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Patterns of commercial fish landings in the Loreto region (Peruvian Amazon) between 1984 and 2006

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Abstract Patterns of commercial fish catches over the period from 1984 to 2006 were studied in the Loreto region and in Iquitos, which is the most important town of the region and the principal fish marketplace of the Peruvian Amazon. Despite important inter-annual variations, the overall fish landings have significantly increased in the region during this period. The same three species dominated the catches during the whole period (*Prochilodus nigricans*, *Potamorhina altamazonica* and *Psectrogaster amazonica*), making up about 62% of the catches. However, the number of species exploited by commercial fisheries increased considerably during the 22 years of this study (from about 21 species in 1984 to over 65 in 2006), although part of the difference may be accounted for by a better identification of individual species nowadays. At the same time, the large high-valued species, such as *Arapaima gigas*, *Colossoma macropomum* and *Brachyplatystoma rousseauxii*, declined significantly and were replaced by smaller, short-lived and lower-valued species. Catches of the silver Arahuana (*Osteoglossum bicirrhosum*) also declined significantly during the studied period, strengthening recent warnings about the species' conservation status (Moreau and Coomes, Oryx 40:152–160, 2006). The relative proportions of the trophic groups (detritivores, omnivores and piscivores) remained relatively constant over the study period, but there were significant changes in the relative abundances of the species groups. The proportion of the dominant group, the Characiformes, which averaged about 81% of the catches, increased between 1984 and 2006, whereas the proportion of the Siluriformes and Perciformes remained constant. On the other hand, the proportion of Osteoglossiformes, represented only by two well known species (*Arapaima gigas* and *Osteoglossum bicirrhosum*), declined sharply during the same period. Important differences were observed between the landings of Iquitos and the landing of the whole Loreto region, indicating that conclusions drawn from the study of the Iquitos landings cannot be extrapolated to the whole landings of the Loreto region. The most important difference was the decreasing fish landings in Iquitos, whereas the total landings increased in the Loreto region at the same time. Potential causes of this phenomenon are discussed. Decreasing fish abundance around Iquitos (because of a higher fishing pressure) and a behavioural adaptation of fishermen

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to better law enforcement in Iquitos are likely explanations to be further investigated.

Keywords Characiformes · Fisheries · Iquitos · Osteoglossiformes · Perciformes · Siluriformes

Introduction

Fishery activities are of primary importance in the Peruvian Amazon. Fish yields were estimated at 80,000 tonnes year^{-1} (Bayley et al. 1992) and generate annual incomes of about 80 million USD (Tello and Bayley 2001). Fish is also the main source of animal protein in the local population's diet (Tello 1998; Tello and Bayley 2001).

The fishery in the Peruvian Amazon is particularly difficult to manage, owing to its multispecific character, to the scant biological information about most target species and the difficulty in identifying stocks (Bayley and Petrere 1989; Tello and Bayley 2001). An added complexity comes from the fishery's structure itself. There are two types of fishery in the Peruvian Amazon: the subsistence fishery and the local market, which comprise about 75% of the total landings, and the commercial fishery, which accounts for the remaining 25% (Tello and Bayley 2001). A further distinction can be made within the commercial fishery: the commercial fishery fleet ("flota pesquera") that lands exclusively fresh fish and the commercial passenger boats ("carga y pasajeros") that land fresh as well as salted and dried fish.

The catch from the commercial fishery is landed mostly in the Loreto (75%) and the Ucayali (25%) regions, both considered as the most notable regions for fishery activities (Tello 1995). This study will focus on the Loreto landings, where more complete long-term information was available. However, it must be kept in mind that fish landed in the Loreto are not necessarily caught in rivers of the Loreto region. Actually, 57% of the fish landed in the Loreto region come from the Ucayali River, which belongs, for a large part, to the Ucayali region (Barthem et al. 1995).

No integral study of flota, carga y pasajeros in its different state of conservation, have been carried out in the Loreto region since 1996 (Tello 1998) and recent reports of decreasing catches have focussed on a reduced part of the fisheries only: the fishery fleet of Iquitos (Garcia and Tello 2006). In this study, patterns of commercial fish catches were studied in the Loreto region over the period from 1984 to 2006. The same analyses were applied to fish landings in Iquitos, which is the most important town of the region and is considered to be the principal fish marketplace and the most important landing port of the commercial fishery fleet of the Peruvian Amazon (Tello 1998). The objectives were to: (1) analyse the long-term trends of fish landings in the region, taking into account the different components of this complex fishery; (2) to analyse the ecological patterns of fish catches; and (3) to assess whether landings in Iquitos are representative of the general trend in the Loreto region.

Materials and methods

There are no currently available data on fish discarding, which is not a common practice in the fisheries of the Peruvian Amazon anyway. Therefore, landings and catches will be used as synonyms in the text.

The study area is the Loreto region, located in the Peruvian Amazon basin (Fig. 1). It includes part of the Amazon and Ucayali Rivers, which are both considered to be the most important basins in Peru (Tello and Bayley 2001). Both rivers are mainly constituted of nutrient-rich white waters originating from the Andes (Hanek 1982). The hydrological conditions produce flood pulses that inundate large, highly productive areas (*várzea*) responsible for the good fisheries production. The most productive flooded area is located in the Ucayali (Tello and Bayley 2001). However, the Loreto region landings also include fishes from the following rivers: Marañon, Huallaga, Napo, Tigre, Putumayo, Nanay, Yavari and Morona.

Statistics of fish landings were provided by DIREPRO (Dirección Regional de Pesquería de Loreto). Reliable data on fishing efforts were available only for the commercial fishery fleet of Iquitos. These were collected in the harbour "Puerto Pesquero" of Iquitos by the Instituto de Investigaciónes de la Amazonía Peruana (IIAP), via semi-structured interviews with fishermen. Additionally, interviews with

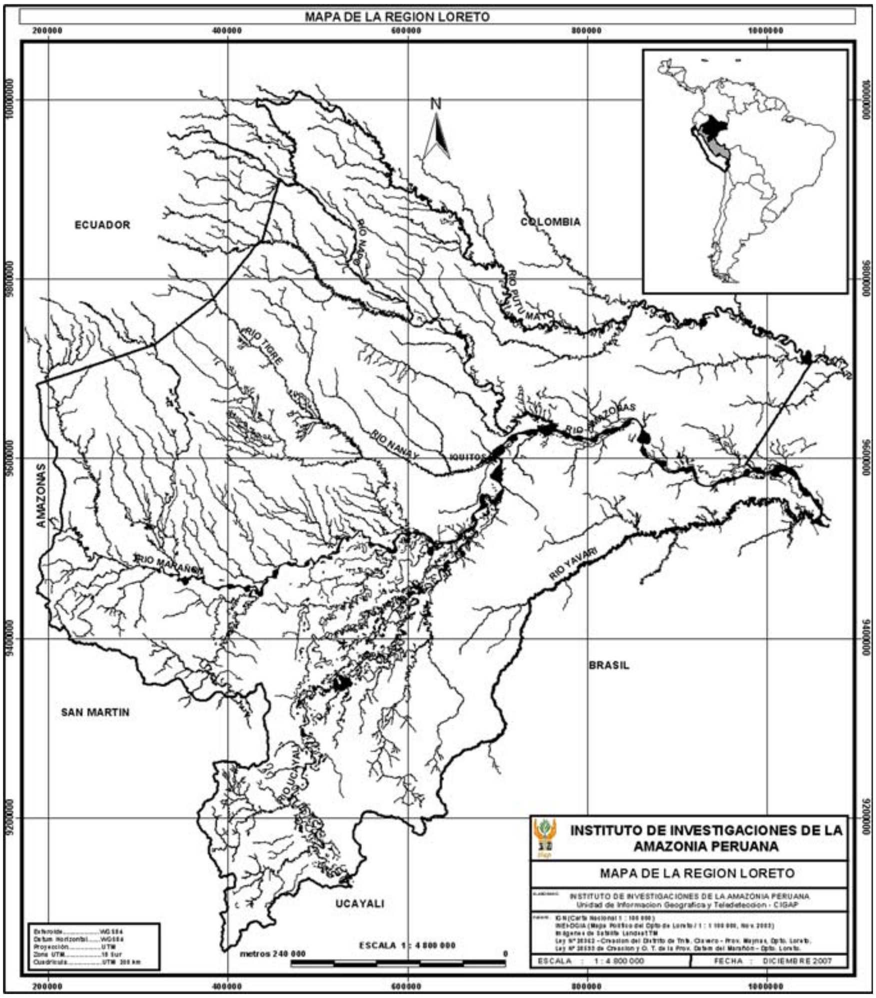


Fig. 1 Hydrographic map of the Loreto region (*black area*) in the Peruvian Amazon (*grey and black areas*), Peru (*white, grey and black areas*)

public functionaries, fishermen and boat owners of the commercial fishery fleet and the passenger boats were carried out.

The information was divided into two data sets: (1) the total landings in the Loreto region between 1984 and 2006 and (2) the total landings and the landings of the commercial fishery fleet (exclusively fresh fish) in Iquitos between 1986 and 2006.

The total landings of the Loreto region take into account the landings from the following towns: Iquitos, Yurimaguas, Nauta, San Pablo, Ullpayacu, El Estrecho, Pevas, Mazan, Caballococha, Contamana, Requena, Santa Rosa, San Lorenzo and so on.

Fish landings in the Loreto region are divided into three main categories: fresh, salted and dried fish. Raw catches of salted and dried fish were converted to fresh fish weight using the conversion factors 1.8 and 2.5, respectively (Hanek 1982; Tello 1998).

The total landings correspond to all of the fish catches, including fresh, salted (converted) and dried (converted) fish.

In multispecies fisheries with as many species as in the Amazon basin, it is almost impossible to obtain reliable information on each species' biology. It is, therefore, necessary to group a number of species according to shared biological parameters and fishery responses in order to facilitate the analysis and assist in the prediction of community changes. It has been suggested that trophic groups respond to environmental changes, including fishing pressure, in a more predictable and robust manner than any individual species (Austen et al. 1994). The fish species were, therefore, grouped into three trophic guilds (Appendix), as described in Bayley (1988), Tello (1998) and Tello and Bayley (2001): (1) primary consumers or detritivores, such as *Prochilodus nigricans*, *Potamorhina* spp. or *Curimata* spp.; (2) secondary consumers or omnivores, such as *Colossoma macropomum*, *Piaractus brachypomus*, *Brycon* spp., *Mylossoma* spp. or *Triportheus* spp.; and (3) tertiary consumers or piscivores, such as *Arapaima gigas*, *Brachyplatystoma rousseauxii*, *B. filamentosum*, *Pseudoplatystoma fasciatum* and other large catfishes.

Statistical analyses

The statistical analyses consisted, essentially, in linear regression analyses and analyses of variance (ANOVA), followed by Tukey post-hoc tests. Whenever the normality of distributions or homoscedasticity conditions was not met, a non-parametric test was applied (Kruskal-Wallis one-way ANOVA on ranks).

Results

Global catches in the Loreto region

Total annual fish catches in the Loreto region, including fresh, salted and dried fish, varied from 8,713 to 16,023 tonnes between 1984 and 2006 (Fig. 2). Despite important inter-annual variations, the fish landings have significantly increased over the last 20 years ($y = 160.452x - 308{,}129.192$, $R^2 = 0.272$, $P = 0.011$). Between 1990 and 2006, the commercial fishery fleet ("flota pesquera") landed, on average, 21% (range 7–44%) of the total catches, whereas the remaining 79% (range 56–93%) were landed by the commercial passenger boats ("carga y pasajeros") (Fig. 3).

Fish landings in the Loreto region are divided into three main categories: fresh, salted and dried fish. Over the study period, data detailing the type of conservation were available for the last 10 years only. During that time, the bulk of the catches was made up of fresh and dried fish, which accounted for, on average, 45% (range 37–57%) and 43% (range 29–51%) of the landings, respectively (Fig. 4). Salted fish landings varied from 9 to 16% and averaged 12%. While fresh fish landings were similar to or slightly below that of dried fish until 2002, the relative importance of fresh fish has increased since 2003 onwards, when it started dominating the catches. As illustrated in Fig. 5, the main state of conservation varied between species. Some were mainly landed dried (such as the Boquichico *Prochilodus nigricans*, the Fasaco *Hoplias malabaricus* and the Gamitana *Colossoma macropomum*), whereas others were mainly landed fresh (Palometa *Mylosoma* spp., Sardina *Triportheus* spp., Zungaro doncella *Pseudoplatystoma fasciatum* and Carachama *Pterygoplichthys multiradiatus*). Only a few species were mainly landed salted.

The most important fish species in the catches over the study period are presented in Table 1. Less than 30 species accounted for 97.7% of the total landings between 1984 and 2006, and three species alone, *Prochilodus nigricans* (Boquichico), *Potamorhina altamazonica* (Llambina), *Psectrogaster amazonica* (Ractacara), made up 62% of the catches (Table 1). Nevertheless, the number of species exploited by the commercial fisheries greatly increased during this period: between 1984 and 1995, only about 21 species made up 100% of the catches, whereas between 1996 and 2006, over 65 species (many

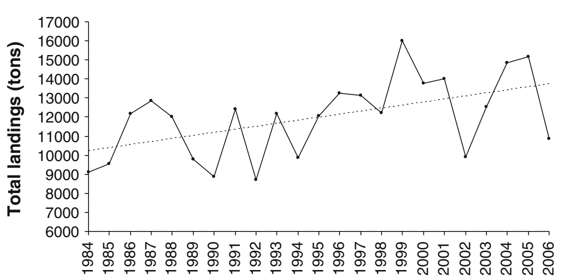


Fig. 2 Total fish landings (in tonnes) in the Loreto region from 1984 to 2006, including fresh, salted and dried fish. The *dotted line* represents the corresponding linear regression

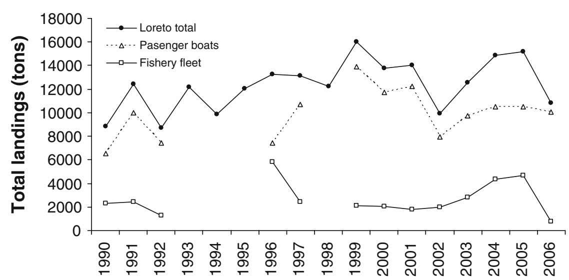


Fig. 3 Catches repartition between the commercial fishery fleet ("flota pesquera") and the commercial passenger boats ("carga y pasajeros") in the total fish landings of the Loreto region between 1990 and 2006

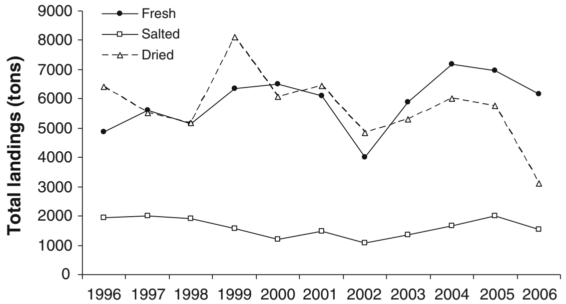


Fig. 4 Proportions of fresh, salted and dried fish in the Loreto region landings between 1996 and 2006

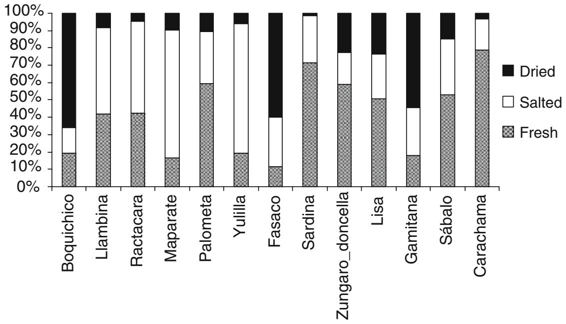


Fig. 5 State of conservation of the most important species in the fish landings of the Loreto region between 1996 and 2006. Species are listed in order of importance. These species made up 84% of the landings and the first three alone represented 61% of the landings

names refer to more than one species) made up 100% of the catches. Although the three same species dominated the catches during the whole study period, there have also been some important changes in specific composition in the last 20 years (Fig. 6). The large, highly valued species, such as the Paiche (*Arapaima gigas*), the Gamitana (*Colossoma macropomum*) or the Zungaro dorado (*Brachyplatystoma rousseauxii*), which, together, accounted for over 10% of the catches in the 1980s, progressively became rarer and represent less than 2% of the catches nowadays. As a general trend, the importance of most large and high-valued species significantly decreased in the catches during the study period (Fig. 7). The most extreme example comes from the largest and most appreciated species, *A. gigas*, which accounted for up to 6% of the total landings in 1984, and less than 0.7% in 2006.

Species pertaining to the order Characiformes dominated the fish landings at all times, making up between 74 and 86% of the catches (average 80.9 ± 3.9SD) (Fig. 8). Characiformes were significantly more abundant than any other order (Kruskal-Wallis one-way ANOVA on ranks, $H = 76.689$, d.f. $= 3$, $P < 0.001$ and Tukey post-hoc tests). The Siluriformes were the second most important species, accounting for 9–16% of the catches (average 12.2 ± 2.5SD). They were significantly more abundant than both Osteoglossiformes ($q = 6.388$, $P < 0.05$) and Perciformes ($q = 5.958$, $P < 0.05$). The Osteoglossiformes, which only comprise two species (*Arapaima gigas* and *Osteoglossum bicirrhosum*), accounted for 1–8% of the catches (average 3.3 ± 2.0SD), whereas the Perciformes, which mainly comprise species of the family Cichlidae and one Sciaenidae (*Plagioscion squamosissimus*), accounted for 2–7% of the catches (average 3.3 ± 1.1SD). Osteoglossiformes and Perciformes did not differ in relative abundance ($q = 0.429$, $P > 0.05$). The species pooled under "others" mainly belonged to the Rajiformes, Gymnotiformes and Clupeiformes, and made up between 0 and 1% of the catches altogether (average 0.2 ± 0.3SD) over the study period. The relative importance of the Characiformes significantly increased between 1984 and 2006 ($y = 0.260x - 438.070$, $R^2 = 0.209$, $P = 0.028$), whereas the proportions of the Siluriformes and Perciformes remained unchanged ($y = 0.0354x - 58.415$, $R^2 = 0.0091$, $P = 0.664$ and $y = -0.051x + 104.5$, $R^2 = 0.099$, $P = 0.142$, respectively). The most striking change came from the steep decline in the relative abundance of the Osteoglossiformes ($y = -0.270x + 542.84$, $R^2 = 0.858$, $P < 0.001$), which is clearly apparent in Fig. 8.

Primary consumers dominated the fish landings over the study period, making up between 60 and 81% of the catches (average 71.2 ± 5.2SD) (Fig. 9). They were significantly more abundant than both secondary consumers (Kruskal-Wallis one-way ANOVA on ranks, $H = 45.434$, d.f. $= 2$, $P < 0.001$ and Tukey post-hoc test, $q = 8.460$, $P < 0.05$) and piscivores ($q = 8.034$, $P < 0.05$), which accounted for 8–23% (average 14.3 ± 3.4SD) and 8–18% (average 14.3 ± 3.0SD) of the catches, respectively. Secondary consumers and piscivores did not differ in relative abundance ($q = 0.426$, $P > 0.05$). Despite a slight decreasing tendency in the relative proportion of the secondary consumers and the piscivores during the study period (Fig. 9), these trends were not significant. The apparent

Table 1 Mean annual catches (tonnes and % ± SD) of the most important species (which made up at least 1% of the catches) over the period 1984–2006 in the Loreto region

Local name	Species	Mean (tonnes)	Min–max (tonnes)	Mean (%)	Min–max (%)
Boquichico	*Prochilodus nigricans*	4,834 ± 1789	805–8,487	39.8 ± 12.1	9.2–58.3
Llambina	*Potamorhina altamazonica*	1,673 ± 632	797–2,823	14.1 ± 5.6	7.2–32.4
Ractacara	*Psectrogaster amazonica*	951 ± 424	308–1,694	8.0 ± 3.6	2.4–17.9
Palometa	*Mylosoma duriventris*	447 ± 150	279–712	3.7 ± 1.0	2.0–5.7
	M. spp.				
Maparate	*Hypophthalmus edentatus*	404 ± 136	186–731	3.4 ± 1.2	2.0–6.9
	H. emarginatus				
Fasaco	*Hoplias malabaricus*	367 ± 104	238–549	2.8 ± 0.7	1.7–4.1
Yulilla	*Anodus* spp.	300 ± 111	157–560	2.6 ± 1.3	1.4–6.3
	Hemiodus spp.				
Sardina	*Triportheus elongates*	259 ± 137	41–526	2.1 ± 1.0	0.4–4.8
	T. angulatus				
Paiche	*Arapaima gigas*	233 ± 148	62–548	2.1 ± 1.5	0.6–6.0
Lisa	*Schizodon fasciatus*	232 ± 93	44–422	2.0 ± 1.5	1.0–8.0
	Leporinus trifasciatus				
Gamitana	*Colossoma macropomum*	230 ± 143	84–785	2.0 ± 1.3	0.6–4.6
Doncella	*Pseudoplatystoma fasciatum*	228 ± 141	56–560	2.0 ± 0.8	0.3–3.5
Dorado	*Brachyplatystoma rousseauxii*	203 ± 137	43–585	1.8 ± 1.2	0.4–4.9
Carachama	*Pterygoplichthys multiradiatus*	192 ± 81	67–354	1.7 ± 0.8	0.6–3.5
Corvina	*Plagioscion squamosissimus*	185 ± 100	69–416	1.6 ± 1.0	0.4–4.7
Sabalo	*Brycon melanopterus*	180 ± 123	29–547	1.5 ± 0.9	0.3–3.4
	B. erythropterum				
Arahuana	*Osteoglossum bicirrhosum*	152 ± 178	14–503	1.2 ± 0.7	0.3–2.5
Paco	*Piaractus brachypomus*	143 ± 72	45–307	1.2 ± 0.5	0.5–2.8
Yahuarachi	*Potamorhina latior*	139 ± 60	68–350	1.2 ± 1.4	0.1–3.8
Tucunare	*Cichla monoculus*	130 ± 22	86–158	1.0 ± 0.5	0.5–2.3
Acarahuazu	*Astronotus ocellatus*	117 ± 44	61–238	1.0 ± 0.1	0.8–1.2
Cunchimama	*Paulicea lutkeni*	99 ± 62	8–256	0.9 ± 0.6	0.1–2.1
Total				97.7	

Underlined are the vernacular names corresponding to more than one species

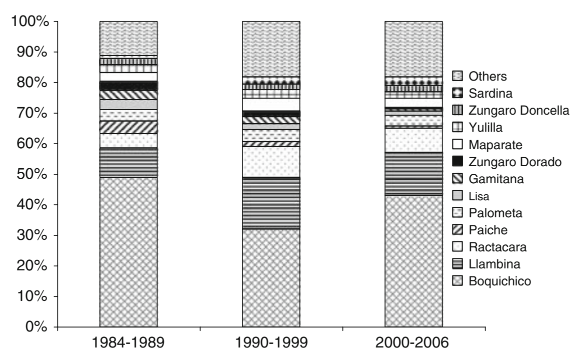


Fig. 6 Changes in specific landings composition between 1984 and 2006 in the Loreto region

increasing proportion of primary consumers over the study period was not significant either.

A similar trend was observed when trophic categories were compared among states of conservation over the period 1996–2006: primary consumers were significantly more abundant than secondary consumers (one-way ANOVA, $F = 79.971$, d.f. $= 2$, $P < 0.001$ and Tukey post-hoc test, $q = 15.655$, $P < 0.001$) and piscivores ($q = 15.318$, $P < 0.001$), which themselves did not differ from one another ($q = 0.336$, $P > 0.05$) (Fig. 10). However, the relative abundance of primary consumers differed significantly among states of conservations (one-way ANOVA, $F = 30.330$, d.f. $= 2$,

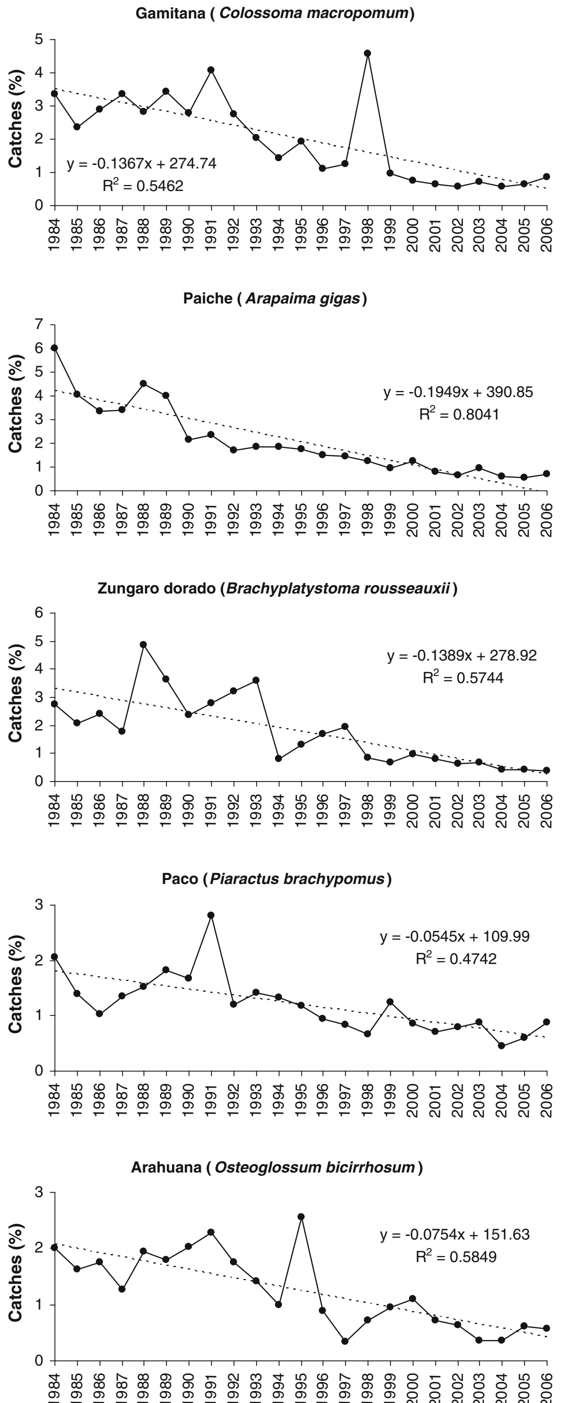


Fig. 7 Catch trends of some of the large, high-valued species over the study period in the Loreto region

$P < 0.001$), being significantly lower in the "fresh" state than in both the "salted" ($q = 8.629$, $P < 0.001$) and "dried" ($q = 10.243$, $P < 0.001$) states, which did not differ from one another ($q = 1.613$, $P > 0.05$). The relative abundance of secondary consumers also differed significantly among all states of conservations (one-way ANOVA, $F = 29.172$, d.f. = 2, $P < 0.001$): it was higher in the "fresh" state than in both the "salted" ($q = 10.651$, $P < 0.001$) and "dried" ($q = 6.887$, $P < 0.001$) states and it was higher in the "salted" than in the "dried" ($q = 3.764$, $P < 0.05$) state. The relative abundance of piscivores also differed significantly among states of conservations (one-way ANOVA, $F = 17.771$, d.f. = 2, $P < 0.001$), being significantly higher in the "fresh" state than in both the "salted" ($q = 8.246$, $P < 0.001$) and "dried" ($q = 5.645$, $P < 0.001$) states, which did not differ from one another ($q = 2.601$, $P > 0.05$).

Catches in Iquitos

The total annual fish catches in Iquitos, including fresh, salted and dried fish, varied from 3,439 to 10,171 tonnes between 1986 and 2006 (Fig. 11). Despite important inter-annual variations, fish landings have significantly decreased in Iquitos over the last 20 years ($y = -200.95x + 407{,}657$, $R^2 = 0.347$, $P < 0.01$). The same trend was observed for the commercial fishery fleet ($y = -73.563x + 148{,}651$, $R^2 = 0.790$, $P < 0.001$), which landed, on average, 29% (range 15–50%) of the total catches. The remaining 71% were landed by the commercial passenger boats. This situation sharply contrasted with the whole fish landings in the Loreto region, which significantly increased during the same period (Fig. 2).

For Iquitos, data detailing the state of conservation were available for the period 1986–2006 (Fig. 12), whereas it was available only from 1996 to 2006 for the Loreto region (Fig. 4). During the first 10 years (86–95), dried fish dominated the landings in Iquitos (45% ± 7SD), followed by fresh (34% ± 8SD) and salted (21% ± 8) fish. During the second decade, fresh fish clearly dominated, making up, on average, 65% (±8SD) of the catches, followed by dried (28% ± 10SD) and salted fish (7% ± 3SD, Fig. 12), whereas during the same period, fresh fish dominated the landings only since 2003 in the Loreto region (Fig. 4).

The main state of conservation in Iquitos landings varied between species (Fig. 13), as observed for the Loreto landings (Fig. 5). During the period from 1996 to 2006, the most important species in fish

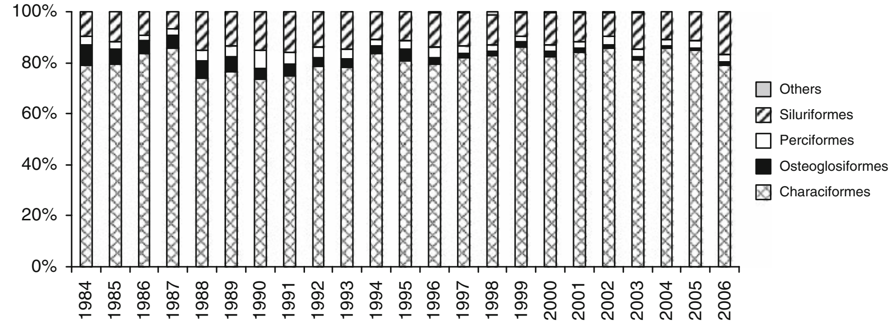


Fig. 8 Relative importance of the main fish groups (sorted by order) in the landings of the Loreto region over the period 1984–2006

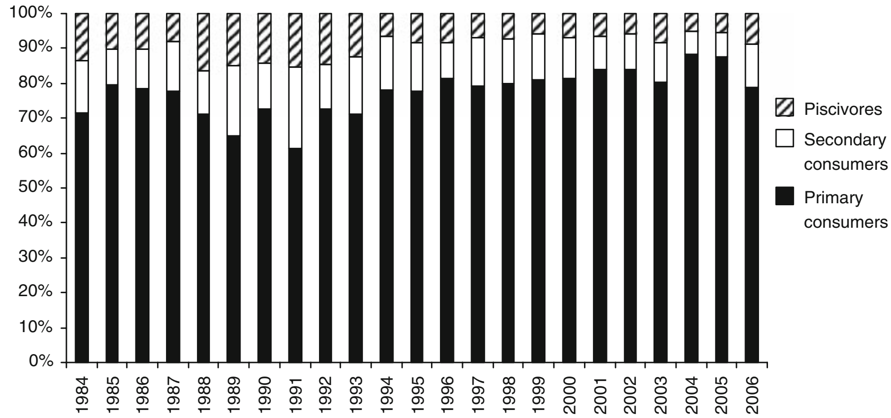


Fig. 9 Relative importance of the main trophic categories in the fish landings of the Loreto region over the period 1984–2006

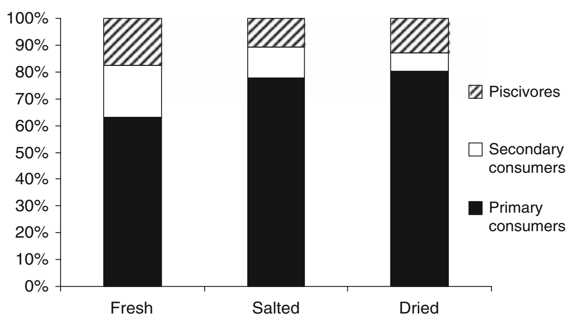


Fig. 10 Relative importance of the main trophic categories in the fish landings of the Loreto region per state of conservation over the period 1996–2006

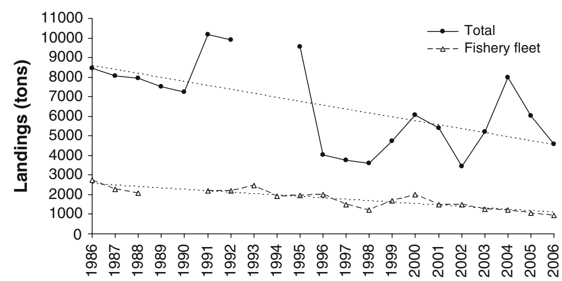


Fig. 11 Trends in the total fish landings and landings of the commercial fishery fleet in Iquitos between 1986 and 2006. The *dotted line* represents the corresponding linear regression

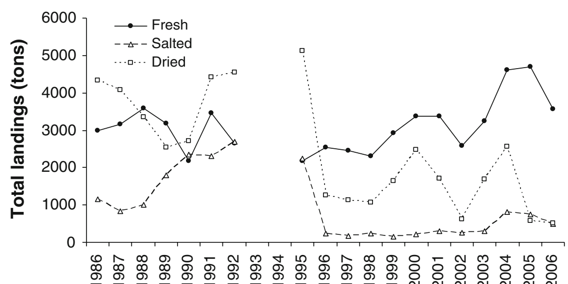


Fig. 12 Proportions of fresh, salted and dried fish in Iquitos landings between 1986 and 2006

landings and their state of conservation were quite similar in Iquitos and in the Loreto region. The main differences were the absence of the Carachama (*Pterygoplichthys multiradiatus*) and the presence of the largest catfish species of the Amazon, *Brachyplatystoma filamentosum* (Zungaro salton), mainly landed dried, among the most important species of Iquitos landings. However, there were large differences in Iquitos landings among the periods 1986–1995 and 1996–2006 (Fig. 13). More species made up the bulk of the catches in the first decade than in the second: 19 species accounted for 87% of the landings in 1986–1995, whereas 13 species accounted for 90% of the landings in 1996–2006. More striking, the first three most important species (Boquichico *Prochilodus nigricans*, Yahuarachi *Potamorhina latior* and Bocon *Ageneiosus brevifilis*) accounted alone for 34% of the landings in the first decade, whereas the first three species alone, two of which were different (Llambina *Potamorhina altamazonica* and Ractacara *Psectrogaster amazonica*) accounted for 63% in the second decade. The proportions in the states of conservation among periods varied slightly for most species. However, these variations were more spectacular for some species, such as the Sardina (*Triportheus* spp.), which was landed at 65% as salted and dried in the first decade and quasi-exclusively landed fresh in the second decade, the Zungaro doncella (*Pseudoplatystoma fasciatum*), whose fresh landings almost tripled or the Gamitana (*Colossoma macropomum*), whose dried landings almost doubled (Fig. 13).

Unfortunately, reasonably accurate catch per unit effort (CPUE) and efforts were only available for the commercial fishery fleet of Iquitos, but not for the total fish landings. Nevertheless, comparison of the total fish landings versus CPUE and effort indicated that the significantly decreasing fish landings of the commercial fishery fleet in Iquitos ($y = -73.563x + 2629.8$, $R^2 = 0.790$, $P < 0.001$) are mainly due to a significantly decreasing effort ($y = -18.091x + 395.82$, $R^2 = 0.691$, $P < 0.001$) (Fig. 14a) because CPUE did not vary significantly over the study period ($y = -0.015x + 4.523$, $R^2 = 0.019$, $P = 0.598$), despite inter-annual variations, and even increased in the last 2 years (Fig. 14b).

Interestingly, the proportion of the trophic categories in the fishery fleet landings (Fig. 15) differed from that of the total fish landings of Iquitos (Fig. 16). Except in 2005 and 2006, the proportion

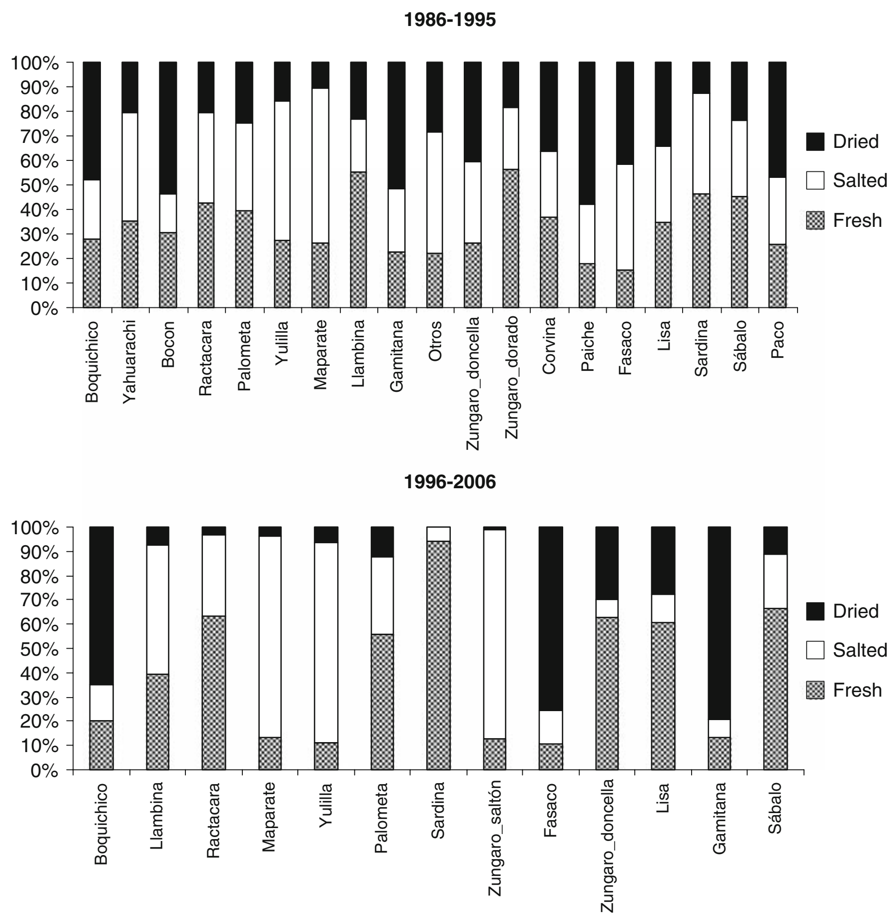


Fig. 13 State of conservation of the most important species in fish landings of Iquitos between 1986 and 2006. The species are listed in order of importance. These species made up 87 and 90% of the landings in the periods 1986–1995 and 1996–2006, respectively. Note that the first three species alone represented only 34% of the landings in 1986–1995, but 63% in 1996–2006

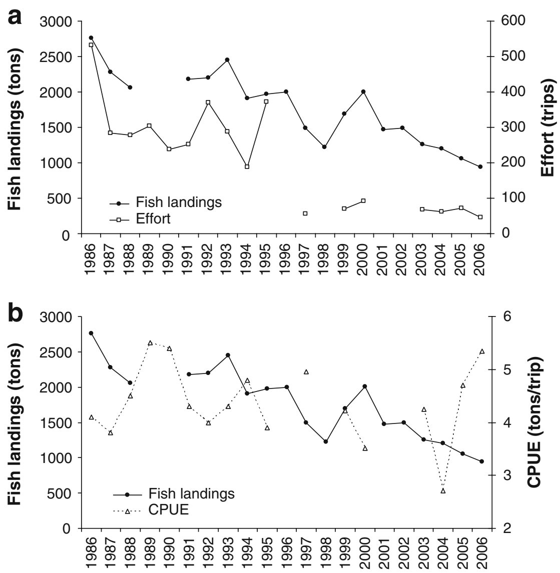


Fig. 14a, b Fish landings of the commercial fishery fleet of Iquitos and (**a**) effort (in number of trips) and (**b**) catch per unit effort (CPUE) during the period from 1986 to 2006

of piscivores was surprisingly low in the fishery fleet landings compared to the total landings of Iquitos. As the fishery fleet lands exclusively fresh fish, this difference might be due to the differential landing proportions of piscivores among the conservation states. However, when the relative contribution of piscivores was compared among states of conservation in the total fish landings of Iquitos, no difference was observed (Kruskal-Wallis one-way ANOVA on ranks, $H = 3.341$, d.f. $= 2$, $P = 0.188$), indicating that piscivorous species were less targetted than other species by the fishery fleet until 2005–2006.

The proportion of the trophic categories in the total landings of Iquitos (Fig. 16) differed from that of the total landings in the Loreto region (Fig. 9). The proportion of primary consumers averaged 59% (range 19–74) in Iquitos, which was significantly lower (Mann-Whitney rank sum test, $T = 306.000$, $P = 0.003$) than the 71% of the Loreto region during the same period (1986–2006). On the other hand, the proportion of secondary consumers was significantly ($T = 547.000$, $P < 0.001$) higher in Iquitos (average 18%, range 11–29) than in the Loreto region (14%). The proportion of piscivores was also significantly ($T = 510.000$, $P = 0.020$) higher in Iquitos (average 23%, range 9–64) than in the Loreto region (14%).

Discussion

In the Loreto region, about 45 fish species are exploited by the commercial fishery and many more by the subsistence fishery (Tello 1995; Tello and Bayley 2001). During the time span of this study, we observed a more than threefold increase in the number of species exploited by the commercial fishery (≈21 species in 1984–1995 to >65 species in 1996–2006). This clearly indicates a diversification of the fishery, but probably also reflects a better distinction of individual species that were pooled under a single name previously. Nevertheless, our results illustrated that less than 30 species accounted for 98% of the total landings between 1984 and 2006, and three species alone, *Prochilodus nigricans* (Boquichico), *Potamorhina altamazonica* (Llambina), *Psectrogaster amazonica* (Ractacara), made up 62%

Fig. 15 Relative importance of the main trophic categories in the fish catches of the commercial fishery fleet in Iquitos over the period 1986–2006

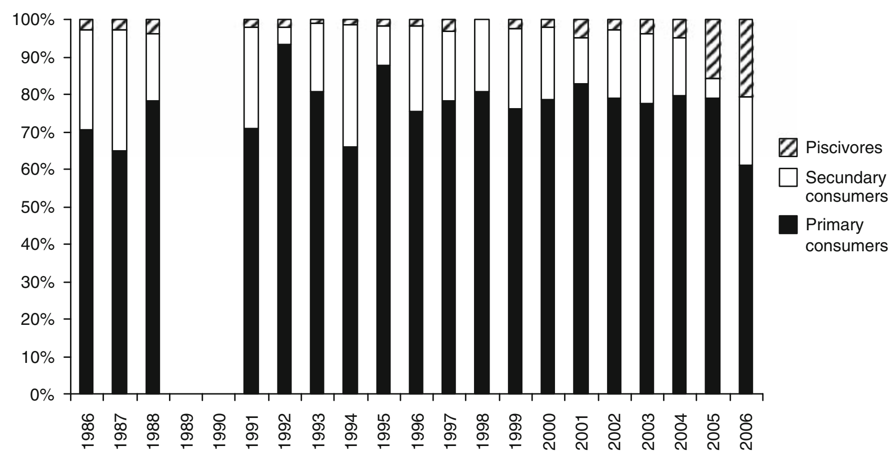
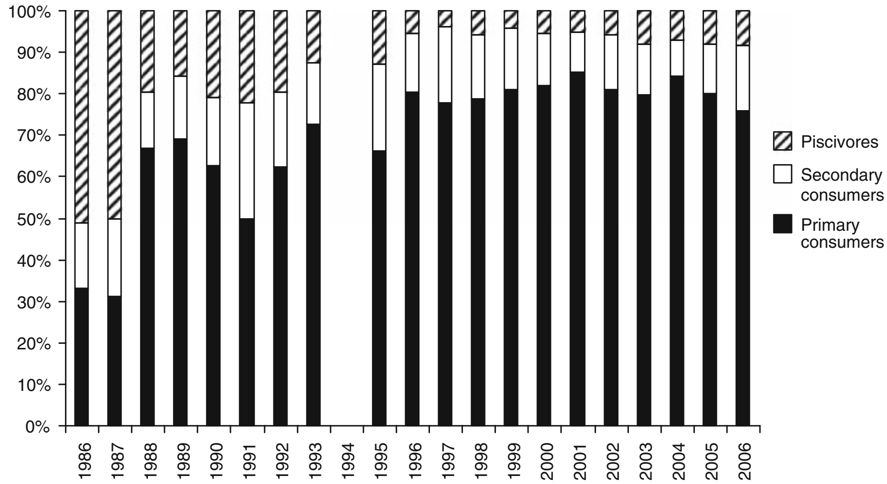


Fig. 16 Relative importance of the main trophic categories in the total fish catches of Iquitos over the period 1986–2006



of the catches. Although the same three species dominated the catches during the 22 years of this study, there have been some important changes in the specific composition of the catches during that time. The most noticeable changes concern the large, highly valued species, such as the piscivorous Paiche (*Arapaima gigas*) and Zungaro dorado (*Brachyplatystoma rousseauxii*), or the secondary consumers (omnivores), such as the Gamitana (*Colossoma macropomum*) or the Paco (*Piaractus brachypomus*), which progressively became rarer. This is a common phenomenon in fisheries worldwide, referred to as "fishing down the food web," where large, long-lived species are progressively being replaced by smaller short-lived species with higher production/biomass ratios (Pauly et al. 2000; Winemiller 2005). In the Loreto region, large species of the omnivore group, such as *Colossoma macropomum*, *Piaractus brachypomus* and, to a lesser extent, *Brycon* spp., were progressively replaced by smaller, faster growing species with lower prices, such as *Mylossoma* spp. or *Triportheus* spp., to cite a few. This trend, which was already observed in 1996 by Tello and Bayley (2001), was accentuated in the last 10 years (Fig. 7). This phenomenon also occurred in other Amazonian fisheries: Bayley and Petrere (1989) observed a rarefaction of the larger species, such as the Paiche or the Gamitana in Manaus, Brazil, and Novoa (1989) noted a reduction of the mean landed size of the large catfishes in the Orinoco. In Peru, the increasing pressure on the large piscivorous species, mainly large catfishes, since the 1980s can be explained by two factors: the introduction of large drifting nets in fishery practices and the opening of the international market, particularly in Colombia (Tello and Bayley 2001).

One particularly concerning case, besides the well-known Paiche, is the Arahuana (*Osteoglossum bicirrhosum*). Contrary to the other species mentioned, the decreasing catches of the Arahuana are probably not due to its commercialisation as a food fish, but, rather, to the highly destructive methods used by the ornamental trade, which often sacrifices the breeding adults to collect the juveniles (Moreau and Coomes 2006). This species supports a heavy, rapidly increasing exploitation from the ornamental trade in Peru (over 1 million juveniles worth 560,000 USD exported in 2001) and the recent opening of the Asian market will further increase it dramatically (Moreau and Coomes 2006). Our results tend to confirm Moreau and Coomes' fears that the Arahuana urgently needs protection measures.

Tello and Bayley (2001) observed an increasing trend in the catches of detritivores (primary consumers) until 1996. We observed such a tendency when 10 more years of data were added, but this trend was not significant. The decreasing tendencies observed for the omnivores and piscivores were not significant either. However, if the relative proportions of the trophic groups remained relatively constant over the study period, there were significant changes in the relative abundances of the species groups. The proportion of the dominant group, the Characiformes, increased between 1984 and 2006, which can be explained by the replacement, mentioned above, of the few large species by several smaller, more productive species. The proportion of the Siluriformes and Perciformes remained constant between 1984 and 2006. The decreasing abundance of the larger Siluriformes (*Brachyplatystoma rousseauxii* or *B. filamentosum*) were compensated for by the appearance of other species in the later years of this study, such as *B. juruense* or the smaller *Hypophthalmus* spp., while the relative abundance of species such as *Pseudoplatystoma* spp. remained constant over the study period. The Perciformes are neither large nor highly targetted species, which could explain their stationary proportions. On the other hand, the proportion of Osteoglossiformes declined sharply during the same period. This order is composed of only two species, *Arapaima gigas* and *Osteoglossum bicirrhosum*, both large and highly targetted. Moreover, both species have low fecundity and provide parental care, which make them particularly vulnerable to exploitation.

One of the objectives of this study was to assess whether the landings in Iquitos, which is the principal marketplace of the Peruvian Amazon, were representative of the general trend in the Loreto region. However, important differences were observed between the landings of Iquitos and the landing of the whole Loreto region: (1) whereas the total landings of Iquitos decreased significantly from 1986 to 2006, the opposite significant trend was observed for the Loreto region; (2) the proportion of the trophic categories in the total landings of Iquitos differed significantly from that of the total landings in the Loreto region, with higher proportions of secondary and tertiary consumers in Iquitos; (3) the predominance of fresh fish in the landings started much earlier in Iquitos (1996) than in the Loreto region (2003). This earlier shift of the Iquitos landings toward fresh fish was reflected in the state of preservation of some important species, such as the Sardina (*Triportheus* spp.), which was landed at 65% as salted and dried between 1986 and 1995, and quasi-exclusively landed fresh afterwards. The same was observed for the Zungaro doncella (*Pseudoplatystoma fasciatum*), whose fresh landings almost tripled after 1996. On the other hand, some of the traditional large and highly valued species, such as the Gamitana (*Colossoma macropomum*), were landed twice as much at a dried state after 1996 than before. This is likely a consequence of the rarefaction of such large commercial species around Iquitos and of the impossibility of bringing them fresh from the remote places where they are caught. These results clearly indicate that conclusions drawn from the study of the Iquitos landings cannot be extrapolated to the whole landings of the Loreto region. The increasing landings in the Loreto region also tend to confirm Tello and Bayley's (2001) hypothesis that the fishery in the Loreto was probably able to durably sustain the levels of exploitation recorded in 1996.

An interesting question arising from these results is why are the landings decreasing in Iquitos whereas they are increasing in the Loreto region? Our results indicated that decreasing fish landings of the commercial fishery fleet in Iquitos are mainly due to a decreasing effort because the CPUE remained more or less constant over the study period, despite interannual variations, and even increased in the last 2 years. But why would the fishing fleet decrease its effort? This phenomenon is likely to be related to the conflict, started in 1996, between the commercial fishery fleet and the riparian human communities around the use of fisheries resources in the most important fishing zones, such as lakes Carocurahuayete or San Pablo Tipischa, among others. Several communities now prohibit the access of their lakes to the commercial fishermen. They exploit themselves the fisheries resources, which are sold to the passenger boats and are, ultimately, landed in Iquitos. Since 1996, the number of fishing zones whose access is now denied to the commercial fishermen by the local communities has been increasing steadily (Garcia et al. 2006), which likely accounts for a large part of the observed decreasing effort of the commercial fishery fleet in Iquitos. There might also be a higher fishing pressure around Iquitos, leading to decreasing catches. However, the fishery fleet represents only 29% of the landings in Iquitos and might not account for the observed decreasing trend of fish landings in Iquitos alone. The commercial passenger boats, which make up the rest of the landings, should also show a decreasing trend. Unfortunately, direct data of the passenger boats landings are not available. But extrapolating them as the difference between the total landings and the fishery fleet landings of Fig. 11, we indeed observed a decreasing trend between 1986 and 2006. The local fishermen selling their catch to the passenger boats might also have decreased their effort, but this is almost impossible to monitor and quite unlikely anyway. This decreasing trend of passenger boat landings, which should have beneficiated from part of the fishery fleet landings (those corresponding to the zones prohibited by the local communities), strengthen the hypothesis of higher fishing pressure around Iquitos. There are, indeed, some indications that the fishing pressure is high around Iquitos. Several of the most important commercial species are being captured below their sizes at first maturity and the minimum authorised sizes established by the "Reglamento de Ordenamiento Pesquero" of the Peruvian Amazon: *Prochilodus nigricans*, *Potamorhina altamazonica*, *Mylosoma duriventris*, *Brachyplatystoma rousseauxii*, *Pseudoplatystoma fasciatum* and *P. tigrinum* (Garcia et al., unpublished data). A complementary explanation to the decreasing fish landings in Iquitos might be a reaction of the fishermen to a better implementation of the fishing regulations around Iquitos (minimum sizes, no-fishing periods or "veda" etc.). In order to avoid those controls, fishermen would sell their production in other landing zones of the region (Luis Moya, INADE, personal communication).

Verifying whether the decreasing fish landings in Iquitos are due to a decreasing fish abundance around Iquitos (because of a higher fishing pressure) or to a behavioural change of fishermen in response to better fishery law enforcement around Iquitos, or both, will need further studies. A comparison of past and current CPUE in the main fishing zone around Iquitos would bring some preliminary answers if such data were available.

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Appendix

Local names, scientific names, order and trophic category of the main commercial fish species in the Loreto region. Underlined are vernacular names corresponding to more than one species. Note that, since 2004, the two species of "Sabalo" are distinguished separately as "Sabalo cola negra" and "Sabalo cola roja" for *Brycon melanopterus* and *B. erythropterum*, respectively.

Name	Species	Order	Trophic category
Acarahuazu	*Astronotus ocellatus*	Perciformes	Piscivore
Añashua	*Crenicichla johanna/proteus*	Perciformes	Piscivore
Arahuana	*Osteoglossum bicirrhosum*	Osteoglossiformes	Omnivore
Banda negra	*Myleus schomburgkii*	Characiformes	Omnivore
Bocon	*Ageneiosus brevifilis*	Siluriformes	Piscivore
Boquichico	*Prochilodus nigricans*	Characiformes	Detritivore
Bujurqui	*Satanoperca jurupari*	Perciformes	Omnivore
Cahuara	*Pterodoras granulosus*	Siluriformes	Omnivore
Carachama	*Pterygoplichthys multiradiatus*	Siluriformes	Detritivore
Chambira	*Raphiodon vulpinus*	Characiformes	Piscivore
Chio chio	*Psectrogaster rutiloides*	Characiformes	Detritivore
Corvina	*Plagioscion squamosissimus*	Perciformes	Piscivore
Curuhuara	*Myleus rubripinnis*	Characiformes	Omnivore
Denton	*Roeboides myersii*/spp.	Characiformes	Piscivore
Fasaco	*Hoplias malabaricus*	Characiformes	Piscivore
Gamitana	*Colossoma macropomum*	Characiformes	Omnivore
Huapeta	*Hydrolycus scomberoides*	Characiformes	Piscivore
Insimiracu	*Curimatella meyeri/C. alburna*	Characiformes	Detritivore
Leguia	*Auchenipterus nuchalis*/spp.	Siluriformes	Detritivore

Appendix continued

Name	Species	Order	Trophic category
Lisa	*Schizodon fasciatus*/*Leporinus trifasciatus*	Characiformes	Omnivore
Llambina	*Potamorhina altamazonica*	Characiformes	Detritivore
Macana	*Sternopygus macrurus*/*Rhamphichthys rostratus*	Gymnotiformes	Omnivore
Maparate	*Hypophthalmus edentatus*/*H. emarginatus*	Siluriformes	Detritivore
Mojarra	*Tetragonopterus argenteus*/*T. chalceus*	Characiformes	Omnivore
Motta	*Calophysus macropterus*/*Pinirampus pirinampu*	Siluriformes	Piscivore
Novia	*Parauchenipterus galeatus*	Siluriformes	Omnivore
Paco	*Piaractus brachypomus*	Characiformes	Omnivore
Paiche	*Arapaima gigas*	Osteoglossiformes	Piscivore
Palometa	*Mylosoma duriventris*/spp.	Characiformes	Omnivore
Paña/Piraña	*Serrasalmus* spp./*Pygocentrus nattereri*	Characiformes	Piscivore
Panshina	*Pellona flavipinnis*	Characiformes	Piscivore
Paje amarillo	*Pellona castelneana*	Characiformes	Piscivore
Ractacara	*Psectrogaster amazonica*	Characiformes	Detritivore
Raya	*Potamotrygon* spp.	Characiformes	Omnivore
Sabalo	*Brycon melanopterus*/*B. erythropterum*	Characiformes	Omnivore
Sardina	*Triportheus elongatus*/*T. angulatus*	Characiformes	Omnivore
Shiripira	*Sorubim lima*	Siluriformes	Piscivore
Shiruy	*Hoplosternum littorale*/*H. thoracatum*	Siluriformes	Omnivore
Shitari	*Loricariichthys* spp.	Siluriformes	Detritivore
Shuyo	*Hoplerythrinus unitaeniatus*	Siluriformes	Piscivore
Tucunare	*Cichla monoculus*	Perciformes	Piscivore
Turushuqui	*Oxydoras niger*	Siluriformes	Omnivore
Yahuarachi	*Potamorhina latior*	Characiformes	Detritivore
Yaraqui	*Semaprochilodus theraponura*	Characiformes	Detritivore
Yulilla	*Anodus* spp./*Hemiodus* spp	Characiformes	Detritivore
Zungaro achacubo	*Sorubimichthys planiceps*	Siluriformes	Piscivore
Zungaro achara	*Leiarius marmoratus*	Siluriformes	Piscivore
Zungaro alianza	*Brachyplatystoma juruense*	Siluriformes	Piscivore
Zungaro cachorro	*Platystomatichthys sturio*	Siluriformes	Piscivore
Zungaro cunchimama	*Paulicea lutkeni*	Siluriformes	Piscivore
Zungaro doncella	*Pseudoplatystoma fasciatum*	Siluriformes	Piscivore
Zungaro dorado	*Brachyplatystoma rousseauxii*	Siluriformes	Piscivore
Zungaro manitoa	*Brachyplatystoma vaillanti*	Siluriformes	Piscivore
Zungaro salton	*Bachyplatystoma filamentosum*	Siluriformes	Piscivore
Zungaro tabla barba	*Goslynea platynema*	Siluriformes	Piscivore
Zungaro tigre	*Pseudoplatystoma tigrinum*	Siluriformes	Piscivore
Zungaro toa	*Hemisurubim platyrhynchos*	Siluriformes	Piscivore
Zungaro torre	*Phractocephalus hemiliopterus*	Siluriformes	Piscivore
Zungaro zorro	*Platysilurus barbatus*	Siluriformes	Piscivore

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