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ESTRUTURA POPULACIONAL DE EPINEPHELIDAE E SERRANIDAE NA RESERVA MARINHA DO ARVOREDO E DUAS OUTRAS ILHAS PRÓXIMAS À COSTA DA ILHA DE SANTA CATARINA

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Dedico este trabalho ao povo do mar, gente simples, que busca na imensidão azul, o bálsamo, o segredo da vida. Fui acolhido, respeitado e chamado de igual _Lagom. O tesouro está nas profundezas das almas dos bravos. Sempre haverá um porto seguro para os peregrinos. Aqui nestes mares inquietos e praias tranquilas encontrei meu agradável e voluntário desterro. Mesmo sabendo que sempre de partida

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RESUMO

Predadores de topo exercem uma profunda influência na estrutura e função de ecossistemas marinhos. As garoupas, chernes e badejos englobam uma ampla gama de tamanhos e morfologias em seus desenhos corporais, variam de 7 cm (e.g. *Serranus baldwini*) a 250 cm (e.g. *Epinephelus itajara*). Habitam ambientes coralinos, fundos rochosos, e outros microhabitats desde águas rasas a profundidades com mais de 200 metros. Vivem em tocas, fendas e saliências, sempre próximos ao substrato. Algumas espécies também se associam a fundos não consolidados. São conhecidas por exibir comportamento territorial e ocuparem posição no topo na cadeia trófica em ecossistemas marinhos. Além de sua importância ecológica também são consideradas espécies comercialmente valiosas no Brasil, representando um papel econômico importante para a pesca local no litoral de Santa Catarina. São espécies alvo para a pesca artesanal, industrial e caça submarina, além de serem apreciadas ao serem observadas durante o mergulho recreativo SCUBA. A estrutura populacional das garoupas, chernes e badejos (Epinephelidae e Serranidae) foi avaliada através do uso de censos visuais subaquáticos (n = 144 transectos de 30x4 m = 120 m²) executados durante os verões de 2009 e 2010. Os dados de riqueza, densidade e biomassa destas populações foram coletado em 8 locais dentro e fora da Reserva Biológica Marinha do Arvoredo, localizada no Estado de Santa Catarina. O objetivo foi avaliar a eficácia da área restrita à pesca (no-take zone) com relação a proteção das espécies em questão. Também foi avaliada a distribuição e uso de hábitat por garoupas, chernes e badejos. Foram detectadas 13 espécies (7espécies de Epinephelidae - espécies alvo da pesca; e 6 espécies de Serranidae- espécies consideradas pouco exploradas neste litoral). Duas espécies de Epinephelidae foram as mais abundantes e com maior biomassa nos locais estudados: *Mycteroperca marginata* (406 indivíduos amostrados e biomassa total de 127.875,40 g) e *Mycteroperca acutirostris* (224 indivíduos e biomassa total de 88.661,49 g). Três espécies de Serranidae foram as mais abundantes: *Serranus flaviventris* (60 ind. e biomassa total 2.389,43 g) *Serranus baldwini* (31 ind. amostrados e biomassa total 150,24 g), e *Diplectrum radiale* (56 ind. e biomassa total de 714.45 g). Análises de variância (ANOVA one way) foram utilizadas para avaliar diferenças nas médias das biomassas e médias das densidades entre os locais estudados. As densidades e as distribuições de biomassa das espécies de garoupas, dentro e fora da Reserva Biológica Marinho do Arvoredo, foram significativamente diferentes ($p<0,001$) indicando a efetividade da zona restrita à pesca para espécies consideradas alvo da pesca (e.g. *Mycteroperca marginata*, “ameaçada”- IUCN). Análises mostraram que espécimes maiores (maior biomassa, principalmente garoupas - Epinephelidae) são mais frequentes dentro da Reserva. Quando comparados os dados obtidos nesse estudo com outras áreas de proteção sem pesca e com uma simulação de biomassa com dados do ano 1960, os resultados indicam que ainda estamos longe de um sistema mais próximo do pristino. Esse resultado sugere que a pesca ilegal ainda ocorra na REBIO Arvoredo, o que é preocupante do ponto de vista da conservação desse sistema, sobretudo porque no litoral de Estado de Catarina de Santa a maioria dos grandes predadores foram eliminados ou sobre-pescados ao seu esgotamento. A baixa capacidade de recuperação dos estoques das famílias *Epinephelidae* e *Serranidae* devido aos seus ciclos de vida complexos também pode ter influenciado estes resultados. Nem um único indivíduo de *Epinephelus Itajara* (criticamente ameaçado-IUCN), tampouco nenhuma espécie de tubarão foi registrada durante este trabalho. Grandes grupos de predadores de topo (mamíferos marinhos), delfinídeos pertencentes à espécie *Tursiops truncatus* ainda habitam a REBIO. A Análise de Correspondência Canônica enfatizou tendências de distribuição das espécies em fatores como “Rugosidade”(Rugosity), “inclinação do costão” (Slope), “tamanho e quantidade de rochas e tocas”(Small rocks, Médium rocks, large rocks, Small holes, médium holes, large holes) tipo de substrato (Sand). Características ambientais de cada local são destacadas neste procedimento pelo comprimento e direções dos vetores das variáveis. As análises de correspondência Canônica (CCA) enfatizaram tendências de distribuição das espécies de acordo com sua biomassa e variáveis ambientais. Conhecer padrões comportamentais de peixes recifais considerados alvo da pesca ou ameaçados é crítico quanto à efetividade de e gestão de Áreas Marinha Protegidas, particularmente no que se refere ao seu projeto e regulamentação.

Palavras-chave: Predadores de topo, Áreas Marinhas Protegidas, Epinephelidae, Serranidae, Estrutura populacional, espécies alvo, uso do habitat, Reserva Biológica Marinha do Arvoredo.

ABSTRACT

Top predators exert a deep influence on the structure and function of marine ecosystems. Groupers and basses include a very wide range of sizes and morphologies, ranging from 7 cm (e.g. *Serranus baldwini*) to 250 cm (e.g. *Epinephelus itajara*). They inhabit coral, rocky bottoms, and other microhabitats from shallow water to depths of more than 200 meters and live in caves, crevices and on ledges, always near the substrate. Some species also live associated to non-consolidated substrate. These species are also known to be substrate-associated and display territoriality and dominance behavior in marine ecosystems. Besides its ecological importance they are also considered commercially valuable species in Brazil, representing an important economic role for local fisheries on the coast of Santa Catarina, and are also target species for spear fishing and of interest to recreational scuba diving. Population structure of groupers, basses (Epinephelidae and Serranidae) was assessed through visual censuses surveys (n = 144 transects of 30x4 m = 120 m²) performed during the summers of 2009 and 2010. Richness and biomass data of these populations were collected in 8 different sites inside and around Arvoredo Marine Biological Reserve, located near the cost of Santa Catarina State. The objective was to evaluate the effectiveness of the no-take zone regarding the protection of the focal species. We also evaluated the habitat use of groupers and basses. We detected 13 species of groupers and basses (7 species of Epinephelidae – targeted species; and 6 species of Serranidae - non exploited species in this coast). Two species of groupers were considered more abundant *Mycteroperca marginata* (406 specimens; total biomass 127875.40 grams) and *Mycteroperca acutirostris* (224 specimens; total biomass 88661.49 grams) detected in all surveyed sites. Three species of basses were considered more abundant *Serranus flaviventris* (60 specimens; total biomass 2389.43 grams) detected in 6 surveyed sites, and *Serranus baldwini* (31 specimens, total biomass 150.24 grams) and *Diplectrum radiale* (56 specimens, total biomass of 714,45 grams). One-way ANOVA was used to evaluate differences in the biomass means and density means among the eight sites. Grouper species density and biomass distributions, inside and outside Arvoredo Marine Biological Reserve, showed significant differences ($p<0,001$) indicating effectiveness of the no-take zone for target and threatened species (e.g. *Mycteroperca marginata*, EN – IUCN). Analysis performed with species biomass means showed that larger targeted species (mostly groupers – Epinephelidae) are more frequent inside the Reserve. Results are consistent with previous studies with reef fish in the same area: targeted species are being protected by the Reserve, however comparisons among other no-take areas and biomass simulations with data from the year 1960, results indicate that we are far from near-pristine system. This result suggests that illegal fisheries still occurs inside Arvoredo Biological marine Reserve, which concerns from the point of view of this system's conservation, especially because in the coast of Santa Catarina State most of the great predators have been eliminated of overexploited to depletion. Not one single individual of *Epinephelus itajara* (critically endangered IUCN) or any shark species was recorded during this work. The Canonical correspondence analysis (CCA) emphasized tendencies of distribution of species according to their biomass and environmental variables. Canonical correspondence analysis (CCA) emphasized tendencies of distribution of species as factors such as "Rugosity", "Slope", size and quantity of rocks, substrate type. Knowing behavioral patterns of target reef fishes is critical to conservation effectiveness and management of MPA's, particularly regarding to their design and regulamentation.

Keywords: Top predators, Marine protected Areas, Epinephelidae, Serranidae, Population structure, Targeted species, Habitat use, Arvoredo Biologic Marine Reserve.

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Figure 6. Canonical correspondence analysis (CCA) joint plots showing distribution of species according to their biomass and environmental variables (cumulative % of variance 82,97)**.** The arrow vectors show the environmental variables, the circles mark the positions of species. Recorded species with a total density smaller than 30 organisms were not considered in this analysis. (Pag.77)

Figure 7. Canonical correspondence analysis (CCA) joint plots showing distribution of 5 dominant species according to their biomass and environmental variables (cumulative % of variance 98,71)**.** The arrow vectors show the environmental variables, the circles mark the positions of species. The green triangles represent the position of species. Circles mark the position of sites: Grey circles mark the no-take sites; black circles mark the sites outside MPA and the white circles mark the sites located in the coast. (Pag.79)

Figure 8. Frequency of occurrence histogram of dominant species according to their vertical position relative to the substrate. Individuals of *M. marginata* (1) were recorded inside or close to their shelters, and the few individuals positioned in the water column were never found vertically higher than 1 meter. Most individuals of *M. acutirostris* (2) were recorded in the water column mostly at 1 meter vertical to the substrate. *Serranus baldwini* (3) individuals were recorded on rodolith beds mostly in Deserta and Galé Islands, never more than a few centimeters (< 30 cm) from the substrate. Individuals of S. flaviventris (4) were recorded in sites located on the coast (Cape Araçá and Cape Sepultura). Most individuals of *D. radiale* (5) are exclusively associated with unconsolidated substrate, never recorded in the water column; all individuals of D. radiale were recorded in a specific site located on the coast (Cape Araçá). (Pag.81)

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INTRODUÇÃO GERAL

A costa brasileira possui uma vasta e diversa comunidade de peixes recifais, porém, relativamente pouco se sabe sobre o impacto da pesca nestas espécies de peixes, e pouco se tem feito com relação ao manejo e esforço para a conservação das mesmas (Floeter *et al.*, 2006; Francini-Filho e Moura, 2008).

Predadores de topo exercem profunda influência na estrutura e função de ecossistemas marinhos. Ainda assim, seu número vem decaindo dramaticamente no século 20, aproximadamente 90% em algumas regiões do mundo. Esta perda pode desencadear o “efeito cascata” sobre os níveis subseqüentes da cadeia trófica comprometendo a estruturação das comunidades marinhas (Heithaus *et al.*, 2008).

A predação é uma dos processos ecológicos mais estudados na ecologia e de maneira geral, referida como uma interação altamente assimétrica. É fator altamente controlador, junto à competição, dos números e hábitos de uma população (Chesson e Kuang, 2008). Alguns autores propõem, através do uso de modelos, que tais interações podem ser consideradas simétricas, limitadoras e promotoras da diversidade (Chesson e Kuang, 2008). Uma abordagem ou uma perspectiva multitrófica é sugerida por Chesson e Kuang, para examinar uma gama maior de possíveis efeitos da predação.

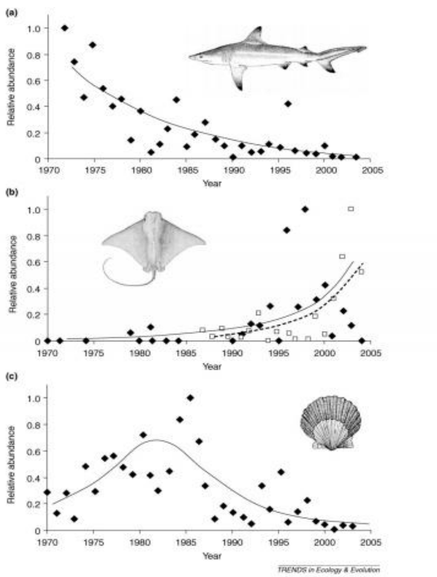
A predação e competição têm o potencial de afetar a diversidade da mesma forma, e cada qual deve promover ambos, coexistência e exclusão. Além disto, é proposto que as interações ecológicas competição e predação interagem entre si (Chesson e Kuang, 2008).

Quando predadores desaparecem do oceano, suas principais espécies predadas, às vezes chamadas mesoconsumidores, podem aumentar em abundância. Estas são espécies intermediárias na cadeia alimentar, como raias, por exemplo, que predam e são predadas por outras espécies marinhas; devido ao aumento pela falta de seu predador, passam a diminuir drasticamente os estoques das espécies que ocupam níveis “inferiores” na cadeira trófica. Desta maneira, toda a estrutura deste ecossistema vê-se desequilibrada e inicia-se o “efeito cascata” (também chamado top-down cascade effect), um processo irreversível (Heithaus *et al.*, 2008).

A perda de predadores de topo em um ecossistema não somente exerce efeito direto sobre o ecossistema na forma de aumento de espécies de mesoconsumidores, como também influencia os padrões comportamentais das espécies (Heithaus *et al.*, 2008).

Vários estudos recentes documentam o declínio dramático das populações de predadores de topo, iniciando subseqüentemente as cascatas tróficas. Para melhor entendimento destes fenômenos e suas reais conseqüências, é necessária uma compreensão maior de como os predadores interagem em suas comunidades por infligirem mortalidade em suas presas, e afetando seu padrão comportamental (risk effects). Ambos os mecanismos são importantes em comunidades marinhas, e o estudo focado somente na mortalidade provocada pelo predador pode subestimar muito a importância e papel funcional do predador (Heithaus *et al.*, 2008).

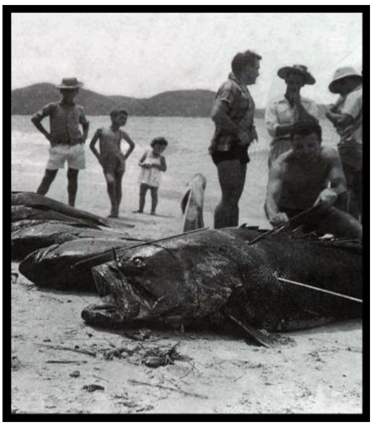
Figura 1. A remoção de predadores marinhos pode resultar em efeitos de cascata nas comunidades. Com a remoção do predador de topo *Carcharhinus limbatus* as populações de raia “cownose ray” *Rhinoptera bonasus* aumentam, exercendo sobre sua presa a vieira *Agropecten irradians,* uma pressão insustentável, provocando o colapso da espécie na base da cadeia alimentar (Heithaus *et al.*, 2008).



O efeito risco representa uma grande questão quando nos referimos ao entendimento das conseqüências ecológicas para a remoção de predadores de topo. Pesquisadores de sistemas marinhos que envolvem grandes predadores freqüentemente afirmam que cascatas tróficas ocorrem via interação direta do predador (lethal effects) com o mesoconsumidor (Heithaus *et al.*, 2008). O efeito risco provoca alteração radical no padrão de comportamento, principalmente com relação ao forrageamento. Estudos mostram que os organismos podem reduzir o risco de serem predados através de mecanismos de defesa comportamentais (Lima e Dill, 1990).

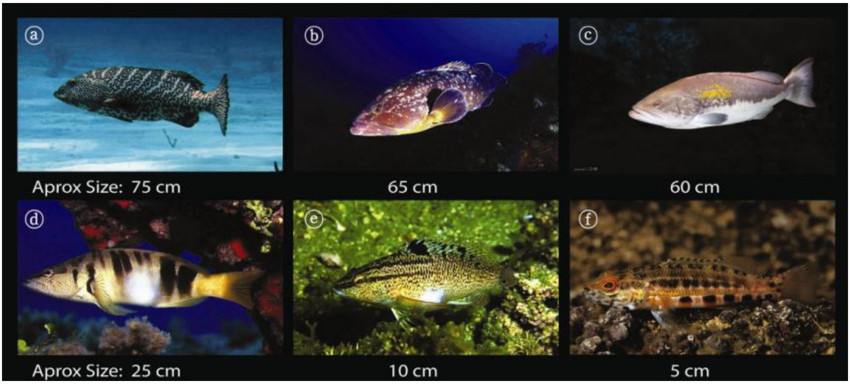
No Brasil a extirpação das grandes espécies de tubarão, da maioria da costa, suas implicações na estrutura das comunidades de peixes recifais, e seus ecossistemas, ainda carecem de informação. Em Santa Catarina a maioria dos grandes predadores de topo foi eliminada pela exploração pesqueira de diversas modalidades nos últimos 50 anos (Souza, 2000). A estrutura das comunidades de peixes recifais como observamos hoje, é um reflexo pálido, da real diversidade deste ecossistema de décadas atrás.

Figura 2. Fotografia modificada de Souza (2000); praia dos ingleses, Ilha de Santa Catarina, 1957. O primeiro peixe na fotografia era um exemplar de Mero (*Epinephelus itajara*) com a biomassa registrada em 317 quilogramas. Em Santa Catarina a maioria dos grandes predadores de topo foi eliminada pela exploração pesqueira de diversas modalidades nos últimos 50 anos (Souza, 2000).



A remoção dos grandes tubarões coloca os golfinhos (*tursiops truncatus* principalmente), as garoupas, chernes e badejos, neste ambiente, como os principais predadores de topo. Estes organismos assumiram os papéis funcionais de controladores "top-down" das demais populações de peixes recifais.

Figura 3. Organismos **r**epresentantes das famílias Epinephelidae (a) *Mycteroperca tigris*, (b) *Mycteroperca marginata*, (c) *Epinephelus costae*; Serranidae (d) *Serranus scriba*, (e) *Serranus flaviventris* e (f) *Serranus baldwini*.



Epinephelídeos são considerados predadores de topo em ambientes recifais, espécies com alta longevidade e uma baixa taxa de mortalidade em ambiente natural. São organismos com baixa capacidade de recuperação dos estoques principalmente por iniciarem a reproduzirem-se tardiamente (Polovina and Ralston, 1987; Sadovy, 1994). Muitas espécies de garoupas, como o Mero (*Epinephelus itajara*), a garoupa de Nassau (*E. striatus*), são alheios à presença do mergulhador, portanto facilmente capturados por várias artes (modalidades) de pesca. Quando suas agregações reprodutivas são detectadas por pescadores locais ou a agregação é prevista dada a sua sazonalidade, populações inteiras são facilmente erradicadas. (Polovina and Ralston, 1987; Sadovy, 1994; Coleman *et al.*, 1999; Sadovy and Eklund, 1999).

Muitas espécies de garoupas (Epinephelidae e Serranidae) são importantes componentes da ictiofauna considerada de alto valor recreacional e comercial. Estes organismos também contribuem para manter a saúde dos ecossistemas marinhos onde ocorrem. Sendo assim, a preservação de populações saudáveis de garoupas é considerada importante economicamente, e de enorme importância e relevância ecológica. Sua biologia e comportamento tornam estes organismos extremamente susceptíveis à depleção causada pela exploração pesqueira (Coleman *et al.,* 1999).

A garoupa-verdadeira (Mycteroperca marginata) considerada espécie ameaçada em diversas listas vermelhas (e.g. IUCN) é exemplo de hermafrodita protogínico com comportamento reprodutivo gregário e uma complexa estrutura social (Zabala *et al.,* 1997; Andrade *et al.,* 2003). Esta espécie matura sexualmente quando alcança os 45 cm e 2 quilogramas. A inversão sexual ocorre quando atinge os 9-10 anos e 90 cm de comprimento (Bruslé, 1985; Marino *et al.,* 2001). Conhecer os padrões comportamentais de deslocamento de peixes recifais importantes para a pesca é crítico para uma conservação efetiva e manejo destas, particularmente em relação ao design e regulamentação de áreas marinhas protegidas (AMP's) (Spedicato *et al.,* 2005, Garcia-Chartón *et al.,* 2008).

Para uma maior efetividade das Reservas Marinhas, no que se refere às garoupas e demais predadores de topo, seu desenho deve incorporar ambientes favoráveis. Atualmente o conhecimento sobre habitats considerados ótimos são escassos. A grande parte do que se sabe sobre estes organismos é meramente anedótico. (Spedicato *et al.,* 2005; Garcia-Chartón *et al.,* 2008; Gibran, 2007).

A REBIO Arvoredo foi criada em 12 de março de 1990, pelo Decreto nº 99.142, e tem como objetivo, preservar uma amostra representativa da biodiversidade presente no ambiente de costão rochoso característico da costa de Santa Catarina. A Reserva Biológica Marinha do Arvoredo (REBIOmar) integra o desenho amostral deste estudo, por ser área de ocorrência destas espécies**,** e várias outras espécies de serranídeos, por possuir ambientes formados por recifes rochosos (Hostim-Silva et al., 2006) e ser área protegida da pesca (D. Federal nº 99.142/90)**.**

Este trabalho (Projeto Ecogaroupa) propôs avaliar a dinâmica populacional de predadores de topo (Epinephelidae e Serranidae) dentro e fora da Reserva Marinha do Arvoredo, para complementar o que se sabe sobre estas espécies e seus papéis funcionais no ecossistema marinho, bem como auxiliar na proteção destas espécies, avaliando a efetividade da reserva marinha, considerando ainda, o papel econômico que estas espécies representam para as comunidades pesqueiras locais.

Este estudo avaliou mediante a utilização da metodologia de censos visuais (Brock, 1954; Goñi *et al.,* 2000; Floeter *et al.,* 2007) quais são as condicionantes ambientais que afetam a distribuição e o uso do hábitat destas espécies, em diferentes fases ontogenéticas de seu ciclo de vida, e ainda a ocupação do hábitat ao longo de seu desenvolvimento, assim, contribuindo para avaliar a efetividade do "design" da REBIOmar. Restrições à pesca em AMP's podem promover um aumento na biomassa de espécies exploradas, e em condições adequadas ocorre o "spillover" (exportação de biomassa) para zonas adjacentes não protegidas, mantendo ou incrementando a pesca local (Roberts e Polunin, 1991; Russ, 2002; Garcia-Chartón *et al.,* 2008, Aburto-Oropeza *et al.,* 2011).

Algumas espécies, por causa de suas características reprodutivas, claramente são mais susceptíveis à exploração pesqueira que outras, por exemplo: espécies que se agrupam para compor agregações reprodutivas e espécies que sofrem câmbio sexual (hermafroditas protogínicos, protândricos e hermafroditas sincrônicos) sempre serão mais susceptíveis aos ataques da indústria pesqueira e demais modalidades da pesca (Olsen e La Place, 1979; Carter *et al.,* 1994; Sadovy, 1994; Sadovy *et al.,* 1994b; Shapiro, 1987).

O manejo de áreas marinhas protegidas no Brasil e no mundo hoje tem pouca ambição de recuperar os ambientes para níveis mais próximos dos pristinos (pré-impactos humanos), e isso se deve ao fenômeno dos pontos de referência dinâmicos "Shifting baselines" (Knowlton e Jackson, 2008).

Parece ser consenso hoje que uma dada área protegida da pesca estar com mais biomassa e peixes alvos da pesca com tamanhos maiores já basta para medir a efetividade dessas áreas protegidas. Os recifes de Kingman e Palmyra no Oceano Pacífico, por exemplo, quase intocados pelo homem, apresentam uma importante biomassa de predadores de topo (tubarões e outros predadores) de forma que a pirâmide trófica de biomassa pode ser interpretada de forma invertida (a maior parte da pirâmide se concentra nos predadores de topo). Em outros recifes já pescados (mesmo que geograficamente próximos) a pirâmide de biomassa se apresenta de modo padrão, com a base mais larga (Sandin *et al.,* 2008; Aburto-Oropeza *et al.,* 2011).

O Conselho Mundial de Desenvolvimento Sustentável, a União Mundial para a Conservação (IUCN), a Comissão de áreas Protegidas, e a Convenção Mundial de Diversidade Biológica, exigiram o estabelecimento de um sistema integrado global eficaz de MPAs para o ano 2012. Embora o Brasil esteja comprometido com estas metas, ainda há poucos estudos sobre os efeitos das MPAs neste país (Floeter *et al.*, 2006; Francini-Filho e Moura, 2008).

REFERÊNCIAS BIBLIOGRÁFICAS

Aburto-Oropeza O., Erisman B., Galland G.R., Mascareñas-Osorio I., Sala E. *et al.* (2011). Large Recovery of Fish Biomass in a No-Take Marine Reserve. PLoS ONE 6(8).

Andrade A.B., Machado L.F., Hostim-Silva M, Barreiros J.P. (2003). Reproductive biology of the dusky grouper Epinephelus marginatus (Lowe, 1834). Brazilian Arch. Biol. Tech. 46(3):373–381.

Brock V.E. (1954). A preliminary report on a method of estimating reef fish populations. J Wildlife Manage 18:297–308.

Bruslé J. (1985). Esposé synoptique des données biologiques sur les mérous Epinephelus aeneus (Geoffroy Saint Hilaire, 1809) et Epinephelus guaza (Linnaeus, 1758) de L`Océan Atlantic et de la Méditerranée. FAO Synop. Pêches 129:64.

Carter. J., F.J. Marrow & V. Pryor. (1994). Aspects of the ecology and reproduction of Nassau grouper, Epinephelus striatus, off the coast of Belize, Central America. Proc. Gulf & Caribbean Fisheries Institute 43: 64-110.

Chauvet C. & Francour P. (1990). Les mérous Epinephelus guaza du parc nacional de Port- Cros (France);Aspects socio-démographiques. Bulletin Societat Zoologique, 114 (4): 5-13.

Chesson P. & Kuang J. J. (2008). The interaction between predation and competition. Vol 456| 13

Claudet J., Pelletier D., Jouvenel J.Y., Bachet F. & Galzin R. (2006). Assessing the effects of marine protected area (MPA) on a reef fish assemblage in a northwestern Mediterranean case study: Identifying community-based indicators. Biol. Conserv., 130, 349–369.

Coleman F. C., C. C. Koenig, A.-M. Eklund, and C. B. Grimes (1999). Management and conservation of temperate reef fish in the southeastern United States. In Life in the slow lane— ecology and conservation of long-lived marine animals (J. A. Musick, ed.), p. 233–242. American Fisheries Society Bethesda, Maryland.

Coleman F.C., Williams S.L. (2002). Overexploiting marine ecosystem engineers: potential consequences for biodiversity. Trends Ecol Evol 17:40-44.

Côté I.M., Mosqueira I., Reynolds J.D. (2001). Effects of marine reserve characteristics on the protection of fish populations: a meta-analysis. J. Fish Biol., 59 (Supplement A):178–189.

Figueiredo J. L. & N. A. Menezes. (1980). Manual de Peixes do Sudeste do Brasil 3. São Paulo Museu de Zoologia, Universidade de São Paulo. 90 pp.

Floeter S.R., Guimarães Z.P., Rocha L.A., Ferreira C.E.L., Rangel C.A. and Gasparini J.L. (2001). Geographic variation in reef-fish assemblages along the Brazilian coast. Global Ecology and Biogeography10, 423–431.

Floeter S. R., Halpern, B. S., Ferreira, C. E. L. (2006). Effects of fishing and protection on Brazilian reef fishes. Biological Conservation, 128: 391-402.

Floeter S. R., Krohling W., Gasparini, J. L., Ferreira C. E. L., Zalmon I. (2007). Reef fish community structure on coastal islands of the southeastern Brazil: the influence of exposure and benthic cover. Environmental Biology of Fishes, 78: 147-160.

Floeter S.R., Rocha L.A., Robertson D.R., Joyeux J.C., Smith-Vaniz W.F., Wirtz P., Edwards A.J., Barreiros J.P., Ferreira C.E.L., Gasparini J.L., Brito A., Falco´n J.M., Bowen B.W. and Bernardi G. (2008). Atlantic reef fish biogeography and evolution. Journal of Biogeography 35, 22–47.

Francini-Filho R.B. and Moura R. L. (2008). Dynamics of fish assemblages on coral reefs subjected to different management regimes in the Abrolhos Bank, eastern Brazil. Aquatic Conserv: Mar. Freshw. Ecosyst. 18: 1166–1179 (2008) Published online 17 June 2008 in Wiley InterScience www.interscience.wiley.com)

García-Charton J.A., Pérez-Ruzafa A., Marcos C., Claudet J.; Badalamenti F., Benedetti- Cecchi L., Falcón J.M., Milazzo M., Schembri P.J., Stobart B., Vandeperre F., Brito A., Chemello R., Dimech M., Domenici P.; Guala I., Le Diréach L., Maggi E., Planes S. (2008). Effectiveness of European Atlanto-Mediterranean MPAs: do they accomplish the expected effects on populations, communities and ecosystems? Journal of Nature Conservation, 16, 193-221.

Gibran F. Z. (2002). The sea basses Diplectrum formosum and D. radiale (Serranidae) as followers of the sea star Luidia senegalensis (Asteroidea) in southeastern Brazil. Brazilian Journal of Biology, 62(4A): 591-594.

Gibran F. Z. (2004). Dying or illness feigning: an unreported feeding tactic of the comb grouper Mycteroperca acutirostris (Serranidae) from the Southwest Atlantic. Copeia, 2004(2): 402-405.

Gibran F. Z. (2007). Activity, habitat use, feeding behavior, and diet of four sympatric species of Serranidae (Actinopterygii: Perciformes) in southeastern Brazil. Neotrop. ichthyol. [online]. Vol.5, n.3, pp. 387-398. ISSN 1679-6225.

Gibran F.Z. (2010). Habitat partitioning, habits and convergence among coastal nektonic fish species from the São Sebastião Channel, southeastern Brazil. *Neotropical Ichthyology*; 8(2):299–310.

Goñi R., Harmelin-Vivien M., Badalamenti F., Le Diréach L., Bernard G. (2000). Introductory guide to methods for selected ecological studies in marine reserves. edit., GIS Posidonie publ., Fr., 2000 : 1-120.

Heithaus M.R., Frid A., Wirsing A.J. and Worm B. (2008). Predicting ecological consequences of marine top predator declines. Trends in Ecology and Evolution 23(4) :202–210.

Hostim-Silva M., Andrade A.B., Machado L.F., Gerhardinger L.C., Daros F.A., Barreiros J.P. and Godoy E.A.S. (2006). Peixes de costão rochoso de Santa Catarina: I. Arvoredo. 1st edition. Itajaı´: Editora da Universidade do Vale do Itajaı´.

Knowlton N., Jackson J.B.C. (2008). Shifting Baselines, Local Impacts, and Global Change on Coral Reefs. PLoS Biol 6(2): e54.

Lima, S.L. and Dill, L.M. (1990). Behavioral decisions made under the risk of predation: a review and prospectus. Can. J. Zool. 68, 619–640.

Marino G., Longobardi A., La Mesa G., Donadelli V. & De Innocentiis S. (2007). Pilotrestocking of hatchery dusky grouper Epinephelus marginatus juveniles in the Mediterranean sea. Symposium on the Mediterranean Groupers. (eds: Francour, P., & Gradiot, J.). Nice University publ., Nice: 129-131.

Olsen D.A. & LaPlace J.A.. (1979). A study of a Virgin Islands grouper fishery based on a breeding aggregation. Proc. Gulf Carib. Fish. Inst. 31: 130-144.

Polovina J. J., and Ralston S. (1987). Tropical snappers and groupers: biology and fisheries management. Westview Press, Boulder, CO, 659 p.

Roberts C.M. & Polunin N.V.C. (1991). Are marine reserves effective in management of reef fisheries? Rev. Fish Biol. Fish., 1, 65–91.

Roberts C.M., Andelman S., Branch G., Bustamante R.H., Castilla J.C., Dugan J.E. *et al.* (2003). Ecological criteria for evaluating candidate sites for marine reserves. Ecol. Appl., 13, S199–S214.

Sadovy Y., P.L. Cohn & Domeier M.L.. (1994). Aggregation and spawning in the tiger grouper, Mycteroperca tigris (Pisces: Serranidae). Copeia 1994: 511-516.

Sadovy Y. (1994). Grouper stocks of the Western Central Atlantic: the need for management and management needs. Proc. Gulf Carib. Fish. Inst., 43:43-64.

Sadovy Y., Rosario A. & Roman. A. (1994b). Reproduction in an aggregating grouper. the red hind, Epinephelus guttatus , Env. v. Biol. Fish. 41: 269-286.

Sadovy Y., Eklund A. M. (1999). Synopsis of biological information on the Nassau grouper, Epinephelus striatus (Bloch 1792), and the jewfish, E. itajara (Lichtenstein 1822). NOAA Tech. Rep. NMFS 146. 65 p.
Sánchez Lizaso J.L., Goñi R., Reñones O., García-Charton J.A. and others (2000) Density dependence in marine protected populations: a review. Environ Conserv 27:144–158.

Sandin S.A., Smith J.E., DeMartini E.E., Dinsdale E.A., Donner S.D. *et al* (2008). Baselines and Degradation of Coral Reefs in the Northern Line Islands. PLoS ONE 3(2): e1548.

Shapiro D.Y. (1987). Reproduction in groupers. pp. 205-327. In: J.J. Polovina & S. Ralston (ed.) Tropical Snappers and Groupers: Biology and Fisheries Management. West view Press. Boulder.

Souza C.H.S. (2000). O Homem da Ilha e os Pioneiros da Caça Submarina. Ed. Dehon, Santa Catarina.

Spedicato M.T., Lembo G., Marmulla G. (2005). Insight into the homing behaviour of the dusky grouper (Epinephelus marginatus Lowe, 1834) around the island of Ustica, Italy Rome, FAO/COISPA. 295p.

Zabala M., Louisy P., Garcia-Rubies A., Gracia V. (1997). Socialbehavioral context of reproduction in the Mediterranean dusky grouper Epinephelus marginatus (Lowe, 1834) (Pisces, Serranidae) in the Medes Islands Marine Reserve (NW Mediterranean, Spain). Scientia Marina 61(1):79–89302 Environ Biol Fish (2009) 85:301–302.

CHAPTER 1:

ASSEMBLAGE STRUCTURE OF GROUPERS (EPINEPHELIDAE) AND BASSES (SERRANIDAE) REVEALS EFFECTIVENESS OF PROTECTION AT THE ONLY NO-TAKE AND NO-ENTRY BRAZILIAN COASTAL MARINE PROTECTED AREA

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ABSTRACT

Top predators exert a deep influence on the structure and function of marine ecosystems. Population structure of groupers, basses (Epinephelidae and Serranidae) was assessed through visual censuses surveys in and around a no-take marine reserve in southern Brazil. Data of density and biomass of these populations was collected in 8 sites inside and outside Arvoredo Biological Marine Reserve, in the cost of Santa Catarina State, and used to evaluate the effectiveness of the no-take area. We detected 13 species of groupers and basses (7 species of Epinephelidae - targeted (exploited) species; and 6 species of Serranidae - non exploited species in this coast). Two species of groupers were dominant Mycteroperca marginata (total density 406 specimens; total biomass 127875.40 grams) and Mycteroperca acutirostris (total density 224 specimens; total biomass 88661.49 grams) detected in all surveyed sites. Two species of basses were dominant Serranus flaviventris (total density 60 specimens; total biomass 2389.43 grams) detected in 6 surveyed sites, and Serranus baldwini (total density 31 specimens, total biomass 150.24 grams) detected in 4 surveyed sites. Grouper species density and biomass distributions, inside and outside Arvoredo Marine Biological Reserve, showed significant differences (p<0,001) indicating effectiveness of the no-take zone for target and threatened species (e.g. Mycteroperca marginata, EN – IUCN). Cluster analysis performed with species biomass means showed that larger targeted species (mostly groupers – Epinephelidae) are more frequent inside the Reserve. Results are consistent with previous studies with reef fish in the same area: targeted species are being protected by the Reserve, however comparisons among other areas and MPAs suggests that illegal fisheries still occurs. Fisheries in this area are mostly artisanal; however, spear fishing is also evident. Knowing behavioral patterns of target reef fishes is critical to conservation effectiveness and management of MPA's, particularly regarding to their design and regulamentation. In the coast of Santa Catarina State most of the great predators have been eliminated or overfished to depletion.

Keywords: Top predators, Marine protected Areas, Epinephelidae, Serranidae, Population structure, Targeted species.

INTRODUCTION

The Brazilian coast shelters relatively diverse communities of reef fish (Floeter et al., 2008) however, little is known about the impacts of fisheries on such communities, and also little has been done regarding the management and efforts for their conservation (Floeter et al., 2006). Fisheries and ecosystem recovery have been largely assessed as indicative of marine reserves' effectiveness (Sale et al., 2005); nonetheless few attempts have been made to generalize their ecological effects (Côté et al., 2001; Halpern, 2003; Micheli et al., 2004; Guidetti & Sala, 2007). Previous works have brought out that the mean size and abundance of targeted fish species increase inside marine reserves in comparison to unprotected areas (Roberts & Polunin, 1991; Dugan & Davis, 1993; Rowley, 1994; Bohnsack, 1998; Russ, 2002; Pelletier et al., 2005).

Top predators have a deep influence on the structure and function of marine ecosystems. Nevertheless, their numbers have been decaying dramatically in the last century – up to 90 % in some regions of the world (Heithaus et al., 2008). Such loss may trigger the top-down cascade effect over the subsequent levels of the trophic chain disturbing the structure of marine communities (Heithaus et al., 2008). Therefore, assessing the baseline of targeted reef fish is critical to the management of Marine Protected Areas, particularly regarding their design, regulation and monitoring (Spedicato et al., 2005; Garcia-Chartón et al., 2008).

Groupers (Epinephelidae; *sensu* Craig & Hastings, 2007) and basses (Serranidae) in example, are represented by many top and medium predator species clearly more susceptible to overfishing due to their life ciclos – slow life histories, some presenting sex-change and spawning aggregations Some species of Epinephelidae (e.g. *Mycteroperca marginata*) integrate several species' red listings within the threatened categories: Red List of Threatened Species (IUCN) (Marino et al., 2003; Cornish & Harmelin-Vivien, 2004). In Brazil, this species was included in the "over-exploited or threatened with over exploitation" list of marine resources (Ministério do Meio Ambiente IN 5, 2004) and in São Paulo State (São Paulo, 2008). The International Union for Conservation of Nature (IUCN) and several other important organs required the establishment of a global and effective MPA management system for the year of 2012. Although Brazil is committed to achieve these proposed goals, there are only few studies on the effects of MPA's in this country (Floeter et al., 2006; Francini-Filho & Moura, 2008). Along the south coast of Brazil, for example, the extirpation of most apex predators (great sharks) and the consequent ecological disturbances over the structure of reef fish communities still lack a lot of information. On the coast of the State of Santa Catarina, the southernmost limit of many tropical reef fish species in the south-western Atlantic (Hostim-Silva et al., 2006; Floeter et al., 2008; Barneche et al., 2009), most of the great predators have been eliminated or overfished to depletion (Souza, 2000). Reef fish that once were secondary top predators (e.g. epinephelids and serranids) are now playing the role of apex predators in these marine ecosystems: yet, their populations have clearly declined along with reef sharks due to overfishing (Souza, 2000).

In this work we focused on the assessment of the assemblage structure of Epinephelidae and Serranidae inside and out Arvoredo Biological Marine Reserve – the only no-take and no-entry Brazilian coastal reserve – in order to evaluate the effectiveness of this MPA.

METHODS

Study area

The sampling effort was focused inside and out the Arvoredo Biological Marine Reserve (REBIOmar Arvoredo), which is located approximately 11km from the north tip of the Island of Santa Catarina (city of Florianópolis, the capital of the State of Santa Catarina; Figure 1). Created on March 1990, the Reserve encompasses 17,800 hectares and is constituted by three islands (Arvoredo, Galés and Deserta) and one tiny rocky slab (Calhau de São Pedro). All four but Arvoredo island are completely inside the reserve; the south side of the latter allows recreational activities yet not fishing and is will be referred as the "Buffer Zone" in this paper. In general, the subtidal environment of the sites is mainly constituted of steep granitic rocky reefs that run into sand bottom generally down to 12-15m of depth (Basei et al., 1992; Hostim-Silva et al., 2006, Tomazzoli & lima, 2006; Robert et al., 2006).

In Brazil, the "Biological Reserve" status designates the highest environmental protection possible, a no-take and no-entry zone where only research and education-related activities are allowed except for boats looking for shelter in bad conditions of navigation (SNUC – Sistema Nacional de Unidades de Conservação da Natureza - Law number 9.985, 2000). Unfortunately Brazil has only two marine Biological Reserves and REBIOmar Arvoredo is the only coastal one – the other, Atol das Rocas Biological Reserve, is located 260km off the coast of northeastern Brazil. Though there has been a great deal to enhance the surveillance efforts in REBIOmar during the last couple of years, it is still far from being effectively protected.

The sampling campaigns were conducted in 2010 and 2011, during austral summer only. All data was collected during the morning. We have selected three areas for data sampling:

1. MPA no-take zone – the REBIOmar Arvoredo itself;
2. Non protected northwest coastal sites, which includes Cape Araçá (city of Porto Belo) and Cape Sepultura (city of Bombinhas);
3. The Buffer Zone and two other non-protected coastal islands: Aranhas and Xavier Island (Figure 1).

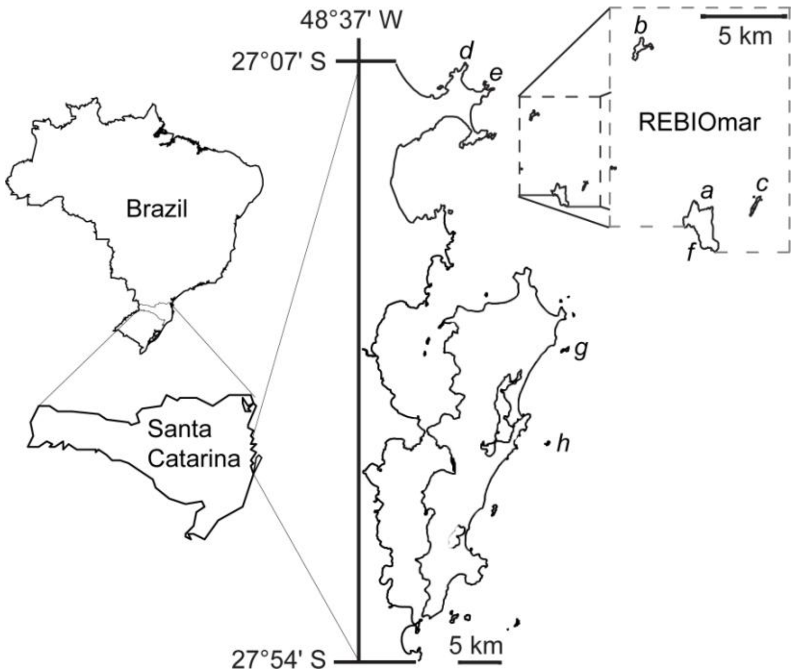

Figure 1. Sampled sites. The dashed polygon represents the limits of the non-entry zone REBIOmar Arvoredo. Letters indicate the study sites for each area. MPA no-take zone: (a) Arvoredo Is., (b) Galé Is. and (c) Deserta Is. Northwest coast (d) Cape Araçá and (e) Cape Sepultura. Non-protected islands: (f) Buffer Zone, (g) Aranhas Is. and (h) Xavier Is. Grey area indicates the city of Florianópolis and 'SC Is.' stands for the Island of Santa Catarina.

Evaluation of epinephelids and serranids community structure

The assemblage structure was assessed through visual censuses in strip transects (30x4m), where only the abundance of all epinephelids and serranids species was counted. Moreover, the individuals were categorized into size-classes of 5cm (e.g., up to 5, 10, 15cm).

Two depth strata have been adopted: reef slope and interface. Slope means from surface to half of the total depth (TD) (e.g. if TD=6cm, slope=0–3m); interface corresponds to the zone of transition from rocky complex bottom (slope) to non-consolidate substratum, i.e., sand bottom. These dimensions were selected considering the species' ecomorphology: body size, habitat distribution, feeding habits, as much as abiotic factors, such as ocean water low visibility (Brock, 1954; Goñi et al., 2000; Sutherland, 2000; Gibran, 2004, 2007; Floeter et al., 2007). During our study, water visibility ranged from 4 to 10m, temperature from 22 to 28°C. The shallower maximum depth reached was 2.5m in Cape Sepultura, and the deepest was 23m, in Xavier Island. For each depth strata 9 transects were executed totalizing 18 transects = 2160 m² sampled per site.

Data analysis

One-way ANOVA was used to evaluate differences in biomass and density among the eight sites (Underwood, 1981; McDonald, 2008). ANOVA's assumptions of normality were assessed with the Kolmogorov-Smirnov test (Zar, 1999). When significant differences were found in ANOVAs, Tukey HSD post hoc test was used to verify the specific sources of variation.

We performed a correspondence analysis (CA) using biomass to explore and highlight undistinguished patterns or tendencies of species occurrence for each site. Correspondence Analysis is most used in ecology to analyze species data (presence-absence or abundance values) at different sampling sites; however, correspondence analysis may be applied to any data set that is dimensionally homogeneous (Ter Braak, 1987; Legendre & Legendre, 1998; Ter Braak & Smilauer, 2002).

For comparisons between studied sites and biomass, a cluster analysis was performed (UPGMA average clustering method) based on the Bray-Curtis dissimilarity index (Legendre & Legendre, 1998).

RESULTS

Epinephelidae and Serranidae assemblage structure

We detected 7 epinephelid (fishing-targeted) and 6 serranid (non-targeted) species. Within the former, 2 species presented dominant distribution and biomass, being detected in all sites: *Mycteroperca marginata* and *M. acutirostris*. The species *Mycteroperca marginata* integrates the IUCN Red List of Threatened Species as endangered (EN) (IUCN, 2011; thereafter referred as *Epinephelus marginatus*)**.** Two other epinephelids herein detected are also included in the list: *Epinephelus morio* as near threatened (NT) and *Hyporthodus niveatus* as vulnerable (VU). Two serranid species presented dominant distribution and biomass: *Serranus flaviventris* (detected in 6 out of 8 sites) and *Serranus baldwini* (4 out of 8 sites; Table 1). No sampled serranid species are listed within the Red List.

Species populations' patterns and similarity among sites

Two islands presented higher richness among all sites in the study area: Deserta Island (MPA no-take zone) and Xavier Island (non-protected islands), both with 9 species detected with the latter presenting lower abundance of targeted species (Table 2). Nevertheless, species richness did not show significant differences among sites inside and outside the MPA (p=0.667).

Species density showed significant differences (ANOVA p<0.001) for Deserta and Galés Island; for those islands located slightly distant from the boundaries of the Buffer Zone, Aranhas and Xavier – where fisheries inflicts severe damage to predators' populations – no significant differences were found. One particular site in the northwest coast (northwest coast) showed significant large density of fish compared to other sites: Cape Araçá. This site is characterized by a high level of human impacts (e.g., recreational fishing, small vessels recreational traffic, running fresh water and sewage disposal) and the relatively high density of fish (*Mycteroperca acutirostris*) could have been attributed to spawning behavior or increased predatory behavior during a period of low water transparency. Predator behavior (for predators that use vision) or behavioral risk of predation displayed by prey could differ according to environmental conditions such as, for instance, habitat complexity and water transparency (Crowder & Cooper, 1982; Miner & Stein, 1996; Skov et al., 2007). However, despite the high density, most individuals of *M. acutirostris* were smaller – lower biomass compared to other sites inside the MPA no-take zone (REBIOmar Arvoredo; Figure 2). We believe that a recent recruitment pulse in the area most likely caused this observation.

Mean biomass of detected fishes showed highly significant difference (ANOVA; p<0.001) for sites inside REBIOmar Arvoredo (Area 1): Deserta, Galé and Arvoredo Islands. These results may have been due to the larger number of fish bigger than 30 cm detected inside the no-take zone (Figure 2).

The correspondence analysis (CA) indicated that the dominant epinephelid species, the targeted *M. marginat32a*, clearly shows higher biomass within the REBIOmar sites (Figure 3). Moreover, it also indicates for a relatively high biomass in the non-protected islands Xavier and Aranhas, however, still significantly smaller than inside the MPA. Other targeted abundant species, M. acutirostris, also showed a distinct pattern of distribution being more related to Arvoredo Island (both inside the MPA and outside in the Buffer Zone) and Cape Araçá (northwest coast). Overall, sites outside MPA presented smaller biomass for all species considered targeted. Species found away from the center of the diagram, but not very near the edges, are the most likely to display clear relationships with the ordination axes. This seems to be the interpretation for *M. marginata* and *M. acutirostris* in the graphic joint plot (Figure 3) (ter Braak, 1987).

Table 1. Epinephelidae and Serranidae species detected in this work. Total density (D) and biomass (B, in grams) for each of the species in all sites (18X120m²=2160 m²). IUCN categories: NT=Near threatened, VU=Vulnerable, EN=Endangered.

		Area 1						**Area 2**				**Area 3**						
	Species	Arvoredo Is.		Deserta Is.		Galés Is.		Cape Sepultura		Cape Araçá		Buffer Zone		Aranhas Is.		Xavier Is.		IUCN
		D	B	D	B	D	B	D	B	D	B	D	B	D	B	D	B	
Epinephelidae	*Epinephelus morio*	1	1270.16	1	213.35	-	-	-	-	-	-	-	-	-	-	-	-	NT
	Hyporthodus niveatus	-	-	-	-	2	155.66	-	-	1	18.08	-	-	1	2.37	-	-	VU
	Mycteroperca acutirostris	44	41064.73	18	8729.58	26	5493.45	11	2287.88	51	8632.60	37	14349.94	18	4423.38	19	3679.91	-
	M. bonaci	-	-	3	3820.14	-	-	1	201.06	-	-	1	578.34	-	-	1	99.78	-
	M. interstitialis	-	-	4	1028.17	-	-	-	-	-	-	2	656.05	-	-	2	18.50	-
	M. marginata	31	13901.60	98	34529.51	102	50201.81	12	3147.23	7	785.39	26	4992.21	69	10151.93	61	10165.73	EN
	M. microlepis	-	-	2	5573.12	-	-	1	181.13	-	-	-	-	-	-	-	-	-
Serranidae	*Diplectrum formosum*	-	-	1	114.15	-	-	-	-	-	-	-	-	1	114.15	1	114.15	-
	D. radiale	-	-	-	-	-	-	-	-	54	566.53	-	-	-	-	2	147.92	-
	Dules auriga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	31.07	-
	Serranus atrobranchus	-	-	-	-	1	15.53	-	-	-	-	-	-	8	130.34	3	52.65	-
	S. baldwini	-	-	19	105.47	-	-	-	-	-	-	2	3.39	8	37.98	2	3.39	-
	S. flaviventris	-	-	1	90.18	8	225.81	15	401.89	34	1647.23	1	22.26	-	-	1	2.04	-

Table 2. Epinephelidae and Serranidae species detected in this work. Total richness and biomass (grams) in each family at all sites ($18X120m^2=2160\ m^2$).

	Richness		Biomass	
	Epinephelidae (targeted spp)	Serranidae	Epinephelidae (targeted spp)	Serranidae
Area 1				
Arvoredo Is.	3	0	56236.49	0.00
Deserta Is.	6	3	53893.89	309.82
Galés Is.	3	2	55850.91	241.35
Area 2				
Cape Sepultura	3	1	5817.32	401.89
Cape Araçá	3	2	9436.08	2213.76
Area 3				
Buffer Zone	4	2	20576.55	25.65
Aranhas Is.	3	2	14577.69	282.48
Xavier Is.	4	6	13963.93	351.23

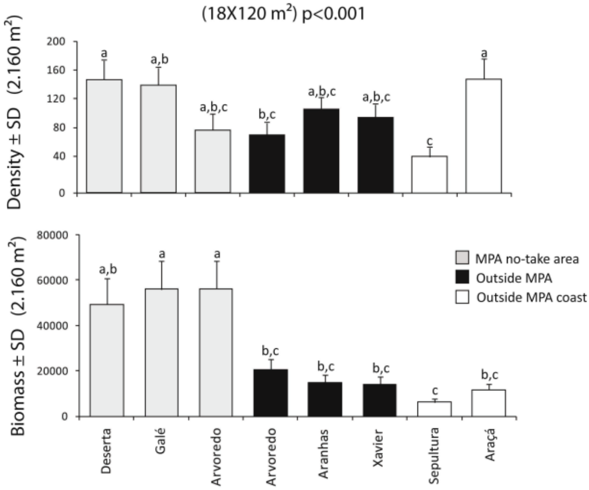

Figure 2. Mean density and biomass/2160 m^2 for detected species in all studied sites. Letters indicate statistical grouping differences (p<0.001) pointed by the Tukey HSD post hoc test.

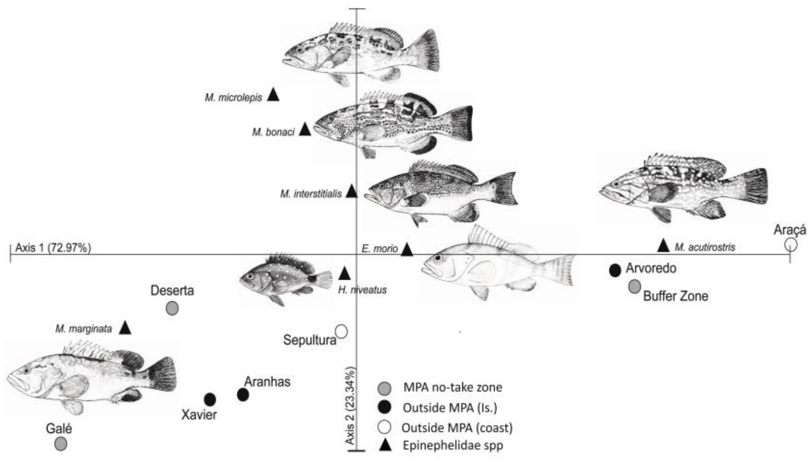

Figure 3. Correspondence analysis joint plots showing Epinephelidae species distribution among sites according to their biomass. The black triangles represent the position of species in the graphic space. Circles mark the position of sites.

Smaller serranid species seem not to benefit from the MPA REBIOmar; instead, their distribution reveals more habitat selectiveness patterns (Figure 4). Three species presented higher biomass: *Serranus baldwini*, *S. flaviventris* and *Diplectrum radiale*. Serranus baldwini was mostly associated with rodolith beds in Deserta Island and is the only species with a significant biomass inside the no-take zone. *S. flaviventris* and *D. radiale* were detected mostly in shallow areas (maximum 5 meters of depth), at the interface between the reef and the sand. Such habitat characteristics seem to be most used by serranid species if compared to epinephelid ones (Figure 6; Table 1).

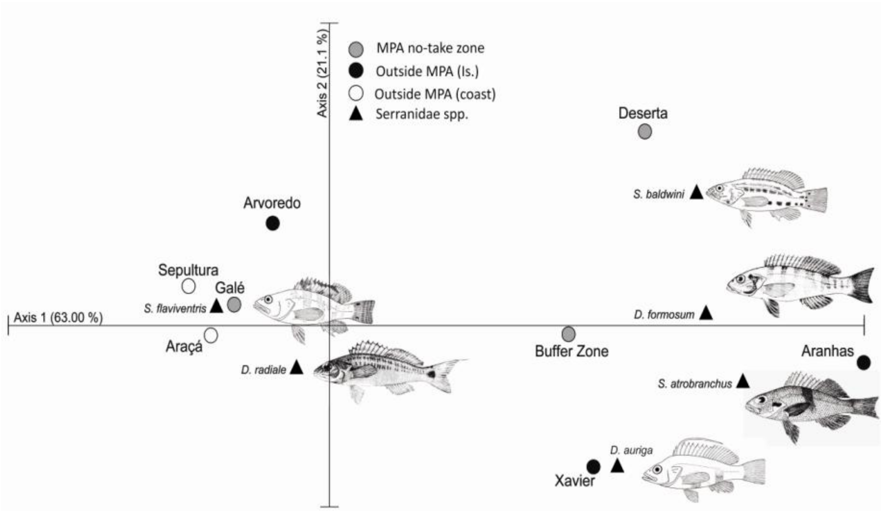

Figure 4. Correspondence analysis joint plots showing Serranidae species distribution among sites according to their biomass. The black triangles represent the position of species in the graphic space. Circles mark the position of sites

Cluster analysis highlighted similarities among sites inside MPA with respect to fish biomass (Figure 5). Sites inside REBIOmar Arvoredo clustered together for their higher biomass evidencing some effectiveness for the no-take zone on protecting targeted species.

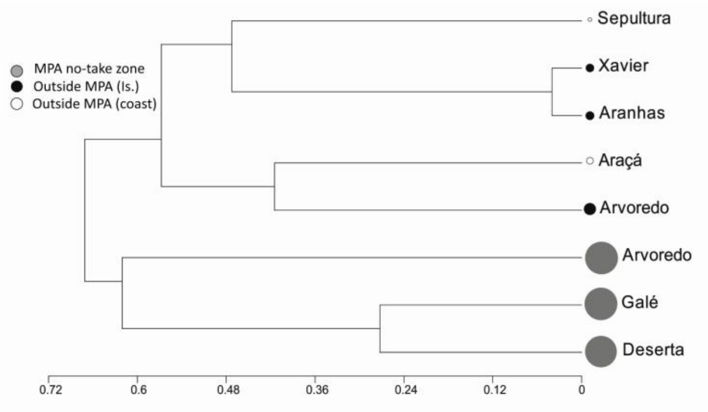

Figure 5. Cluster analysis (UPGMA average clustering method; Bray Curtis dissimilarity) comparing biomass means among sites. Circle sizes are proportional to the biomass detected in each site. Grey circles represent REBIOmar Arvoredo (MPA no-take zone), black circles the islands outside the MPA and white circles the non-protected sites on the coast.

Marine Protected Areas effectiveness regarding fisheries and ecosystem restoration has been widely studied (Sale et al., 2005, Claudet et al., 2008), however, few attempts have been made to generalize their ecological effects (Côté et al., 2001; Halpern, 2003; Micheli et al., 2004; Guidetti & Sala, 2007). Previous analyses have highlighted that the density of harvested fish species inside marine reserves increases compared to unprotected areas; there are many documented examples showing that targeted species have benefited from reserve establishment, particularly through increases in size and biomass (Roberts & Polunin, 1991; Dugan & Davis, 1993; Rowley, 1994; Bohnsack, 1998; Russ, 2002; Halpern, 2003; Pelletier et al., 2005).

REBIOmar Arvoredo is a 20-year-old no-take Marine Protected Area, 17.800 hectars large and structurally complex, and, according to the results herein shown, top predators' biomass stands for some effectiveness if compared to the other sites in this work. Dominant species biomass (large individuals) is significantly different inside the no-take area (Figure 6).

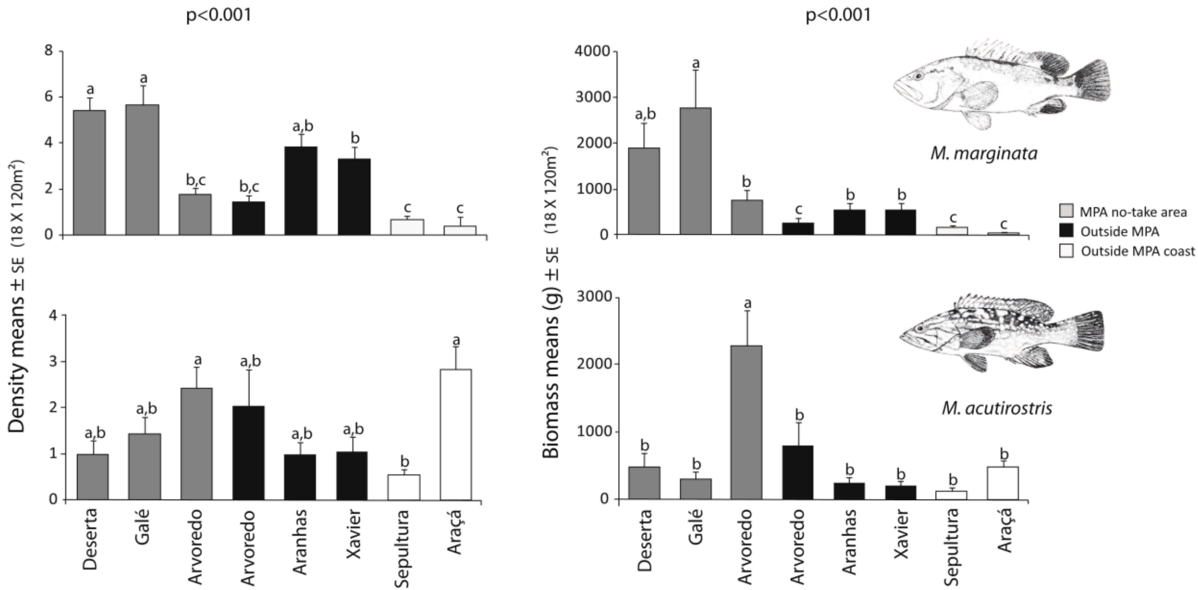

Figure 6. Analysis of variance (ANOVA) for dominant species showing significant differences ($p<0.001$) among sites considering density and biomass of the organisms. Letters indicate statistical grouping differences ($p<0.001$) pointed by the Tukey HSD post hoc test.

If we consider only epinephelid species (targeted) effectiveness evidence is even clearer – as fisheries impact increases (decreasing from the coast to non-protected islands to the no-take area) fish populations and biomass likely decrease. Nevertheless, these effects are not significant for the smaller non-targeted serranid species (Figure 7).

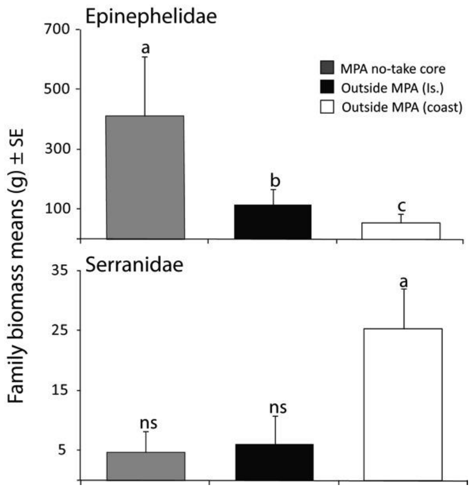

Figure 7. ANOVA for overall biomass between the three studied areas with regard to fishery restriction. Letters indicate differences ($p<0.001$) pointed by the Tukey HSD post hoc test.

DISCUSSION

Seems to be a recent consensus that the presence of higher biomass due to higher abundance of bigger targeted fish species is a good proxy for a Marine Protected Area efficient effectiveness (Claudet et al., 2008). In terms of sustainability, large predatory fish have significant higher reproductive potential and produce larvae with better survival rates than those from smaller or younger fishes (Birkeland & Dayton, 2005). The reefs of Kingman and Palmyra in the Pacific Ocean, for example, barely unspoiled by humans, present such outstanding top-predators' biomass (sharks and other fish) that the trophic pyramid of biomass could be inverted, i.e., higher biomass on the top rather than the base (but see discussions in Aburto-Oropeza et al., 2011). In other nearby exploited reefs the trophic pyramid of biomass is rather presented in a 'standard' way, with a larger base (Sandin et al., 2008; but also see Ward-Paige et al., 2010). Theoretical studies had proposed that large protected areas tend to be more effective than small ones for conservation purposes (Botsford et al., 2001, 2003; Hastings & Botsford, 2003; Roberts et al. 2003). However, empirical studies did not support such hypothesis (Côté et al., 2001; Halpern, 2003; Guidetti & Sala, 2007). This difference could represent a problem of the theory or the analysis of data across temperate and tropical ecosystems that could mask the size effects (Guidetti & Sala, 2007). Other empirical studies have reached opposite results about time and protection (Halpern & Warner, 2002; Micheli et al., 2004; Russ & Alcala, 2004).

The time needed for a MPA to become considerably effective regarding targeted fish species restoration as well as biodiversity as a whole is a key subject for marine resources management (Lotze et al., 2006). Studies showed fish density and species richness increasing after three years of protection (Halpern & Warner, 2002; Russ et al., 2005; Claudet et al., 2006) while others pointed to decades instead (Micheli et al., 2004). According to Aburto-Oropeza et al. (2011), a complete recovery of a degraded fish community can be expected if placed in the right area and managed correctly, even to the level that is comparable to remote habitats that never have been impacted by fishing and other local human impacts. The cabo pulmo marine reserve, which has been protected for 15 years now, showed a great recovery of fish biomass in general, being compared to the near pristine reefs documented up to date (Aburto-Oropeza et al. 2011).

In our study REBIOmar Arvoredo showed a higher predatory fish biomass, which demonstrated a reasonable effectiveness. However, given the fact that it now has more than 20 years since its creation, and encompasses a considerable geographical area, the results can be considered unsatisfatory if placed side by side with pristine reefs in terms of biomass (Figure 8). One may argue that MPAs placed in different biogeographical provinces as well as latitudes could not lead to direct biomass comparisons.

In that sense, we have assessed some historical records of fisheries around the islands inside REBIOmar Arvoredo in order to show the recovery potential we could expect for the area. In Figure 9 we show a picture taken in the early 60's (after Souza, 2000) in which two local fishermen, during a 3-hour spearfishing at Galé Island, took five specimens of the Grey Nurse Shark, *Carcharias taurus*, as well as three specimens of Atlantic Goliath Grouper, Epinephelus itajara. In any of the 60 hours of SCUBA diving conducted in the present study, not a single individual of both species were seen. In fact, more than 300 hours of monitoring have been conducted in the area during the last five years with no sights for these species (Barneche & Floeter, personal communication). Moreover, anecdotal accounts from older scuba diver Julio da Silva state that very large groupers and sharks were not seen since 1980 when he founded his diving school. We then recalculate the estimated biomass summing with the present data (Figure 8). Given that our simulation may be quite underestimated – there are many more similar records in Souza (2000) including for the heavily fished coastal beaches – we believe that the top-predators' biomass in the area was probably very similar (if not higher) to those reported in near-pristine reefs (Sandin et al., 2008; Aburto-Oropeza et al., 2011).

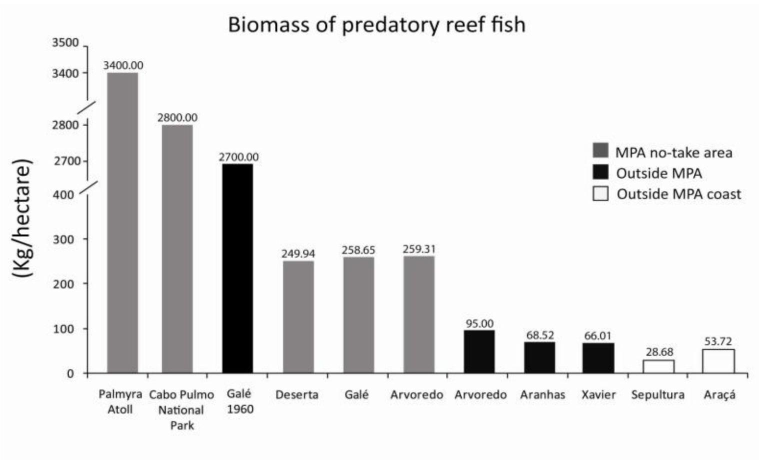

Figure 8. Mean biomass among sites with and without restrictions to fisheries. We simulated the estimated biomass in Galés Island (REBIOMar Arvoredo) based on historical records from the early 60's (see text for explanation; Figure 9). Results are compared with the ones presented for Cabo Pulmo National Park and Palmyra Atoll (after Aburto-Oropeza et al., 2011 and Sandin et al., 2008, respectively).

Figure 9. Picture taken in January 1rst, 1960, showing the result of 3 hours of fishing effort of 2 spear fishermen in Galé Island, Santa Catarina State, southern Brazil: 3 specimens of Epinephelus itajara on the left and 5 specimens of Carcharias taurus on the right. Picture shown under authorization of Souza (2000; p. 163).

Unfortunately there has been many illegal fishing inside REBIOmar Arvoredo since its creation even though protection efforts have been increasing in the last couple of years. Management efforts focused on people's education tend to increase significantly the effectiveness of MPAs (Aburto-Oropeza et al., 2011). Despite recent efforts to show people the importance of the MPA (Godoy et al., 2006; Gerhardinger et al., 2009; 2011) there is still a lot of controversial opinions of local fishermen regarding this subject.

Conservation of Brazilian coasts progress is crystallized in time since 1992, when a protocol has been signed (Decree Number 2.519 de March, 16, 1998) during CDB convention (Eco 1992, Rio de Janeiro) assuring that until 2014 10% of brazilian's ocean area would be considered protected from fisheries. Less than 1% is considered free from fisheries (no-take area) so far.

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REFERENCES

Aburto-Oropeza, O., Erisman B., Galland G.R., Mascareñas-Osorio I., Sala E., et al., 2011. Large Recovery of Fish Biomass in a No-Take Marine Reserve. PLoS ONE 6(8): e23601.

Barneche, D.R., Anderson, A. B., Floeter, S.R., Silveira, M., Dinslaken, D.F. and Carvalho Filho A., 2009. Ten new records of reef fish on the coast of Santa Catarina State, Brazil. Marine Biodiversity Records, page 1 of 4. #2009 Marine Biological Association of the United Kingdom Vol. 2; e143; 2009 Published online.

Basei, M.S. A., Siga, Jr. O., Machiavelli, A., Mancini, F., 1992. Evolução tectônica dos terrenos entre os Cinturões Ribeira e Dom Feliciano (PR-SC). Rev. Brasileira de Geociências, 22(2):216-221.

Birkeland, C. & Dayton, P., 2005. The importance in fishery management of leaving the big ones. Trends Ecol. Evol., 20, 356–358.

Bohnsack, J.A., 1998. Application of marine reserves to reef fisheries management. Austr. J. Ecol., 23, 298–304.

Botsford, L.W., Hastings, A. & Gaines, S.D., 2001. Dependence of sustainability on the configuration of marine reserves and larval dispersal distance. Ecol. Lett., 4, 144–150.

Botsford, L.W., Micheli, F. & Hastings, A., 2003. Principles for the design of marine reserves. Ecol. Appl., 13, S25–S31.

Brock, V.E., 1954. A preliminary report on a method of estimating reef fish populations. J Wildlife Manage 18:297–308.

Carter, J., Marrow, F.J. & Pryor, **V.,** 1994. Aspects of the ecology and reproduction of Nassau grouper, *Epinephelus striatus***,** off the coast of Belize, Central America. Proc. Gulf & Caribbean Fisheries Institute 43: 64-110.

Claudet ,J., Pelletier, D., Jouvenel, J.Y., Bachet, F. & Galzin, R., 2006. Assessing the effects of marine protected area (MPA) on a reef fish assemblage in a northwestern Mediterranean case study: Identifying community-based indicators. Biol. Conserv., 130, 349–369.

Claudet, J. et al., 2008. Marine reserves: size and age do matter. Ecology letters, 11(5), pp.481-9.

Côté I.M., Mosqueira I., Reynolds J.D. (2001). Effects of marine reserve characteristics on the protection of fish populations: a meta-analysis. J. Fish Biol., 59 (Supplement A):178–189.

Craig ,M.T. & Hastings, P.A., 2007. A molecular phylogeny of the groupers of the subfamily Epinephelinae (Serranidae) with a revised classification of Epinephelini. Ichthyological Research, 54, 1–17.

Crowder, L. B. & Cooper, W. E., 1982. Habitat structural complexity and the interaction between bluegills and their prey. Ecology 63, 1802–1813.

Dugan, J.E. & Davis, G.E., 1993. Application of marine refugia to coastal fisheries management. Can. J. Fish. Aquat. Sci., 50, 2029–2041.

Floeter, S. R., Halpern, B. S., Ferreira, C. E. L., 2006. Effects of fishing and protection on Brazilian reef fishes. Biological Conservation, 128: 391-402.

Floeter, S. R., Krohling, W., Gasparini, J. L., Ferreira, C. E. L., Zalmon, I., 2007. Reef fish community structure on coastal islands of the southeastern Brazil: the influence of exposure and benthic cover. Environmental Biology of Fishes, 78: 147-160.

Floeter, S.R., Rocha, L.A., Robertson, D.R., Joyeux, J.C., Smith-Vaniz, W.F., Wirtz, P., Edwards, A.J., Barreiros, J.P., Ferreira, C.E.L., Gasparini, J.L., Brito, A., Falcon, J.M., Bowen, B.W. and Bernardi, G., 2008. Atlantic reef fish biogeography and evolution. Journal of Biogeography 35, 22–47.

Francini-Filho, R.B. and Moura, R. L., 2008. Dynamics of fish assemblages on coral reefs subjected to different management regimes in the Abrolhos Bank, eastern Brazil. Aquatic Conserv: Mar. Freshw. Ecosyst. 18: 1166–1179.

García-Charton, J.A., Pérez-Ruzafa, A., Marcos, C., Claudet, J., Badalamenti, F., Benedetti-Cecchi, L., Falcón, J.M., Milazzo, M., Schembri, P.J., Stobart, B., Vandeperre, F., Brito, A., Chemello, R., Dimech, M., Domenici, P., Guala, I., Le Diréach, L., Maggi, E., Planes, S., 2008. Effectiveness of European Atlanto-Mediterranean MPAs: do they accomplish the expected effects on populations, communities and ecosystems? Journal of Nature Conservation, 16, 193-221.

Gerhardinger, L. C. et al., 2009. Fishers' resource mapping and goliath grouper Epinephelus itajara (Serranidae) conservation in Brazil. Neotropical Ichthyology, 7(1), pp.93-102.

Gerhardinger, L. C. et al., 2011. Marine protected dramas: the flaws of the Brazilian National System of Marine Protected Areas. Environmental management, 47(4), pp.630-43.

Gibran, F. Z., 2004. Dying or illness feigning: an unreported feeding tactic of the comb grouper Mycteroperca acutirostris (Serranidae) from the Southwest Atlantic. Copeia, 2004(2): 402-405.

Gibran, F. Z., 2007. Activity, habitat use, feeding behavior, and diet of four sympatric species of Serranidae (Actinopterygii: Perciformes) in southeastern Brazil. Neotrop. ichthyol. [online]. Vol.5, n.3, pp. 387-398. ISSN 1679-6225.

Godoy, E.A.S., Gerhardinger, L.C. & Daros, F., 2006. Utilization of Bottom Trawling and Underwater Visual Census Methodologies on the Assessment of the Fish Communities from Arvoredo Biological Marine Reserve , SC , Brazil. Journal of Coastal Research, 2004(39), pp.1205-1209.

Goñi, R., M. Harmelin-Vivien, F. Badalamenti, L. Le Diréach, Bernard G., 2000.Introductory guide to methods for selected ecological studies in marine reserves. edit., GIS Posidonie publ., Fr., 2000 : 1-120.

Guidetti, P. & Sala, E., 2007. Community-wide effects of marine reserves in the Mediterranean Sea. Mar. Ecol. Prog. Ser., 335, 43–56.

Halpern, B., 2003. The impact of marine reserves: do reserves work and does reserve size matter? Ecol. Appl., 13, S117– S137.

Halpern, B.S. & Warner, R.R., 2002. Marine reserves have rapid and lasting effects. Ecol. Lett., 5, 361–366.

Heithaus, M.R., Frid, A., Wirsing, A.J and Worm, B., 2008. Predicting ecological consequences of marine top predator declines. Trends in Ecology and Evolution 23(4) :202–210.

Hostim-Silva, M., Andrade, A.B., Machado, L.F., Gerhardinger, L.C., Daros, F.A., Barreiros, J.P. and Godoy, E.A.S., 2006. Peixes de costão rochoso de Santa Catarina: I. Arvoredo. 1st edition. Itajaı´: Editora da Universidade do Vale do Itajaı´.

IUCN (International Union for Conservation of Nature), 2010. IUCN Red List of threatened species. Version 2010.2. Available from www.iucnredlist.org (accessed August 2010).

Legendre, P., and Legendre L., 1998. Numerical Ecology. Elsevier: Amsterdam, 853 p.

Lotze, H.K., Lenihan, H.S., Bourque, B.J., Bradbury, R.H., Cooke, R.G., Kay, M.C. et al., 2006. Depletion, degradation, and 488 J.

Claudet et al. Letter recovery potential of estuaries and coastal seas. Science, 312, 1806–1809.

McDonald, J. H., 2008. Electronic publication World Wide Web, 21 novembro de 2008. http://udel.edu/~mcdonald/statintro.html

Micheli, F., Halpern, B., Botsford, L.W. & Warner, R.R., 2004. Trajectories and correlates of community change in no-take marine reserves. Ecol. Appl., 14, 1709–1723.

Miner, J. G. & Stein, R. A., 1996. Detection of predators and habitat choice by small bluegills: effects of turbidity and alternative prey. Transactions of the American Fisheries Society 125, 97–103.

Olsen, D.A. & LaPlace, J.A., 1979. A study of a Virgin Islands grouper fishery based on a breeding aggregation. Proc. Gulf Carib. Fish. Inst. 31: 130-144.

Pelletier, D., García-Charton, J.A., Ferraris, J., David, G., Thébaud, O., Letourneur, Y. et al., 2005. Designing indicators for assessing the effects of marine protected areas on coral reef ecosystems: A multidisciplinary standpoint. Aquat. Living Resour., 18, 15–33.

Robert, J., Marcel, G., Tomazzoli, E. R., Bauzys, F., Bini, M. P. & Wilvert, S. R., 2006. Mapeamento Geológio-geomorfológico do Setor Norte da Ilha de Santa Catarina, 248-261.

Roberts, C.M. & Polunin, N.V.C., 1991. Are marine reserves effective in management of reef fisheries? Rev. Fish Biol. Fish., 1, 65–91.

Roberts, C.M., Andelman, S., Branch, G., Bustamante, R.H., Castilla, J.C., Dugan, J.E. et al., 2003. Ecological criteria for evaluating candidate sites for marine reserves. Ecol. Appl., 13, S199–S214.

Rowley, R.J., 1994. Case studies and reviews - Marine reserves in fisheries management. Aquat. Conserv: Mar. Freshw. Ecosyst., 4, 233–254.

Russ, G.R., 2002. Yet another review of marine reserves as reef fishery management tools. In: Sale P (ed) Coral reef fishes. Academic Press, San Diego, CA, p 421–443.

Russ, G. & Alcala, A., 2004. Marine reserves: long-term protection is required for full recovery of predatory fish populations. Oecologia, 138, 622–627.

Sadovy, Y., Cohn, P.L. & Domeier, M.L., 1994. Aggregation and spawning in the tiger grouper, Mycteroperca tigris (Pisces: Serranidae). Copeia 1994: 511-516.

Sadovy, Y., 1994. Grouper stocks of the Western Central Atlantic: the need for management and management needs. Proc. Gulf Carib. Fish. Inst., 43:43-64.

Sale, P., Cowen, R., Danilowicz, B., Jones, G., Kritzer, J., Lindeman, K. et al., (2005). Critical science gaps impede use of no-take fishery reserves. Trends Ecol. Evol., 20, 74–80.

Sandin, S.A., Smith, J.E., DeMartini, E.E., Dinsdale, E.A., Donner, S.D. et al., 2008. Baselines and Degradation of Coral Reefs in the Northern Line Islands. PLoS ONE 3(2): e1548.

Shapiro, D.Y., 1987. Reproduction in groupers. pp. 205-327. In: J.J. Polovina & S. Ralston (ed.) Tropical Snappers and Groupers: Biology and Fisheries Management. West view Press. Boulder.

Skov, C., Nilsson, P. A., Jacobsen, L. and Bronmark, C., 2007. Habitat-choice interactions between pike predators and perch prey depend on water transparency. Journal of Fish Biology 70, 298–302.

Smith, W.L. & Craig, M.T., 2007. Casting the Percomorph net widely: the importance of broad taxonomic sampling in the search for the placement of the serranid and percid fishes. Copeia, 1:35 55.

Souza, C.H.S., 2000. O Homem da Ilha e os Pioneiros da Caça Submarina. Ed. Dehon, Santa Catarina.

Spedicato, M.T., Lembo, G., Marmulla, G. (eds.), 2005. Insight into the homing behaviour of the dusky grouper (Epinephelus marginatus Lowe, 1834) around the island of Ustica, Italy Rome, FAO/COISPA. 295p.

Ter Braak, C. J. F., 1987. Ordination. 91-173 in: R. H. G. Jongman, C. J. F. ter Braak & O. F. R van Tongeren [eds.] Data analysis in community and landscape ecology. Pudoc, Wageningen, The Netherlands. Reissued in 1995 by Cambridge Univ. Press, Cambridge, England. [390, 418, 419, 456, 457, 462, 466, 470, 474, 475, 486, 583, 592, 594, 596, 601, 617, 634].

Ter Braak, C. J. F., and Smilauer, P., 2002. CANOCO Reference Manual for CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power, Ithaca, NY. www.canoco.com.

Tomazzoli, E. R. , lima, E. F., 2006. Magmatismo Ácido-Básico na Ilha do Arvoredo - SC. Revista Brasileira de Geociências, São Paulo (SP), v. 36, n. 1, p. 61-80.

Underwood, A.J., 1981. Techniques of analysis of variance in experimental marine biology and ecology Oceanogr. Mar. Biol. Ann. Rev. 19 19: 513-605.

Ward-Paige, C., Mills Flemming, J. & Lotze, H.K., 2010. Overestimating fish counts by non-instantaneous visual censuses: consequences for population and community descriptions. PloS one, 5(7), p.e11722.

Zar, J. H.,1999. Biostatistical Analysis. Prentice Hall, New Jersey, 663 pp.

CHAPTER 2:

SPATIAL DISTRIBUTION AND HABITAT USE OF PREDATOR FISHES (EPINEPHELIDAE AND SERRANIDAE) IN ROCKY REEF SYSTEMS OF SOUTHERN BRAZIL.

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SPATIAL DISTRIBUTION AND HABITAT USE OF PREDATORY FISHES (EPINEPHELIDAE AND SERRANIDAE) IN ROCKY REEF SYSTEMS OF SOUTHERN BRAZIL.

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ABSTRACT

Groupers and basses include a wide range of sizes and morphologies, ranging from 7 cm (e.g. Lantern bass, *Serranus baldwini*) to 250 cm (e.g. Goliath grouper, *Epinephelus itajara*). They inhabit coral and rocky bottoms, and other microhabitats from shallow waters to depths of more than 200 meters, living in caves, crevices and on ledges. In marine ecosystems, these species are known to be substrate-associated, and also display territoriality and dominance behavior. Aside from their ecological importance, they are also considered commercially valuable species in Brazil representing an important economic role for local fisheries along the coast of Santa Catarina, and are also target species for spear fishing and of interest to scuba diving. In this work we assessed the distribution and habitat use of groupers and basses, using a non-destructive method of underwater visual censuses surveys, inside and around the Arvoredo Biological Marine Reserve. A total of 144 transects (30X4 – 120 m²) were performed during the summers of 2009 and 2010. We recorded 7 species of the family Epinephelidae (*sensu* Craig and Hastings, 2007) and 6 species of the family Serranidae in 18 transects for each of the 8 sites, inside and around Arvoredo Biological Marine Reserve. A total of 13 species considered top predators were recorded. Five species considered dominant (n > 30) due to their densities and biomass were studied: *Mycteroperca marginata, Mycteroperca acutirostris, Diplectrum radiale, Serranus flaviventris* and *Serranus baldwini*. The dominant species of Epinephelidae and Serranidae studied in this work are all directly associated to specific topographic characteristics, which can be considered as optimum for their protection against predation and their reproductive and feeding behaviors in this particular environment.

Keywords: Habitat use, Epinephelidae, Serranidae, Arvoredo Biologic Marine Reserve.

INTRODUCTION

For fisheries and ecological perspectives, Epinephelids and Serranids are key organisms of the tropical reef fauna (Randall & Heemstra 1991). Besides their ecological importance, they are also considered commercially valuable species in Brazil (Figueiredo and Menezes 1980), representing an important economic role for local fisheries along the coast of Santa Catarina (Medeiros *et al.* 1997), and acting as target species for spear fishing and also of interest to scuba diving. Considered as top predators, they perform a very important ecological role regulating trophic community structure in both tropical and temperate reefs (Almany 2003; 2004; Almany and Webster 2004, Hixon 1991). As well, some species function as marine ecosystem engineers that modify, maintain and create habitats (Jones *et al.* 1994, Coleman and Williams 2002). Despite their large influence on the structure and functioning of marine ecosystems, their numbers have dramatically dropped in the last century to approximately 90 % in some regions of the world. Such loss may trigger the top-down cascade effect over the subsequent levels of the trophic chain disturbing the structure of marine communities (Heithaus *et al.* 2008).

Groupers and basses include a very wide range of sizes and morphologies, ranging from 7 cm (e.g. Lantern bass, *Serranus baldwini*) to 250 cm (e.g. Goliath grouper, *Epinephelus itajara*). They inhabit coral and rocky bottoms and other microhabitats from shallow waters to depths of more than 200 meters and live in caves, crevices and on ledges (Tortonese, 1986, Randall and Heemstra 1991). These species are also known to be substrate-associated and display territoriality and dominance behavior in marine ecosystems (Kline *et al.* 2011). The families Epinephelidae and Serranidae have complex long-living species, with organized social structures, and complex sexual behaviors. Some species are clearly more susceptible to overfishing due to their reproductive characteristics (e.g. species which present sex change, and social behavior during spawning aggregations) (Olsen & La Place 1979; Carter *et al.* 1994; Sadovy 1994; Sadovy *et al.* 1994b; Shapiro 1987).

This work evaluated the spatial distribution and habitat use of groupers and basses (Epinephelidae and Serranidae - *sensu* Craig and Hastings, 2007) inside and around the no-take zone of the Arvoredo Biological Marine Reserve, evaluating, with the use of species density, biomass, and environmental data, their habitat use.

Observations of Epinephelidae and Serranidae feeding behavior revealed that several species use stalking behaviors when approaching prey. These behaviors are all directly connected to the structural complexity of the environment and predatory fish use (Montgomery 1975; Karplus 1978; Ormond 1980; Shpigel and Fishelson 1989; Dubin 1982; Diamant and Shpigel 1985; Strand 1988; Shpigel and Fishelson 1989; Heemstra and & Randall 1993).

In this work we focused on assessing the distribution and habitat use of Epinephelidae and Serranidae (*sensu* Craig and Hastings, 2007), using a non-destructive method of underwater visual censuses surveys. These efforts are definitively necessary to improve MPA designs and management, which might contribute to maximizing the sheltering effects for target and non-target reef fishes.

The southern rocky reefs of Brazil are habitats for vast and diverse communities of reef fishes, however, there are few studies on the impacts of fisheries for these species, and little has been done regarding the management and efforts for their conservation (Floeter *et al.* 2006). The coast of Santa Catarina, characterized by granitic and basaltic rocky reefs, is also known to be the southernmost limit of most tropical reef fish species in the south-western Atlantic (Basei *et al.* 1992; Diehl e Horn Filho 1996, Floeter *et al.* 2001; Hostim-Silva *et al.* 2006; Barneche *et al.* 2009).

One very important attempt to protect and understand the ecology of these species is the implementation of Marine Protected Areas worldwide. The Arvoredo Biological Marine Reserve was created in March, 12, 1990; Decree number 99.142, aiming to preserve a representative sample of the biodiversity present in the rocky reef environment, which characterizes the coast of Santa Catarina State, southern Brazil (Basei *et al.* 1992; Diehl e Horn Filho,1996; Hostim-Silva *et al.*,2006). The total surface area represents 17.600 hectares and a total perimeter of 54.8 kilometers. In this environmental context we selected the islands inside the no-take zone and 5 other sites outside the Reserve boundaries (Figure 1) to assess, with the use of underwater visual censuses (Brock 1954; Goñi *et al.* 2000, Floeter *et al.* 2007), top predators population structures (Epinephelidae and Serranidae). Furthermore, to understand their distribution and habitat use we collected environmental data (environmental topographic complexity variables).

Along the coast of Santa Catarina the extirpation of most of the apex predators (great sharks, large goliath groupers), as well as it's ecological implications in the structure of reef fish communities and ecosystems, still lacks a lot of information. Most of the great predators have been eliminated or overfished to depletion (Souza 2000). Data required for decisions in marine resource management are frequently regarded as insufficient or inexistent, especially when considering small geographic scales (Johannes 1998; Drew 2005).

Knowing behavioral patterns of target reef fishes is critical to conservation effectiveness and management of MPA's, particularly regarding their design and regulamentation (Spedicato *et al.* 2005, Garcia-Chartón *et al.* 2008).

METHODS

Study area

This work was carried off the coast of Santa Catarina, southern Brazilian coast, located between the latitudes 25°57'41" south and 29°23'55" west, representing approximately 7 % of the Brazilian coast (Diehl e Horn Filho 1996). The geomorphology of these oceanic bottoms is basically characterized by Precambrian basaltic and granitic rocky reefs (Basei *et al.* 1992). This coast is considered to be the southern limit for most tropical rocky reef fishes of the Western Atlantic Ocean (Barneche *et al*. 2009, Hostim-Silva *et al*. 2006; Floeter *et al*. 2001; 2008).

The Arvoredo Marine Biological Reserve located 11 km from the island of Santa Catarina, consists of 4 rocky islands: Arvoredo Island, Deserta Island, Galé Island and Calhau de São Pedro (the smallest). These islands belong almost integrally to the MPA, created in

March, 1990. The Marine Reserve total area corresponds to 17.800 hectares. The islands Deserta, and Galé Island are totally restricted from fishing, and the Arvoredo Island distinguished from other sites for having 1 part (north) totally restricted from fishing, and 1 portion (south) located in the buffer zone (Hostim-Silva *et al.* 2006). The islands bottoms are formed by magmatic rocks which are mostly covered by algae. The Islands are connected to each other and to the coast by sand (Barneche *et al.* 2009; Hostim-Silva *et al.* 2006) (Fig. 1).

The sampling plan was designed considering the 3 divisions of the study area: Sector 1, northwest coastal portion near the MPA: including Cape Araçá, located in the city of Porto Belo (27° 18' 16.42"S 48° 30' 19.22"W), and Cape Sepultura in the city of Bombinhas (27° 08'16.42"S 48° 30' 15.94"W); Sector 2, the Marine Protected Area no-take core: which includes the Arvoredo Marine Biologic Reserve archipelago (27^{o}17'2.93"S 48^{o}21'56.51"W), enclosing the Islands: Arvoredo (no-take core), Deserta and Galé Islands; and finally, Sector 3, Arvoredo Island: insular portion of the buffer zone; Aranhas Island (27° 29' 15.13"S 48° 20' 54.94"W) and Xavier Island (27° 36.37' 00.46"S 48° 19' 27.50" W) (outside the Buffer Zone) (Figure 1). All data was collected during the summers of 2010/2011.

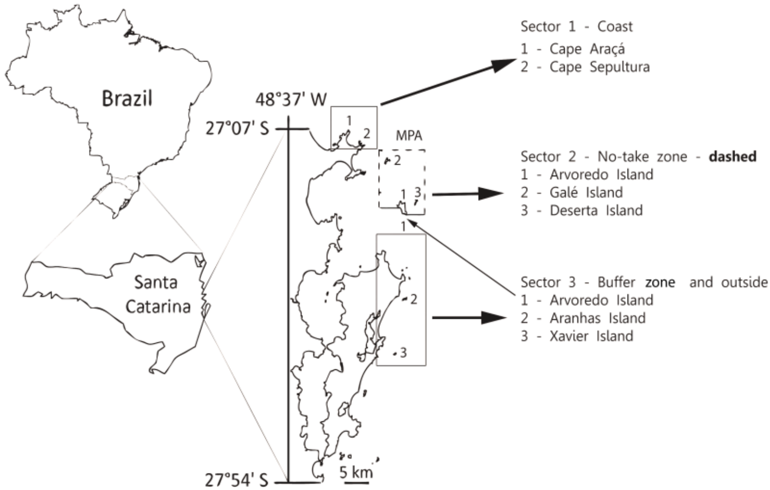

Figure 1: Sampled sites inside the study area. The dashed polygon represents the limits of the MPA Arvoredo Marine Biological Reserve. The numbers indicate the study sites for each sector. Sector one - northwest coastal portion: 1) Cape Araçá (Porto Belo City), 2) Cape Sepultura (Bombinhas City); Sector two - no-take Zone: 1) Arvoredo Island, 2) Galé Island and 3) Deserta Island; Sector three - southern insular portion: 1) Arvoredo Island, 2) Aranhas Island and 3) Xavier Island.

Spatial distribution and habitat use

The data of fish population structure, their spatial distribution and habitat use was assessed through the use of underwater visual censuses, to count and identify the fishes during diving expeditions (SCUBA) (Brock 1954; Goñi *et al*. 2000, Floeter *et al.* 2007).

For this study, two distinct strata were considered: slope and interface where slope is from surface to half of total depth (TD) (e.g. TD = 6m, Slope = from 0-3m); interface corresponds to the zone of transition from rocky complex bottom (Slope) to non-consolidated substrate (sand bottom) (Figure 2).

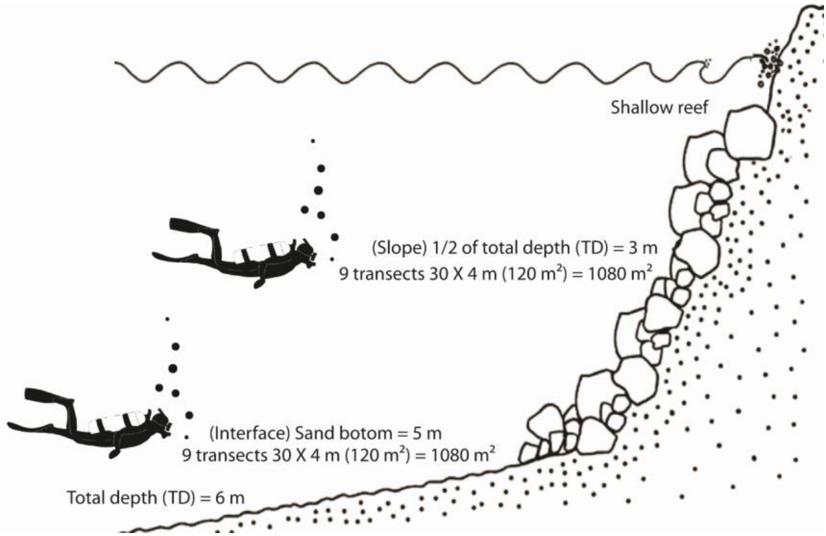

Figure 2: Two depth strata: Slope from surface to half of total depth (TD) (e.g. TD = 6m, Slope = from 0-3m); Interface which corresponds to the transition zone between rocky complex bottom (Slope) and non-consolidated substrate (sand bottom). For each depth strata, 9 transects were executed totalizing 18 transects per site. The transect dimensions selected for this study were 30 meters of length by 4 meters width (30X4m). Each transect (30X4m) covers 120 m² of sampled area; 18 transects were executed totalizing 2.160 m² sampled for each site.

Transects with the dimensions of 30 meters in length by 4 meters width were used to assess Epinephelidae and Serranidae communities. These dimensions were selected considering the species ecomorphology such as, body size and shape, habitat distribution, and feeding habits just as much as abiotic factors like shelter availability and ocean water low visibility. A total of 144 transects (30X4 – 120 m²) were performed during the summers of 2009 and 2010.

Each transect (30X4m) covered 120 m² of sampled area, 18 transects were executed totaling 2.160 m² sampled for each site. The individuals were counted while the diver unrolls the tape measure along the length of the transect (Figure 3). The distance from the bottom of the recorded specimens was also noted during this procedure. Specimen's body sizes were categorized within size classes from 5 to 5 cm (e.g 5, 10, 15 cm). Specimen's body sizes were used to estimate biomass using weight-length ($W=TL*A^b$) references published for each species of

Epinephelidae (sensu Craig and Hastings 2007) and Serranidae (Froese and Pauly 2005). While folding back the tape measure the divers noted the environmental data, stopping at every 5 meters along the total 30 meters length, totaling 6 environmental data samples per transect. The variables selected were rugosity, inclination of the reef (slope), number of small, medium and large rocks, number of small, medium and large holes (shelters), and finally percentage of sand in substrate.

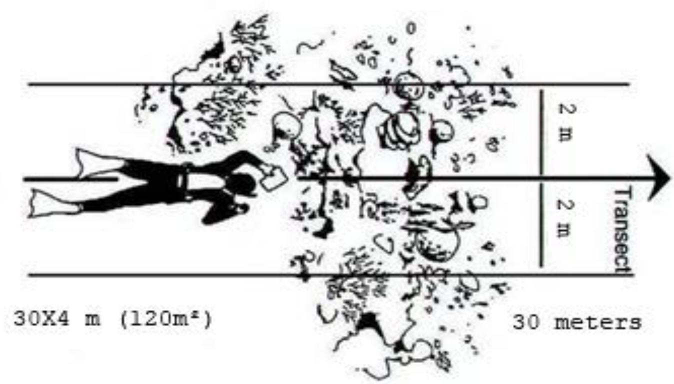

Figure 3: Transect dimensions: 30 meters in length, 4 meters width (120 m²). The fishes are counted while the diver unrolls the tape measure along the transect length. While folding back the tape measure the divers noted the environmental data, stopping each 5 meters along the length of the transect (30 meters), totaling 6 environmental data sampling for each transect.

Data analysis

In order to explore and highlight undistinguished patterns, occurrence and species distribution tendencies we performed a canonical correspondence analysis (CCA), in which fish biomass in each site was correlated with environmental variables (Ter Braak 1987; Legendre & Legendre 1998; Zar 1999; Leps and Smilauer 2007). Such statistical method allows direct correlations among population and environmental variations, once the ordination axes are chosen in respect to the variables (Ter Braak 1986; 1987).

Principal component analysis (PCA) was performed with species total biomass and environmental variables to explore which variable is mostly related to a specific site. Environmental characteristics of each site are highlighted in this procedure by the length and directions of the variables vectors.

To achieve statistical tests requirements species biomass data were Log_{X+1} transformed for both methods (Ter Braak 1987; Legendre & Legendre 1998; Zar 1999; Leps and Smilauer 2007).

RESULTS

Environmental characterization

Each of the 8 sites presented particular environmental characteristics, shown in the principal component analysis (PCA), which tends to directly influence species distribution (Figure 4). Arvoredo archipelago (Marine Protected Area), Arvoredo island (outside no-take zone), Aranhas Island, and Xavier Island, despite their similar environmental structural complexity have different biomass distribution which emphasizes the no-take effect for targeted large Epinephelidae species. Individuals larger than 40 cm total length (TL) were recorded mostly inside the Arvoredo Marine Biological Reserve no-take zone (Figure 4). Arvoredo Island has the largest reef area, formed mostly by medium (blocks < 50 cm) and large rocks (blocks > 50 cm) that also provide medium and large shelters (Figure 4). Galé and Deserta islands presented the largest biomass amongst all sites. They are also structurally similar in terms of rugosity. The large rodolith beds (marine benthic coralline algae) formed by innumerous small round calcareous structures found mostly in Deserta and Galé Islands, explains the "small rocks" vector in the PCA analysis. Aranhas Island is consited of two granitic small Islands of similar size connected to each other by a rocky bottom. The majority of the reef area of the smaller western Island is characterized by very large boulders that increase the inclination of the reef area (slope vector). The bottom of Xavier Island is similar to Arvoredo Island, therefore the Xavier biomass is significantly smaller

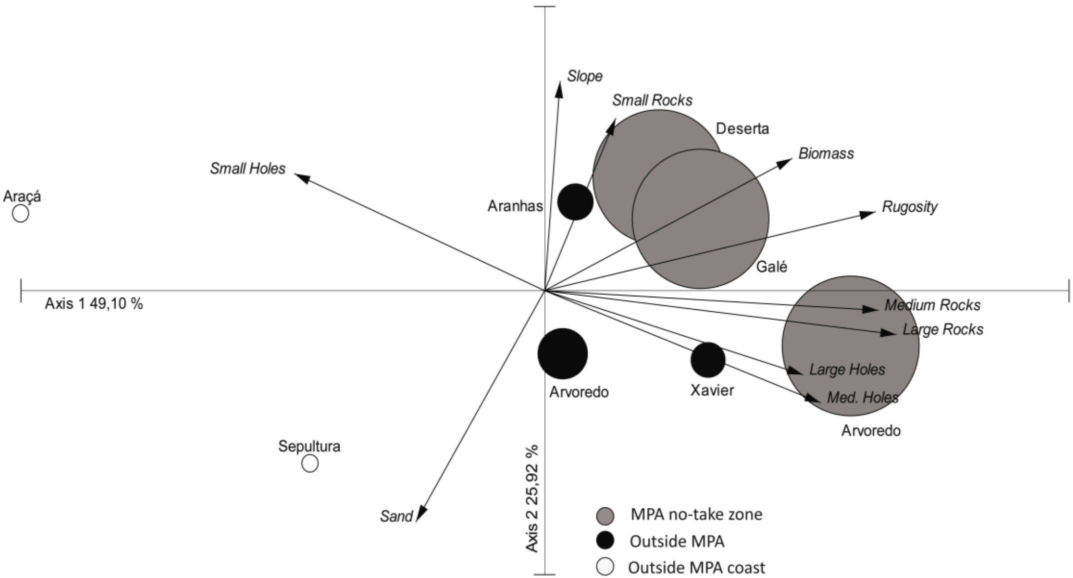

Figure 4: Principal component analysis (PCA) joint plots showing the topographic characteristics among sites (cumulative % of variance 75,02). Circles mark the position of sites: Grey circles mark the no-take sites; black circles mark the sites outside MPA and the white circles mark the sites located in the coast. The circles sizes are proportional to the total species biomass for each site.

which may be due to overfishing since Xavier is well known by local spear fishermen. The sites Cape Araçá and Cape Sepultura showed low structural complexity, with a short vertical reef area (maximum depth 5 meters). Cape Araça's bottom is formed mostly by small granitic and basaltic rocks, that form a large amount of small holes (shelters), explaining the "small holes" vector in the analysis. Cape Sepultura shallow bottom is mostly formed by sand, explain the "sand" vector in the analysis.

Epinephelidae and Serranidae spatial distribution and habitat use

We recorded 7 species of the family Epinephelidae (*sensu* Craig and Hastings, 2007) and 6 species of the family Serranidae in 18 transects for each of the 8 sites, inside and around Arvoredo Biological Marine Reserve. A total of 13 species were recorded. These numbers are consistent with previous works (Hostim-Silva *et al.* 2006). Members of the family Serranidae (a non-target species in this environmental context) did not appear in local or other threatened red lists. Three species presented dominant distribution and biomass: *Serranus flaviventris* (Cuvier, 1829) commonly referred as ***t***winspot bass, detected in 6 of 8 sites, *Serranus baldwini* (Evermann & Marsh, 1899) commonly referred as lantern bass, detected in 4 of 8 sites, and *Diplectrum radiale* (Quoy & Gaimard, 1824) commonly referred as pond perch, recorded in Xavier Island and specially in Cape Araçá. As well, the family Epinephelidae presented dominant distribution for 2 species which were recorded in all 8 sites: *Mycteroperca marginata* (*sensu* Craig and Hastings 2007) commonly referred as dusky grouper, and *Mycteroperca acutirostris* (Valenciennes, 1828) commonly referred as comb grouper. The species *M. marginata* enters in the IUCN Red List of Threatened Species as endangered (EN) (IUCN, 2011.1).In this list, this species is referred as *Epinephelus marginatus* (Lowe, 1834). Two other members of the family Epinephelidae (target species) recorded in this study also enter in the same list: *Epinephelus morio* (Valenciennes**,** 1828), commonly referred as the Red grouper, considered near threatened (NT) and *Hyporthodus niveatus* (Valenciennes, 1828) commonly referred as Snowy grouper, considered vulnerable (VU) (table 1)**.**

Table 1: Species distribution among sites in 4 size classes. Large Epinephelidae (>30cm) remained rare. The family Epinephelidae presented two dominant species distribution and biomass, being detected in all 8 sites: *Mycteroperca marginata*, mostly individuals smaller than 30 cm (*sensu* Craig and Hastings, 2007) and *Mycteroperca acutirostris*. Three species of the family Serranidae (*sensu* Craig and Hastings, 2007) presented dominant distribution: *Serranus flaviventris* commonly called twinspot bass, detected in 6 of 8 sites, and Serranus baldwini commonly called lantern bass, detected in 4 of 8 sites**.** *Diplectrum radiale* commonly referred as pond perch, recorded in Xavier Island and especially in Cape Araçá (n=50).

Total density distribution (size class)

Species	**Galé Island no-take zone**				
	5 -10	**10 -20**	**20 - 30**	**> 30**	Total
Mycteroperca marginata	9	47	24	22	102
Mycteroperca acutirostris		15	8	3	26
Mycteroperca bonaci					
Mycteroperca interstitialis					
Mycteroperca microlepis					
Hyporthodus niveatus	1	1			2
Epinephelus morio					
Diplectrum radiale					
Diplectrum formosum					
Serranus flaviventris	8				8
Serranus baldwini					
Serranus atrobranchus	1				1
Dules auriga					
	5 -10	**10 -20**	**20 - 30**	**> 30**	
	Deserta island no-take zone				
	5 -10	**10 -20**	**20 - 30**	**> 30**	Total
Mycteroperca marginata	9	42	28	19	98
Mycteroperca acutirostris		6	5	7	18
Mycteroperca bonaci		1	1	1	3
Mycteroperca interstitialis		3		1	4

Mycteroperca microlepis				2	2
Hyporthodus niveatus					
Epinephelus morio			1		1
Diplectrum radiale					
Diplectrum formosum		1			1
Serranus flaviventris	1				1
Serranus baldwini	19				19
Serranus atrobranchus					
Dules auriga					
	5 -10	**10 -20**	**20 - 30**	**> 30**	

Arvoredo Island no-take zone

	5 -10	**10 -20**	**20 - 30**	> 30	Total
Mycteroperca marginata	1	12	5	13	31
Mycteroperca acutirostris		4	5	35	44
Mycteroperca bonaci					
Mycteroperca interstitialis					
Mycteroperca microlepis					
Hyporthodus niveatus					
Epinephelus morio				1	1
Diplectrum radiale					
Diplectrum formosum					
Serranus flaviventris					
Serranus baldwini					
Serranus atrobranchus					
Dules auriga	**5 -10**	**10 -20**	**20 - 30**		

Aranhas Island

	5 -10	**10 -20**	**20 - 30**	> 30	Total
Mycteroperca marginata	11	39	14	5	69
Mycteroperca acutirostris	2	9	4	3	18
Mycteroperca bonaci					
Mycteroperca interstitialis					
Mycteroperca microlepis					

Hyporthodus niveatus	1				1
Epinephelus morio					
Diplectrum radiale					
Diplectrum formosum		1			1
Serranus flaviventris					
Serranus baldwini	8				8
Serranus atrobranchus	8				8
Dules auriga					
	5 -10	**10 -20**	**20 - 30**	**> 30**	

	Xavier Island				
	5 -10	**10 -20**	**20 - 30**	> 30	Total
Mycteroperca marginata	17	25	13	6	61
Mycteroperca acutirostris		11	6	2	19
Mycteroperca bonaci		1			1
Mycteroperca interstitialis		2			2
Mycteroperca microlepis					
Hyporthodus niveatus					
Epinephelus morio					
Diplectrum radiale		2			2
Diplectrum formosum		1			1
Serranus flaviventris	1				1
Serranus baldwini	2				2
Serranus atrobranchus	3				3
Dules auriga	2				2

	Arvoredo Island				
	5 -10	**10 -20**	**20 - 30**	**> 30**	Total
Mycteroperca marginata	5	13	6	2	26
Mycteroperca acutirostris	3	12	7	15	37
Mycteroperca bonaci				1	1
Mycteroperca interstitialis			2		2
Mycteroperca microlepis					

Hyporthodus niveatus					
Epinephelus morio					
Diplectrum radiale					
Diplectrum formosum					
Serranus flaviventris	1				1
Serranus baldwini	2				2
Serranus atrobranchus					
Dules auriga	**5 -10**	**10 -20**	**25 - 30**	**> 30**	

		Cape Araçá coast			
	5 -10	**10 -20**	**25 - 30**	> 30	Total
Mycteroperca marginata		4	3		7
Mycteroperca acutirostris	2	25	22	2	51
Mycteroperca bonaci					
Mycteroperca interstitialis					
Mycteroperca microlepis					
Hyporthodus niveatus					
Epinephelus morio					
Diplectrum radiale	50	4			54
Diplectrum formosum					
Serranus flaviventris	20	14			34
Serranus baldwini					
Serranus atrobranchus					
Dules auriga					

		Cape Sepultura coast			
	5 -10	**10 -20**	**25 - 30**	> 30	Total
Mycteroperca marginata		5	6	1	12
Mycteroperca acutirostris	3	5	1	2	11
Mycteroperca bonaci			1		1
Mycteroperca interstitialis					
Mycteroperca microlepis		1			1
Hyporthodus niveatus	1				1

Epinephelus morio					
Diplectrum radiale					
Diplectrum formosum					
Serranus flaviventris	15				15
Serranus baldwini					
Serranus atrobranchus					
Dules auriga	**5 -10**	**10 -20**	**25 - 30**	**> 30**	

The Canonical correspondence analysis (CCA) emphasized tendencies of distribution of species according to their biomass and environmental variables (Ter Braak, 1987)**.** Targeted dominant species of the family Epinephelidae *M. marginata*, showed a very clear pattern of distribution positioned near “rugosity” (environmental complexity), “slope” (reef inclination), “medium rocks”, “small holes” and “small rocks” vectors, which is explained by the large amount of small individuals (<30cm) recorded in this work, and such environmental characteristics can also be considered as an optimum feeding habitat pattern for individuals of *M. marginata* in this ontogenetic stage (La Mesa et al. 2002; Gibran 2007; Condini *et al.* 2011) **.** Other targeted dominant species like *M. acutirostris* also showed a distinct pattern of distribution, positioned near “large rocks”, “large holes”, “sand” (non-consolidated substrate) and “medium holes (shelters) vectors, which is explained by the high mobility of these species according to their habitat use and feeding behavior (Heemstra and Randall 1993; Gibran 2007; 2010). Recorded species with a total density smaller than 30 organisms (*M. microlepis*, *M. bonaci*, *M. interstitialis*, *E. morio* and *H. niveatus*) may affect the vector positioning, therefore, were not considered in this analysis (Figure 5)**.**

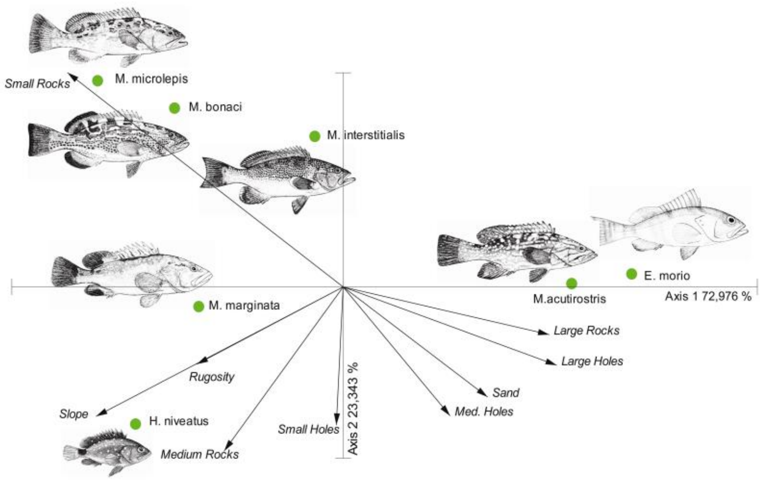

Figure 5: Canonical correspondence analysis (CCA) joint plots showing distribution of Epinephelidae species according to their biomass and environmental variables *(cumulative % of variance 96,31)***.** The arrow vectors show the environmental variables, the circles mark the positions of species. Recorded species with total densities smaller than 30 organisms were not considered in this analysis.

Three Serranidae species presented higher density and biomass among other species: *S. baldwini*, S. flaviventris and D. radiale. *Serranus baldwini* was mostly associated with rodolith beds ("small rocks" vector) in Deserta Island and is the only Serranidae species with an important density biomass inside the no-take zone; such distribution may be due to feeding and reproductive behaviors (Petersen and Fisher 1986). *Serranus flaviventris* and *D. radiale* were detected mostly in shallow areas (maximum 5 meters deep), at the interface of the complex reef with sand bottoms ("sand" and "small holes" vectors). These shallow reefs or habitat conditions seem to be optimum for feeding and reproductive behaviors for these non-targeted small Serranidae species along the coast of Santa Catarina, southern Brazil (Figure 6).

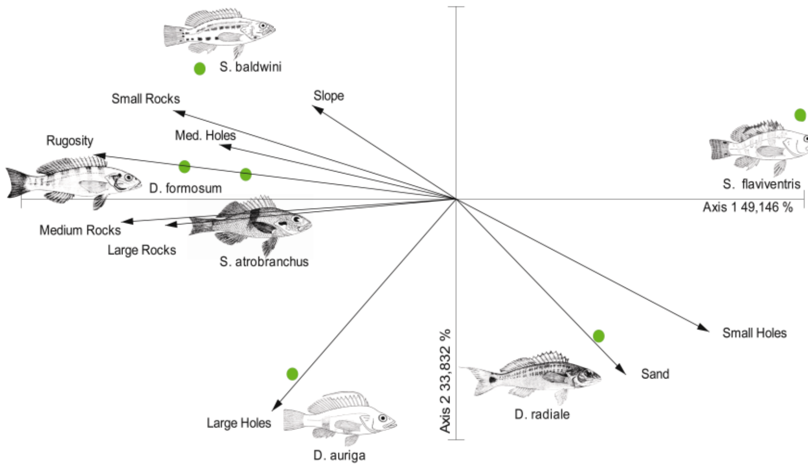

Figure 6: Canonical correspondence analysis (CCA) joint plots showing distribution of Serranidae species according to their biomass and environmental variables (cumulative % of variance 82,97)**.** The arrow vectors show the environmental variables, the circles mark the positions of species. Recorded species with a total density smaller than 30 organisms were not considered in this analysis.

DISCUSSION

The dominant species of Epinephelidae (*M. marginata* and *M. acutirostris*) and Serranidae (*S. Baldwini*, *S. flaviventris* and *D. radiale*) studied in this work are all directly associated to the topographic characteristics optimum for their protection against predation, reproductive and feeding behaviors (Figure 7).

Most individuals of *M. marginata* were juveniles (< 30 cm TL) and were recorded inside or close to their shelters, and the few individuals positioned in the water column were never vertically higher than 1 meter. These behavioral patterns emphasize these species preferences for optimum sheltering and feeding habits. During this ontogenetic stage, topographic variables seem more important than food resources (La Mesa *et al*. 2002; Machado *et al*. 2003; Gibran 2007). According to Gibran (2007), juveniles of *M. marginata* show cryptic

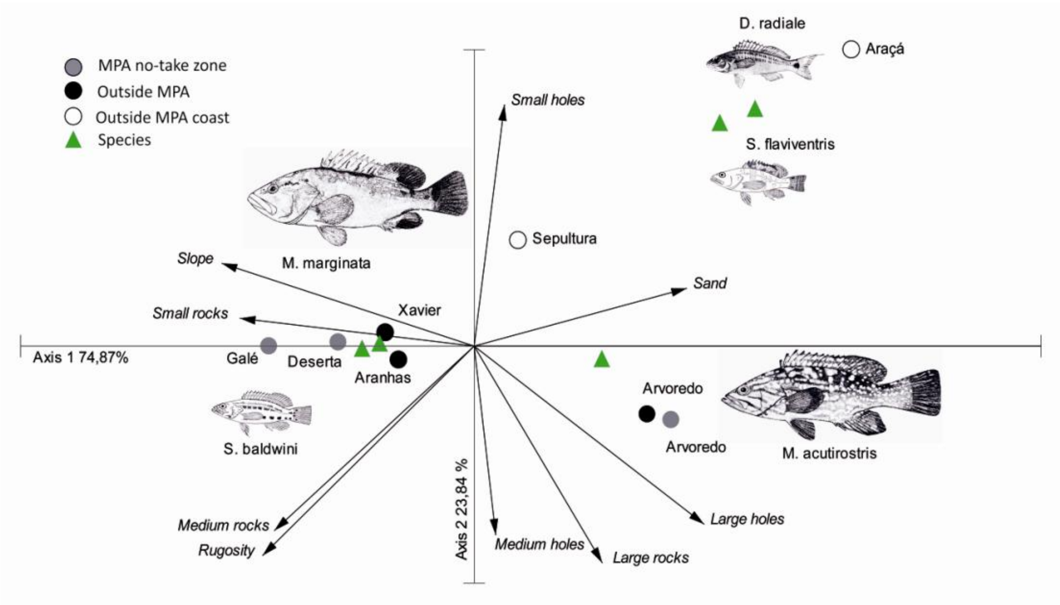

Figure 7: Canonical correspondence analysis (CCA) joint plots showing distribution of 5 dominant species according to their biomass and environmental variables (cumulative % of variance 98,71). The arrow vectors show the environmental variables, the circles mark the positions of species. The green triangles represent the position of species. Circles mark the position of sites: Grey circles mark the no-take sites; black circles mark the sites outside MPA and the white circles mark the sites located in the coast.

behavioral patterns living associated with the substrate and also avoiding distant dislocations from their shelters. Such habitat association tends to be closely related to the necessity for shelter, which seems to be an important factor in determining the optimum microhabitat for *M. marginata* individuals < 30 cm TL (Smith 1961; Parrish 1987; Derbal and Kara 1995; La Mesa *et al*. 2002; Gibran 2007) (Figure 8).

Individuals of *M. acutirostris* (fast swimming Epinephelids) are considered as more opportunistic and versatile predators due to ecomorphological attributes such as body shape (e.g. slender body with truncated tail) which favors this species distribution, protection against predation and feeding habits which includes benthic crustaceans and small fishes (Sazima 1986; Bonaldo *et al.* 2004; Gibran 2007). Most individuals of *M. acutirostris* were recorded in the water column positioned mostly at 1 meter vertical to the substrate (Figure 8). These behavioral patterns emphasize these species preferences for optimum feeding habits, and also highlights that individuals are not conditioned to shelter availability (Sazima 1986; Bonaldo *et al.* 2004; Gibran 2004; 2007).

Small species of the family Serranidae (smaller organisms) are all directly associated to unconsolidated substrate such as rodolith beds, low complexity bottoms, sand, and gravel or muddy bottoms (Petersen and Fisher 1986, Gibran 2007). All three dominant species presented similar activity and habitat use. Most individuals were recorded at the interface between the rocky reef and the sandy bottom (Fig.2). Individuals of *S. flaviventris* and *S. baldwini* were recorded in the water column only when escaping from the diver during the unrolling of the transect. Individuals of *D. radiale* were all recorded at substrate level (Fig. 8). Most individuals of *D. radiale* are exclusively associated with unconsolidated substrate (Gibran 2007). All individuals were recorded in a specific site located on the coast (Cape Araçá). Individuals of *S. flaviventris* were recorded on small rocks and inside small shelters. According to Gibran (2007) S. *flaviventris* can be regarded as an ecomorphological equivalent of the *Diplectrum* species from hard substrata. Most individuals were also recorded in sites located on the coast (Cape Araçá and Cape Sepultura). These sites are characterized by high levels of anthropogenic activities such as: recreational fishing, small vessel boat traffic, fresh-running water, and sewage disposal. Their low density on other insular sites may be due to the large number of Epinephelidae predators recorded in these sites. These behavioral patterns emphasize these species territoriality, which serve both feeding and spawning.

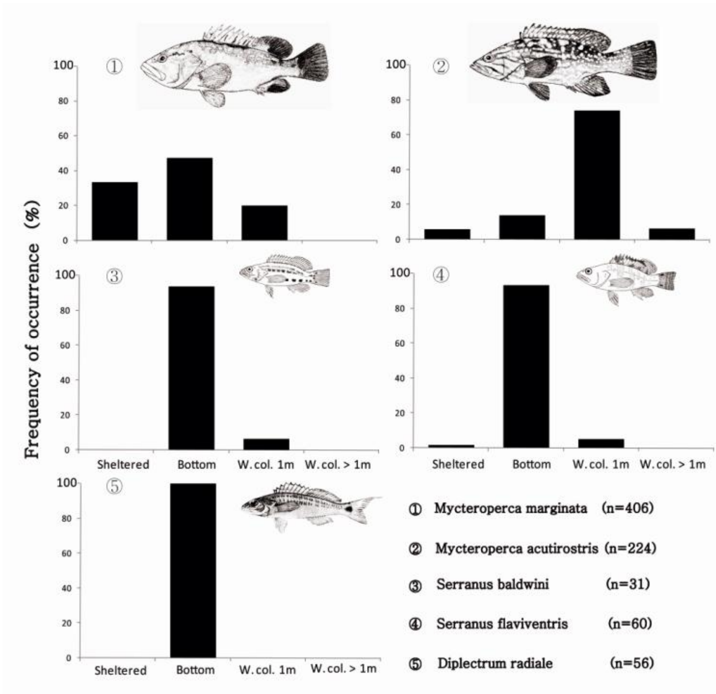

Figure 8: Frequency of occurrence histogram of dominant species according to their vertical position relative to the substrate. Individuals of *M. marginata* (1) were recorded inside or close to their shelters, and the few individuals positioned in the water column were never found vertically higher than 1 meter. Most individuals of *M. acutirostris* (2) were recorded in the water column mostly at 1 meter vertical to the substrate. *Serranus baldwini* (3) individuals were recorded on rodolith beds mostly in Deserta and Galé Islands, never more than a few centimeters (< 30 cm) from the substrate. Individuals of S. flaviventris (4) were recorded in sites located on the coast (Cape Araçá and Cape Sepultura). Most individuals of *D. radiale* (5) are exclusively associated with unconsolidated substrate, never recorded in the water column; all individuals of D. radiale were recorded in a specific site located on the coast (Cape Araçá).

The most aggressive and territorial species was *S. baldwini*. Most individuals were recorded on rodolith beds (marine benthic coralline algae) formed by innumerous small round calcareous structures found especially in Deserta and Galé Islands. Individuals recorded in the water column were never more than a few centimeters (< 40 cm) from the substrate. Such behavior was detected during aggressive attacks on other individuals of the same species. According to Petersen and Fisher (1986) territories serve as both feeding and spawning sites. Males aggressively interacted and displaced smaller hermaphrodites. While hermaphrodites often interacted aggressively among themselves, it remains unclear whether all of them, especially smaller ones, also maintained territories.

Knowing key species habitat use and behavioral patterns may provide us with important clues when deciding design and management of Marine Protected Areas (Spedicato *et al.* 2005, Floeter *et al.* 2006, Garcia-Chartón *et al.* 2008). The lack of biological knowledge may lead to arbitrary designs and poor management which may negatively affect a MPAs effectiveness.

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REFERENCES

Aburto-Oropeza O, Erisman B, Galland GR, Mascareñas-Osorio I, Sala E, *et al* (2011) Large Recovery of Fish Biomass in a No-Take Marine Reserve. PLoS ONE 6(8) e23601

Almany GR (2003) Priority effects in coral reef fish communities. Ecology 84:1920-1935

Almany GR (2004) Priority effects in coral reef fish communities of the Great Barrier Reef Ecology 85:2872-2880

Almany GR, Webster MS (2004) Odd species out as predators reduce diversity of coral-reef fishes. Ecology 85:2933-2937

Barneche DR, Anderson A B, Floeter SR, Silveira M, Dinslaken DF and Carvalho filho A (2009) Ten new records of reef fish on the coast of Santa Catarina State, Brazil. Marine Biodiversity Records, page 1 of 4. #2009 Marine Biological Association of the United Kingdom Vol. 2; e143; 2009 Published online

Basei MSA, Siga Jr O, Machiavelli A, Mancini F (1992) Evolução tectônica dos terrenos entre os Cinturões Ribeira e Dom Feliciano (PR-SC). Rev. Brasileira de Geociências, 22(2):216-221

Bonaldo R M, Krajewski J P & Sazima I (2004) Does the association of young fishes with jellyfishes protect from predation? A report on a failure case due to damage to the jellyfish. Neotropical Ichthyology, 2(2): 103-105

Brock VE (1954) A preliminary report on a method of estimating reef fish populations. J Wildlife Manage 18:297–308

Carter J, Marrow FJ & Pryor V (1994) Aspects of the ecology and reproduction of Nassau grouper, Epinephelus striatus, off the coast of Belize, Central America. Proc. Gulf & Caribbean Fisheries Institute 43: 64-110

Coleman FC, Williams SL (2002) Overexploiting marine ecosystem engineers: potential consequences for biodiversity. Trends Ecol Evol 17:40-44

Condini M V, Seyboth E, Vieira J P, & Garcia A M (2011) Diet and feeding strategy of the dusky grouper *Mycteroperca marginata* (Actinopterygii : Epinephelidae) in a man-made rocky habitat in southern Brazil. Neotropical Ichthyology, 9(1), 161–168

Craig MT & Hastings PA (2007) A molecular phylogeny of the groupers of the subfamily Epinephelinae (Serranidae) with a revised classification of Epinephelini. Ichthyological Research, 54, 1–17

Derbal F & Kara MH (1995) Habitat et comportement du mérou *Epinephelus marginatus* dans la région d'Annaba (Algérie). Cahiers de Biologie Marine, 36: 29-32

Diehl FL & Horn Filho NO (1996) Compartimentação geológico-geomorfológica da zona litorânea e planície costeira do Estado de Santa Catarina. Notas Técnicas, 9:39-50

Drew J (2005) Use of Traditional Ecological Knowledge in Marine Conservation. Conservation Biology, 19(4): 1286-1293

Figueiredo JL & Menezes NA (1980) Manual de Peixes do Sudeste do Brasil 3. São Paulo Museu de Zoologia, Universidade de São Paulo. 90 pp

Floeter SR, Guimarães ZP, Rocha LA, Ferreira CEL, Rangel CA and Gasparini JL (2001) Geographic variation in reef-fish assemblages along the Brazilian coast. Global Ecology and Biogeography10, 423–431

Floeter SR, Halpern B S, Ferreira CEL (2006) Effects of fishing and protection on Brazilian reef fishes. Biological Conservation, 128: 391-402

Floeter SR, Krohling W, Gasparini JL, Ferreira CEL, Zalmon I (2007) Reef fish community structure on coastal islands of the southeastern Brazil: the influence of exposure and benthic cover. Environmental Biology of Fishes, 78: 147-160

Floeter SR, Rocha LA, Robertson DR, Joyeux JC, Smith-Vaniz WF, Wirtz P, Edwards AJ, Barreiros JP, Ferreira CEL, Gasparini JL, Brito A, Falcón JM, Bowen BW and Bernardi G (2008) Atlantic reef fish biogeography and evolution. Journal of Biogeography 35, 22–47

Froese R, Pauly D (2005) FishBase: World Wide Web electronic publication

García-Charton JA, Pérez-Ruzafa A, Marcos C, Claudet ., Badalamenti F, Benedetti- Cecchi L, Falcón JM, Milazzo M, Schembri PJ, Stobart B, Vandeperre F, Brito A, Chemello R, Dimech M, Domenici P, Guala I, Le Diréach L, Maggi E, Planes S (2008) Effectiveness of

European Atlanto-Mediterranean MPAs: do they accomplish the expected effects on populations, communities and ecosystems? Journal of Nature Conservation, 16, 193-221

Gibran FZ (2004) Dying or illness feigning: an unreported feeding tactic of the comb grouper *Mycteroperca acutirostris* (Serranidae) from the Southwest Atlantic. Copeia, 2004(2): 402-405

Gibran FZ (2007) Activity, habitat use, feeding behavior, and diet of four sympatric species of Serranidae (Actinopterygii: Perciformes) in southeastern Brazil. Neotropical Ichichthyology. [online]. Vol.5, n.3, pp. 387-398. ISSN 1679-6225

Gibran FZ (2010) Habitat partitioning, habits and convergence among coastal nektonic fish species from the São Sebastião Channel, southeastern Brazil. *Neotropical Ichthyology*; 8(2):299–310

Goñi R, Harmelin-Vivien M, Badalamenti F, Le Diréach L, Bernard G (2000) Introductory guide to methods for selected ecological studies in marine reserves. edit., GIS Posidonie publ., Fr., 2000 : 1-120

Heemstra PC, Randall JE (1993) FAO species catalogue. Vol. 16. Groupers of the world (family Serranidae, subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date. FAO Fish. Synop. 125(16):382 p

Heithaus MR, Frid A, Wirsing A and Worm B (2008) Predicting ecological consequences of marine top predator declines. Trends in Ecology and Evolution 23(4) :202–210

Hixon MA (1991) Predation as a process structuring coral reef fish communities. In: Sale P.F. (ed) The ecology of fishes on coral reefs. Academic Press, San Diego, p 475-508

Hostim-Silva M. Andrade AB, Machado LF, Gerhardinger LC, Daros FA, Barreiros JP and Godoy EAS (2006) Peixes de costão rochoso de Santa Catarina: I. Arvoredo. 1st edition. Itajaı´: Editora da Universidade do Vale do Itajaı´

Johannes RE (1998) The case for data-less marine resource management: examples from tropical nearshore finfisheries. Trends in Ecology & Evolution, 13: 243-246

Jones CG, Lawton JH, Shachak M (1994). Organisms as ecosystem engineers. Oikos 69:373-386

Karplus I (1978) A feeding association between the grouper Epinephelus fasciatus and the moray eel Gymnothorax griseus. Copeia, 1: 164

Kline RJ, Khan IA, Holt GJ (2011) Behavior, Color Change and Time for Sexual Inversion in the Protogynous Grouper (Epinephelus adscensionis). PLoS ONE 6(5): e19576

La Mesa LGP & Vacchi M (2002) Assessment of microhabitat preferences in juvenile dusky grouper (Epinephelus marginatus) by visual sampling. Marine Biology, 140(1): 175-185

Legendre P and Legendre L (1998) Numerical Ecology. Elsevier: Amsterdam, 853 p

Leps J Smilauer P (2007) Multivariate analysis of ecological data using CANOCO. Cambridge University Press, Cambridge, UK, 269 pp

Machado LF, Andrade AB, Hostim-Silva M & Barreiros JP (2003) Habitat use by the juvenile dusky grouper *Epinephelus marginatus* and its relative abundance, in Santa Catarina, Brazil. Aqua, Journal of Ichthyology and Aquatic Biology, 6(4): 133-138

Medeiros RP, Vizinho SC, Macedo CX, & Polette M (1997) Diagnóstico sócio-econômico e cultural das comunidades pesqueiras artesanais do litoral centro-norte do Estado de Santa Catarina. Notas Técnicas da FACIMAR/UNIVALI , 1: 33-42

Montgomery WL (1975) Interspecific associations of sea-basses (Serranidae) in the Gulf of California. Copeia, 4: 785-787

Olsen DA & LaPlace JA (1979) A study of a Virgin Islands grouper fishery based on a breeding aggregation. Proc. Gulf Carib. Fish. Inst. 31: 130-144

Ormond RFG (1980) Aggressive mimicry and other interspecific feeding associations among Red Sea coral reef predators. J. Zool., Lond., 191: 247-262

Parrish JD (1987) The trophic biology of snappers and groupers. In: Polovina, J. J. & S. Ralston (Eds.). Tropical Snappers and Groupers: Biology and Fisheries Management. Boulder, Westview Press, 659p

Petersen CW and Fisher EA (1986) Mating System of the Hermaphroditic Coral-Reef Fish Serranus baldwini, Behavioral Ecology and Sociobiology, Springer Vol. 19, No. 3 (1986), pp. 171-178

Randall JE & Heemstra PC (1991) Revision of Indo-Pacific groupers (Serranidae: Epinephelinae), with descriptions of five new species. Indo-Pac. Fish., 20: 1-332

Sadovy Y, Cohn PL & Domeier ML (1994) Aggregation and spawning in the tiger grouper, Mycteroperca tigris (Pisces: Serranidae). Copeia 1994: 511-516.

Sadovy Y (1994) Grouper stocks of the Western Central Atlantic: the need for management and management needs. Proc. Gulf Carib. Fish. Inst., 43:43-64

Sazima I (1986) Similarities in feeding behaviour between some marine and freshwater fishes in two tropical communities. Journal of Fish Biology, 29: 53-65

Shapiro DY (1987) Reproduction in groupers. pp. 205-327. In: J.J. Polovina & S. Ralston (ed.) Tropical Snappers and Groupers: Biology and Fisheries Management. West view Press. Boulder

Shpigel M & Fishelson L (1989) Food habits and prey selection of three species of groupers from the genus Cephalopholis. Environ. Biol. Fish., 24(1): 67-73

Smith C L (1961) Synopsis of biological data on groupers (*Epinephelus* and allied genera) of the western North Atlantic FAO Fisheries Biology Synopses, 23: 1-61

Souza CHS (2000) O Homem da Ilha e os Pioneiros da Caça Submarina. Ed. Dehon, Santa Catarina

Spedicato MT, Lembo G, Marmulla G (eds.) (2005) Insight into the homing behaviour of the dusky grouper (Epinephelus marginatus Lowe, 1834) around the island of Ustica, Italy Rome, FAO/COISPA. 295p

Ter Braak CJF (1986) Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology, v.67, n.6, p.1167-79

Ter Braak C.J.F. (1987). The analysis of vegetation environment relationships by canonical correspondence analysis. Vegetatio, v.69, p.69-77

Ter Braak CJF (1987) Ordination. 91-173 in: R. H. G. Jongman, C. J. F. ter Braak & O. F. R van Tongeren [eds.] Data analysis in community and landscape ecology. Pudoc, Wageningen, The Netherlands. Reissued in 1995 by Cambridge Univ. Press, Cambridge, England. [390, 418, 419, 456, 457, 462, 466, 470, 474, 475, 486, 583, 592, 594, 596, 601, 617, 634]

Tortonese E (1986) Serranidae. 780-792. In: Whitehead, P.J.P., Bauchot, J.C., Nielsen, J. & E. Tortonese, (eds.) Fishes of the North-eastern Atlantic and the Mediterranean. Unesco, Paris, vol.II 1473 PP

CONCLUSÕES

A efetividade da Reserva Biológica Marinha do Arvoredo foi evidenciada principlamente pela biomassa das duas espécies mais abundantes e de distribuição homogênea: *Mycteroperca Marginata* e *Mycteroperca Acutirostris.* Porém, considerando o tempo de existência (21 anos) e as dimensões (17.800 ha) da REBIOMAR, e se compararmos os resultados de densidade e biomassa, com outras reservas marinhas com menor área e tempo de implementação, conclui-se que a efetividade da REBIOMAR pode ser considerada regular. Apesar da presença de indivíduos maiores que 40 cm ser maior dentro da área de exclusão da pesca da REBIOMAR, indivíduos maiores que 50 cm foram considerados raros. Estes resultados se devem principlamente a evidências de pesca ilegal dentro da reserva, além de uma série de outros fatores.

Ao se considerar grupos ou níveis tróficos para a avaliação de efetividade de reservas marinhas há que se considerar organismos que ocupem os níveis superiores na cadeia trófica, por apresentarem padrões mais claros quanto à distribuição dentro e fora da área protegida da pesca. Quanto maior a pressão exercida pela pesca sobre os organismos (e.g. *M. marginata*-EN-IUCN, 2011.1) maior parece ser o efeito positivo com relação ao aumento da biomassa proporcionado pela existência da área marinha totalmente restrita à pesca. Outros grupos tróficos posicionados em níveis subjacentes aos dos organismos considerados predadores de topo de cadeia alimentar, podem não revelar o real efeito de proteção proporcionado pela área fechada para a pesca, por serem organismos cuja pressão pesqueira exercida varia de forma a neutralizar, em parte, a redundância da existência de uma área de total exclusão da pesca. Para estudos de efetividade com estes organismos metodologias específicas deverão ser desenvolvidas, ou outros organismos focais deverão ser selecionados durante o desenvolvimento de um plano amostral.

A transecção linear com as dimensões (30X4 = 120m²) trinta metros de comprimento, por dois metros de largura para cada lado do comprimento do transecto, mostrou-se eficiente para avaliação de estrutura de comunidades de predadores de topo neste contexto ambiental de pouca visibilidade. A área aumentada do campo visual considerada pelo mergulhador favorece uma melhor inferência considerando a visibilidade da água variando entre 2 (mínimo) e 10 metros (máximo).

As análises multivariadas empregadas neste trabalho, principalmente a Análise de Correspondência Canônica (CCA) mostraram uma relação importante destes organismos com características específicas do ambiente (variáveis ambientais). A espécie *M. marginata* mostrou uma relação com a posição relativa ao substrato e a disponibilidade de tocas. A maioria dos indivíduos foi detectada na linha do substrato, em tocas proporcionais aos seus atributos ecomorfológicos (e.g. tamanho corporal) ou posicionadas próximas a estas tocas. Considerando que maioria dos indivíduos desta espécie detectados neste estudo foram menores que 40 cm, pode-se explicar assim sua relação com os vetores "tocas pequenas", "rochas pequenas", "Inclinação do fundo", e rugosidade. Conclui-se que indivíduos de *M. marginata* se relacionam com o substrato por territorialidade, hábitos alimentares e disponibilidade de abrigo. Indivíduos da espécie *M. acutirostris* por outro lado, apresentaram um relação com os vetores "tocas grandes", "rochas grandes" principalmente. Considerando seus atributos ecomorfológicos (e.g. formato corporal mais hidrodinâmico) e que a maioria dos indivíduos foi detectada na coluna d'água, conclui-se que sua relação com o habitat depende da disponibilidade de recursos. Já as espécies menores *S. baldwini*, *S. flaviventris* e *D. radiale* foram detectadas posicionadas na linha do substrato em ambientes pouco complexos (interface entre o costão rochoso e o substrato não consolidado), o que explica sua relação com os vetores "areia", "rochas pequenas" e "tocas pequenas".

Considerando as famílias Epinephelidae e Serranidae em 6 locais (e.g. 2 locais dentro da REBIOMAR, 2 ilhas fora da REBIOMAR e 2 locais na costa) nota-se que à medida que os pontos amostrais se aproximam da costa, as populações das espécies alvo (*M. marginata*) diminuem significativamente. Já as espécies menores (S. *flaviventris*) e pouco exploradas aumentam também de forma significativa. Isto sugere uma cascata trófica em que os grandes predadores de topo de cadeia alimentar nestes locais foram substituídos por pequenos carnívoros, estes, sem condições de desempenhar o mesmo papel funcional ecossistêmico que seus predecessores.

Tendo em vista que nos últimos anos os gestores da REBIOMAR têm trabalhado exaustivamente para garatirem a eficiência da reserva, estes esforços e seus efeitos somente poderão ser detectados em estudos de longa duração. Novos estudos focados na efetividade da REBIOMAR deverão ser incentivados.

Este trabalho foi desenvolvido com o intuito de contribuir com a avaliação da efetividade da REBIOMAR através de suas populações de garoupas, chernes, badejos e demais espécies de Epinephelidae e Serranidae presentes nestes locais, e também avaliar o uso do habiat por estes organismos, para que os órgãos gestores da REBIOMAR bem como o de outras áreas marinhas protegidas, possam se valer destes dados como referência (baseline), contribuindo assim com a otimização dos efeitos de reserva, conservação e exportação de biomassa destes locais.

REFERÊNCIAS

Aburto-Oropeza O., Erisman B., Galland G.R., Mascareñas-Osorio I., Sala E. *et al.* (2011). Large Recovery of Fish Biomass in a No-Take Marine Reserve. PLoS ONE 6(8

Andrade A.B., Machado L.F., Hostim-Silva M, Barreiros J.P. (2003). Reproductive biology of the dusky grouper Epinephelus marginatus (Lowe, 1834). Brazilian Arch. Biol. Tech. 46(3):373–381.

Brock V.E. (1954). A preliminary report on a method of estimating reef fish populations. J Wildlife Manage 18:297–308.

Bruslé J. (1985). Esposé synoptique des données biologiques sur les mérous Epinephelus aeneus (Geoffroy Saint Hilaire, 1809) et Epinephelus guaza (Linnaeus, 1758) de L`Océan Atlantic et de la Méditerranée. FAO Synop. Pêches 129:64.

Carter. J., F.J. Marrow & V. Pryor. (1994). Aspects of the ecology and reproduction of Nassau grouper, Epinephelus striatus, off the coast of Belize, Central America. Proc. Gulf & Caribbean Fisheries Institute 43: 64-110.

Chauvet C. & Francour P. (1990). Les mérous Epinephelus guaza du parc nacional de Port- Cros (France);Aspects socio-démographiques. Bulletin Societat Zoologique, 114 (4): 5-13.

Chesson P. & Kuang J. J. (2008). The interaction between predation and competition. Vol 456.

Claudet J., Pelletier D., Jouvenel J.Y., Bachet F. & Galzin R. (2006). Assessing the effects of marine protected area (MPA) on a reef fish assemblage in a northwestern Mediterranean case study: Identifying community-based indicators. Biol. Conserv., 130, 349–369.

Coleman F. C., C. C. Koenig, A.-M. Eklund, and C. B. Grimes (1999). Management and conservation of temperate reef fish in the southeastern United States. In Life in the slow lane— ecology and conservation of long-lived marine animals (J. A. Musick, ed.), p. 233–242. American Fisheries Society Bethesda, Maryland.

Coleman F.C., Williams S.L. (2002). Overexploiting marine ecosystem engineers: potential consequences for biodiversity. Trends Ecol Evol 17:40-44.

Côté I.M., Mosqueira I., Reynolds J.D. (2001). Effects of marine reserve characteristics on the protection of fish populations: a meta-analysis. J. Fish Biol., 59 (Supplement A):178–189.

Fasola M., Canova L., Foschi F., Novelli O. & Bressan M. (1997). Resource use by a Mediterranean rocky slope fish assemblage. Marine Ecology 18(1), 51-66.

Figueiredo J. L. & N. A. Menezes. (1980). Manual de Peixes do Sudeste do Brasil 3. São Paulo Museu de Zoologia, Universidade de São Paulo. 90 pp.

Floeter S.R., Guimarães Z.P., Rocha L.A., Ferreira C.E.L., Rangel C.A. and Gasparini J.L. (2001). Geographic variation in reef-fish assemblages along the Brazilian coast. Global Ecology and Biogeography10, 423–431.

Floeter S. R., Halpern, B. S., Ferreira, C. E. L. (2006). Effects of fishing and protection on Brazilian reef fishes. Biological Conservation, 128: 391-402.

Floeter S. R., Krohling W., Gasparini, J. L., Ferreira C. E. L., Zalmon I. (2007). Reef fish community structure on coastal islands of the southeastern Brazil: the influence of exposure and benthic cover. Environmental Biology of Fishes, 78: 147-160.

Floeter S.R., Rocha L.A., Robertson D.R., Joyeux J.C., Smith-Vaniz W.F., Wirtz P., Edwards A.J., Barreiros J.P., Ferreira C.E.L., Gasparini J.L., Brito A., Falco´n J.M., Bowen B.W. and Bernardi G. (2008). Atlantic reef fish biogeography and evolution. Journal of Biogeography 35, 22–47.

Francini-Filho R.B. and Moura R. L. (2008). Dynamics of fish assemblages on coral reefs subjected to different management regimes in the Abrolhos Bank, eastern Brazil. Aquatic Conserv: Mar. Freshw. Ecosyst. 18: 1166–1179.

Friedlander A.M., Brown E.K., Jokiel P.L., Smith W.R., Rodgers K.S. (2003). Effects of habitat, wave exposure, and marine protected area status on coral reef fish assemblages in the Hawaiian archipelago. Coral Reefs 22:291–305.

Friedlander A.M., Brown E., Monaco M.E. (2007). Defining reef fish habitat utilization patterns in Hawaii: comparisons between marine protected areas and areas open to fishing. Mar Ecol Progr Ser 351:221–233.

García-Charton J.A., Pérez-Ruzafa A., Marcos C., Claudet J.; Badalamenti F., Benedetti- Cecchi L., Falcón J.M., Milazzo M., Schembri P.J., Stobart B., Vandeperre F., Brito A., Chemello R., Dimech M., Domenici P.; Guala I., Le Diréach L., Maggi E., Planes S. (2008). Effectiveness of European Atlanto-Mediterranean MPAs: do they accomplish the expected effects on populations, communities and ecosystems? Journal of Nature Conservation, 16, 193-221.

Gibran F. Z. (2002). The sea basses Diplectrum formosum and D. radiale (Serranidae) as followers of the sea star Luidia senegalensis (Asteroidea) in southeastern Brazil. Brazilian Journal of Biology, 62(4A): 591-594.

Gibran F. Z.(2004). Dying or illness feigning: an unreported feeding tactic of the comb grouper Mycteroperca acutirostris (Serranidae) from the Southwest Atlantic. Copeia, 2004(2): 402-405.

Gibran F. Z. (2007). Activity, habitat use, feeding behavior, and diet of four sympatric species of Serranidae (Actinopterygii: Perciformes) in southeastern Brazil. Neotrop. ichthyol. [online]. Vol.5, n.3, pp. 387-398.

Gibran F.Z. (2010). Habitat partitioning, habits and convergence among coastal nektonic fish species from the São Sebastião Channel, southeastern Brazil. *Neotropical Ichthyology*; 8(2):299–310.

Goñi R., Harmelin-Vivien M., Badalamenti F., Le Diréach L., Bernard G. (2000). Introductory guide to methods for selected ecological studies in marine reserves. edit., GIS Posidonie publ., Fr., 2000 : 1-120.

Heithaus M.R., Frid A., Wirsing A.J. and Worm B. (2008). Predicting ecological consequences of marine top predator declines. Trends in Ecology and Evolution 23(4) :202–210.

Hostim-Silva M., Andrade A.B., Machado L.F., Gerhardinger L.C., Daros F.A., Barreiros J.P. and Godoy E.A.S. (2006). Peixes de costão rochoso de Santa Catarina: I. Arvoredo. 1st edition. Itajaı´: Editora da Universidade do Vale do Itajaı´.

Knowlton N., Jackson J.B.C. (2008). Shifting Baselines, Local Impacts, and Global Change on Coral Reefs. PLoS Biol 6(2): e 54.

Lima, S.L. and Dill, L.M. (1990). Behavioral decisions made under the risk of predation: a review and prospectus. Can. J. Zool. 68, 619–640.

Luckhurst B.E., Luckhurst K. (1978). Analysis of the influence of substrate variables on coral reef fish communities. Mar Biol 49:317–323.

Marino G., Longobardi A., La Mesa G., Donadelli V. & De Innocentiis S. (2007). Pilotrestocking of hatchery dusky grouper Epinephelus marginatus juveniles in the Mediterranean sea. Symposium on the Mediterranean Groupers. (eds: Francour, P., & Gradiot, J.). Nice University publ., Nice: 129-131.

Olsen D.A. & LaPlace J.A.. (1979). A study of a Virgin Islands grouper fishery based on a breeding aggregation. Proc. Gulf Carib. Fish. Inst. 31: 130-144.

Polovina J. J., and Ralston S. (1987). Tropical snappers and groupers: biology and fisheries management. Westview Press, Boulder, CO, 659 p.

Roberts C.M. & Polunin N.V.C. (1991). Are marine reserves effective in management of reef fisheries? Rev. Fish Biol. Fish., 1, 65–91.

Roberts C.M., Andelman S., Branch G., Bustamante R.H., Castilla J.C., Dugan J.E. *et al.* (2003). Ecological criteria for evaluating candidate sites for marine reserves. Ecol. Appl., 13, S199–S214.

Sadovy Y., P.L. Cohn & Domeier M.L.. (1994). Aggregation and spawning in the tiger grouper, Mycteroperca tigris (Pisces: Serranidae). Copeia 1994: 511-516.

Sadovy Y. (1994). Grouper stocks of the Western Central Atlantic: the need for management and management needs. Proc. Gulf Carib. Fish. Inst., 43:43-64.

Sadovy Y., Rosario A. & Roman. A. (1994b). Reproduction in an aggregating grouper. the red hind, Epinephelus guttatus , Env. v. Biol. Fish. 41: 269-286.

Sadovy Y., Eklund A. M. (1999). Synopsis of biological information on the Nassau grouper, Epinephelus striatus (Bloch 1792), and the jewfish, E. itajara (Lichtenstein 1822). NOAA Tech. Rep. NMFS 146. 65 p.
Sánchez Lizaso J.L., Goñi R., Reñones O., García-Charton J.A. and others (2000) Density dependence in marine protected populations: a review. Environ Conserv 27:144–158.

Sandin S.A., Smith J.E., DeMartini E.E., Dinsdale E.A., Donner S.D. *et al* (2008). Baselines and Degradation of Coral Reefs in the Northern Line Islands. PLoS ONE 3(2): e1548.

Shapiro D.Y. (1987). Reproduction in groupers. pp. 205-327. In: J.J. Polovina & S. Ralston (ed.) Tropical Snappers and Groupers: Biology and Fisheries Management. West view Press. Boulder.

Souza C.H.S. (2000). O Homem da Ilha e os Pioneiros da Caça Submarina. Ed. Dehon, Santa Catarina.

Spedicato M.T., Lembo G., Marmulla G. (2005). Insight into the homing behaviour of the dusky grouper (Epinephelus marginatus Lowe, 1834) around the island of Ustica, Italy Rome, FAO/COISPA. 295p.

Ter Braak C.J.F.(1986). Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology, v.67, n.6, p.1167-79.Ter Braak C.J.F. (1987). The analysis of vegetation environment relationships by canonical correspondence analysis. Vegetatio, v.69, p.69-77.

Ter Braak C. J. F. (1987). Ordination. 91-173 in: R. H. G. Jongman, C. J. F. ter Braak & O. F. R van Tongeren [eds.] Data analysis in community and landscape ecology. Pudoc, Wageningen, The Netherlands. Reissued in 1995 by Cambridge Univ. Press, Cambridge, England. [390, 418, 419, 456, 457, 462, 466, 470, 474, 475, 486, 583, 592, 594, 596, 601, 617, 634].

Ter Braak C. J. F. and Prentice, I. C. (1988). A theory of gradient analysis. Adv. Ecol. Res. v. 18, p.271-313.

Ter Braak C.J.F. (1995). Ordination. In: Jongman, R.H.G.; Ter Bbraak, C.J.F.; Van Tongeren, O.F.R. (Eds.) Data analysis in community and landscape ecology. Cambridge: Cambridge University Press, p.91-173.

Ter Braak C. J. F., and Smilauer P. (2002). CANOCO Reference Manual for CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power, Ithaca, NY. www.canoco.com.

Zabala M., Louisy P., Garcia-Rubies A., Gracia V. (1997). Socialbehavioral context of reproduction in the Mediterranean dusky grouper Epinephelus marginatus (Lowe, 1834) (Pisces, Serranidae) in the Medes Islands Marine Reserve (NW Mediterranean, Spain). Scientia Marina 61(1):79–89302 Environ Biol Fish (2009) 85:301–302.

Zar J. H.(1999). Biostatistical Analysis. Prentice Hall, New Jersey, 663 pp.