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Investigations on the feeding behavior of juvenile milkfish (*Chanos chanos* Forsskål) in brackishwater lagoons on South Tarawa, Kiribati

Nahrungswahlverhalten juveniler Milchfische (*Chanos chanos* Forsskål) in Brackwasserlagunen auf South Tarawa, Kiribati

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Summary: This study evaluated the feeding behavior of the milkfish (*Chanos chanos* Forsskål) in extensively managed brackishwater lagoons on South Tarawa, Kiribati (Central Pacific) in August 1998. Feed intake, dietary overlap, fish condition and morphometric intestine parameters were determined. The daily ration of fish was estimated using the "modified Bajkov model". Fish stomach content did not differ significantly between samples from day and night, but prey preferences showed significant differences ($p < 0.05$). Results were compared with a data set of juvenile milkfish from the Philippines raised under similar conditions.

Keywords: milkfish (*Chanos chanos*), fish condition, feeding behavior, brackishwater lagoons, Kiribati

Zusammenfassung: Diese Studie untersuchte das Nahrungswahlverhalten von Milchfischen (*Chanos chanos* Forsskål) in extensiv bewirtschafteten Brackwasserlagunen auf South Tarawa, Kiribati (Zentral Pazifik) im August 1998. Nahrungsaufnahme, Nahrungsüberlappung, Fisch Kondition und morphometrische Parameter des Verdauungstraktes wurden bestimmt. Die Tagesration der Fische wurde mittels eines Mageninhaltsmodelles ("modifiziertes Bajkov Modell") berechnet. Der Mageninhalt der Fische, die während des Tages und während der Nacht gefangen wurden, zeigten keine signifikanten Unterschiede. Es konnten jedoch signifikante Unterschiede ($p < 0.05$) für bestimmte Nahrungskomponenten mit Hilfe von Nahrungswahl-Indices ermittelt werden. Die Ergebnisse wurden mit Daten von juvenilen Milchfischen verglichen, die auf den Philippinen unter ähnlichen Bedingungen gehalten wurden.

Schlüsselwörter: Milchfisch (*Chanos chanos*), Fisch Kondition, Nahrungswahlverhalten, Brackwasserlagunen, Kiribati

1. Introduction

Chanos chanos is the sole species in the family Chanidae, which belongs to the order Gonorynchiformes. The milkfish occurs in the Indo-Pacific region within the 20°C winter-surface isotherm and its occurence is also closely related to the abundance of reef corals (Bagarinao 1991). Milkfish production is widely spread in the Asian-Pacific region. The importance of milkfish to the livelihood and nutrition of the Asian-Pacific people is evidenced by the enormous amounts of land, water and human resources involved in milkfish culture. Nearly 750,000 ha of ponds and inland waters are utilized for milkfish culture in that region. Most milkfish are produced in South-East Asia by Indonesia, the Philippines and Taiwan. Less is known about milkfish production in the small micronesian states in the Central Pacific, where it is becoming increasingly important (FAO 2000). Crear (1980) published data about reproduction of milkfish in hypersaline ponds on Christmas Island (Kiribati). Hiatt (1944) reported size-selective feeding of juvenile milkfish in Hawaiian fish ponds, while Sumagaysay (1994) described the intake of natural food in milkfish in Philippine inland waters. However, there are no data on feeding behavior of milkfish in Kiribati.

The aim of this study was to monitor feeding behavior of juvenile milkfish kept in extensively managed brackishwater lagoons in Kiribati, as an example for Central Pacific island groups.

2. Materials and methods

A lagoon was monitored in Bikenibeu, South Tarawa, Kiribati (1° 25' N; 173° 00' E) in August 1998. Air temperature varied from 31.5°C during daytime to 28 °C at night. The wind direction was steady from north-east at a speed of 3 on the Beaufort scale. No rain occured during the sampling. Water parameters, such as temperature, salinity and dissolved oxygen were regularly measured. The water temperature ranged between

27.2°C at 06.00h and 35.2°C at 16.00h, while the salinity was steady at around 22 ± 1 ppt. Dissolved oxygen values were between 1.9 mg l^{-1} at 07.00h and 9.4 mg l^{-1} at 16.00h. The monitored lagoon had a size of 0.2 ha (200 m length, 10 m width) and was around 30 cm deep. Water exchange was by tidal flushing. The bottom of the lagoon consisted predominantly of fine coral sand (76%). Two other fractions, silt (14%) and clay (10%) completed the structure of the soil. The organic content of the lagoon soil was very low at 2%.
A total of 8 fish were caught on 4 different occasions at 06.00h, 12.00h, 18.00h and 24.00h with a cast net at randomly selected sampling stations. The fish were killed and body dimensions such as length and height were measured to the nearest mm. Body mass was determined to the nearest 0.1 g. On the basis of these factors the fish condition (Richter et al. 2000) was calculated using the following formula:

$$B' = M / (L \times H^2) \qquad \text{(Eq. 1)}$$

where M = body mass, L = body length, H = body height.

The dimensions used for our analysis were total length, height at the anterior edge of the dorsal fin and total weight. A multiplier of 100 was used for the sake of standardisation.
For further analysis the intestinal tracts were removed. Storage of mesenteric fat was determined using a 5-level scale from 0 (0% coverage) to 4 (100% coverage) with subdivisions at one quarter-, half- and three quarter coverage, while a rough estimate of the fullness of the intetstine was done using the same scale (0 = empty; 4 = 100% filled). The length of the intestines and of the stomachs were determined to the nearest cm and mm respectively. Thereafter relative intestine length RIL (intestine length / body length), relative stomach length RSL (stomach length / body length) and the Zihler's Index ZI (Zihler 1982) were calculated:

$$ZI = IL / 10 \times M^{1/3} \qquad \text{(Eq. 2)}$$

where IL = intestine length, M = body mass

For diet analysis, only the stomach contents were considered. Stomach samples of fish from the sampling area were preserved in 70 % ethanol. The full stomach was weighed to the nearest 0.01 g. After this the stomach was cut open using a scalpel and evacuated by squeezing out the contents, after which the wet weight of the contents was determined. The empty stomach was cleaned with distilled water and weighed empty also to the nearest 0.01 g. To identify the stomach contents qualitatively a part of the contents (10% of the wet weight) was separated and kept in 70% ethanol for further microscopic analysis. The remaining 90% of the stomach contents was transferred into a drying oven to determine the dry weight (5 h at 95°C). The dry weight was measured to the nearest 0.001 g. The separated samples for qualitative examinations were homogenised together with 0.125 ml distilled water and were analysed microscopically for major taxonomic groups. To get reliable results from one fish, 5 to 10 slides had to be used. The slides were analysed following a meandering observation scheme. Food items were categorized at magnifications of 40 and 100 times and the percent contribution to the total volume of the contents was estimated visually. The following categories could be identified: Chlorophyta, Cyanophyta, Bacillariophyta, Copepoda, Phyllopoda, Nauplii, Ciliata, Dinoflagellata and Rotatoria. Unidentified matter was counted as detritus.
The results were compared with a plankton sample, taken with a 250 µm push net during the same time. During sampling the plankton net was drawn in a meandering manner over the whole width of the lagoon to ensure that the collected sample represented the lagoon plankton population adequately.
Prey preferences were displayed by the Ivlev Electivity Index (Jacobs 1974) and determined with the following formula:

$$E = (r - p) / (r + p) \qquad \text{(Eq. 3)}$$

where r = percentage of dietary item in ingested food, p = percentage of prey in the environment

E ranges from -1 to +1, where -1 to 0 stands for negative selection, while values > 0 to +1 can be interpreted as positive selection of that prey item. Subsequent investigation from Lazzaro (1987) showed, that a true positive or negative prey selection can be interpreted only at values > 0.3 or < -0.3 respectively.
Dietary overlap between fish caught during daytime and fish caught at night was compared using the index suggested by Schoener (1970):

$$O = 1 - 0.5\, \Sigma\, |p_a - p_b| / 100 \qquad \text{(Eq. 4)}$$

where p_a = percentage of food items in species a, p_b = percentage of food items in species b

The index will give values between 0 (no overlap) and 1 (complete overlap). Finally, the daily feed intake was estimated by gravimetric analyses of stomach contents followed by mathematical modelling using an estimate of the average stomach contents over a period of time in conjunction with the gut passage time (Bajkov 1935). Eggers (1979) changed the gut passage time to a stomach evacuation rate which was dependent on the level of stomach contents ("modified Bajkov model"):

$$R_d = 24 \times E \times S_{avg} \qquad \text{(Eq. 5)}$$

where R_d = daily ration, E = evacuation rate, S_{avg} = average stomach contents over 24-hour period

For the "modified Bajkov model", best suited to continuously feeding fish, knowledge of the rate of stomach evacuation rate is required. This rate was taken from a dataset of juvenile milkfish in the Philippines (Kühlmann 1998), where the main factors known to effect the evacuation rate (e.g. water temperature, body mass, salinity) were similar.
The data on different ingested food items and variations in the electivity index were tested for differences between fish caught during the day and night, using the t-test (STATISTICA StatSoft Inc.). The significances of observed differences were tested at a level of $p < 0.05$. Results are given as means ± S.D.

3. Results
Monitored fish had a mean weight of 100.1 ± 13.5 g (n =8) and an average condition factor of 20.4 ± 1.7 as listed in table 1. The fish condition corresponds well with data from the Philippines (Lückstädt et al. 2000). For the sake of comparison, the Fulton condition factor ($K = M / L^3$) was estimated to be 0.9 ± 0.1 for all caught milkfish from the brackishwater lagoon in Kiribati.

Tab. 1: Morphometric data on milkfish caught at South Tarawa, Kiribati in August 1998
Tab. 1: Morphometrische Parameter von Milchfischen, gefangen auf South Tarawa, Kiribati, im August 1998

	Overall catch	Catch at day-time	Catch at night-time
n	8	4	4
BM⁺ in g	100.1±13.5	105.3±15.1	95.0±11.3
TL⁺⁺ in cm	22.4±1.8	23.6±1.2	20.9±1.2
H† in cm	4.7±0.3	4.7±0.2	4.7±0.4
B'‡	20.4±1.7	20.1±0.5	20.7±2.4

+BM = body mass; ++TL = total length; †H = height at the anterior edge of the dorsal fin
‡condition factor $B' = 100 \times (M / (L \times H^2))$

After removal of the intestines, the carcasses of the monitored fish had a mean weight of 79.0 g. The fat stores in all fish were low. The mesenteric fat covered only around 25% of the intestinal surface.
Data on the intestinal tract showed remarkable differences from a dataset from the same size-class from the Philippines (n = 39; Lückstädt et al. 2001). The stomachs tended to be relatively longer, even though this difference was not statistically significant. Stomach length of juvenile milkfish from Kiribati was on average 44.2 ± 11.5% of total body length and ranged from 28.5% to 58.8%, while fish from the Philippines had an average relative stomach length of only 39.0 ± 4.5%. Relative intestine length did not increase with increased relative stomach length. Milkfish from Kiribati reached a RIL of 5.1 ± 0.7. Here, this factor ranged from 4.8 to 6.3. However, juvenile milkfish from the Philippines had a mean relative intestine length of 6.4 ± 0.8. This difference was statistically significant at $p < 0.05$. Taking the body mass of the fish into account, the Zihler's index, ZI, showed only slight variations between the two datasets. The values of the ZI were 53.6 ± 7.2 and 54.5 ± 6.8 for Kiribati and the Philippines respectively. The difference between the two areas was not significant.

Tab. 2: Stomach content analysis of milkfish from Bikenibeu, Kiribati in August 1998 (in %)
Tab. 2: Mageninhaltsanalysen von Milchfischen aus Bikenibeu, Kiribati, gefangen im August 1998 (in %)

Time	Chlorophyta	Cyanophyta	Diatoms	Crustacea	Others⁺	Detritus
day	17.3±9.2	38.7±22.5	8.0±12.7	5.3±8.5	5.0±6.4	25.7±29.2
night	15.8±9.3	53.5±18.5	0.3±0.5	0.7±1.0	3.5±2.1	26.2±15.3

+Others = Ciliata, Dinoflagellata and Rotatoria

Results of the stomach contents, as listed in table 2, indicate a huge dominance of algae. The stomach content consisted mainly of single cellular green algae (Chlorophycae) and of single cellular and filamentous blue-green algae (Cyanophyta). Both diet items made up around 60% of the total stomach contents during night and day.

Diatoms and crustaceans, like copepods, phyllopods and nauplii, as well as "others" (Ciliata, Dinoflagellata and Rotatoria) made up only a small fraction of the fish diet. The large amount of detritus in the stomach suggests, that the milkfish in these lagoons are benthic oriented feeders. Furthermore, diatoms and crustacea were mainly consumed during daytime. However, the differences between feed intake of specific diet items during night and day were not statistically significant.
When results were compared with a plankton sample from the pond water (table 3), it turned out that Cyanophyta were positively selected by fish during the night, while diatoms were negatively selected during the same time. The difference in the diatom electivity was significant between night and day at $p < 0.05$. On the other hand, the food items included in the category "others" were seldom chosen by the fish either during the day or during the night, even if they were abundant in the environment.

Tab. 3: Plankton sample and resulting Ivlev index from milkfish at Kiribati, August 1998
Tab. 3: Plankton Probe und resultierender Ivlev Index von Milchfischen aus Kiribati, August 1998

	Chlorophyta	Cyanophyta	Diatoms	Crustacea	Others
Plankton sample (%)	37	26	2	2	33
Ivlev index E[+] (day)	-0.4±0.2	0.1±0.3	0.1±0.5[a]	-0.1±0.8	-0.8±0.3
Ivlev index E (night)	-0.4±0.2	0.3±0.2	-0.8±0.3[b]	-0.6±0.5	-0.8±0.1

[+]Ivlev index E = -1 to < -0.3 for negative selection; > 0.3 to +1 for positive selection (after Lazzaro 1987)
Values in a column with a different superscript differ significantly at $p < 0.05$

The dietary overlap estimated with the Schoener-Index gave a value of 0.63 ± 0.14. Visual observations estimated mean gut fullness to be more than 76%. At no time of the observation period were the guts found to be empty. Gut fullness increased from around 25% at 06.00h to more than 93% at noon and remained steady at that level until midnight. An average stomach fullness of 0.14 ± 0.20% Body Mass Equivalent (% BME) was determined. The pre-set evacuation rate of 0.5 h^{-1} from a dataset from the Philippines led to a roughly estimated daily ration of 1.7% BME, if calculated with the aid of the "modified Bajkov model". The hourly stomach evacuation rate was estimated to be 39%, if ingestion had stopped. This led to a half-life of the stomach contents of 76 minutes, again assuming ingestion had stopped.

4. Discussion

Investigations of the diet of milkfish in brackishwater lagoons on South Tarawa showed that the milkfish is mostly a benthic feeder, obtaining its food from the cyanobacterial mats and plant debris found in the littoral zone of the lagoon. Therefore, around 90% of its diet consisted of plants or detritus, so that the fish feeds as a herbivore (Hiatt 1944). Nektonic items, such as clupeids and nauplii, were ingested as well, but in much smaller quantities. The cyanobacterial mats are probably sustained by a high level of available phosphate in the bottom of the lagoon (23.7 ppm). Hiatt (1944) did not find any variations in the annual or seasonal feeding behaviour. Our results also suggested that there are no diurnal variations in the composition of the feed consumed by the fish. These findings are well correlated with a Schoener-Index of 0.6, suggesting a broad overlap of prey and diet types for juvenile milkfish in brackishwater lagoons, during both day and night. However, the tendency towards a decreased intake of diatoms at night was displayed by a significantly different Ivlev-Index.
Kramer and Bryant (1995) showed for various freshwater species that the relative intestine length is highly variable within the three dietary categories (carnivore, omnivore, herbivore) and, for example, varies between 5.4 and 28.7 in herbivorous fish with a total body length up to 20 cm. We found that milkfish from in the same size class reached a RIL of 5.1 which falls only slightly outside the range determined by Kramer and Bryant (1995). Furthermore, the same authors calculated a Zihler Index between 50 and 100 for fish at or above 30 g grazing on periphyton. In Kiribati we determined a value of nearly 54 for milkfish, which corresponds well with the fish feeding on cyanobacterial mats. Differences in the RIL between milkfish from the Philippines and Kiribati feeding on the same diet (Lückstädt et al. 2001), may be due to population differences (as indicated by variations in vertebral number), as reported by Bagarinao (1994).
The quantitative feed uptake of milkfish in the monitored lagoon can be described as continuous, with peaks in the afternoon and evening. Since the fish did not stop feeding throughout the day, the ”modified Bajkov model” was well suited to analyse the dataset. The model prediction gave a result of around 1.7% BME. Sumagaysay (1993) determined daily rations for juvenile milkfish feeding exclusively on natural food between 0.9% and 1.1% BME. However, these fish did not feed throughout the day, but emptied their guts around 22.00h. Therefore the higher daily ration of fish from Kiribati can be explained by the more prolonged feeding period. Furthermore, it is also likely that the daily ration was underestimated, since Richter et al. (2002) reported violations in one of the basic assumptions of food consumption models, one of which was used in this study. Therefore, more comprehensive data from milkfish from the area studied here, as well as fully validated models are necessary to confirm the daily ration estimate.

We conclude from our study that the milkfish feeding behaviour in brackishwater lagoons in Kiribati is closely related to the feeding habits of cultured milkfish from the Philippines. The milkfish in both locations are rather dependent on benthic algal mats, which can be sustained by fertile soils.

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