Available online at www.sciencedirect.com
SCIENCE DIRECT®
Fisheries Research 74 (2005) 223–231
FISHERIES RESEARCH
www.elsevier.com/locate/fishres

The mean trophic level of Uruguayan landings during the period 1990–2001

Andrés C. Milessi [a,*], Hugo Arancibia [c], Sergio Neira [d], Omar Defeo [b,e]

[a] Programa de Doctorado en Oceanografía, University of Concepción, P.O. Box 160-C, Concepción, Chile
[b] DINARA, Dirección Nacional de Recursos Acuáticos, Constituyente 1497, CP 11200 Montevideo, Uruguay
[c] Department of Oceanography, University of Concepción, P.O. Box 160-C, Concepción, Chile
[d] Zoology Department, University of Cape Town, Rondebosch 7701, Cape Town, South Africa
[e] Centro de Investigación y de Estudios Avanzados del IPN, AP 73 Cordemex, 97310 Mérida, Yucatán, Mexico

Received 24 August 2004; received in revised form 28 January 2005; accepted 2 February 2005

Abstract

The worldwide increasing trend in fishing catches together with the impact of fishing on ecosystems and inefficient fishery management have led to overfishing and frequent collapse of traditional fish stocks. In this context, the assessment of fishery-induced impacts and the implementation of ecosystem-based fisheries management programs are urgently required. In this study, the mean trophic level (TLm) and the fishing-in-balance (FIB)-index of Uruguayan landings during 1990 and 2001 were estimated using the trophic level of 60 fishery resources.

A decline in total landings (*Y*) is observed, which is explained by the lower fishing yield in major fishery resources (especially demersal). Moreover, a marked decreasing trend in TLm at a rate of approximately 0.28 trophic levels per decade, and a decreasing trend in FIB-index since 1997 were observed. The present situation of fishery resources in Uruguay (fully exploited or overexploited) and the drop in Y, FIB and TLm can be considered as indirect indicators of the fishing impacts on the trophic structure of Uruguayan marine communities. We suggest that a more holistic ecosystem-based fisheries management could help to alleviate the critical situation of fish stocks in Uruguayan waters.

Keywords: Ecosystem management; Trophic structure; Fisheries; Overfishing; Uruguay

1. Introduction

The increasing trend in world catches (FAO, 2002), the fisheries impact on ecosystems (Goñi, 1998; Hall, 1999; Hollingworth, 2000; Pauly, 2003), the failure in traditional stock assessment and management and the economic subsidies of fisheries (Pauly et al., 2002) lead to overfishing of marine resources, and, in some cases,

* Corresponding author. Present address: Department of Oceanography, University of Concepción, P.O. Box 160-C, Concepción, Chile. Tel.: +56 41 204239; fax: +56 41 256571/225400.
E-mail address: amilessi@udec.cl (A.C. Milessi).

0165-7836/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.fishres.2005.02.002

to stock collapse (Botsford et al., 1997). In addition, Pauly et al. (2003) predict further decreasing trends in world catches and vast effects on marine biodiversity. In this context, an ecosystem-based approach has been suggested as a complement to the traditional fisheries stock assessment and management (Christensen et al., 1996; NRC, 1998; ICES, 2000; FAO, 2001; Sinclair et al., 2002; Pauly et al., 2003; Pikitch et al., 2004). Consequently, ecosystem indicators (EIs; Rochet and Trenkel, 2003; Trenkel and Rochet, 2003) and ecosystem models have been developed to assess the impact of fishing (Hollowed et al., 2000; Shannon et al., 2000).

The mean trophic level (TLm) of landings of a particular area has been proposed as an indicator of fishery-induced impacts at the food web level (Pauly et al., 1998, 2001, 2002; Rochet and Trenkel, 2003). Over last 45 years, TLm has showed a clear decreasing trend at a rate of 0.10 per decade. This process is called "fishing down marine food webs" (FDMFW *sensu* Pauly et al., 1998). Although TLm is sensitive to economic and technological factors (Caddy et al., 1998), several studies have confirmed this trend at regional and local scales (Stergiou and Koulouris, 2000; Pauly et al., 2001; Pinnegar et al., 2003; Arancibia and Neira, in press; Sala et al., 2004).

Uruguayan waters within the Argentine–Uruguayan Common Fishing Zone (AUCFZ) have displayed a long-term decreasing trend in catches and fishing yield of the main fishery resources, especially those of traditional target species (e.g. *Merluccius hubbsi*: DINARA, 2001). As a result, the fishing effort has been re-directed to new fisheries resources and previously incidental or by-catch species (Defeo et al., 1994; Gutiérrez and Defeo, 2003), which, in turn, are also susceptible to over-exploitation (Milessi and Defeo, 2002). However, the impact of fishing in Uruguayan waters remains unclear or poorly understood. In this paper we test whether the TLm of Uruguayan landings declines with time or not.

2. Materials and methods

We used landings and trophic levels of the main 60 species (from a total of 95) captured in Uruguayan

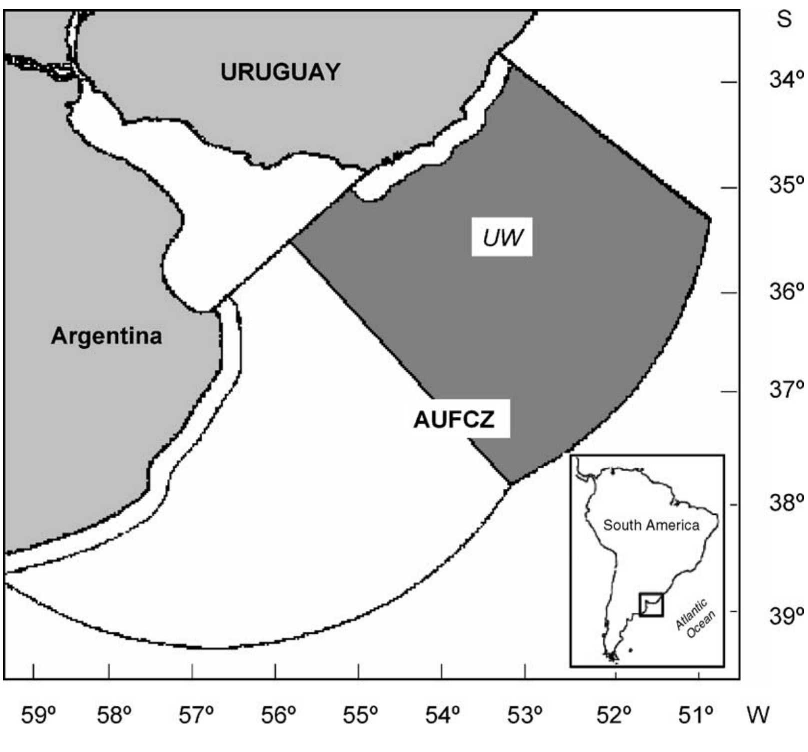

Fig. 1. Study area corresponding to Uruguayan waters (UW) of Argentinean–Uruguayan common fishing zone (AUCFZ).

waters of AUCFZ (Fig. 1) to calculate de TLm of landings. Species were selected considering that they comprise 85–98% of the total landings, and the information on trophic level and/or diet composition was fully available. Landing statistics were obtained from the Annual Statistical Yearbook of the National Fisheries Institute (DINARA, 2001).

The trophic level of the 60 selected species (TL_i) was obtained from feeding studies and information from FishBase, which provides TL estimates from food items for many fish species (Froese and Pauly, 2000) (Table 1). Species such as krill (*Euphausia* spp.) and Patagonian toothfish (*Dissostichus eleginoides*) were not considered in this analysis, since most of their catches occur outside the AUCFZ (DINARA, 2001). Freshwater fish species (e.g. catfish *Pimelodus* spp., characin *Leporinus obtusidens*) and cultured fish species (e.g. Siberian sturgeon *Acipenser baeri*, common carp *Cyprinus carpio*) were not included in this analysis because they inhabit inland ecosystems and/or they are artificially fed. Other species such as marine snails (e.g. *Adelomelon* spp., *Zidona dufresnei*) and some fishes (i.e. *Percophis brasiliensis*) were also excluded due to lack of basic information of their diet. In the case of species grouped under a common name in the DINARA landing reports (e.g. flounders), we considered the trophic information for the genus (i.e. *Paralichthys*) as representative of those single species (i.e. *P. brasiliensis* and *P. patagonicus*; Table 1).

Following Pauly et al. (2002), species were separated into those with TL > 3.5 such as large fishes (e.g. tunas, sea bass), whose food tends to be a mixture of low- and high-TL organisms (TL = 3.5–4.5); TL < 3.5, in order to observe changes in the contribution of each group to total landings. TLm was estimated as follows (Pauly et al., 1998):

$$\mathrm{TLm} = \frac{\sum \mathrm{TL}_{ij} Y_{ij}}{\sum Y_{ij}} \quad (1)$$

where TLm is the mean trophic level of landing in year j, Y_{ij} the landing of species i in year j and TL_i is the trophic level of species i.

To account for the effect of species of low trophic levels on the long-term trend of TLm, two analyses were conducted. First, the TLm was calculated considering the 60 selected species. Then, TLm was recalculated excluding landings of scallop *Zygochlamys patagonica* and red crab *Chaceon notialis* because both species showed an increasing significance in landings and economic value in the last analyzed years.

On the other hand, the fishing-in-balance index (FIB) was also estimated as follows:

$$\mathrm{FIB} = \log\left(Y_i\left(\frac{1}{\mathrm{TE}}\right)^{\mathrm{TL}_i}\right) - \log\left(Y_0\left(\frac{1}{\mathrm{TE}}\right)^{\mathrm{TL}_0}\right) \quad (2)$$

where Y_i is landing at year i, TL_i the mean TL of the landing at year i, TE the trophic efficiency (here set at 0.10), and Y_0 and TL_0 are the landing and mean TL of the first year of the series. The FIB-index can be an indicator of a “trophic level balance” objective in fishery management, assessing whether fisheries are ecologically balanced. Values of FIB < 0 may be associated with unbalanced fisheries, i.e. a lower current catch than the theoretical catch (Pauly et al., 2000) based on the productivity of the food web.

3. Results

Landings in Uruguayan fisheries are shown in Fig. 2. Although total landings decreased after 1991, this trend was not significant (Spearman’s $r = -0.32$; $P > 0.05$; Fig. 2a). However, landings of large pelagic fishes ($r = 0.73$; $P < 0.01$; Fig. 2b), chondrichthians ($r = 0.62$; $P < 0.05$; Fig. 2d), crustaceans and mollusks ($r = 0.83$; $P < 0.01$; Fig. 2e) showed significant increasing trends. Both, small and medium pelagic fishes exhibit an increasing, but non-significant, trend ($r = 0.65$; $P > 0.05$; Fig. 2c).

The analysis of landings by fish groups showed that, at the beginning of the time series, total landings were dominated by demersal fishes (hake, white croaker), while landings of large (tunas, swordfish), medium (rouge scad, parona leatherjacket) and small pelagic fishes (anchovy) as well as chondrichthians (rays and sharks), mollusks (squid, scallop) and crustaceans (red crab) were not important. This trend was reversed at the end of the time series (1997–2001; Fig. 2b–e), with landings of the latter groups representing a higher fraction of total landings, while demersal species showed a significant decreasing trend ($r = -0.66$; $P < 0.05$; Fig. 2f).

Table 1
Trophic level (TLi) of the main species landed from Uruguayan waters of the AUCFZ, from 1990 to 2001

Common name	Scientific name	TL_i	Groups
Argentine anchovy	*Engraulis anchoita*	2.48[a]	Small pelagics
Silverside	*Odontesthes* spp.	2.57[a]	
Brazilian menhaden	*Brevoortia* spp.	2.75[a]	
Chub mackerel	*Scomber japonicus*	3.35[a]	Medium pelagics
Rough scad	*Trachurus lathami*	3.45[a]	
Mullet	*Mugil* spp.	2.0[a]	
Parona leatherjacket	*Parona signata*	3.4[a]	
Yellowtail amberjack	*Seriola lalandi*	4.07[a]	
Largehead hairtail	*Trichiurus lepturus*	4.2[a]	
Atlantic Bonito	*Sarda sarda*	4.34[a]	
Bluefish	*Pomatomus saltatrix*	4.5[a]	
Albacore	*Thunnus alalunga*	4.5[a]	Large pelagics
Swordfish	*Xiphias gladius*	4.5[a]	
Oil fish	*Lepidocybium flavobrunneum*	4.34[a]	
Bigeye tuna	*Thunnus obesus*	4.3[a]	
Yellowfin tuna	*Thunnus albacares*	4.5[a]	
Dolphinfish	*Coryphaena hippurus*	4.37[a]	
Butterfly kingfish	*Gasterochisma melampus*	4.35[a]	
Billfish	*Makaira* spp., *Tetrapturus* spp.	4.45[a]	
Southern bluefin tuna	*Thunnus maccoyii*	4.5[a]	
Others tunas	*Thunnus* spp.	4.45[a]	
Pink cusk-eel	*Genypterus* spp.	4.34[a]	Demersals
Common seabream	*Pagrus pagrus*	3.55[a]	
Brazilian codling	*Urophycis brasiliensis*	3.79[a]	
Hawkfish	*Nemadactylus bergi*	3.18[a]	
Whitemouth croaker	*Micropogonias furnieri*	2.95[a]	
Stripped weakfish	*Cynoscion guatucupa*	4.23[a]	
Argentine hake	*Merluccius hubbsi*	4.08[a]	
Argentine croaker	*Umbrina canosai*	3.7[a]	
King weakfish	*Macrodon ancylodon*	3.9[a]	
Flounders	*Paralichthys* spp.	4.5[a]	
Southern kingcroaker	*Menticirrhus americanus*	3.5[a]	
Argentine conger	*Conger orbignianus*	3.4[a]	
Black drum	*Pogonias cromis*	3.89[a]	
Bigeye grenadier	*Macrourus holotrachys*	3.71[a]	
Sea bass	*Acanthistius brasilianus*	4.01[a]	
Plata pompano	*Trachinotus marginatus*	3.85[a]	
South American Silver porgy	*Diplodus argenteus argenteus*	3.13[a]	
Blackbelly rosefish	*Helicolenus dactylopterus lahillei*	3.4[a]	
Angelshark	*Squatina* spp.	4.1[b]	Chondrichthians
Sand tiger shark	*Carcharias taurus*	4.4[b]	
Shortfin mako	*Isurus oxyrinchus*	4.3[b]	
Blue shark	*Prionace glauca*	4.3[b]	
Soupfin shark	*Galeorhinus galeus*	4.2[b]	
Spoted spiny dogfish	*Squalus acanthias*	4.0[b]	
Porbeagle	*Lamna nasus*	4.2[b]	
Yellownose skate	*Dipturus chilensis*	4.29[a]	
Bignose fanskate	*Sympterygia acuta*	3.0[c]	
Night shark	*Carcharhinus signatus*	4.2[b]	
Sandbar shark	*Carcharhinus plumbeus*	4.1[b]	
Brazilian guitarfish	*Rhinobatos* spp.	3.6[a]	

Table 1 (*Continued*)

Common name	Scientific name	TL_i	Groups
Narrownose shark	*Mustelus schmitthi*	3.6[b]	
Elephantfish	*Callorhinchus callorhynchus*	3.23[a]	
Southern eagle ray	*Myliobatis goodei*	3.55[a]	
Red crab	*Chaceon notialis*	2.52[b]	Mollusks, crustaceans
Shrimp	*Farfantepenaeus paulensis*	2.52[b]	
Scallop	*Zygochlamys patagonica*	2.0[b]	
Blue mussel	*Mytilus edulis*	2.0[b]	
Squid	*Illex argentinus*	3.8–4.1[c]	

[a] TLs were derived from FishBase.
[b] TLs were derived from Cortés (1999).
[c] TLs were derived from Shannon et al. (2000).

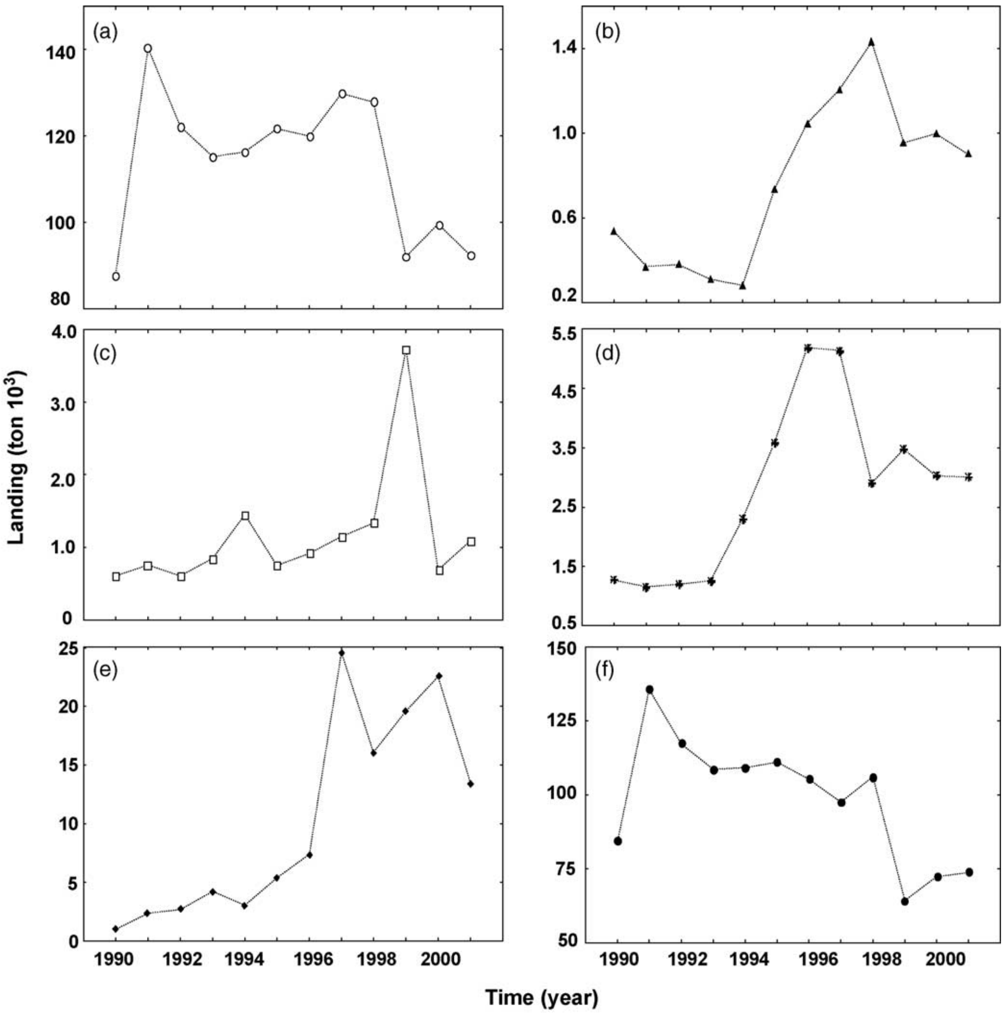

Fig. 2. Annual landings ($\times 10^3$ t) in Uruguayan waters of AUCFZ: (a) total; (b) large pelagics; (c) small and medium pelagics; (d) chondrichthians; (e) crustaceans and mollusks; (f) demersals (note the different scales on the *y*-axis).

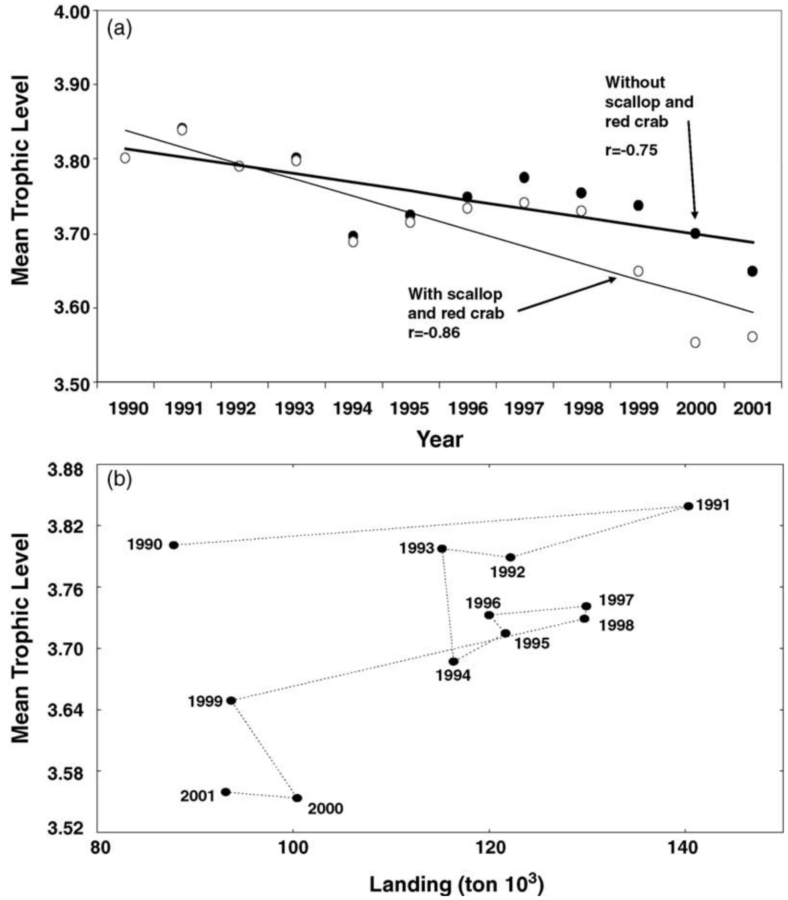

Fig. 3. (a) Mean trophic level (TLm) of landings in Uruguayan waters of AUCFZ, without (●) and with (○) scallop and red crab (r = Spearman rank correlations). (b) Long-term variation in the TLm vs. total landings during the period 1990–2001.

TLm significantly decreased from 1990 to 2001 ($r = -0.86$; $P < 0.001$; Fig. 3a). The maximum value of TLm occurred in 1991, which coincided with the historical peak in landings of demersal fishes (ca. 135 000 t). The decreasing trend in TLm was also significant even when scallop and red crab landings were excluded from the analysis ($r = -0.75$; $P < 0.01$; Fig. 3a), suggesting a fishing down process in the study area. FDMFW is also confirmed when the relationship between landings and their corresponding TLm was analyzed (Fig. 3b). Whereas the TLm and landings increased from 1990 to 1991, TLm declined from 1991 to 2001. In general, TLm of Uruguayan landings decreased at a rate of 0.28 per decade. The lowest value of the TLm was recorded in 2000–2001, which can be explained by the increasing landings of species with low TL, i.e. small- and medium-sized pelagic fishes (i.e. anchovy) and invertebrates (e.g. scallop, red crab).

The FIB-index showed a steady upward trend from 1990 to 1993 owing to the increase of both landings and TLm, suggesting that the fishery was expanding to stocks only lightly exploited. Landings peaked in 1991, thereafter FIB showed a stepwise decline, with negative values. The only exception was year 1997, when FIB = 0 (Fig. 4). Finally, the percentage of the landings of species of TL > 3.5 also declined during that period (Fig. 5).

4. Discussion

We showed direct impact of fishing on target species in Uruguayan waters of AUCFZ. A decreasing trend in

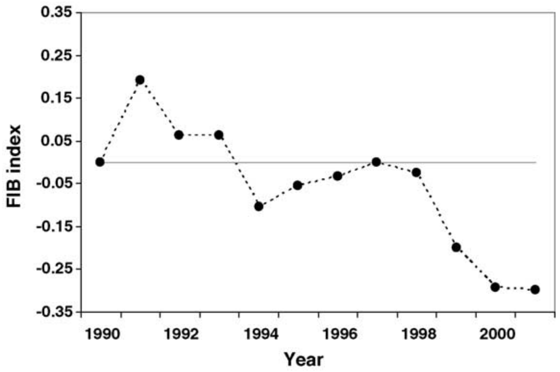

Fig. 4. Fisheries in balance index (FIB) in landings of the AUCFZ (1990–2001).

catch per unit of effort in last years has been documented (DINARA, 2001). In addition, recent stock assessment of the main fishery resources revealed that they are close to their maximum sustainable yield, while others are overexploited (Defeo and Masello, 2000; Pin and Defeo, 2000). The fishing pressure on target species is likely to have indirect impacts on the whole ecosystem by releasing competitors and prey, and by decreasing food availability for predators. Our result shows a long-term change of the exploited fish communities from a holistic (ecosystem) point of view the study area.

The decline in TLm (ΔTLm = 0.28 trophic level per decade) in Uruguayan waters of AUCFZ is almost three times higher than the rate (ΔTLm = 0.10) reported by Pauly et al. (1998) at a global scale. When compared with local/regional studies, ΔTLm in our study zone is higher than in the coastal upwelling system

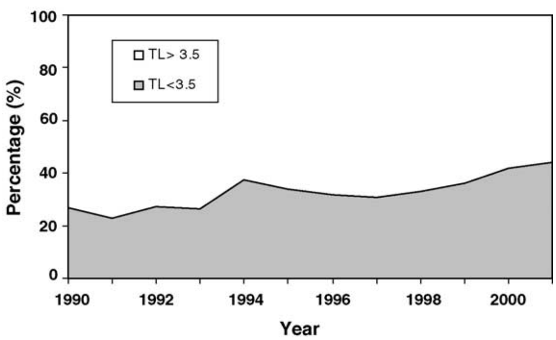

Fig. 5. Annual landings (%) of Uruguay discriminated by trophic level (TL): TL > 3.5 and TL < 3.5.

off Central Chile (ΔTLm = 0.15; Arancibia and Neira, in press) and in Mediterranean waters (ΔTLm = 0.15; Pinnegar et al., 2003), but comparable to those estimated for marine waters of Greece (ΔTLm = 0.30; Stergiou and Koulouris, 2000) and the Gulf of California (ΔTLm = 0.40; Sala et al., 2004).

Caddy et al. (1998) and Caddy and Garibaldi (2000) pointed out that TLm could be sensitive not only to fishery-induced changes at the ecosystem level, but also to economic and technological factors. This could be argued to explain the temporal variation in total landings and TLm in the study area. In fact, the decreasing trend in landings of the most important fishery resources (i.e. demersal fishes) in AUCFZ during mid 1990s determined a redirection of fishing effort to new fisheries based on more valuable target species located at low TL, such as the red crab *C. notialis* and the scallop *Z. patagonica* (Riestra and Barea, 2000; DINARA, 2001; Gutiérrez and Defeo, 2003), which influenced the TLm. However, when the landings of these species were excluded from the analysis, TLm still showed a significant decreasing trend (Fig. 3a). Therefore, the FDMFW process in Uruguayan waters of AUCFZ can be related to community changes induced by the fishery, since economic and/or technological factors related to increasing landings of high valuable species of low TL did not seem to affect long-term trends in TLm. In addition to fisheries, long-term environmental variation can also affect the structure and functioning of marine communities (ICES, 2000; Pauly et al., 2002; Watters et al., 2003). However, there are no evident signs of such kind of variation in Uruguayan waters of the AUCFZ (Guerrero et al., 2003), and thus the strong and significant decrease in the observed TLm (Fig. 3) unambiguously indicate that fisheries strongly impact the community structure and functioning in our study zone.

FDMFW is also supported by the decreasing trend observed in FIB and the landings of predators' species. Therefore, TLm proved to be a good indicator of the status of exploited fishing resources in a multispecific context, especially in those ecosystems where fisheries primarily tend to catch slow growing large predators as in Uruguayan waters. Further supporting evidence of the deteriorated health of fisheries in this area is that by-catch species, which were previously discarded by traditional fisheries (i.e. sharks), are now being retained on board, increasing their importance in total landings (Milessi and Defeo, 2002). Unfortunately, current management programs do not consider these species, which are very vulnerable to fishing (Stevens et al., 2000).

Results of this study can be considered as indicators of fishery-induced impacts on the community structure of commercial fish species in Uruguayan waters of the AUCFZ. Although it is not possible to project our results to the whole ecosystem, the observed trends are indirect evidence of ecosystem deterioration caused by the fishing process, even though our analysis does not consider the aggravating effect of a decline in TL due to a fishing-induced reduction in the mean size of individual species, a situation already confirmed for some species in Uruguayan waters (Milessi and Defeo, 2002). Therefore, the observed decrease in TLm is probably underestimated.

It is concluded that FDMFW is a process that has affected the community structure of the commercially exploited species in Uruguayan waters of the AUCFZ, as indicated by the significant decreasing trend in TLm. Considering that FDMFW could be revealing fishing impacts on the trophic structure of this ecosystem, we suggest that the goal of management programs and biological-fishing studies in the Uruguayan waters should be to reverse this trend in the long-term using a ecosystem-based approach.

Acknowledgements

A.C. Milessi is grateful to the German Service for Academic Exchange (DAAD), through which a grant (A/01/17601) for post-graduate studies at the Oceanography Department, University of Concepción was kindly provided. The authors wish to thank Dr. Knapp for help with the language and two anonymous referees that improved the present work.

References

Arancibia, H., Neira, S., in press. Long-term changes in the mean trophic level of central Chile fishery landings. Sci. Mar.

Botsford, L.W., Castilla, J.C., Peterson, C.H., 1997. The management of fisheries and marine ecosystems. Science 277, 509–515.

Caddy, J.F., Garibaldi, L., 2000. Apparent changes in the trophic composition of world marine harvests: the perspective from the FAO capture database. Ocean Coast. Manage. 43, 615–655.

Caddy, J.F., Csirke, J., Garcia, S.M., Grainger, R.J.R., 1998. How pervasive is fishing down marine food webs? Science 282, 1383–1385.

Christensen, N.L., Bartuska, M., Brown, J., Carpenter, S., D'Antonio, C., Francis, R., Franklin, J., MacMahon, J., Noss, R., Parsons, D., Peterson, C., Turner, M., Woodmansee, R., 1996. Report of the Ecological Society of American Committee on the scientific basis for ecosystem management. Ecol. Appl. 61, 665–691.

Cortés, E., 1999. Standardized diet compositions and trophic levels of sharks. ICES J. Mar. Sci. 56, 707–717.

Defeo, O., Gómez, M., Abdala, J., Medero, R., 1994. Planificación de actividades pesqueras en base a recursos subexplotados de la Zona Común de Pesca Argentino–Uruguaya. Fr. Mar. (Uruguay) 15, 165–172.

Defeo, O., Masello, A., 2000. La pesquería de cangrejo rojo *Chaceon notialis* en el Uruguay: un enfoque de manejo precautorio (1995 y 1996). In: Recursos Pesqueros no Tradicionales: Moluscos, Crustáceos y Peces Bentónicos, Marinos, Proyecto, URU/92/003. ISBN 9974-563-16-X, pp. 7–22 (available in http://www.dinara.gub.uy/publicaciones).

DINARA, 2001. Informe Sectorial Pesquero 200–2001, Montevideo, p. 63.

FAO, 2001. Reykjavik conference on responsible fisheries in the marine ecosystem: http://www.refisheries2001.org (Abstracts 13 pp.).

FAO, 2002. Estadísticas mundiales de pesca, http://www.fao.org.

Froese, R., Pauly, D. (Eds.), 2000. FishBase: Concepts, Design and Data Sources. ICLARM, Los Baños, Laguna, Philippines, 344 pp.

Goñi, R., 1998. Ecosystem effects of marine fisheries: an overview. Ocean Coast. Manage. 40, 37–64.

Guerrero, R., Osiroff, A.P., Molinari, G., Piola, A.R., 2003. Análisis de datos históricos de temperatura y salinidad del Río de la Plata y la plataforma adyacente. 5° Jornadas Nacionales de Ciencias del Mar. Mar del Plata, Argentina (available in http://www.freplata.org/documentos).

Gutiérrez, N., Defeo, O., 2003. Development of a new scallop *Zygochlamys patagonica* fishery in Uruguay: latitudinal and bathymetric patterns in biomass and population structure. Fish. Res. 62, 21–36.

Hall, S.J., 1999. The Effects of Fishing on Marine Ecosystems and Communities. Blackwell Science, Oxford.

Hollingworth, C.E. (Ed.), 2000. Ecosystem effects of fishing, Proceedings of an ICES/SCOR Symposium. ICES J. Mar. Sci. Symp. Ed. 210, 465–792.

Hollowed, A.B., Bax, N., Beamish, R., Collie, J., Fogarty, M., Livingston, P., Pope, J., Rice, J.C., 2000. Are multispecies models an improvement on single-species models for measuring fishing impacts on marine ecosystems? ICES J. Mar. Sci. 57, 707–719.

ICES, 2000. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES, Copenhagen, ICES CM2000/ACME:02, Ref: ACFM + E, 93 pp.

Milessi, A.C., Defeo, O., 2002. Long-term impact of incidental catches by tuna longlines: the black escolar (*Lepidocybium flavobrunneum*) of the southwestern Atlantic Ocean. Fish. Res. 58, 203–213.

National Research Council (NRC), 1998. Sustaining marine fisheries. National Academy Press, Washington, DC.
Pauly, D., 2003. Ecosystem impacts of the world's marine fisheries. Global Change NewsLett. 55, 21–23.
Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., Torres, F., 1998. Fishing down marine foods webs. Science 279, 860–863.
Pauly, D., Christensen, V., Walters, C., 2000. Ecopath, ecosim and ecospace as tools for evaluating ecosystem impact of fisheries. ICES J. Mar. Sci. 57, 697–706.
Pauly, D., Palomares, M.L., Froese, R., Sa-a, P., Vakily, M., Preikshot, D., Wallace, S., 2001. Fishing down Canadian aquatic food webs. Can. J. Fish. Aquat. Sci. 58, 51–62.
Pauly, D., Christensen, V., Guénette, S., Pitcher, T.J., Sumaila, U.R., Walters, C.J., Watson, R., Zeller, D., 2002. Towards sustainability in world fisheries. Nature 418, 689–694.
Pauly, D., Alder, J., Bennett, E., Christensen, V., Tyedmers, P., Watson, R., 2003. The future for fisheries. Science 302, 1359–1361.
Pikitch, E.K., Santora, C., Babcock, E.A., Bakun, A., Bonfil, R., Conover, D.O., Dayton, P., Doukakis, P., Fluharty, D., Heneman, B., Houde, E.D., Link, J., Livingston, P.A., Mangel, M., McAllister, M.K., Pope, J., Sainsbury, K.J., 2004. Ecosystem-based fishery management. Science 305, 346–347.
Pin, O., Defeo, O., 2000. Modelos de producción captura-mortalidad para la pesquería de corvina (*Micropogonias furnieri*) (Desmarest, 1823) en el Río de la Plata y Zona Común de Pesca Argentino–Uruguaya (1975–1986). In: Rey, M., Arena, G. (Eds.), Modelos de Producción Excedente Aplicados a los Recursos Corvina y Pescadilla. INAPE-PNUD URU/92/003. ISBN 9974-563-15-1, pp. 31–65 (available in http://www.dinara.gub.uy/publicaciones).
Pinnegar, J.K., Polunin, N.V.C., Badalamenti, F., 2003. Long-term changes in the trophic level of western Mediterranean fishery and aquaculture landings. Can. J. Fish. Aquat. Sci. 60, 222–235.
Riestra, G., Barea, L., 2000. La pesca exploratoria de la vieira *Zygochlamys patagonica* en aguas uruguayas. In: Rey, M. (Ed.), Recursos pesqueros no tradicionales: moluscos bentónicos marinos. INAPE-PNUD, Montevideo, Uruguay, pp. 145–152 (available in http://www.dinara.gub.uy/publicaciones).
Rochet, M.J., Trenkel, V.M., 2003. Which community indicators can measure the impact of fishing? A review and proposals. Can. J. Fish. Aquat. Sci. 60, 86–99.
Sala, E., Aburto-Oropeza, O., Reza, M., Paredes, G., López-Lemus, L.G., 2004. Fishing down coastal food webs in the Gulf of California. Fisheries 29, 19–25.
Shannon, L.J., Cury, P., Jarre, A., 2000. Modelling effects of fishing in the southern Benguela ecosystem. ICES J. Mar. Sci. 57, 720–722.
Sinclair, M., Arnason, R., Csirke, J., Karnicki, Z., Sigurjonsson, J., Rune Skjoldal, H., Valdimarsson, G., 2002. Responsible fisheries in the marine ecosystem. Fish. Res. 58, 255–265.
Stergiou, K.I., Koulouris, M., 2000. Fishing down the marine food webs in the Hellenic seas. CIESM Workshop Series, No. 12, pp. 73–78.
Stevens, J.D., Bonfil, R., Dulvy, N.K., Walker, P.A., 2000. The effects of fishing on sharks, rays and chimaeras (Chondrichthians), and the implications for marine ecosystems. ICES J. Mar. Sci. 57, 476–494.
Trenkel, V.M., Rochet, M.J., 2003. Performance of indicators derived from abundance estimates for detecting the impact of fishing on a fish community. Can. J. Fish. Aquat. Sci. 60, 67–85.
Watters, G.M., Olson, R.J., Francis, R.C., Fiedler, P.C., Polovina, J.J., Reilly, S.B., Aydin, K.Y., Bogas, C.H., Essington, T.E., Walters, C.J., Kitchell, J.F., 2003. Physical forcing and the dynamics of the pelagic ecosystem in the eastern tropical Pacific: simulations with ENSO-scale and global-warming climate drivers. Can. J. Fish. Aquat. Sci. 60, 1161–1175.