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Tee-Jay A. San Diego
Bureau of Fisheries and Aquatic Resources, Region 6, Iloilo City, Philippines, and Environmental Science Program, Oklahoma State University, Stillwater, OK, USA
Email: tjasandiego@yahoo.com

William L. Fisher
U. S. Geological Survey, New York Cooperative Fish and Wildlife Research Unit, and Department of Natural Resources, Cornell University, Ithaca, NY, USA
Email: wlf9@cornell.edu
Tel: 1- 607-2552839

Correspondence:
Tee-Jay San Diego
87-A Bonifacio Street, Arevalo, Iloilo City, Philippines 5000.
Email: tjasandiego@yahoo.com
Tel: 63-033-3360148

Trends in the capture fisheries in Cuyo East Pass, Philippines

Tee-Jay A. San Diego and William L. Fisher

ABSTRACT
Findings are presented of a comprehensive analysis of time series catch and effort data from 2000 to 2006 collected from a multi-species, multi-gear and two-sector (municipal and commercial) capture fisheries in Cuyo East Pass, Philippines. Multivariate techniques were used to determine temporal variation in species composition and gear selectivity that corresponded with annual trends in catch and effort. Distinct annual variation in species composition was found for five fisheries classified according to sector-gear combination, corresponding decline in catch diversity, noted shifts in gears used, and an erratic CPUE trend as a result of catch variation. These patterns and trends illustrate the occurrence of ecosystem overfishing for Cuyo East Pass. Our approach provided a holistic representation of the fishing situation, condition of the fisheries and corresponding implications to the ecosystem, fitting well within the context of the ecosystem approach to fisheries management.

Keywords: Capture fisheries, Multivariate Analysis, Ordination Techniques, Overfishing, Stock assessment, Temporal trends

1. Introduction

Capture fisheries, including large-scale industrial and small-scale artisanal fisheries, are renewable natural resources that require a sustainable level of harvest within the capacity of the stock to regenerate. The increasing demand for fish and fishery products for domestic consumption and exportation coupled with the growing human population is contributing to a decline in fish stocks in the Philippines [1, 2, 3 4]. This problem is symptomatic of declining fish stocks worldwide [5, 6, 7] and requires immediate and appropriate attention by fisheries managers and the participation of the stakeholders.

The species-rich marine environment of the Philippines is a highly valuable natural resource and an important component of the nation's economy [2]. In 2004, the total Philippine capture fisheries production of over 2.2 million metric tons generated 94 billion pesos or about 2.2 billion U S dollars [8]. Coastal villages depend on fisheries resources (e.g. fish, crustaceans, mollusks, and other invertebrates) in seagrass beds, mangroves, coral reefs, and marine ecosystems as sources of food and income. Thus, a decline in fish abundance can be devastating, particularly to the more than two million Filipinos who directly rely on this resource for subsistence [4].

Fisheries resource depletion in the Philippines can be attributed to several factors that primarily point to the open access nature of Philippine capture fisheries [4]. Typically, fishers are free to catch whatever species are abundant wherever they occur, which is leading to non-sustainable harvest (over-harvest) [2]. To maximize revenue, species with high market demand and economic value are initially targeted making them prone to over-exploitation [9].

When this leads to the decline of targeted species, fishers switch to more abundant species that were previously of lesser economical value. The decline in abundance of target species is linked to medium and long term changes in composition of species catch for various fisheries worldwide [10]. The switching of target species, as documented with changes in catch species composition, is one of the serious indicators of a continuously overfished ecosystem [11]. Thus, tracking changes in species composition through time, particularly in open access fisheries, is crucial to evaluating ecosystem fisheries management.

In most fisheries management programs, stock assessment is initially undertaken to determine the extent of degradation and depletion of the resource based on predefined objectives [12]. The Philippine government through the Bureau of Fisheries and Aquatic Resources (BFAR) conceived the National Stock Assessment Project (NSAP) in 1998 to monitor fish catch at selected fish landing sites throughout the country. Analysis of these data follows established quantitative approaches (e.g. length-based catch analysis of certain tuna species) [13], and the reporting process highlights total annual fisheries production by sector (commercial or municipal), geographic region, and most abundant species.

The current data analysis and reporting approaches used in the Philippines, however, do not provide a comprehensive evaluation of the multi-species, multiple-gear characteristics of the Philippine capture fisheries and their yield trends. Presenting total fisheries production or annual catch and effort alone is insufficient to assess the dynamic nature of fish stocks [14]. Information is needed on the effects of gear type and effort on species diversity and size composition [15]. Identification of highly threatened species and monitoring of the catch trend per species are needed to formulate site specific fisheries policies [16]. Temporal variation in yield is another important indicator of ecosystem health and integrity that is needed to assess the sustainability of fisheries [11]. Finally, a more a holistic ecosystem-based management approach, rather than focusing on a single-species management initiatives, is required to address overfishing problems [11]. Comprehensive assessment of captured fish stocks is essential to determine the present condition of fisheries resources in the Philippines so that appropriate management interventions can be implemented.

These identified inadequacies in comprehensively evaluating the impact of fishing on marine resources stem from the single-species approach to data analysis [11, 17, 18, 19]. The ecosystem-based approach to fisheries management is a concerted framework that addresses global fisheries depletion and loss of biodiversity [20, 21, 22]. This approach has gained recognition by many countries and has been the subject of discussion in several international fora such as the 13th International Council for the Exploration of the SEA [23] and the 2002 World Summit on Sustainable Development [24]. As evidence of its gaining popularity, a number of international organizations conceptualized their own definitions [23]. The central theme of the ecosystem-based approach is the incorporation of various aspects (biotic, abiotic and human components) that influence the health and integrity of a specified ecosystem. Works by Jennings [25], Garcia & Cochrane [26], Marasco *et al.* [23] and Leslie & McLeod [27] elaborately explain the scope of implementation, distinct characteristics, specific research needs, and the role of key facilitators such as scientists, policy makers, resource managers. These authors all stress, directly or indirectly, the need to develop a simple, easy to interpret tool that could fully illustrate the anthropogenic impacts and particularly those resulting from fishing activities to marine ecosystems towards better management goals.

Murawski [11] defined attributes of overfishing from an ecological perspective that form the foundation of ecosystem-based fisheries management. The four defining characteristics are: 1) reduction in biomass and production of important system components, 2) changes in diversity that relates to size and species selectivity, 3) year-to-year catch variability, and 4) socio-economic benefits. One key research challenge is illustrating dynamic trends of a fishery in an easy to comprehend format [13]. Using data from the BFAR NSAP from the Cuyo East Pass fishing grounds, the primary aim of this study was to analyze and illustrate changes in catch composition using an ordination method that is recognized for its strength in capturing relatively large datasets and representing it in a clear graphical form [27]. A secondary aim was to assess the species selectivity of commonly used gear in the fishing grounds, again using ordination as an assessment tool or model**.** Representations of vital facts, which can be obtained in ordination methods, are essential to assess and manage the fisheries harvest in an ecological perspective [13].

2. Materials and Methods

2.1 Study Area

Cuyo East Pass refers to the marine waters on the west- central region of the Philippines (Figure 1). It is bounded on the west by Panay Island (where the province of Antique is located) and on the east by group of small islands known as Cuyo archipelago. On a broader ecological scale, the Cuyo East Pass area is part of the Sulu-Sulawesi Marine Ecoregion, a tropical oceanic zone known for its rich biodiversity. A comprehensive biophysical assessment of this ecoregion contains vital information about Cuyo East Pass [28].

Typical of tropical regions, relative humidity is constantly high at 80%. Asian Monsoon governs the wind and rain pattern. Common weather disturbances consist of short-lived convective thunderstorms that are either due to the Intertropical Convergence Zone or easterly waves. Affecting most parts of the Philippines, tropical cyclones are the more serious weather disturbance and they commonly cancel most fishing operations because of their strong winds and rains. The climate in Cuyo East Pass is characterized by a distinct rainy season from June to October (mean monthly rainfall of greater than 400 mm) and a dry season from December to April. Sea surface temperature ranges from 26-29 ^{o}C and the average water salinity is 33.5 psu (practical salinity unit).

The Cuyo East Pass contributed an average of 3.12 % of Philippine fisheries production from 1977-1995. Highly migratory species are an important component of the catch because the area is a migratory path for tuna (Scombridae) and tuna-like (Xiphiidae and Istiophoridae) species [29]. Reef associated species caught in the coral reefs surrounding Cuyo Archipelago also represent a significant portion of the catch. These coral reef ecosystems are highly threatened by illegal fishing activities, particularly blast fishing [28]. The coral reef in the Cuyo East Pass area is classified in poor condition with only 0-25 percent coral cover [28].

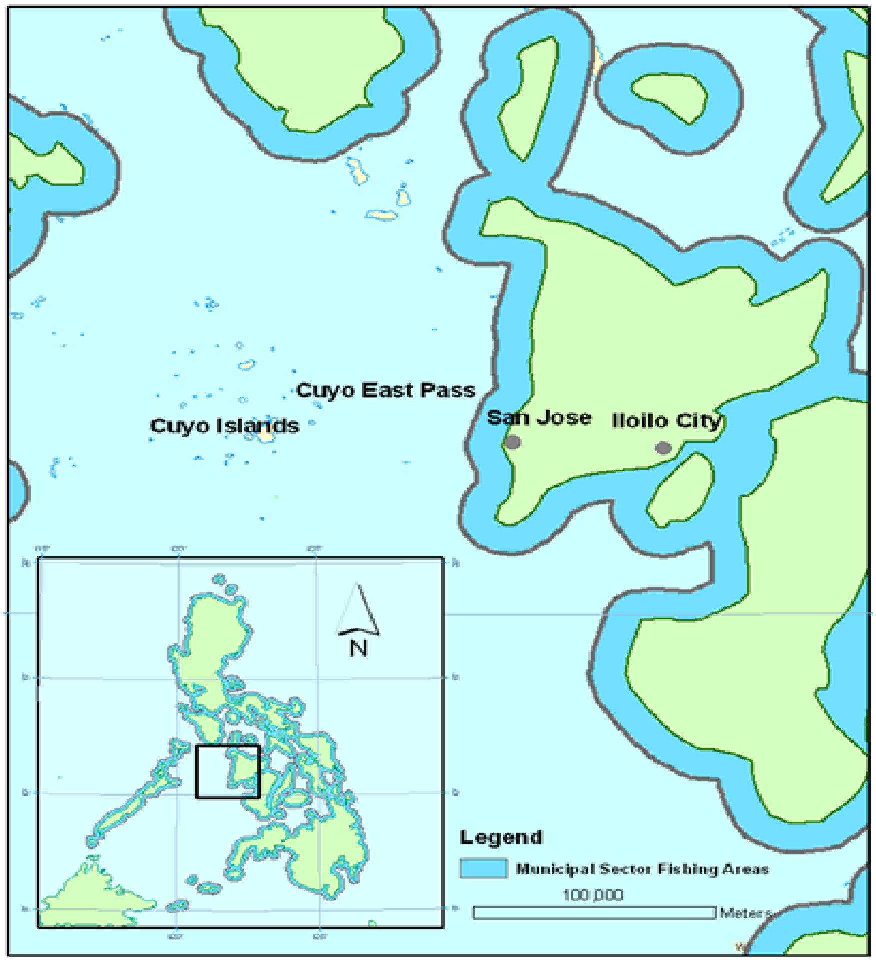


Fig 1: The Philippine Archipelago showing Cuyo East Pass Fishing Ground.

Cuyo East Pass is the major fishing ground of the Province of Antique and traverses the entire provincial coastline. The province has 19 municipalities and 15 of these have portions facing Cuyo East Pass. Each municipality has designated landing centers and municipal fishers usually bring their catch to the center located closest to their area of residence (BAS-Antique, unpublished data). Most commercial fishers in the province reside in the capital town of San Jose, based on the commercial fishing vessel inventory conducted by the BFAR Provincial Office in 2004.

2.2 Fishing Sectors

The Philippine capture fishery has two sectors, commercial and municipal, classified on the size or weight of the boat used and the location of the target fishing area. The municipal and commercial fishing sectors capture fish nearshore and offshore, respectively. The municipal sector is composed of fishers operating in the municipal waters with boats weighing less than 3 gross tons. The Philippine Fisheries Code defines municipal waters as the area up to 15 kilometers from the main shore, which is under the jurisdiction of the local government units for protection and management [30]. Registered municipal fishers have exclusive rights to fish within municipal waters. The commercial sector includes fishers operating beyond the 15-kilometer boundary of the municipal waters and up to the Philippine Exclusive Economic Zone (EEZ) with boats greater than 3 gross tons. By law, only licensed commercial fishing vessels have rights to fish in this relatively large body of water. Licensing of commercial fishing boats is implemented by BFAR, the main government agency responsible for the sustainable utilization of the fisheries resources in the country.

2.3 Data Collection

The NSAP data collection program provides monthly baseline information about landed catch quantity of each commercial species and fishing effort. Surveys are conducted at major fish landing sites where most of the yields are brought for market distribution. Commercially important species are segregated upon landing and the total weight is determined through container calibration.

Data collection and management of the landed catch from Cuyo East Pass was initiated in May 2000 by BFAR Region 6, which is based in Iloilo City (southern central part of Panay Island; Fig. 1). Two enumerators monitor the catch at three fish landing sites (Maybato North, San Angel, and Malaiba) in San Jose, Antique. To achieve data consistency and validity, sampling of the catch is conducted on specific dates of each month for both municipal and commercial sectors. Landed catch and corresponding effort for commercial and municipal sectors are alternately monitored 10 days of each month: commercial on the 1st, 4th, 7th, 10th, 13th, 16th, 19th, 22nd, 25th and 28th day, and municipal on the 2nd, 5th, 8th, 11th, 14th, 17th, 20th, 23rd, 26th, and 29th day. Gear type used is also recorded. Survey data are then consolidated and encoded into a spreadsheet file at the BFAR Regional Office in Iloilo City. NSAP personnel involved in the data collection process provided the data for this study.

2.4 Fishing Gears

Commercial fishers operating at Cuyo East Pass consistently use three gear types: handline (HL), multiple handline (MHL), and ring net (RN). Purse seine (PS) was only used in 2005 and 2006. The municipal sector uses HL and MHL gear types, and these gears can be used interchangeably depending on the size of target species fishers perceived to be abundant. HL commonly targets larger individuals because it uses larger hook size and thicker nylon line. Ring nets and purse seines are encircling gears that require more manpower to operate, thus their use is mainly commercial.

2.5 Statistical Analyses

Sampling data from June 2000 to December 2006 were used to examine the dynamics of the capture fisheries in Cuyo East Pass, including yearly trends (total landings, total amount of effort expressed by the recorded number of fishing days for HL and MHL or hours for PS and RN, and species richness). Multivariate techniques were used to determine gear selectivity and variation in species composition.

For the purpose of this study, a sample consisted of each combination of year, month, sector, and gear type. The recorded total sampling catch of all species (all fishing boats included) from the municipal sector using HL for the month (e.g. June 2000) corresponded to the aggregate catch for that sample. The relative abundance of each species caught in a sample was determined based on the summed total catch of all the species recorded within the ten-day sampling period. A summary of the relative abundances of each species in the entire sample (a total of 378 samples) was used as a set of response variables in subsequent multivariate analyses.

To predict species composition in a particular time period and the gear type used, dummy environmental variables were assigned as explanatory variables [31]. This included all the months, years, and gears that were represented in the sampling period. A value of 1 was assigned if the samples occurred in a category and zero if not. The summary of the assigned dummy value in each sample served as the set of explanatory variables.

Using Canoco for Windows (version 4.5) software, Detrended Correspondence Analysis (DCA) was performed to determine the distribution of each sample along two ordination axes. This process identified outliers, which were removed to focus on the remaining samples. The outliers were from gillnet and seine samples collected only in 2000, which obviously have distinct species catch composition. Canonical Correspondence Analysis (CCA) was performed on the remaining samples, originally with all the dummy environmental variables included. To improve interpretation, only gear type was illustrated in the resulting biplot because it was the only factor that contributed to the variability of species scores. Species were then classified according to their habitat type using the classify feature of Canoco to aid in visualizing which species were most closely associated with each gear type.

Samples by gear type were segregated to specifically evaluate the effect of gear on species composition. In each category, DCA was applied to identify the outliers. The DCA ordination scatter plot of samples for HL and MHL gears showed an observable separation of samples into two groups according to sector, which necessitated further segregation of the data into two sectors. This process created five groups of samples or data sets that included commercial HL, MHL, and RN, and municipal HL and MHL. DCA was performed on each group of data for the purpose of removing outliers. After removing the outliers, Partial Canonical Correspondence Analysis (pCCA) was used to determine the multi-year trend in each of the data sets. To show annual trends, year dummy variables served as environmental variables and month dummy variables as co-variables (year given month). The analysis consequently created an ordination biplot that illustrates the position and association of year and species scores along two ordination axes.

Variance partitioning analysis was conducted to examine the specific variances explained by each group of variables in each of the data sets. The total variance explained by all dummy environmental variables (years and months) was the sum of all canonical eigenvalues determined through canonical correspondence analysis. Another pCCA analysis was performed with the year dummy variables as covariables. The sum of all the canonical eigenvalues determined through pCCA is the percentage of variability specifically explained only by month and year dummy variables.

3. Results

3.1 General Trends

A total of 219 species from 47 families were represented in the total catch within the sampling period from June 2000 to December 2006. The majority of these species (61%) are classified as reef associated, 14% as small pelagic, 9% as demersal, 7% as migratory pelagic (tuna and tuna-like species), 5% as benthopelagic, and 4% as invertebrates.

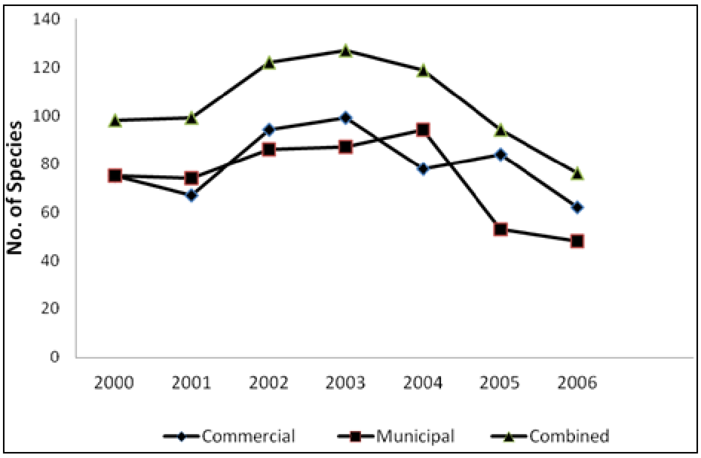


Fig 2: Trend of total species richness in each year of sampling for the commercial, municipal and combination of two sectors.

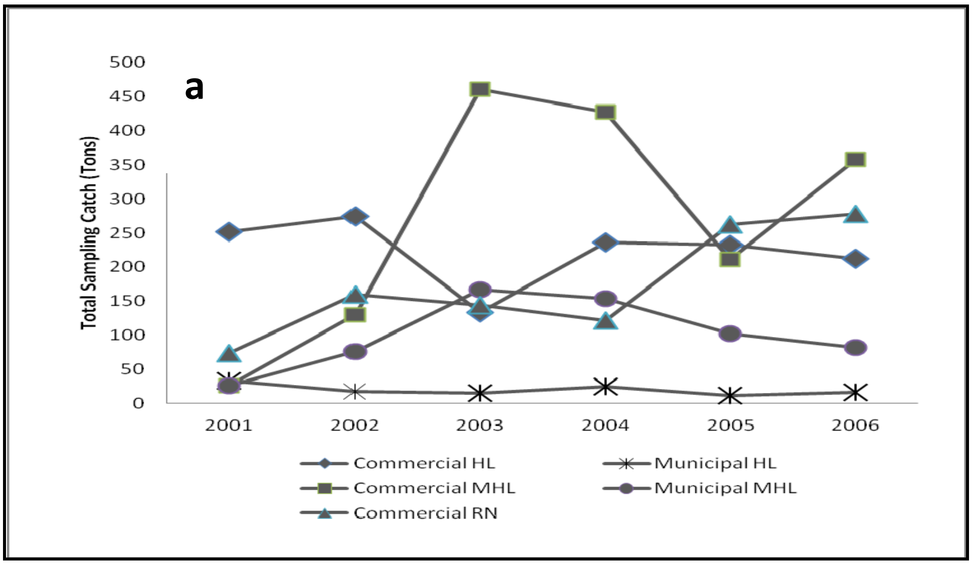
Even though only 7% of the fish caught were classified as migratory pelagic, the biomass of this category consistently formed the majority of the overall mass of the catch (Table 1). Migratory pelagic species often constituted more than 50% of the total catch that was present in almost all of the samples. Total species richness for the commercial, municipal and both sectors combined increased from 2000-2003 but decreased thereafter (Fig. 2). The lowest number of species was for the municipal sector in 2006.

Table 1: Consolidated total catch of 60 most abundant species from the Commercial and Municipal Sectors, Cuyo East Pass, Philippines.

Abbreviation	Genus	Species	Common Name	Habitat Classification	Total Catch in kilograms
Decamaca	*Decapterus*	*macarellus*	Mackerel scad	Small pelagic	93,654.50
Menemacu	*Mene*	*maculata*	Moonfish	Small pelagic	71,506.25
Decatabl	*Decapterus*	*tabl*	Roughear scad	Small pelagic	35,040.75
Decamacr	*Decapterus*	*macrosoma*	Shortfin scad	Small pelagic	33,652.50
Selacrum	*Selar*	*crumenophthalmus*	Bigeye scad	Small pelagic	20,930.50
Sardlong	*Sardinella*	*longiceps*	Indian oil sardine	Small pelagic	17,866.00
Decakurr	*Decapterus*	*kurroides*	Redtail scad	Small pelagic	10,031.50
Sardgibb	*Sardinella*	*gibbosa*	Goldstripe sardinella	Small pelagic	8,495.50
Stolpunc	*Encrasicholina*	*punctifer*	Buccaneer anchovy	Small pelagic	6,522.00
Rastkana	*Rastrelliger*	*kanagurta*	Indian mackerel	Small pelagic	6,282.75
Scomcomm	*Scomberomorous*	*commerson*	Narrow-barred spanish mackerel	Small pelagic	4,918.00
Sardfimb	*Sardinella*	*fimbriata*	Fringescale sardinella	Small pelagic	3,477.00
Stolindi	*Stolephorus*	*indicus*	Indian anchovy	Small pelagic	3,147.50
Sardsp.	*Sardinella*	*sp.*	Sardines	Small pelagic	3,132.50
Sardorie	*Sarda*	*orientalis*	Striped bonito	Small pelagic	1,763.50
Prisseib	*Pristipomoides*	*sieboldii*	Lavender jobfish	Benthopelagic	2,524.00
Nemibath	*Nemipterus*	*bathybius*	Yellowbelly threadfin bream	Demersal	99,118.75
Nemivirg	*Nemipterus*	*virgatus*	Golden threadfin bream	Demersal	51,553.25
Nemihexo	*Nemipterus*	*hexodon*	Ornate threadfin bream	Demersal	31,931.70
PriSmult	*Pristipomoides*	*multidens*	Goldbanded jobfish	Demersal	7,316.50
Securuco	*Secutor*	*ruconius*	Deep pugnose ponyfish	Demersal	2,450.00
Paraerio	*Parascolopsis*	*erioma*	Rosy dwarf monocle bream	Demersal	1,601.75
ThunAlba	*Thunnus*	*albacares*	Yellowfin tuna	Pelagic migratory	1,627,397.95
Auxiroch	*Auxis*	*rochei rochei*	Frigate tuna	Pelagic migratory	1,352,166.25

Katspela	*Katsuwonus*	*pelamis*	Skipjack tuna	Pelagic migratory	746,064.75
Auxithaz	*Auxis*	*thazard thazard*	Bullet tuna	Pelagic migratory	317,053.25
Coryhipp	*Coryphaena*	*hippurus*	Common dolphinfish	Pelagic migratory	86,812.50
Thunobes	*Thunnus*	*obesus*	Bigeye tuna	Pelagic migratory	46,925.00
Xiphglad	*Xiphias*	*gladius*	Swordfish	Pelagic migratory	18,334.25
EuthAffi	*Euthynnus*	*affinis*	Kawakawa	Pelagic migratory	14,626.00
Acansola	*Acanthocybium*	*solandri*	Wahoo	Pelagic migratory	9,138.75
Makamaza	*Makaira*	*mazara*	Indo-pacific blue marlin	Pelagic migratory	4,421.00
Istiplat	*Istiophorus*	*platypterus*	Indopacific sailfish	Pelagic migratory	3,082.75
Elagbipi	*Elagatis*	*bipinnulata*	Rainbow runner	Reef associated	30,313.50
Aprivire	*Aprion*	*virescens*	Green jobfish	Reef associated	18,881.00
Saurundo	*Saurida*	*undosquamis*	Brushtooth lizardfish	Reef associated	6,517.00
Lutjboha	*Lutjanus*	*bohar*	Two-spot red snapper	Reef associated	5,652.60
Gymnunic	*Gymnosarda*	*unicolor*	Dogtooth tuna	Reef associated	5,349.75
Caratill	*Caranx*	*tille*	Tille trevally	Reef associated	4,669.00
Lethmini	*Lethrinus*	*miniatus*	Trumpet emperor	Reef associated	4,398.25
Apharuti	*Aphareus*	*rutilans*	Rusty jobfish	Reef associated	4,389.75
Etelcarb	*Etelis*	*carbunculus*	Ruby snapper	Reef associated	4,260.05
Selaboop	*Selar*	*boops*	Oxeye scad	Reef associated	3,917.00
Priataye	*Priacanthus*	*tayenus*	Purple-spotted bigeye	Reef associated	3,713.25
Lutjseba	*Lutjanus*	*sebae*	Emperor red snapper	Reef associated	3,338.25
Serilala	*Seriola*	*lalandi*	Yellowtail amberjack	Reef associated	3,295.00
Lethelon	*Lethrinus*	*microdon*	Smalltooth emperor	Reef associated	3,078.50
Caraigno	*Caranx*	*ignobilis*	Giant trevally	Reef associated	2,999.20
Caramela	*Caranx*	*melamphygus*	Bluefin trevally	Reef associated	2,830.25
Sufffrae	*Suffalamen*	*fraenatum*	Masked triggerfish	Reef associated	2,710.25
Carcsp.	*Carcharhinus*	*sp.*		Reef associated	2,564.00
Epinaero	*Epinephelus*	*aerolatus*	Areolate grouper	Reef associated	1,829.75
Sphybarr	*Sphyraena*	*barracuda*	Great barracuda	Reef associated	1,790.00
Epinambl	*Epinephelus*	*amblycephalus*	Banded grouper	Reef associated	1,583.00
Carasexf	*Caranx*	*sexfasciatus*	Bigeye trevally	Reef associated	1,441.00
Cephmini	*Cephalopholis*	*mMiniata*	Coral hind	Reef associated	1,123.55
Saurtumb	*Saurida*	*tumbil*	Greater lizardfish	Reef associated	1,102.75
Lutjvitt	*Lutjanus*	*vita*	Brownstripe red snapper	Reef associated	1,060.25

Gnatspec	*Gnathanodon*	*speciosus*	Golden trevally	Reef associated	1,043.00
Notophil	*Nototodarus*	*philippinensis*	Philippine flying squid	Demersal	4, 938.50



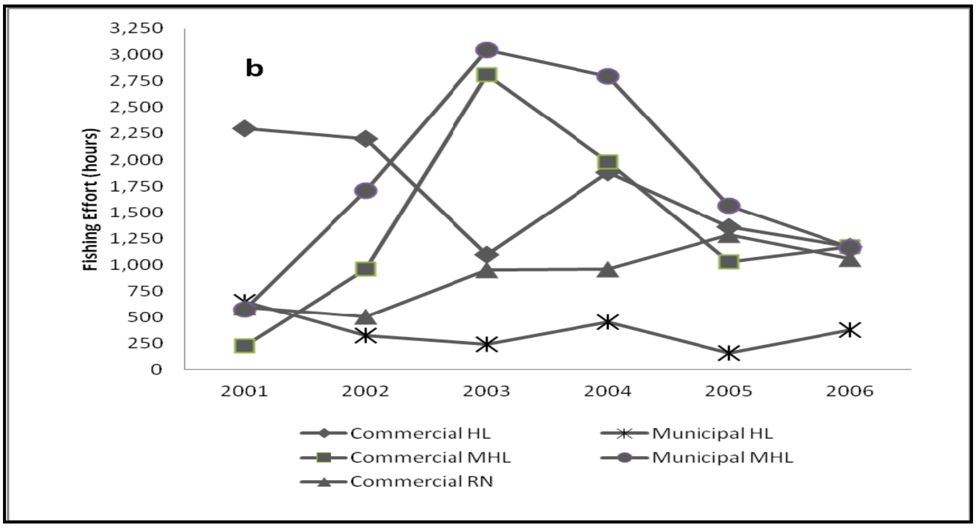


Fig 3: Trend of a) total yearly catch and b) total fishing effort (days for HL and MHL and hours for RN) on each year of sampling period for each sector gear combination.

The annual total catch and effort from landings for each sector-gear combination exhibited a similar trend except for RN (Fig. 3). For HL and MHL in both sectors, catch and effort correspondingly increased or decreased within a certain time period. In contrast, the RN pattern indicated a variable catch-effort relationship. From 2001 to 2002, catch increased even though effort decreased. The trend was reversed from 2002 to 2004 when effort increased but catch declined. From 2004 to 2005, both catch and effort increased but in the succeeding year (2006), catch continued to increase even though effort decreased. Furthermore, a shift between HL and MHL was observed for both sectors. When catch and effort for HL decreased, MHL increased correspondingly except in 2005 when catch and effort for each gear declined. HL was the predominant gear type used from 2000-2002 but the use of MHL increased dramatically in 2003 for both sectors.

3.2 Gear Selectivity

The most abundant species in the landings were segregated primarily by gear type (Fig. 4). Small pelagic species were predominantly caught by RN (*Selar crumenophthalmus*, *Encrasicholina punctifer*, *Sardinella gibbosa*, *Mene maculata*, *Decapterus macarellus*, *D. macrosoma*, *D. tabl*, and *D. kurroides*). Demersal species were mostly represented in the catch of MHL with three threadfin bream species as the most abundant (*Nemipterus virgatus*, *N. hexodon* and *N. bathybius*). Reef-associated species were well represented in the catch of each gear but the most abundant ones were mostly caught by HL (*Lutjanus sebae*, *L. bohar*, *Pristipomoides multidens*, *P. sieboldii*, *Lethrinus microdon*, *Aphareus rutilans*, *Aprion* *virescens).* Although migratory pelagic species were caught by all gear types, HL was the most successful method. Exceptions to this were the three tuna species (*Auxis thazard thazard, A. rochei rochei,* and *Euthynnus affinis*), which are clustered at the center of the plot (Fig. 4). The two encircling gears, RN and PS, were more similar in species composition than any other gear types.

3.3 Trends in Species Abundance

Catch composition for abundant species segregated by sector gear exhibited annual variability. More than 50% of the variance in the species-environment correlation was captured in the first pCCA axis for Commercial HL, Municipal MHL, and Commercial MHL (Table 2). The percent variability captured by canonical component 2 ranged from 18-25%. Variance partitioning analysis for years and months revealed

that total variance explained ranged from 29.7% (Municipal HL) to 40.7% (Municipal MHL) (Table 3). A greater percentage of the variance was attributed to the year effect (years as the environmental variables and months as co-variables) for the MHL gear of both sectors. Almost 60% of the explained variance was accounted for by the year effect for the commercial MHL. In contrast, the month effect was slightly higher for the HL and RN gears.

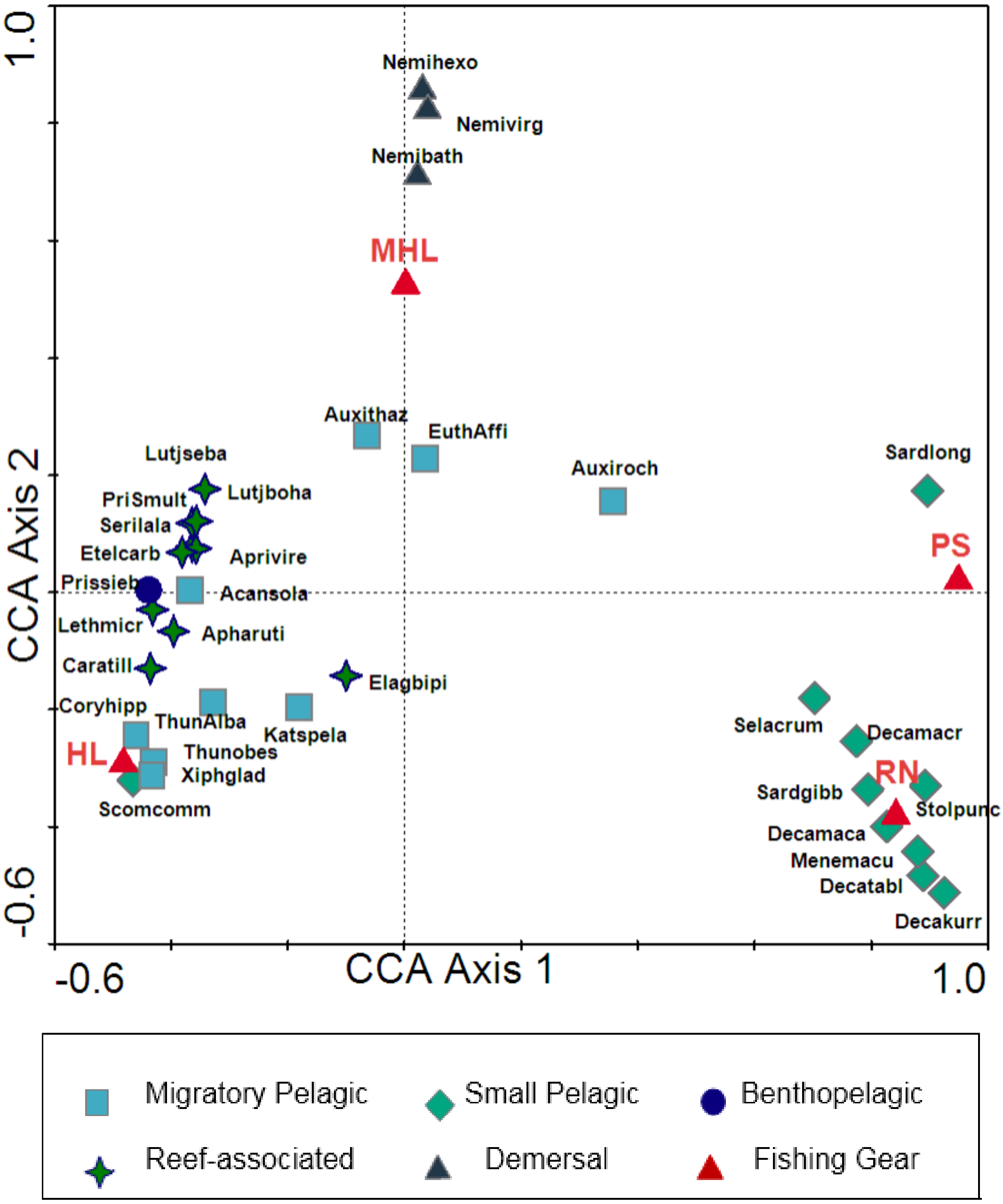


Fig 4: Canonical Correspondence Analysis (CCA) ordination biplot representing gear selectivity for the most abundant species. HL = handline, MHL = multiple handline, PS = purse seine, RN = ring net. Only species points whose species weight range is between 1 to 100% (highest weight is set to 100%) were included. Red triangles indicate gear (environmental) scores.

The pCCA ordination biplot for the commercial sector using HL shows the 58 most abundant species that were caught (Fig. 5). Annual variation in species composition was clearly illustrated by the wide separation of years along the two axes. Noteworthy is the location of frigate tuna (*A. thazard thazard*) on the biplot between 2001 and 2002 variable scores (Fig. 5).

This was one of the most abundant species caught in 2001, but it declined sharply after 2002 with few captures in subsequent years (Fig. 6). Another of the most abundantly caught species was the bigeye tuna (*Thunnus obesus*) occurred only between 2005 and 2006. Yellow fin tuna (*Thunnus albacares*) and skipjack tuna (*Katsuwonus pelamis*) consistently comprised a major portion of the catch throughout the six years (Fig. 6). Other migratory pelagic species that were a major component of the HL harvest were common dolphinfish (*Coryphaena hipporus*), rainbow runner (*Elagatis bipinnulata*), and swordfish (*Xiphias gladius*). Annual variation in species composition was less pronounced for the municipal sector using HL due to a strong correlation among years (Fig. 7). The ordination biplot illustrates the high correlation in catch composition between 2005 and 2006 and also among 2000, 2001, and 2003. The 2002 PCA score was widely separated from the other years because of the uniquely large catch of sea chub (*Kyphosus sp*), which was 233 kilos in August. Frigate tuna was only evident in the early part of the sampling and completely disappeared after 2002. Wahoo (*Acanthocybium solandri*) was located close to 2001 and 2003 because a substantial catch was noted during these years (Fig. 6).

Table 2: Cumulative percent variances of species data and species-environmental (year) data explained by pCCA axes with months as co-variables for capture fisheries of Cuyo East Pass, Philippines.

Gear and data type	Axis 1	Axis 2	Axis 3	Axis 4
Municipal Handline (HL)				
Species Data	5.8	10	12.5	14.1
Species-Environment Data	35.3	60.5	75.3	85.1
Commercial Handline (HL)				
Species Data	9.6	12.9	15.2	16.7
Species Environment Data	53.9	72.7	85.7	93.8
Municipal Multiple Handline (MHL)				
Species Data	14.1	19.6	23.0	24.5
Species-Environment Data	53.1	74.0	86.8	92.6
Commercial Multiple Handline (MHL)				
Species Data	15.8	20.5	23.3	24.5
Species-Environment Data	61.2	79.4	90.5	94.9
Commercial Ringnet (RN)				
Species Data	6.0	10.0	13.7	15.5
Species-Environment Data	33.9	56.2	77.0	87.3

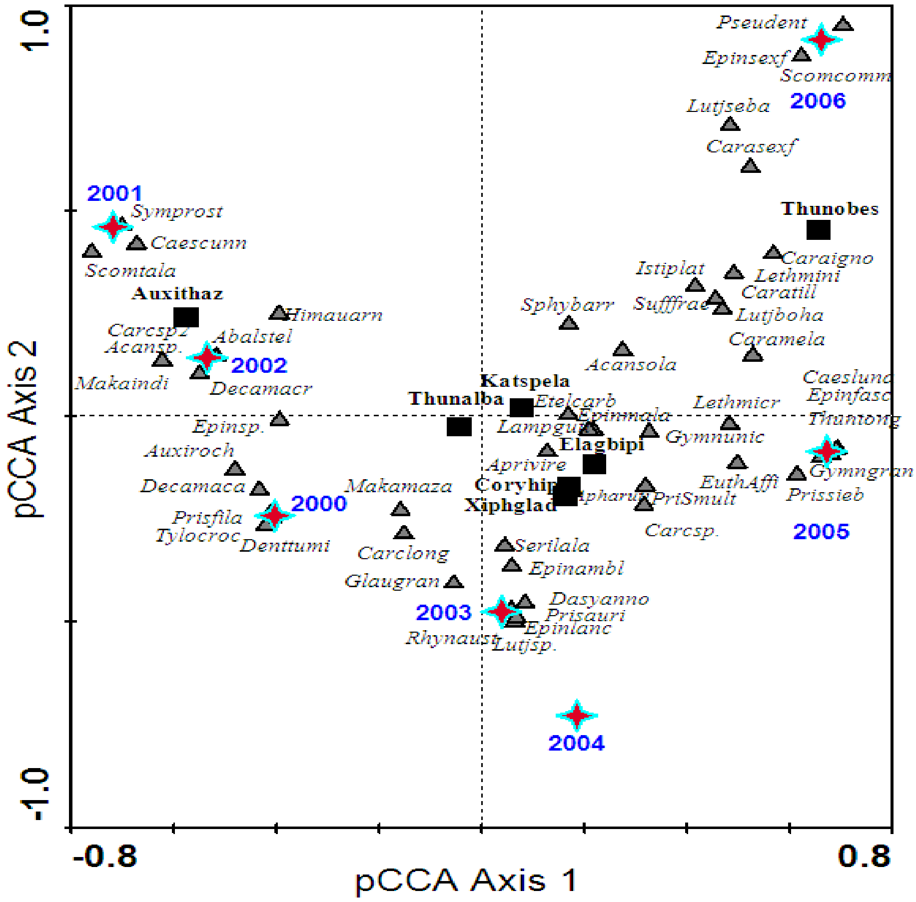


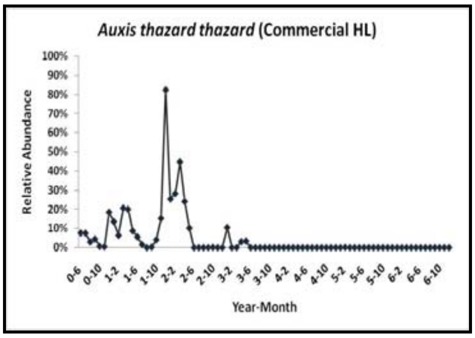
Fig 5: Partial Canonical Correspondence Analysis (pCCA) biplot for the most abundant species caught by the commercial sector using HL. Species points whose species weight range is between 1 to 100% (highest weight is set to 100%) were marked by black squares.

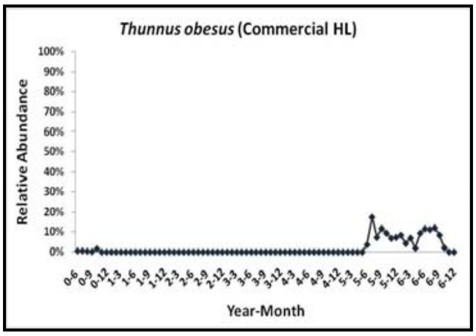
Table 3: Results of the variance partitioning analysis to examine the variances explained by for capture fisheries of Cuyo East Pass, Philippines. Dummy variables are years and months for each fishery.

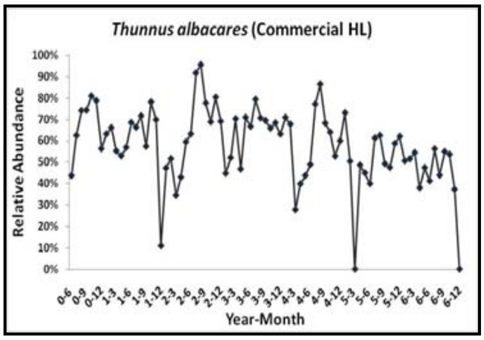
	Municipal MHL	**Commercial MHL**	**Municipal HL**	**Commercial HL**	**Ringnet RN**
Total Inertia	4.079	3.339	6.509	1.625	6.005
Year union Month (CCA)					
Sum of all canonical eigenvalues	1.660	1.216	1.935	0.512	1.927
Percent of Explained Variance	40.7%	36.4%	29.7%	31.5%	32.1
Year union Month (pCCA)					
Sum of all canonical eigenvalues	0.873	0.736	0.907	0.240	0.889
Percent of Explained Variance	21.4%	22.0%	13.9%	14.8%	14.8%
Month union Year (pCCA)					
Sum of all canonical eigenvalues	0.773	0.448	1.023	0.267	1.019
Percent of Explained Variance	19.0%	13.4%	15.7%	16.4%	17%

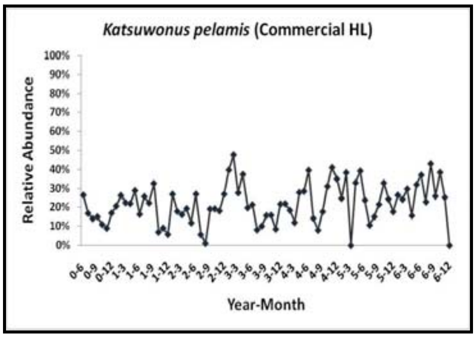
The ordination biplot for the commercial sector using MHL showed that years from 2003 to 2006 were highly correlated in terms of their catch composition while years from 2000 to 2002 varied significantly (Fig. 8). This was mainly because predator migratory pelagic species (e.g. *T. albacares*, *Katsuwonus pelamis*, *A. rochei rochei*) were consistently the majority of the catch during 2003-2006 (Fig. 6). Two demersal species (*Nemipterus bathybius*, *N. hexodon*) were predominantly caught in 2001 and 2002 but have not appeared in the catch after that period (Figs. 6 & 8). Frigate tuna also constituted most of the catch during this period, but its contribution to the total catch was minimal in the succeeding years (Fig. 6).

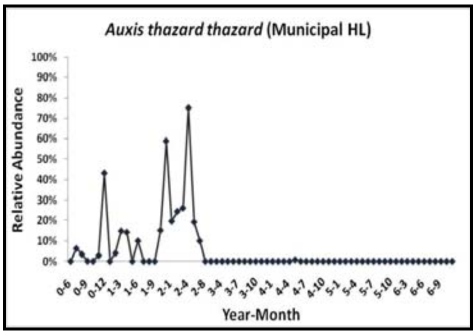
Distinct annual patterns were observed in the ordination biplot of the municipal sector using MHL (Fig 9), mirroring the pattern for the commercial HL sector (Fig. 5). An exception to this was the high correlation between the 2003 and 2004 catch (Fig. 9). Other years were segregated along the two axes.

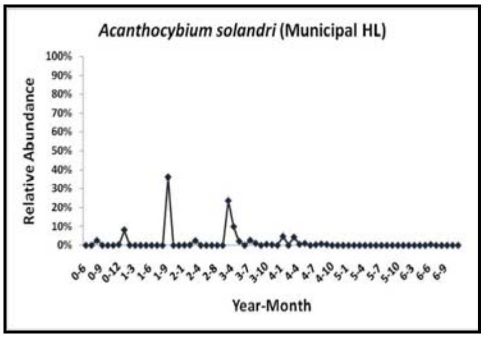


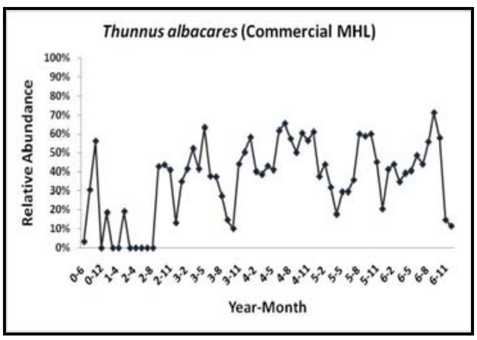


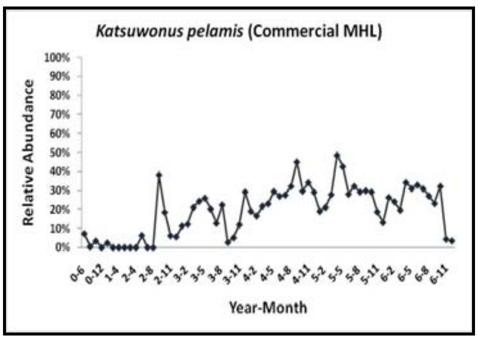


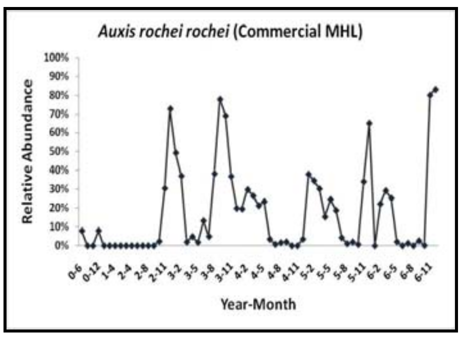












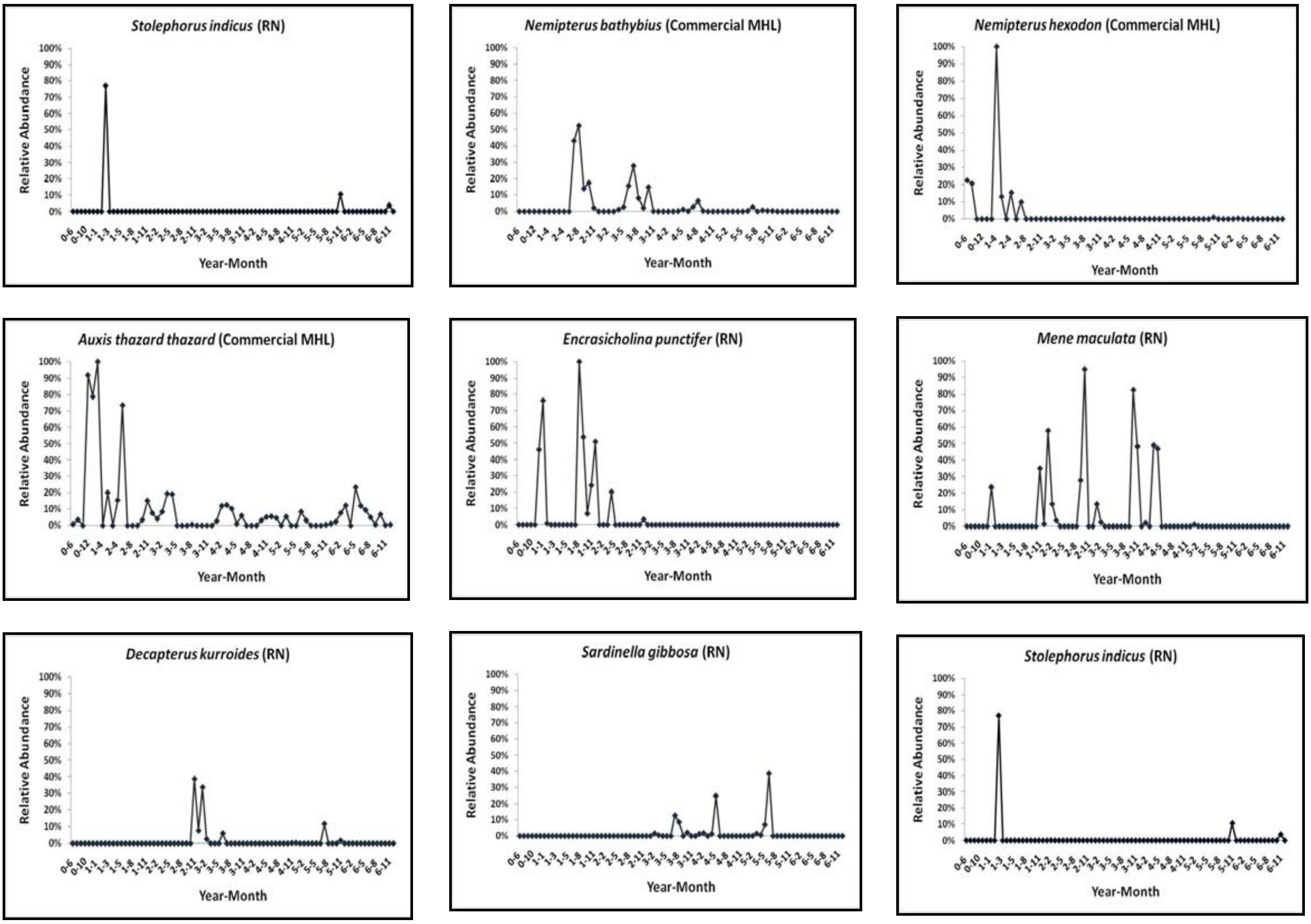


Fig 6: Relative abundance of 9 species caught by different gears from the commercial and municipal sectors in Cuyo East Pass, Philippines.

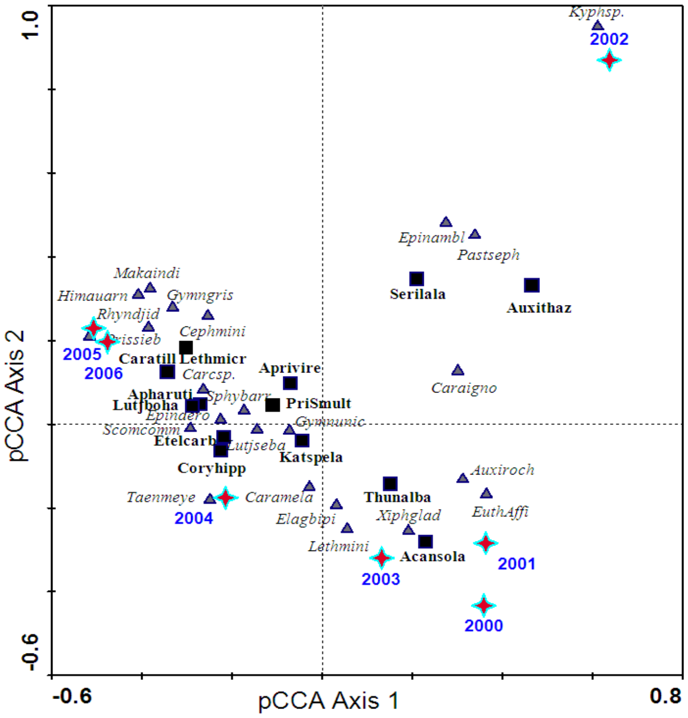


Fig 7: Partial Canonical Correspondence Analysis (pCCA) biplot for the most abundant species caught by the Municipal Sector using HL. Species points whose species weight range is between 1 to 100% (highest weight is set to 100%) were marked by black squares.

Small pelagic species were the main catch of RN, but the ordination biplot showed that different species became a significant portion of the total catch from year to year (Fig. 10). Engraulids (e.g. *Encrasicholina punctifer*, *Stolephorus indicus*) were only abundant in 2001. Relatively high value small pelagic species such as moonfish (*M. maculata*), redtail scad (*D. kurroides*), Indian mackerel (*Rastrelliger kanagurta*), and frigate tuna were highly correlated with 2003 and 2004 indicating that they were abundantly caught during these periods, but except for Indian mackerel, they completely disappeared after that period (Fig. 6). The 2005 and 2006 catch was highly correlated. During that period, sardines and other engraulid species (*Sardinella longiceps, S. gibbossa, Stolephorus indicus*) were abundant.

4. Discussion

The analytical approach used in this study captured the short-term changes of the capture fisheries at Cuyo East Pass and maximized the use of time series information. From the fisheries-dependent data, which is the only information about fisheries resources in developing countries such as the Philippines [32], the multivariate technique used provided a holistic representation of the fishing situation in Cuyo East Pass and its corresponding implications for the marine ecosystem. Elucidating such vital facts [33] fits well within the context of the ecosystem approach to fisheries (EAF) management. Methratta & Link [34], Mace [35] and Cury [36] emphasized the necessity of developing an extensive tool to evaluate large marine ecosystems as a primary step toward the implementation of this contemporary resource management approach.

The analysis used in this study clearly demonstrated that two of the four defining characteristics of ecosystem overfishing [11] have occurred in Cuyo East Pass: 1) variability in catch related to species composition that could translate to biomass reduction, and 2) a decline in catch diversity. Ecosystem overfishing, characterized as ecological imbalance caused by excessive removal of target species [2], is a serious threat to resource sustainability [37].

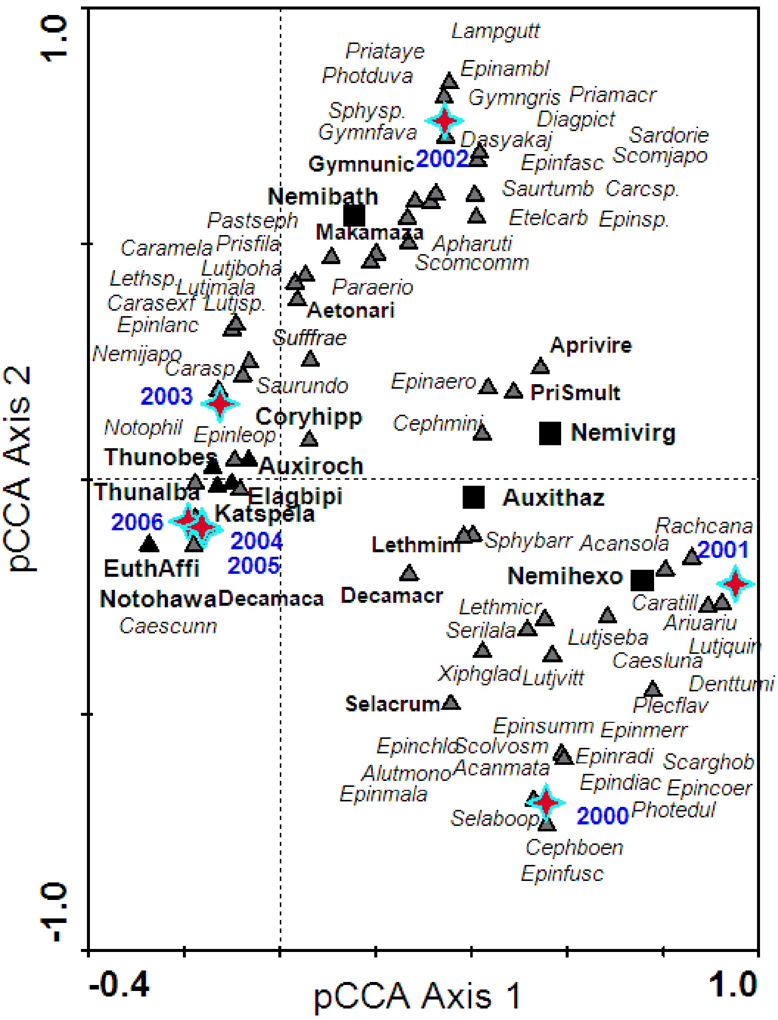


Fig 8: Partial Canonical Correspondence Analysis (pCCA) biplot for the most abundant species caught by the commercial sector using MHL. Species points whose species weight range is between 1 to 100% (highest weight is set to 100%) were marked by black squares.

The varying trends in species catch linked to ecosystem overfishing [11, 38] have been clearly observed in the Cuyo East Pass fisheries with the use of ordination techniques. The resulting ordination biplots, in particular, were useful visual guides to further investigate species that were no longer being caught and the species that replaced them. Using this approach, it was possible to pinpoint the decline in catch of commercially valuable species and the resulting shift to capture of other available species. Scheffer, Carpenter & de Young [39] warn that not only are target species in severe danger of significant decline, but this shift also disrupts interactions of all organisms in an ecosystem. The decline of demersal species such as threadfin bream species and reef associated species in the catch of the commercial sector MHL gear, for instance, has resulted in increased fishing pressure of large pelagic migratory tuna species. Another compelling example of this condition is the removal of bullet tuna (*Auxis rochei rochei*) using RN in 2006, which was the highest quantity of landed catch in the entire sampling period (NSAP unpublished catch monitoring data) after once abundant pelagic species such as moonfish, buccaneer anchovy (*Encrasicholina punctifer*) and redtail scad were no longer represented in the catch (Fig. 6). A very similar shift in target species has also occurred in the still thriving artisanal fisheries in Eritrea [32].

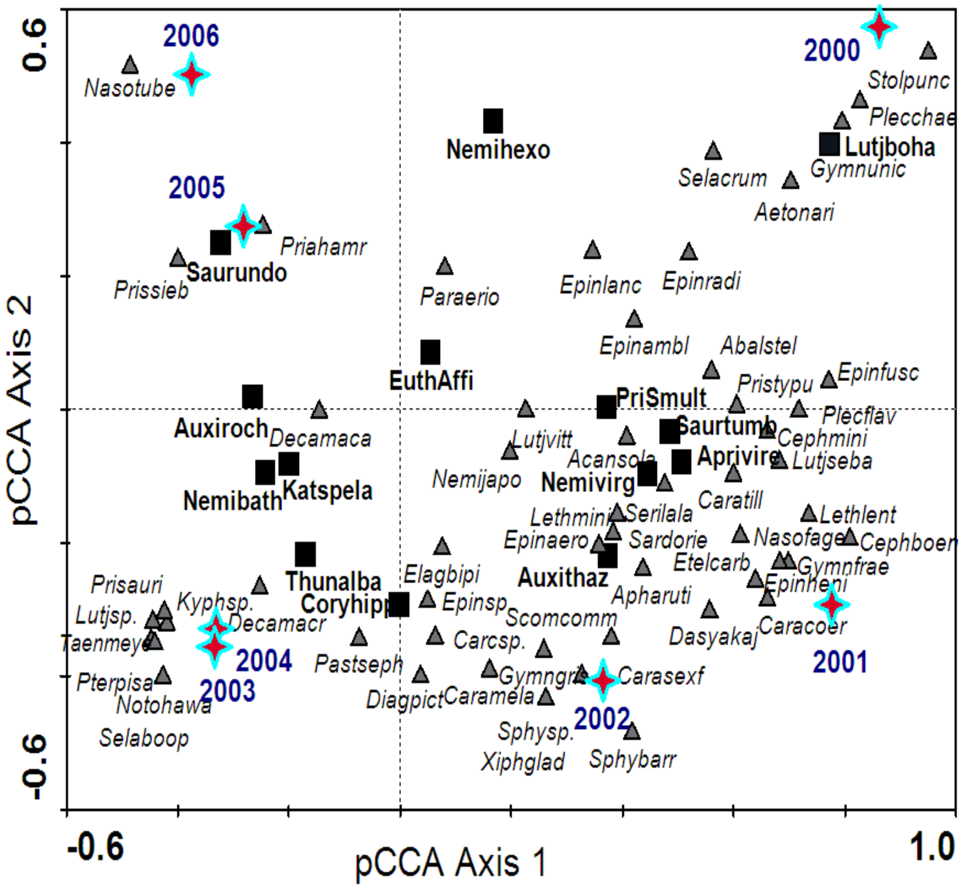


Fig 9: Partial Canonical Correspondence Analysis (pCCA) biplot for the most abundant species caught by the municipal sector using MHL. Species points whose species weight range is between 1 to 100% (highest weight is set to 100%) were marked by black squares.

The shift in target species could suggest that a substantial amount of effort was expended in capturing higher value than lower value small pelagic species using RN. Because of the abundance of engraulids in 2001, a comparatively higher CPUE (increasing catch with decreasing effort) occurred. When higher value small pelagic species such as moonfish, redtail scad, frigate tuna, and Indian mackerel became the target of the catch in 2003-2004, CPUE declined (decreasing catch with increasing effort), which led to their eventual disappearance. Catch per unit effort increased again when fishers targeted sardines (*Sardinella longiceps* and *Sardinella gibbosa*) and frigate tuna in 2005-2006. A similar situation happened in the Gulf of Thailand demersal fisheries in the 1960s when a significant increase in squid and cuttlefish in the catch have been observed after the noted catch decline of its competitors and predators [11]. Lotze [40] stressed that resource depletion compels fishers to shift to less desirable species as a management strategy.

The decline in the diversity of the Cuyo East Pass catch provides another example of ecosystem overfishing [11]. This decline is attributed to the absence of several reef associated species in the latter years of the study, which was particularly indicated in the commercial MHL catch. Furthermore, investigating the catch trend of the commercial sector using MHL emphasized that fishing pressure for pelagic species has intensified since 2003. Thus, there is an apparent shift in species targeting and an increase in fishing pressure to migratory pelagic species towards the latter years of the survey. Correspondingly, fishers in Cuyo East Pass could have also shifted fishing location, as indicated by the shift in catch composition from shallow portions of the fishing ground where reef associated species abound to deeper areas where migratory pelagic species are present. A shift in species targeting is due to either diminishing abundance of previously targeted species or other species have become more abundant [11].

This study identified species selectivity by gear type, including the subsequent finding that three migratory pelagic species were caught by all types of gears (overlap in gear selectivity). Mclanahan & Mangi [15] assessed selectivity of fishing gears in Kenyan artisanal fisheries, noting that this is highly integral information for fisheries resource management. Facts about the kind of species caught by each type of gear could lead to appropriate measures to manage the catch of certain species that are found to be overly depleted. In particular, frigate tuna were found to be severely depleted probably because they were a major component of the catch of all gear types from 2000-2002. A further point is that aside from small-pelagic fish, tuna species also constitute a significant proportion of RN catch, which poses a serious threat to the sustainability of this fishery. With an encircling gear, juveniles and smaller individuals are not spared from being trapped and could be the main constituent of the catch [41].

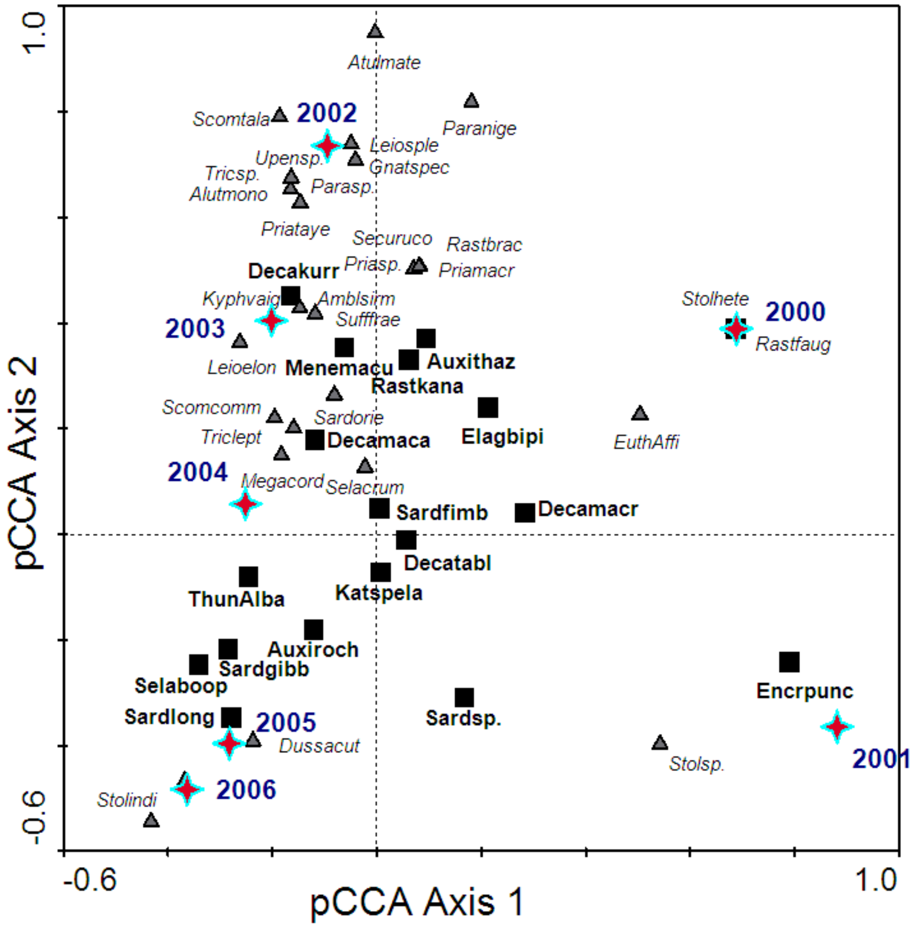


Fig 10: Partial Canonical Correspondence Analysis (pCCA) biplot for the most abundant species caught by the commercial sector using RN. Species points whose species weight range is between 1 to 100% (highest weight is set to 100%) were marked by black squares.

5. Conclusion

The varying trends documented in this study, particularly the succession of species in the catch, would have been difficult to assess with a more traditional approach to data presentation and analysis, such as what is currently in use in the Philippines. Although it may seem obvious that small pelagic species are commonly caught only by ringnets and demersal species by multiple handlines, for instance, illustrating gear selectivity provides further evidence to the specific trend of each species by sector and gear combination. In the case of commercial MHL, in particular, continually steady or increasingly abundant catch of tuna species may tend to mask the significance of the drastic decline of lesser abundant species such as threadfin breams (Figs. 6 & 8). This pattern is similar to what occurred in the Gulf of Thailand Fisheries in the 1990s [11]. Not having adequate information to document this effect, one could conclude that there is nothing wrong because the aggregate catch continued to increase, only to realize later that the entire ecosystem may have been impacted by overfishing, such as observed by [42].

Using a multivariate approach to analyze data facilitated the evaluation fisheries trends in Cuyo East Pass. These trends fit well within the context of ecosystem approach to fisheries management. Therefore, fisheries managers might consider this approach to analyze other data sets gathered by NSAP from other fishing grounds in the Philippines.

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