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Impacts of fishing by dewatering on fish assemblages of tropical floodplain wetlands: A matter of frequency and context

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ABSTRACT

Tropical floodplain wetlands and the fish communities they support are subject to great pressure from human demands for water and aquatic living resources. In densely populated agricultural areas where such pressures are greatest, floodplain wetlands may be dewatered for the dual purpose of crop irrigation and fish harvesting. Viewed as highly destructive to fish communities, the practice is widely discouraged but remains common. We investigated the impacts of dewatering on fish abundance and assemblage structure in permanent floodplain wetlands of the lower Mekong region. Draining was carried out only in wetlands where access for fishing and water withdrawal was exclusive to individual households or groups, and where fishing was restricted to draining events. Subsequently, the impacts of draining were found to be equivalent to those of intensive fishing, rather than entirely catastrophic. Many wetlands were drained and fished repeatedly in a single dry season, with catches declining by 72% on average between consecutive events. Species richness and mean length of fish also declined with consecutive dewatering events. Fish biomass was higher in drained wetlands prior to the first and second draining events than in open access, non-drained wetlands. These surprising results suggest that draining of floodplain wetlands is not as fundamentally destructive to fish populations as is often assumed. Where fishing pressure under open access conditions is high, allocation of exclusive rights to fish and dewater wetlands can aid fish conservation as long as dewatering is carried out only once.

1. Introduction

Tropical floodplain rivers are among the most biologically diverse and productive ecosystems on Earth (Tockner and Stanford, 2002; Welcomme, 1979). Many floodplains are centres of human settlement, often leading to substantial modifications of hydrology, geomorphology and land cover as well as intensive exploitation of biological resources such as fisheries. This is particularly true for Asian floodplains which are subject to the highest average population densities and consequent extreme pressures on land, water and biological resources. These pressures threaten the biological productivity and biodiversity of the floodplains and are of high conservation concern.

Tropical floodplain environments are characterised by highly seasonal hydrology and ecology (Tockner and Stanford, 2002). Widespread flooding during and after the monsoon season gives way to dry land, with water becoming increasingly confined within depressions and channels which form characteristic permanent or semi-permanent standing waters in the form of sloughs in oxbows, meander scroll depressions, residual channels left by former courses of the river or back swamps. The smallest of these sometimes dry out completely through evaporation, while even the permanent standing waters of the floodplain become shallow (<4 m) (Welcomme, 1979).

Agricultural land use in floodplains brings with it changes in both land cover and hydrology. Many of the hydrological changes involve flood control and land drainage, resulting in a substantial net loss of wetland habitat, although in rice agriculture the duration of the flooded period may be extended by dykes that retain water in paddy fields (Nguyen Khoa et al., 2005; Tockner and Stanford, 2002). In either case, high demand for irrigation water often occurs during the dry season and may lead to draining of local wetlands (Shankar et al., 2004), however this water abstraction is seen as a threat to freshwater ecosystems (Abell et al., 2007; Hoagstrom et al., 2010).

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Fish and other aquatic animals have adapted to the hydrological seasonality of tropical floodplains by moving into flooded areas during the high water season and returning to permanent wetlands in the dry season. Based on their habitat use and migration patterns, tropical river floodplain fishes are broadly classified as 'whitefish' and 'blackfish'. Whitefish spend the low-water season in the river channels, while blackfish spend the low-water season in floodplain wetlands and are physiologically adapted to withstand adverse environmental conditions such as hypoxia often associated with such habitats (Moss, 1980; Welcomme et al., 2006). Fish abundance and biological production are dependent on both wet and dry season aquatic habitat. While biological production occurs primarily during the flooded period, dry season habitat is critical to fish survival and its availability imposes strong limits on standing stocks (Hoggarth et al., 1999; Welcomme, 1979).

Many tropical floodplain rivers support productive fisheries, often of great importance to the local human population (Hoggarth et al., 1999; Welcomme, 1979). Fishers often target migratory pathways when floods rise or recede and fish migrate in large numbers into, or out of the flooded area. At the height of the flooded period fish populations are so widely dispersed that fishing is relatively inefficient, whereas in the dry season fish are highly aggregated in permanent wetlands and may be harvested very efficiently (Craig et al., 2004).

Permanent wetlands may be open to fishing by anyone (open access), or subject to exclusive communal or individual use rights (Garaway et al., 2006; Hirsch, 1998). Exclusive access to wetland resources allows those holding the rights to regulate use of water and fisheries resources to adopt more efficient management techniques than is possible under open access. Often, wetlands under exclusive access arrangements are exploited less intensely and maintain higher standing stocks of fish than local open access wetlands (Lorenzen et al., 1998). However, such wetlands may also be subject to very intensive exploitation of both water and fisheries resources. Perhaps the most extreme form of this is fishing by dewatering. Dewatering of wetlands during the dry season is a common practice in many tropical floodplains, particularly those that are densely populated and used agriculturally (Craig et al., 2004; Hoggarth et al., 1999). Draining may be carried out exclusively for irrigation or for efficient fish harvesting, but is more often a dual purpose activity. In some regions, 'drain-in ponds' or 'trap ponds' are specifically constructed for the purpose of storing water and fish in the dry season and are eventually drained. Dewatering involves the complete drainage of a wetland or pond by bailing with hand-held baskets or using diesel pumps to remove water so that fish are stranded in the exposed muddy substrate and may be collected by hand (Welcomme, 1979). In larger wetlands, these draining operations can take days to complete and involve

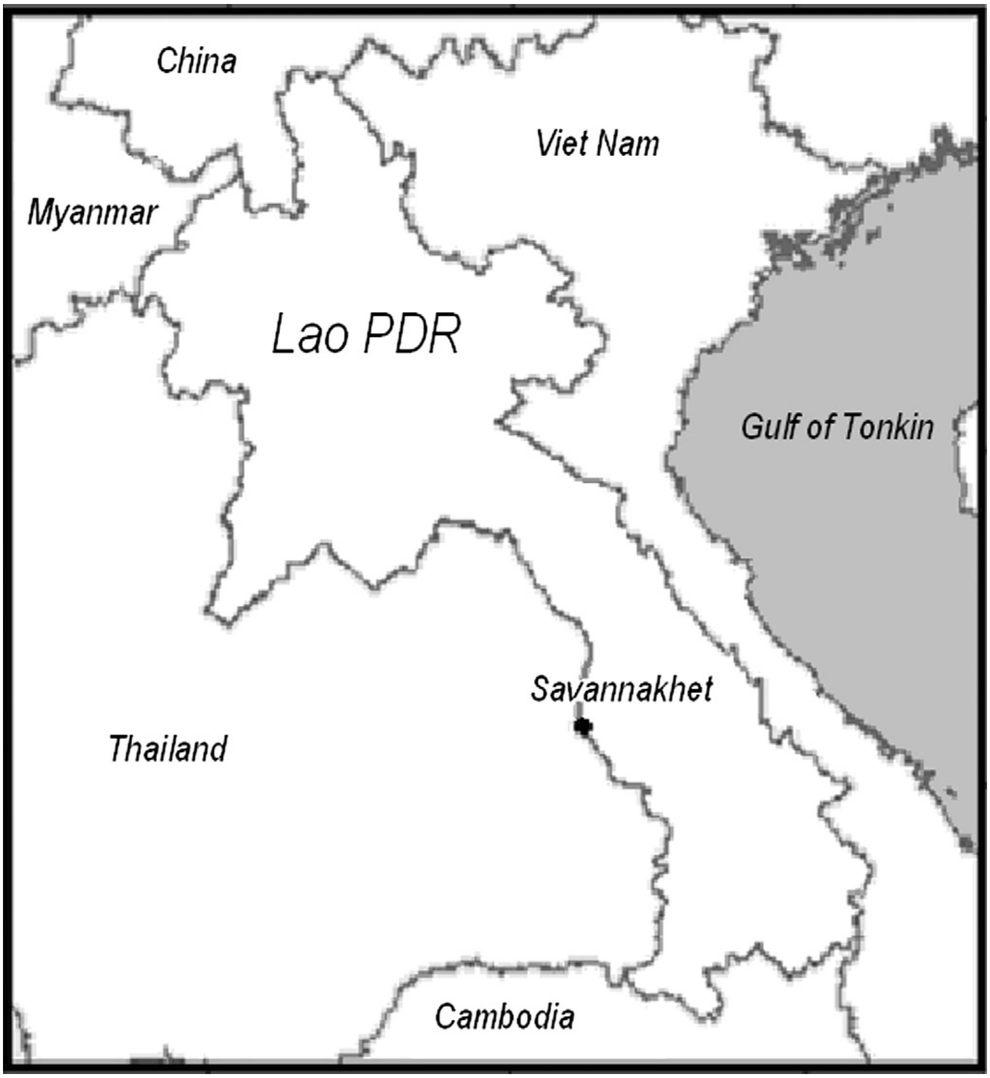

Fig. 1. Map of the study area, Savannakhet, Lao PDR.

considerable investment in fuel and labour, but may be highly profitable in terms of extending the cropping season and providing a substantial fish harvest. Permanent floodplain lakes often re-fill with water from groundwater seepage and irrigation return flows, enabling draining to be carried out multiple times in a dry season.

Dewatering represents perhaps the most intensive use of both water and aquatic biological resources in the floodplain. The practice is seen as a key threat to freshwater fishes due to its destructive impact on habitat and fish populations at a critical time of year (Cowx, 2002; Shankar et al., 2004; Welcomme, 1979). Our aim in this paper is to provide the first quantitative assessment of impacts of dewatering on fish catches, biomass and assemblage structure in order to promote greater awareness and improved decision making by stakeholders.

2. Materials and methods

The study was carried out by identifying wetlands about to be drained by local villagers and conducting experimental gillnetting prior to, and catch sampling during the dewatering events. Additional information was obtained from experimental gillnetting in wetlands that had not been drained.

2.1. Study area

The field study was carried out in floodplain wetlands of the Xe Champhone river, an important tributary of the Mekong in Savannakhet Province, southern Lao PDR (Claridge, 1996) (Fig. 1). Lao PDR has a tropical climate with an average daily maximum temperature of 31 °C and an average annual precipitation of 1500 mm, about 75% of which occurs in the monsoon season (May–October). The floodplain landscape is comprised of rice paddy (accounting for about 80% of the cultivated area), wetlands, swamp forests and freshwater marshes (Claridge, 1996; Nguyen Khoa et al., 2005; Wiszniewski et al., 2005). Fisheries resources in the area are productive and diverse, with average annual catches of about 60 kg ha^{-1} in the floodplain, consisting of over 120 known species (Nguyen Khoa et al., 2005). The main occupation of rural people is subsistence-oriented rice agriculture supplemented by other activities such as fishing and small livestock rearing (Garaway et al., 2006). Fishing is carried out year-round with peak catches obtained at the end of the wet season, however fishing is particularly important as a source of food and income in the dry season due to low agricultural labour demand and an increased risk of food insecurity. Consequently, dry season open access wetlands are subject to high fishing pressure (Garaway, 1999; Lorenzen et al., 2003).

2.2. Identification of study wetlands and collection of contextual information

Surveying took place from February to April 2008, the end of the dry season, during which time many local dewatering operations take place. Fisheries officers from every district known to have dewatering events in Savannakhet Province were informed of the study and information was requested about all intended dewatering events. All responses were followed up, resulting in the identification of 19 wetlands which were subjected to experimental gillnetting prior to, and catch sampling during dewatering. Contextual information on access arrangements and management history of each wetland was obtained through interviews at dewatering events. Direct observation was used to monitor the dewatering activities (Jackson and Ingles, 1998; Mukherjee, 1993). This took place in an involved fashion in which observers were taught methods and took part in the local fishing activities themselves to gain a better rapport with fishers and a greater understanding of the process (Chambers, 1992). Information obtained using this method has been shown to have high validity and reliability (Chambers, 1994).

In addition to the drained wetlands, experimental gillnetting data collected in 2000 for 10 non-drained wetlands in the region subject to open access for fishing were also included in the study in order to provide comparative information on fish abundance.

2.3. Dewatering catch surveys

Data collection, including the taxonomic identification of specimens, was carried out in the field by a parataxonomist from the Provincial Department of Livestock and Fisheries Section of Savannakhet. Fish were identified to species level as far as possible, sorted into 5 cm length classes and biomass was recorded using electronic scales precise to ±1 g. Once all large and medium-sized fish had been recorded, the total biomass of the remaining mixture at the bottom of fish baskets composed of very small fish (<3 cm) combined with various crustacea, water snails and sticks, was weighed. A representative sample (1–5%) of this mixture was weighed and then sorted into fish and non-fish, identified to species level and weighed again. The difference in biomass between the sorted and unsorted sample was used to estimate total species composition of the remaining mixture. This only represented a small fraction of the total biomass and ensured the procedure was rapid enough to prevent the decay of fish returned to the fishers. However due to field conditions and restrictions in time and expertise, not all samples were identified beyond genus level.

2.4. Experimental gillnetting

In order to obtain comparable estimates of relative abundance of fish in different wetlands, experimental gillnetting was carried out in all wetlands prior to dewatering. Gillnets were a standard size of 30 m total length and 1.5 m depth, composed of panels of 5 m length, each of a different mesh size (1, 2, 4, 6, 8 and 10 cm). These were constructed by a local fisherman using locally available netting. The multi-mesh nature of the gillnets aimed to prevent selectivity bias, and the long length of the nets aimed to prevent saturation effects. Multi-mesh panel research gillnets are common sampling gears which sample a range of species and sizes with low vulnerability to saturation compared to other gear types. Experimental fishing effort was standardised to one multimesh gillnet, randomly placed, set at 1800 h and collected at 0600 h by experienced local fishermen. Individual fish were extracted and identified to species level. Electronic scales, precise to ±1 g were used to measure the biomass of individuals of each species. Total body length was measured into 5 cm length classes.

2.5. Statistical analyses

Effects of dewatering frequency on total catch, length distribution, assemblage structure and diversity indices of catch and experimental gillnet CPUE were explored using a combination of graphical methods, linear and non-linear regression modelling and multivariate analyses.

The similarity of assemblages having undergone differing frequencies of dewatering events was tested using catch biomass at different taxonomic levels. Data were standardised to represent the relative biomass of each taxon and square root transformations were performed prior to implementation of the Bray–Curtis similarity measure (Bray and Curtis, 1957). This transformation was performed to down-weight the effect of the very abundant species which was important as samples were often dominated by a few species. This type of 'intermediate' transformation is likely to give the best balance between a ‘narrow view’ of community structure based only on the abundances of a few dominant taxa and a ‘wide view’ in which too much weight is given to the occurrence of the rarest taxa (Oslgard et al., 1997). An analysis of similarity (ANOSIM) was then performed in which average rank similarities within and between groups were compared in order to generate a test statistic ‘*R*’. This was used as a measure of separation between wetland assemblages at different frequencies of dewatering using a randomisation test for significance (Clarke and Warwick, 1994).

Biodiversity (of genera) was compared among wetlands in terms of biomass using both the Shannon (H') and Simpson ($1\text{-}D$) Indices. The Shannon diversity index is more sensitive to sample size and is weighted towards species richness (Sanjit and Bhatt, 2005), whereas Simpson’s Index is recommended for its ability to consistently rank assemblages when sample size varies (Magurran, 2004). The measures of evenness associated with Shannon and Simpson diversity were also used (J' and E respectively). The difference in mean genus richness, defined as the mean number of genera, was compared among wetlands of each dewatering frequency. Assemblages were also analysed for similarity of trophic group structure, and since size is an important indicator in characterising fish assemblages (Layman et al., 2005; Welcomme, 1999), composition was also analysed in terms of length structure, following an approach used by Benfield et al. (2008). One wetland was omitted from the community analyses as although total biomass information was available, due to the large biomass and limited staff numbers during the particular study period, fish had not all been individually classified, so could not be used in the community analyses.

3. Results

3.1. Fishing by dewatering and its context

A total of 19 wetlands subject to fishing by dewatering were included in the study (Table 1). These ranged in surface area from 80 m^2 to 21,000 m^2 (average 2000 m^2) and in mean depth from 0.3 to 2 m (average 0.8 m). Dewatering was generally conducted for the combined purposes of fishing and irrigating dry season rice paddy. All wetlands where fishing by dewatering was observed were subject to exclusive access rights vested in individual households, groups of households or in one case, a whole village. In some cases the wetlands were on private land while in others households or groups had rented them from the village for the dry season, allowing them exclusive use of water and aquatic resources during this period. In these wetlands, fishing by outsiders was not permitted and fishing by holders of exclusive rights occurred only, primarily in connection with the dewatering events. Dewatering often involved sharing inputs and benefits between households. Benefits were gained for one or two families or for an entire village, e.g. a wetland previously kept as a reserve was dewatered in order to provide funds for the construction of a road through the village. While ten of the wetlands studied had not previously been dewatered in the season, nine had already been dewatered one or more times previously in the same season.

Table 1
Waterbodies surveyed, location and morphology.

Waterbody	District	Village	Area (m^2)	Depth (m)
Hong Lali 1	Xonbouly	Dong Boun	560	0.60
Hong Lali 2	Xonbouly	Dong Boun	120	0.50
Hong Lali 3	Xonbouly	Dong Boun	500	0.60
Hong Nong Sim	Xonbouly	Dongnaer	1200	0.80
Nong Puae	Xonbouly	Nong Pham	600	1.50
Nong Thomkaer	Champhone	Haumeuang	1105	0.34
Nong Kam Deng 1	Champhone	Dorn Yeng	80	1.50
Nong Keo	Champhone	Dorn Yeng	210	0.65
Hong Lee 1	Xonbouly	Nong Pham	16,000	1.20
Nong Phoem	Champhone	Dorn Yeng	600	0.60
Nong Dernkingua	Xonbouly	Nong Pham	21,000	2.00
Nong Kam Deng 2	Champhone	Dorn Yeng	800	0.83
Nong Lek	Champhone	Dorn Yeng	400	1.00
Nong Gee 2	Champhone	Dorn Yeng	600	0.30
Nong Gee 3	Champhone	Dorn Yeng	600	0.55
Nong Boun manii	Champhone	Sekhun Tay	1500	0.65
Nong Sink 2	Champhone	Dorn Yeng	600	0.90
Nong Gee 1	Champhone	Dorn Yeng	300	1.15
Nong Sink 1	Champhone	Dorn Yeng	225	0.45

Dewatering activities ranged from a few hours of activity for a single family to a week’s work for a village. Handheld diesel tractor engines, commonly used for farming activities, were engineered to pump water from the wetland into the irrigation channels of the adjacent rice fields. Mechanical breakdowns were observed frequently during the dewatering processes, so overnight dewatering was less common and the draining process was fairly slow. Fishers (men, women and children) waded into the water as it became shallower with baskets and occasionally scoop nets which were more frequently used to place over the pump outflow to ensure small fish were also caught. Fish were caught by hand from the water, and later mud, in an activity locally known as ‘*ngum pa*’ (Fig. 2) and collected in carefully designed baskets to prevent escape. The wetlands were pumped until only mud remained and every fish that could be seen or felt by hand up to approximately half a metre deep in the mud was taken from the wetland. Water snails and shrimp were also collected.

3.2. Impacts of draining on fish catches and community structure

Catches at each dewatering event declined with increasing frequency of dewatering. A constant decline rate model with decline rate of 72% (95%CI 47–86%) was highly significant ($p < 0.001$; Fig. 3a). This implies that where a wetland is dewatered repeatedly, 72% of the cumulative catch is obtained at the first event and over 92% in the first and second event (Fig. 3b).

The assemblages were mainly composed of fish of the blackfish guild with a high proportion of air-breathing species. The species with the highest total biomass density was the snakehead *Channa striata* (205.7 g^{-3}), present in 16 of the 18 sites subject to community analyses. The clustering of groups based on the relative genus abundance was significantly related to the number of dewatering events, showing a moderate degree of separation between assemblages at different frequencies of dewatering (ANOSIM $R = 0.37$, $p < 0.01$). The distinction between groupings declined with increasing taxonomic level (family: $R = 0.29$, $p < 0.05$). Carnivores were the dominant trophic group in every wetland, comprising a mean of 80% across all wetlands and there was no significant difference between groups of differing dewatering frequencies in terms of trophic structure ($R = 0.13$, $p = 0.15$).

There were 51 genera recorded in total from all wetlands, with a maximum of 27 genera found in a wetland subject to only one dewatering event. This wetland also had the highest number of families represented (14). Regression analysis was used to determine whether there was a correlation between genus richness, diversity, evenness and the frequency of dewatering events for each wetland during the season (Fig. 4). There was a significant decrease in the mean number of genera ($p < 0.05$), a significant increase in Simpson’s diversity index ($1\text{-}D$, $p < 0.001$) and a significant increase in Pielou’s measure of evenness (J', $p < 0.01$) with increasing dewatering events. However, there was no significant change in Shannon diversity (H') or Simpson’s evenness (E) with frequency of dewatering events. As Pielou’s measure of evenness and Simpson’s diversity both increased with increasing frequency of draining, this suggests that samples were less dominated by few genera in more frequently dewatered wetlands.

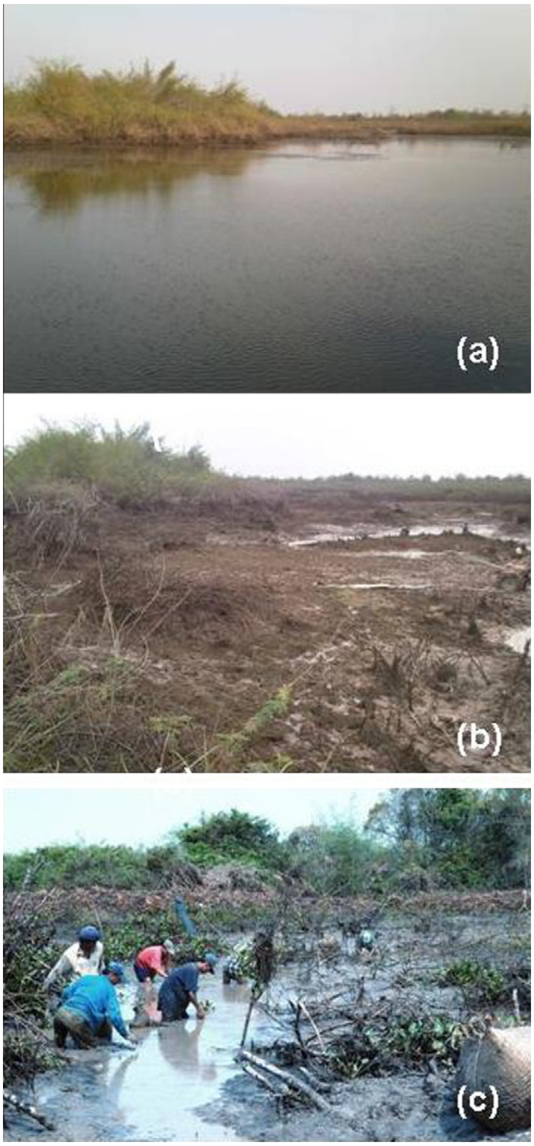

Fig. 2. Floodplain lake before (a), after (b) and during (c) draining.

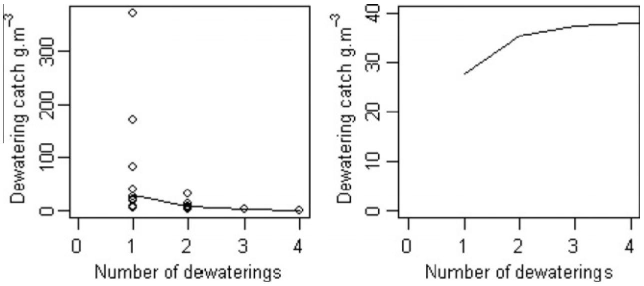

Fig. 3. (a) Biomass and (b) cumulative biomass of fish caught per unit volume of water at each frequency of dewatering events.

An analysis of the length structure of fish among wetlands of differing dewatering frequencies indicated that a greater proportion of large species were found in wetlands that had been dewatered fewer times during the season (Fig. 5). However, the single waterbody that had been drained four times did not fit this trend, but was instead composed of similar percentages of four species across a range of sizes (33% *Trichopsis vittata*, 26% *Esomus metallicus*, 19% *Toxotes microlepis*, 22% *Oxyleotris marmorata*).

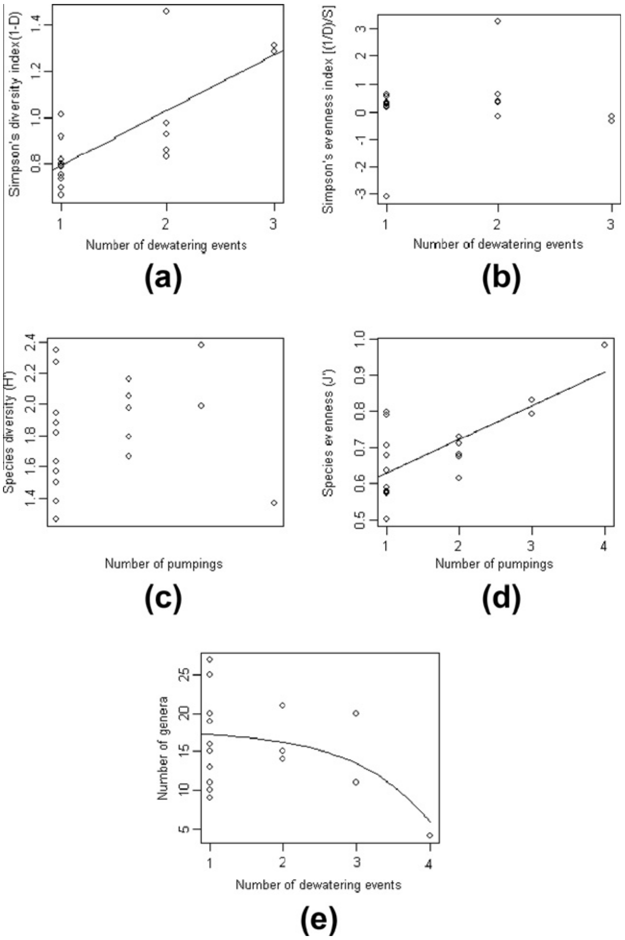

Fig. 4. Correlations of (a) Simpson's diversity (1-*D*), (b) Simpson's evenness ([1/*D*]/*S*), (c) Shannon diversity (*H*), (d) Shannon evenness (*J*) and (e) genus richness ($S = a + \exp(b * \text{dewatering events})$) with frequency of dewatering events (biomass was too low to calculate Simpson's index for the wetland subject to four dewatering events).

Assemblages were also analysed with respect to the length of individuals across all species. The smallest length classes dominated the catch at each frequency of draining events, however the size range decreased with each subsequent draining event (Fig. 6) and there was a significant negative correlation between the number of dewatering events and mean length of fish ($p = 0.05$). In addition to the significant trend in mean length of all individuals, the mean length composition (untransformed) of fish genera also differed significantly with the number of dewatering events (ANOSIM $R = 0.31$, $p = 0.02$). The separation between groups in terms of mean genus length was not as strong as the separation in terms of genus abundance, suggesting the observed trends in declining size was mainly attributable to a change in genus composition rather than to a change in the size of those genera.

3.3. Experimental gillnet CPUE in drained and non-drained wetlands

Experimental gillnet CPUE prior to dewatering declined with increasing number of dewatering events, albeit at a lower rate of 58% (95%CI 8–81%) per event than that estimated for catch decline (72%). A comparison of experimental gillnet CPUE between non-dewatered wetlands open to fishing and wetlands subject to exclusive use rights, restricted fishing and dewatering showed that average CPUE was higher in the latter wetlands except those that had been dewatered more than once (Fig. 7). These interesting

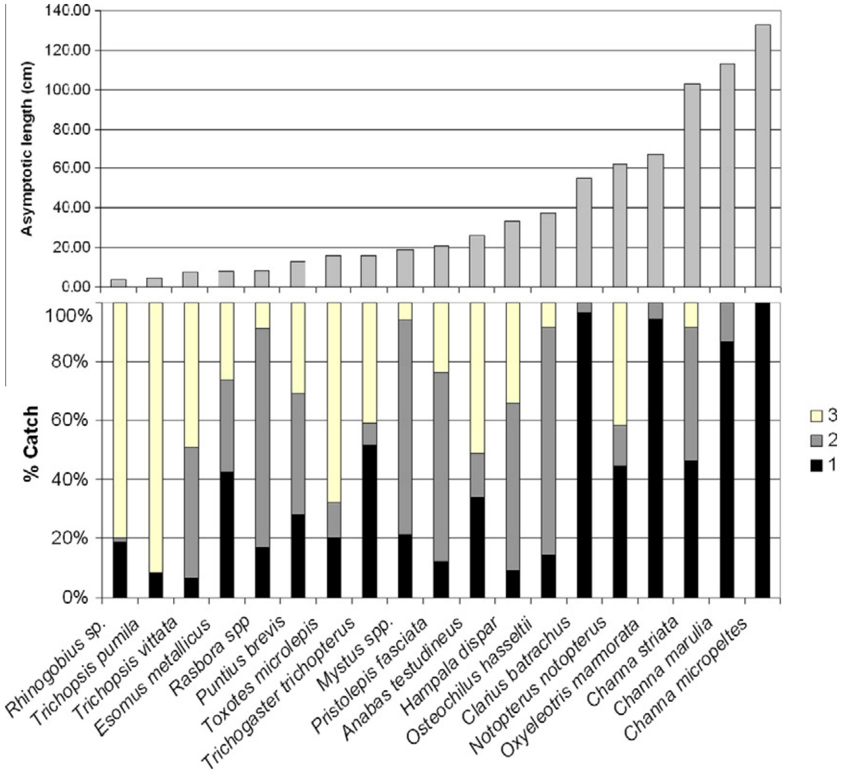

Fig. 5. Species by maximum length (source fishbase.org) and mean relative biomass of species at each dewatering frequency (>2%) as a percentage of all dewatering groups.

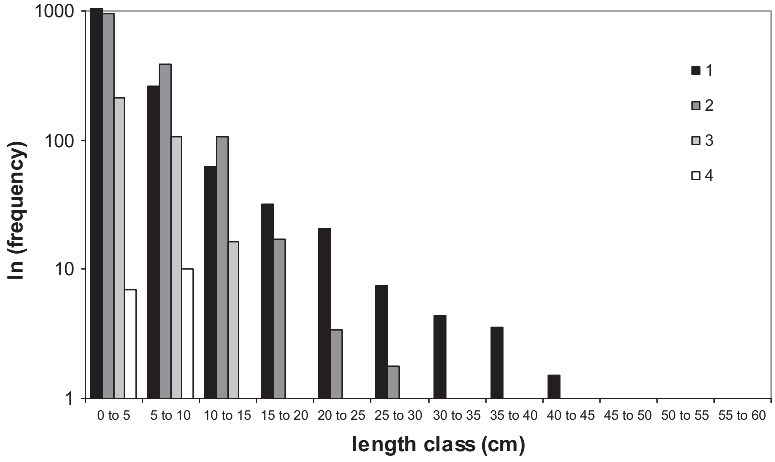

Fig. 6. Mean length–frequency distribution of fish caught at each number of dewatering events.

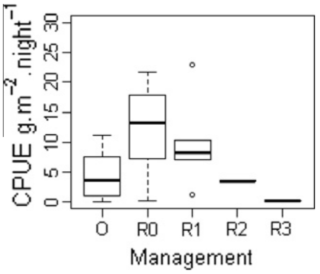

Fig. 7. Relative abundance (measured by experimental gillnet CPUE) of fish in open access (O) and restricted access lakes prior to first draining (*R*0) and drained once, twice or three times (*R*1, *R*2, *R*3), *n* = 29.

results indicate the importance of the social access arrangements associated with the fishing method.

4. Discussion

4.1. Impacts of fishing by dewatering on catches and fish assemblages

Perhaps the single most important and surprising result of our study is that the impacts of fishing by dewatering were not as catastrophic as has generally been assumed and that wetlands can indeed maintain fish populations and yield catches even after multiple dewatering events. The biomass available after successive drainings is maintained through the survival of fish in the water and mud remaining at the end of dewatering, the survival of eggs or fry of very early spawners, and possible immigration of fish from the surrounding rice paddies and their subsequent growth (Welcomme, 2001). Given the frequency with which some wetlands dry out completely and the borderline status of many wetlands between permanent and temporary, it has been suggested that recolonisation is an essential factor in the maintenance of floodplain lake fish communities (Jackson et al., 2001). Growth is generally slowest during the dry season and often ceases completely, however there are many exceptions including the amphibious fishes such as the obligate air-breathing Channids and labyrinth fishes, e.g. *Anabas testudineus* and *Trichogaster trichopterus* (Sayer, 2005) which due to their ability to utilise atmospheric oxygen have the ability to continue feeding throughout the dry season (Welcomme, 2001). Other species such as the catfish *Clarias batrachus* are facultative air-breathers, supplementing oxygen uptake by cutaneous respiration and using gills as sites of aerial gaseous exchange (Sayer, 2005). Many of these fishes, such as Channids and catfish are also adapted to burrowing in mud. These adaptations to desiccation may allow many fish to survive dewatering events. Catches appear to decline slightly more rapidly than stock biomass (as indicated by CPUE) in consecutive dewatering events, perhaps indicating that there may be a stock segment that is fairly inaccessible to fishing by draining.

All wetlands were dominated by carnivores, which is likely to be attributable to the strong inter-specific interactions that can shape assemblage structure when fish are increasingly concentrated during the dry season (Rodriguez and Lewis, 1994). Despite this dominance of carnivores and fish from the 'black' or lentic fish guild (Welcomme et al., 2006), there were significant differences in the composition of genera among wetlands subject to different frequencies of dewatering, with those assemblages in more frequently drained wetlands composed of smaller genera and smaller individuals. This decreasing trend in body length corresponds to the well-documented fishing-down process (Allan et al., 2005; Welcomme, 1999). Impacts of fishing by dewatering are akin to those of other methods of fishing and dependent on intensity (in this case, frequency of dewatering).

4.2. Fishing by dewatering vs. other fishing methods

Fishing by dewatering is perceived by rural people as an efficient way of harvesting fish and irrigating crops in the dry season. It is for this reason that people use this practice in wetlands on their own land or in public wetlands to which they have obtained exclusive rights through rental arrangements. However fishing by dewatering is worthwhile only if stocks have not been depleted prior to dewatering. Hence fishing in wetlands destined to be dewatered is restricted to holders of exclusive rights and even they will tend to minimise their own fishing prior to dewatering. Therefore fish stocks in such wetlands are effectively protected from exploitation until dewatering occurs and may remain at a higher abundance even after the 72% removal associated with dewatering than stocks in wetlands that are not dewatered but subject to open access fishing. Our results suggest that this is indeed the case in the floodplain wetlands of the lower Mekong, where fishing intensity in open wetlands is extremely high (Claridge, 1996; Lorenzen et al., 1998).

4.3. Implications for management

Our results show that fishing by dewatering has major impacts on fish biomass and assemblage structure consistent with known effects of intensive fishing, but is not catastrophic. Indeed, fishing by a single draining event may provide better outcomes both for fishing-farming households and for conservation than open access fishing where exploitation pressure is high. This suggests that fishing by dewatering should not be wholly discouraged but managed to a sustainable level. Our results provide a solid basis for informing stakeholders, management and policy on sustainable levels of fishing by dewatering. Because the opportunity to engage in dewatering and associated, efficient fish harvesting is a major incentive for seeking exclusive access rights to wetlands, the practice may even be promoted (at a sustainable level) in areas where pressure on open access resources is so high it leads to less sustainable outcomes.

Fishing once by dewatering efficiently harvests about 2/3 of the standing stock, leaving about 1/3 in place, and having only moderate impacts on assemblage composition and size structure. Any subsequent fishing/draining events provide much lower catches for the same effort and are thus relatively inefficient from a fisheries perspective while simultaneously having extremely negative conservation outcomes. Multiple dewatering events therefore take place primarily for irrigation and results suggest the practice should be highly discouraged for both fisheries management and conservation reasons. Where repeated draining is necessary for irrigation purposes, it may be best to avoid intentional harvesting of fish and to retain a minimum water level in the wetland. This is a practical and plausible alternative as incomplete dewatering of dry season wetlands already occurs in some areas of Savannakhet as well as in other rice–fish farming areas such as Malaysia, where fish are intentionally left behind to provide stock for the following season (Halwart and Gupta, 2004). Encouragement of this practice is likely to be beneficial for fisheries management purposes and conservation.

Rapidly increasing human populations has led to the intensity of natural resource use in many tropical floodplains. There has been an increasing occurrence of dry season water abstraction for dry season rice irrigation in areas such as Bangladesh (Shankar et al., 2004) and a government push for Lao PDR to do likewise. Nonetheless, the economic realities of pumped irrigation (highly priced fuel and fertiliser and low priced rice) combined with the mechanical failure of small, transportable diesel pumps, appear to have contributed to a general decrease in the area of dry season rice being cultivated Lao PDR in recent years, so imminent increase in the practice of draining for irrigation (which is associated with the negative impacts of multiple drainings) is unlikely at present (Shoemaker et al., 2001; World Bank, 2008).

Wetlands constructed specifically to attract populations of wild fish at the end of the wet season and to maintain them during the dry season until fishing by dewatering (e.g., trap or drain in ponds, Amilhat et al., 2009; Welcomme, 1979) are likely to benefit conservation at landscape level, given that the practice of a single draining removes only about 2/3 of the standing stock. However, if there is a change in the social access arrangements and the practice begins to take place in open access wetlands, there will be substantial cause for conservation concern.

Permanent wetlands form an important and highly connected part of the river-floodplain ecosystem. The range of management arrangements and operational rules is broad, and fishing by dewatering forms just one method of resource use within these (Garaway et al., 2006). Impacts of dry season fishing and water management practices in permanent wetlands cannot be fully assessed in isolation from the management practices taking place during the flooded season and in other wetland areas (Halls et al., 2007; Hoggarth et al., 1999; Welcomme, 1979). Our study demonstrates that fishing by dewatering need not be more of a concern than the intensive fishing without dewatering found under open access conditions and under certain conditions, may be less of a concern. We note, however, that the impacts of dry season fishing in permanent wetlands on annual fisheries yields and fish biodiversity are poorly quantified and that no safe biological limits have been established. We encourage further studies to evaluate impacts and establish limits to exploitation and drainage at the landscape level.

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