M.D.E., Heales, D.S., Kenyon, R.A., Loneragan, N.R. & Pendrey, R.C. (1996). How far do prawns and fish move into mangroves ? Distribution of juvenile banana prawns Penaeus merguiensis and fish in a tropical mangrove forest in northern Australia. *Methods*, 131, 115–124.

81.

Vasconcelos Filho, A. de L. & Oliveira, A.M.E. de. (1999). Composição e ecologia da ictiofauna do Canal de Santa Cruz (Itamaracá - PE, Brasil). *Trab. Ocean. Univ. Fed. PE*, 27, 101–113.

82.

Vilar, C., Spach, H.L. & Souza-Conceição, J. (2011). Fish assemblage in shallow areas of Baía da Babitonga, southern Brazil: structure, spatial and temporal patterns. *Panam. J. Aquat. Sci.*, 6, 303–319.

83.

Whitfield, A.K. (1999). Ichthyofaunal assemblages in estuaries: A South African case study. *Rev. Fish Biol. Fish.*, 9, 151–186.

84.

Xavier, J.H.A., Cordeiro, C.A.M.M., Tenório, G.D., Diniz, A.F., Paulo Júnior, E.P.N., Rosa, R., *et al.* (2012). Fish assemblage of the Mamanguape Environmental Protection Area, NE Brazil: abundance, composition and microhabitat availability along the mangrove-. *Neotrop. Ichthyol.*, 10, 109–122.

Diferenciação com as diferentes categorias

A Modelagem ecológica dos dados de peixes da Baía da Babitonga mostrou que, dependendo da escala analisada, diferentes modelos são elencados e, consequentemente, são diferentes processos internos que guiam a distribuição das abundâncias.

Apesar do modelo elencado para a comunidade de peixes como um todo (Normal-Logarítmico), mostrar que a Baía ainda apresenta um estágio com baixo grau de impacto, esse resultado deve ser considerado com cuidado, uma vez que os dados foram coletados antes da implantação do Porto de Itapoá.

A falta de estudos com dados empíricos na aplicação dos modelos ainda é uma lacuna grande nos estudos da área, assim, este trabalho vem no intuito de ajudar a entender a aplicabilidade e inferências possíveis a partir da utilização das DAEs em comunidades naturais. Como nenhum inferência encontrado neste trabalho divergiu das inferências propostas por cada um dos modelos, acreditamos que a utilização desse método é eficaz no entendimento e desenvolvimento de planos de pesquisa.

Para futuros estudo, acredito que a comparação entre os modelos das curvas, e a aplicação de dados de biomassa nos modelos são caminhos promissores para a complementação do entendimento tanto de comunidades, quanto dos próprios modelos.