Importance of different primary producers in supporting a mangrove fish community in Sikao Creek, Thailand

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ABSTRACT
Stable carbon and nitrogen isotope analyses were used to study the importance of different primary producers for a trophic support of a fish community in Southern Thailand. These data were combined with results from gut content analysis. Based on gut content analysis the fish species were divided in 6 different trophic groups. The planktivorous fish had the highest average $\delta^{13}C$ values indicating that they rely mostly on phytoplankton production; however the other trophic groups had lower average $\delta^{13}C$ values. This combined with IsoSource model results provides indications that the mangrove tree production plays a greater role in supporting the fish community than documented in other locations. We explain this by Sikao Creek being isolated from other coastal habitats with alternative primary food source leading to an increased mangrove production importance.

Keywords: Mangrove estuary, food webs, stable isotope analysis

INTRODUCTION
A range of scientists during the last decades have agreed that mangrove habitats are highly productive ecosystems nutritionally supporting populations of commercially important fish species (e.g. Robertson and Duke 1990). In order to clarify the exact role mangrove habitats play in the terms of trophic support it is crucial to quantify the importance of different primary sources of nutrition for the fish associated with mangrove habitats (e.g. Marguillier et al 1997). The first researchers that addressed this issue came to a conclusion that the estuarine food webs are primarily supported by a mangrove based resource pool (Odum and Heald 1975). However during the last decades several authors have shown that the role of mangrove tree production in supporting the estuarine food webs is overestimated and that other primary sources of nutrition may be more important than mangrove trees themselves in supporting coastal fisheries (reviewed in Layman 2007). A common and very useful approach often used to clarify such questions is combining stable isotope with gut content analysis.

Stable isotope analysis uses the fact that the stable isotope ratios (C and N) vary in between different primary producers. In the case of C consumers are assumed to keep the isotopic signatures of the original source of carbon allowing estimating the relative importance of each primary food source in supporting the organism in question. In the case of N it has a relatively fixed fractionation ratio (around 3‰) with each trophic level thus allowing establishing the position of an organism in the food web in question (Bouillon et al 2008). Gut content analysis in its turn allows direct observation to determine the contents of short - term diet of fish (e.g. Marguillier et al 1997). Seeing the prey composition and concurrently following the flow of carbon through a foodweb allows understanding which of the ingested food items are actually assimilated thus being the most important in sustaining the fish community in question.

There have been few studies reported from Southeast Asia and a model explaining the importance of different mangrove habitat's primary producers in supporting the fish populations has yet to be demonstrated. The objective of this study was to clarify the role of different primary producers in supporting a fish community in a tidal mangrove creek in the south of Thailand.

METHODS
Sampling was conducted in Sikao Creek, a mangrove estuary in the South of Thailand (Fig.1.). The study took place in December 2009.

Sampling was performed in a mangrove creek 1.5 km from a shallow coastal bay (Fig.1.) with no seagrass meadows or coral reefs in near vicinity. In the beginning of the study mangrove leaf samples were collected for stable isotope analysis. The fish were sampled using a trap net and a beach seine. Up to 10 individuals from each available fish species were collected and placed on ice slurry immediately. Additionally potential prey items were collected for stable isotope analysis. Afterwards the material was transported to the laboratory, fish gut contents extracted and placed in formalin and a piece of white muscle of fish, crabs, and shrimp cut out and dried for stable isotope analysis. Further on the items of the gut contents of the fish were identified to the lowest possible taxon and their relative volumes estimated.

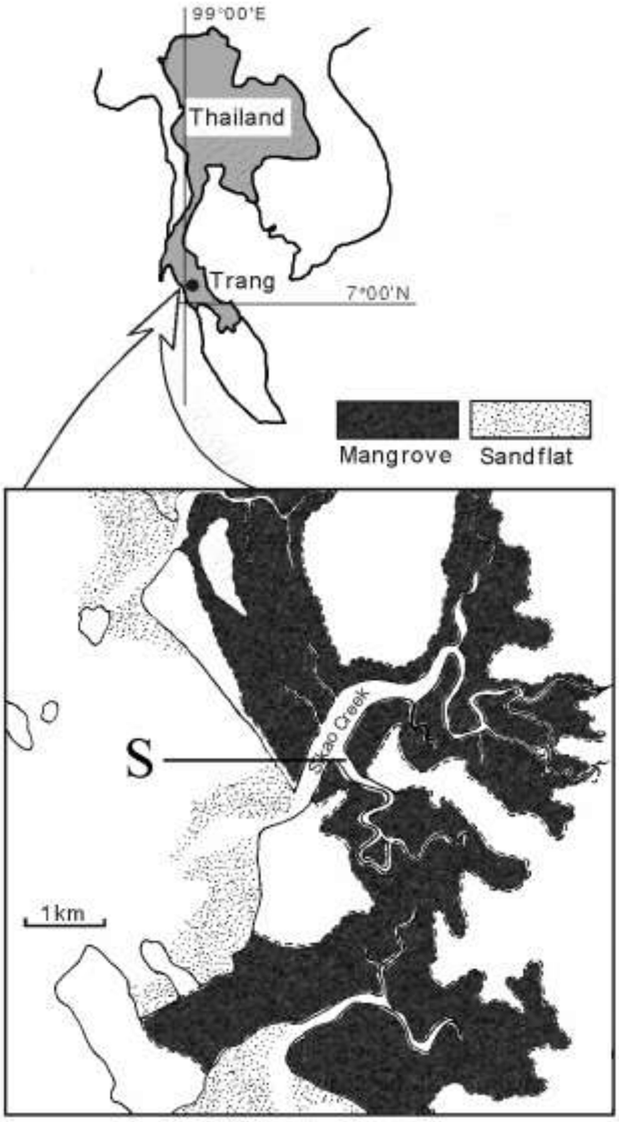

Figure 1. Map of Sikao Creek. S indicates sampling location.

Stable isotope ratios of carbon and nitrogen were measured by a continuous-flow isotope-ratio mass spectrometer with an elemental analyzer. Carbon and nitrogen isotope ratios were expressed in the conventional delta notation ($\delta^{13}C$, $\delta^{15}N$ relative to standard reference materials (V-PDB for $\delta^{13}C$, and atmospheric N2 for $\delta^{15}N$).

The importance of each primary food source in supporting the fish species was tested using the IsoSource model (Phillips and Gregg, 2003).

RESULT

Fish gut content analysis

In total 455 individuals representing 20 species were analyzed. Thirteen different food types were distinguished in the gut contents. Based on the cluster analysis the community was divided in 6 trophic groups.

Stable isotope ratios of primary producers and fish food items

The primary organic carbon sources included 3 species of mangroves, phytoplankton and microphytobenthos dominated by benthic diatoms (Kon et al 2007). Mangrove leafs had the lowest average $\delta^{13}C$ values of the available producers (-28.78 ± 2.66 ‰). Isotopic data from the same study site (Kon et al 2007) showed that phytoplankton (-23.1 ± 0.8 ‰) and phytobenthos (-18.2 ± 0.6 ‰) $\delta^{13}C$ values were relatively enriched (Fig. 2.).

Nitrogen isotope ratios within and between the primary food sources were variable ranging from 1.2 ‰ for phytobenthos and 1.7 ‰ for mangrove leaves to 4.8 ‰ for phytoplankton.

Stable isotope ratios of the fish community

The average $\delta^{13}C$ ratios for fish species covered a wide range, varying from -20.45 ‰ for *Yongeichthys nebulosus* to -26.24 ‰ for *Ambassis interruptus.* For most of species within the trophic groups there was little variation in $\delta^{13}C$ values (Fig. 2.). Stable nitrogen ratios, which are indicative of trophic levels, varied from 6.43 ‰ for herbivorous *Amoya moloanus* to 11.43 ‰ for carnivorous *Stronglyura stronglyura*. Herbivores had the lowest average $\delta^{15}N$ value of 7.5 ‰ and carnivores the highest of 10.08 ‰. For different species within most of the trophic groups there was little variation in $\delta^{15}N$ values (Fig. 2.).

Potential contribution of different primary food sources to nutrition of the fish community.

The IsoSource model showed that phytoplankton provided 0 – 86 % of primary nutrition for the different fish species, mangrove and phytobenthos production contributed 0 – 70%.

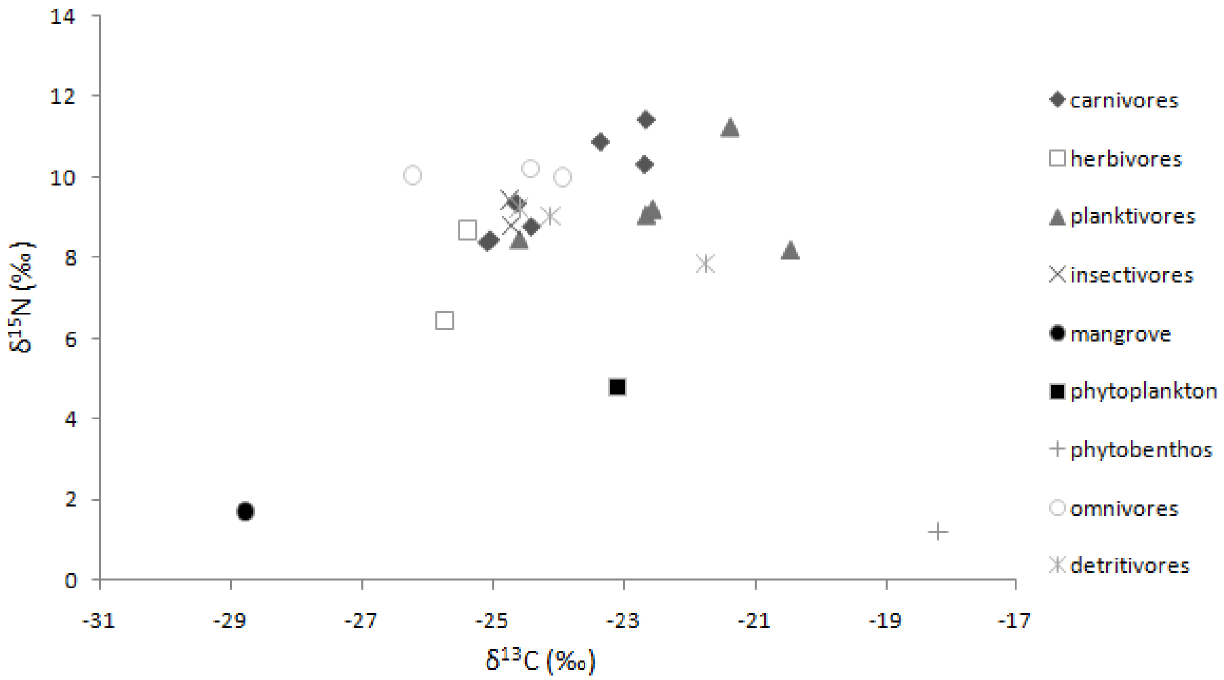

Figure 2. Stable isotopic signatures of primary producers and different feeding guilds of fish. Each symbol represents a different species

DISCUSSION

The isotopic values of potential carbon sources supporting the fish community in Sikao Creek were within the range reported by several authors from other mangrove habitats (e.g. Thimdee et al 2008, Abrantes and Sheaves 2010). The signatures were well separated in $\delta^{13}C$ values making it feasible to use this data for finding their potential contribution in trophically supporting the fish species analyzed.

In the group of carnivorous fish *Acentrogobius viridipunctatus*, *Butis butis*, *Apogon hyalosoma* and *Tetraodon sp.* had low $\delta^{13}C$ values of around -25 ‰ indicative of high mangrove material contribution to their diets. The gut contents data showed that these species fed mostly on mangrove invertebrates which are known to derive their diets from mangrove material (Kon et al 2007). The IsoSource model gave further proof that mangrove material made an important contribution to the diet of this group as it showed that mangroves provided 35 – 54 % of primary nutrition. The important dietary contribution of phytoplankton and microphytobenthos derived material can be explained by the carnivores feeding also on shrimp and fish which had higher $\delta^{13}C$ values and are known to feed on varied diet (Abrantes and Sheaves 2010). For *Lutjanus russellii* and *S. strongylura* $\delta^{13}C$ values were less negative probably because of their selectively feeding on shrimp and fish. However, the values for all the species in this group were lower than found by other studies on similar species from mangrove habitats (Abrantes and Sheaves 2010). This was the case also for the omnivorous fish. *A. interruptus* had the lowest $\delta^{13}C$ value and IsoSource suggested important contribution of mangrove carbon. The fish was feeding mostly on isopoda which to our knowledge has not been reported in the literature but they are assumed to derive their diets mostly from mangrove material (Si et al 2002) explaining the very low $\delta^{13}C$ values. *Ambassis vachellii* and *Thryssa hamiltonii* also had relatively low $\delta^{13}C$ values. Their gut contents revealed that two of the dominant food items for these species were polychetae and crab zoeae. Polychetae are known to be feeding on benthic, possibly mangrove derived material (Nyunja et al 2009). There is no data available on isotopic values of crab zoeae, however we assume that they were close to those of adult crabs which in many cases depend on mangrove production (Kon et al 2007). This provides explanation for the relatively low carbon isotopic values and the observed important contribution of mangrove carbon for the two species. *A. vachellii* and *T. hamiltonii* fed also on other, mostly planktonic food objects explaining the important contribution of plankton derived material and the relatively higher $\delta^{13}C$ values. The group of planktivorous fish was characterized by the most varied carbon isotopic values. *Cynoglossus puncticeps* had the lowest $\delta^{13}C$ value in this group. Unfortunately very little information on the feeding habits of the species was obtained as only 4 fish had small quantities of food items in their guts.

However, the available literature data (Fishbase: http://fishbase.org) and the results from running the IsoSource model suggest that the fish is a benthic feeder depending mostly on mangrove derived material explaining the low carbon isotopic value. *Neostethus lankesteri* and *Oryzias javanicus* were feeding exclusively on zooplankton providing explanation for the $\delta^{13}C$ value being very close to that of zooplankton and the importance of phytoplankton derived material in their diet suggested by the IsoSource model. The results suggesting large possible contribution of phytobenthos derived material for *Y. nebulosus* agree with the observed relatively high carbon isotopic value, which is close to that of phytobenthos. This could be caused by the species feeding mostly on benthic harpacticoid copepods or other benthic crustaceans deriving their diets from benthic microalgae, however the observed very small amount of food items from the limited amount of analyzed fish make our gut content data unreliable. Generally the observed $\delta^{13}C$ values for planktivorous fish were lower than reported before by other authors (Nyunja et al 2009) suggesting an important dietary contribution of mangrove derived material. In the case of insectivores, herbivores and detritivores carbon isotopic values were also lower than expected from literature data and an important contribution by mangrove material was suggested. This can possibly be explained by the greater part of insects in the mangrove habitats deriving their diets from mangrove leafs. This is probably the same for herbivorous and detritivorous fish as most of the plant material as well as detritus is mostly derived from mangrove material (Kon et al 2007). Our results for all the fish species and trophic groups showed enrichment in $\delta^{15}N$ values with increasing trophic level. As expected from the literature (e.g. Abrantes and Sheaves 2010) and our gut content data the highest $\delta^{15}N$ values were observed for the piscivorous fish and the lowest for the strictly herbivorous *A. moloanus*.

Most of the previous studies have stated that mangrove production is unimportant in supporting coastal fish communities (Layman 2007). The gut content data for majority of the species in our study was consistent with the information available in the literature (e.g. Marguillier et al 1997). However the $\delta^{13}C$ values were clearly more depleted than reported by previous studies and the IsoSource model in many cases indicated a relatively important mangrove production contribution in trophic support of the analyzed fish species. In most of the other locations where similar studies have been conducted mangrove forests are usually just one element in a diverse, well connected habitat mosaic and at least one other coastal habitat (e.g. seagrass meadows, coral reefs) providing a major source of primary production besides mangrove leafs, phytoplankton and microphytobenthos is located near a study site (e.g. Marguillier et al 1997). In our study site however the creek opens to a shallow, sandy bay with the closest seagrass or coral reef habitats located far from Sikao creek (see Methods). Thus we suggest that the importance of mangrove tree production in supporting estuarine food webs is linked to the structure of a habitat mosaic at the exact location in question. As Sikao creek is “isolated” from other coastal habitats and has only three main sources of primary production we hypothesize that the whole food chain is more mangrove dependent explaining the relatively increased importance of the tree production in supporting the fish community.

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