SHARING, CONSUMPTION, AND PATCH CHOICE ON IFALUK ATOLL

Evaluating an Explanatory Hypothesis

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Anthropological tests of patch choice models from optimal foraging theory have primarily employed acquisition rates as the currency of the model. Where foragers share their returns, acquisition rates may not be similar to consumption rates and thus may not be an appropriate currency to use when modeling foraging decisions. Indeed, on Ifaluk Atoll the distribution patterns of fish vary by fishing method and location. Previous analyses of Ifaluk patch choice decisions suggested that if Ifaluk fishers are trying to maximize their production rates they should rarely torch fish for dogtoothed tuna. However, some men do spend considerable time and energy exploiting the dogtoothed tuna patch. To improve our understanding of the constraints and motivations influencing men's decisions to exploit this patch, here I use per capita consumption rates as a currency, rather than production rates, to evaluate predictions generated from a patch choice model. Results indicate that although fish caught in other patches are more widely distributed than fish caught in the dogtoothed tuna patch, the consumption rates of torch fishers and their kin are still considerably lower than the consumption rates of men pursuing fish in other patches. Although these results are unable to explain why Ifaluk men exploit the dogtoothed tuna patch, an important explanatory hypothesis is eliminated.

KEY WORDS: **Food sharing; Human behavioral ecology; Micronesia; Optimal foraging theory; Patch choice**

Received: February 28, 2000; accepted April 26, 2000.

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Human Nature, Vol. 12, No. 3, pp. 221–245. 1045-6767/01/$1.00+.10

Behavioral ecologists regularly employ optimal foraging models to understand the constraints and selective pressures that influence an organism's foraging decisions. Behavioral ecologists studying nonhuman populations have adopted a wide range of currencies to evaluate resource acquisition choices, such as minimizing risk of starvation (Houston and McNamara 1985) and the trade-off between predation and foraging (Abrahams and Dill 1989; Gilliam and Fraser 1987), although the most widely used currency is the rate of net caloric intake (see Stephens and Krebs 1986). In contrast, human behavioral ecologists have almost exclusively employed acquisition rates, typically caloric gains per hour, as the currency to evaluate alternative prey and patch options among foragers (e.g., Hill and Hawkes 1983; Hill et al. 1987; Smith 1991; cf. Hill 1988). It is generally assumed in this work that acquisition and consumption rates are similar, or at least positively correlated. However, in many populations where resources are widely shared, gains in production do not result in similar gains in consumption (e.g., Bliege Bird and Bird 1997; Kaplan and Hill 1985). Hawkes (1993a) has argued that among foragers who frequently share their returns the assumed goal of production rate maximization may not be appropriate. She suggests that consumption rates, especially family consumption rates, may be more important than production or acquisition rates in understanding human foraging decisions. This insight may be particularly valuable for understanding patch choice decisions among human foragers, since foraging method and prey type often influence food-sharing patterns.

On Ifaluk Atoll in Micronesia, men exploit five fishing patches during the trade wind season: the yellowfin tuna, reef fish, lagoon-bottom, nine-mile reef, and dogtoothed tuna patch. I have previously shown (Sosis in press) that predictions derived from a patch choice model that used per capita production rate as a currency were generally consistent with patch choice decisions of Ifaluk fishers. Nevertheless, decisions to fish in the dogtoothed tuna patch uniformly generated deviant results; given the low profitability of the dogtoothed tuna patch, men were expected to exploit the patch less frequently than they did. Here I will extend these analyses to incorporate the effects of the fish-sharing patterns on Ifaluk, and evaluate whether using consumption rates as a currency can improve our understanding of why Ifaluk fishers exploit the dogtoothed tuna patch at the observed frequency.

PATCH CHOICE DECISIONS ON IFALUK ATOLL: PREVIOUS RESULTS

Extending the marginal value theorem (MVT; Charnov and Orians 1973; Charnov 1976), Smith (1991:257–258) argued that within-patch profitability (net energy gain per unit of time) should be positively correlated with patch residence time. In previous work I predicted that mean per capita within-patch return rates of patches that could be exploited during similar seasonal and weather conditions would be positively correlated with the total hours spent exploiting each patch (see Sosis [in press] for justification of assumptions). Of the four patches that could be exploited under similar environmental conditions, men spent the most hours in the most profitable patch (yellowfin tuna patch) and the fewest hours in the least profitable patch (nine-mile-reef patch). However, the time spent in the patches with the second- and third-ranked profitabilities was not consistent with the prediction. Although men spent more than twice as many hours in the dogtoothed tuna patch (585 hr) as they did in the lagoon-bottom patch (214 hr), the mean per capita return rate from exploiting the lagoon-bottom patch was more than twice as high as that for the dogtoothed tuna patch (0.81 kg/hr vs. 0.38 kg/hr; $t = 8.78$; df = 117; $p < .0001$).

These analyses raised an additional question; if the yellowfin tuna patch is the most profitable patch, why would fishers ever exploit any other patch? Although men fish most frequently in the yellowfin tuna patch, patch profitabilities are likely to vary each day. Men are expected to respond to this variation in patch productivity, and it is assumed that on any given day men will fish in the most profitable patch *on that day*. It was therefore expected that on mornings when men troll for yellowfin tuna, the mean per capita return rate for any alternative patches exploited on that day would be higher than the mean per capita return rate achieved from trolling for yellowfin tuna. Indeed, on 11 of 13 days that men exploited the yellowfin tuna patch and subsequently exploited either the lagoon-bottom or the reef fish patch, the mean per capita returns of the lagoon-bottom or reef fish patch were higher than the returns from exploiting the yellowfin tuna patch. However, on only 5 of 10 days that men exploited both the dogtoothed tuna patch and the yellowfin tuna patch were the returns higher for exploiting the dogtoothed tuna patch.[1] Even on the 5 days that the return rates for exploiting the dogtoothed tuna patch were higher, it was not a result of successful torch fishing, but primarily a consequence of unsuccessful morning trolling. Table 1 shows that on 4 of these 5 days, no fish were caught in the yellowfin tuna patch. In other words, with the exception of one day, the dogtoothed tuna patch only had higher patch profitabilities than the yellowfin tuna patch when no fish were caught in the yellowfin tuna patch.

The cumulative implication of these results suggests that why men exploit the dogtoothed tuna patch needs to be further explored. Here I will evaluate whether using per capita consumption rates as a currency to test predictions generated from patch choice models, rather than production rates, can improve our understanding of the constraints and motivations influencing men's decisions to exploit the dogtoothed tuna patch.

Table 1. Mean Daily per Capita Production Rates of 10 Days That Men Trolled and Torch-Fished

Event	*Date (Month/Day)*	*Trolling Production Rate (kg/hr)*	*Torch Fishing Production Rate (kg/hr)*
1	2/18	0.992	0.005
2	2/19	0.521	0.053
3	2/21	0.785	0.193
4	2/22	0.000	0.479
5	2/23	4.290	0.570
6	2/24	0.000	2.196
7	2/25	0.000	0.539
8	2/28	0.085	0.011
9	3/1	0.256	0.486
10	3/2	0.000	0.183

ETHNOGRAPHIC BACKGROUND

Ifaluk is a coral atoll located in Yap State in the Caroline Islands of the Federated States of Micronesia at 7°15' north latitude and 147° east longitude. The nearest inhabited atoll is Woleai, 53 km west of Ifaluk, and Yap, the largest island in Yap State, is located about 560 km northwest of Ifaluk. Ifaluk consists of four atolls, two of which are inhabited. The total landmass of the four atolls is 1.48 km^2 and the nearly circular lagoon is 2.43 km^2 (Freeman 1951:237–238, 273–274). The two inhabited atolls, Falalop and Falachig, are separated by a 35-m-wide channel that is less than a meter deep during high tide and completely dry during low tide. The channel can easily be crossed on foot, even during high tide. It is estimated that Ifaluk receives between 254 and 305 cm of rain per year (Tracey et al. 1961). Daily temperatures range from 21 to 35°C and remain nearly constant throughout the year. The two seasons on Ifaluk are differentiated by the presence of northeast trade winds from October through May.

There are four villages on Ifaluk, two on each inhabited atoll. Villages consist of 5–13 matrilocal compounds. The 36 total compounds on Ifaluk range in size from 1 to 4 houses and 3–35 residents. Houses are composed of either nuclear or extended families. There are seven ranked matriclans on Ifaluk; the five highest are chiefly clans (see Sosis 1997). Clans are not localized, and members of each clan can be found in all four villages. The observational data presented in this paper were collected on Falalop atoll. Of the 189 individuals who lived on Falalop during the 1994–1995 field session, 99 resided in Iyeur village and 90 resided in Iyefang village.

SUBSISTENCE

Ifaluk maintains a subsistence economy. The diet largely consists of pelagic and reef fish, taro, breadfruit, and coconut. Pigs, chickens, and dogs are also raised for consumption and usually only prepared for bimonthly feasts. There is no refrigeration on Ifaluk. Fish are occasionally smoked, but competition with dogs, cats, and rats makes long-term storage difficult. For a more detailed description of subsistence activities see Sosis 1997.

Fishing is the primary means of protein acquisition on Ifaluk and is exclusively pursued by males. Fishing activities differ significantly by season. Here I will focus on fishing patterns observed during the trade wind season (October–May).

Patches are typically defined according to location and species. However, the technology and foraging strategies used among human populations present an additional dimension that must be considered (Smith 1991). If the foraging technology operates indiscriminately across a range of species (e.g., fishing nets), different prey in the same location may constitute one patch. On the other hand, if the technology or strategies used to pursue certain species are mutually exclusive, prey in a similar location may constitute more than one patch. On Ifaluk, no fishing methods could be used simultaneously. Therefore, here I have defined fishing patches according to location, prey species, and fishing method. There are five fishing patches exploited during the trade wind season, four of which are exploited by unique fishing methods. Here I describe three patches that will be discussed in the analyses below (see Table 2 for summary of patch descriptions). Descriptions of the remaining two fishing patches can be found in Sosis (in press).

Yellowfin Tuna Patch

Most mornings before dawn during the trade wind season, males congregate at the central canoe hut on Falalop to prepare for fishing. After the canoes are prepared, all the males who are present help to push each canoe that will be sailing that morning into the lagoon. The canoes will then sail outside the reef and troll primarily for yellowfin tuna, which accounted for 89% by weight of the harvest during the observation period (n = 114 days).[2] Upon their return, men throw their catch into a pile that is distributed by a divider after all the canoes have returned (see Sosis 2000a).

There are four large sailing canoes on Falalop, the atoll where this study was conducted. Each canoe is owned and maintained by a specific matriline and, hence, compound. Compounds that do not own a canoe are

Table 2. Fishing Method, Prey Type, Location, and Time of Exploitation of Each Fishing Patch

Patch Type	*Fishing Method*	*Prey*	*Location*	*Time of Day Exploited*
yellowfin tuna	trolling	yellowfin tuna	mid to high sea beyond reef	early morning
dogtoothed tuna	torch fishing	dogtoothed tuna	deep sea beyond reef	dusk through evening
lagoon-bottom	rope fishing	reef fish	lagoon bottom	late morning through midafternoon
9-mile reef*	trolling	yellowfin tuna, reef fish	mid to high sea, 9-mile reef	early afternoon through early evening
reef fish*	line, spear, trap fishing (solitary fishing)	reef fish	lagoon	morning, afternoon, evening

* see Sosis (in press) for description

historically associated with a particular canoe; typically men from that compound helped to build the canoe. Men generally fish on the canoe that is associated with the compound where they were raised (Sosis et al. 1998).

Dogtoothed Tuna Patch

Men also use the large sailing canoes to torch fish for dogtoothed tuna. Torch fishing occurs in two stages. First, torch fishers catch flying fish in small hand nets roughly 2 ft in diameter. Men use torches made from dried coconut fronds to attract the flying fish to the sailing canoe. In the second stage, the flying fish are used as bait for deepwater trolling to catch large dogtoothed tuna [80% by weight of all fish caught by torch fishing were dogtoothed tuna (n = 114 observation days)].

Torch fishing is the most ritualized fishing method on Ifaluk. Men must prepare for several weeks before they can torch fish. Preparations primarily consist of collecting and drying coconut fronds that they will wrap tightly together and use as torches. Around the time of each new moon, the magician determines whether the cycle of the moon is favorable for torch fishing.[3] If it is deemed propitious, those canoes that are prepared may fish. The first evening that a canoe is allowed to torch fish during a cycle is referred to as an *entry day*. Men who do not fish on the entry day must wait until the following cycle to participate. For the duration of the moon's cycle, men who fished on an entry day are expected to be at the canoe house at dusk, where it will be decided who will fish each evening. Those men who will not be fishing help the others prepare the canoe and fishing supplies.

Lagoon-Bottom Patch

Rope fishing occurs in Ifaluk's lagoon and specifically targets species that live in certain areas on the lagoon floor. Rope fishing is an atoll-wide event; that is, all men who reside on the atoll are expected to participate. Rope fishing utilizes two ropes that are each more than 50 m long. Preparations mainly consist of collecting coconut fronds that are tied to these long ropes. The elders of the community lead the fishing party in two or three middle-sized paddling canoes. On 20–25 solitary outrigger canoes, the rest of the men travel to the fishing site where the elders will organize all of the canoes into a circle. The two ropes are tied together and passed along to each of the canoes. A fishing net is secured in the center of the circle. Most of the men proceed into the water, while a few remain above to watch the canoes. Wearing diving masks, men place the ropes on the lagoon floor and, swimming slowly and in synchrony, move them toward the fishing net. The coconut-frond-covered rope is intended to frighten the fish and hence drive them toward the net. When the circle created by the men becomes small, the men scream and splash, making a great commotion to chase the fish into the net. The nets are then emptied into the canoes of the elders. This process is repeated 4 or 5 times at different locations in the lagoon. The fish are then placed in a communal pile and divided amongst the residents of the atoll.

PREDICTIONS

As discussed above, previous results suggest that production rate may not be the appropriate currency for determining why Ifaluk men exploit the dogtoothed tuna patch, or specifically why men torch fish. The differences in fish distribution patterns across patches suggest that consumption rates may be a more appropriate currency for evaluating patch choice decisions. If returns from torch fishing are less widely distributed than returns from other fishing methods, men may be maximizing their consumption rates, or the consumption rates of their families, by choosing to exploit the dogtoothed tuna patch.

Within-patch profitability (net energy gain per unit of time) should be positively correlated with patch residence time (Smith 1991). However, men spend more than twice as many hours in the dogtoothed tuna patch than the lagoon-bottom patch, even though for nearly all recorded events the dogtoothed tuna patch per capita production rates were lower than the lagoon-bottom patch per capita production rates. Here I extend Smith's prediction to account for differences in sharing patterns across patches by replacing net energetic production per unit time with net energy intake per unit time as the currency of the model. In other words, consumption rates of fishers and their families should be positively correlated with patch residence time. Given that men spend more time in the dogtoothed tuna patch, we expect that for each hour spent in the dogtoothed tuna or lagoon-bottom patch, fishers and their families on average consume more fish from the dogtoothed tuna patch than the lagoon-bottom patch.

Prediction 1: The mean per capita consumption rate of exploiting the dogtoothed tuna patch will be higher than the mean per capita consumption rate of exploiting the lagoon-bottom patch.

The first foraging decision of the day for an Ifaluk fisher is whether or not to troll for yellowfin tuna. Yellowfin tuna was the most profitable and frequently exploited fishing patch over the observation period. Thus, here I consider the choice of whether or not to exploit the yellowfin tuna patch as a baseline decision and evaluate how responses to this decision influence subsequent patch choice decisions. Although Ifaluk men fish most frequently in the most profitable patch, patch profitabilities are likely to vary each day. Men are expected to respond to this variation in patch productivity, and it is assumed that on any given day men will fish in the most profitable patch *on that day*. However, as discussed above, patch profitabilities do not account for sharing patterns and thus consumption. Here I extend the prediction that men will fish in the most profitable patch on a given day to account for differences in the sharing patterns across patches. We expect that men will fish in the patch that results in the highest consumption rate for themselves and their families.

Prediction 2: On days that men exploit the yellowfin tuna and dogtoothed tuna patch, the mean per capita consumption rate of exploiting the dogtoothed tuna patch will be higher than the mean per capita consumption rate of exploiting the yellowfin tuna patch.

The above predictions share the following assumptions.

1. All patches have negatively accelerating daily gains curves. This may be due to prey depletion, changing environmental conditions (e.g., calming winds or rising moon), or daily fluctuations in prey species' behavior.
2. Decisions concerning which patch to exploit and which fishing method to use are interdependent. Choosing to exploit a certain

patch implies that a specific fishing method will be used. All fishing methods are mutually exclusive; the same men cannot engage in more than one fishing method at a time.

3. Handling and processing times are similar for all species of fish caught. No species of fish requires any more processing or cooking time than others. Women partake in processing and cooking for at least some events following each fishing method.
4. All fish caught have similar caloric values. Indeed, the caloric value of yellowfin tuna is 1,080 kcal and the average caloric value of five species of reef fish is 1,074 kcal (Genesis R&D Nutrition and Labeling Software).[4]

METHODS

The data presented in this paper were collected over 75 continuous days from December 19, 1994, to March 3, 1995. These data are part of a larger sample of Ifaluk fishing data collected from October 1994 to April 1995 that have been reported on elsewhere (Sosis et al. 1998; Sosis 2000a). This 75-day subset of the data was chosen, here as well as in the previous patch choice study discussed above, because it is the largest block of continuous data on fishing activities that was collected during the 1994–1995 field session. During the field session I resided on Falalop atoll and collected observational data on fishing activities in Falalop's two villages: Iyeur and Iyefang.

During the observational period, trolling activities were monitored every morning. Data on torch- and rope-fishing activities were collected opportunistically, but these activities were easily monitored since they were public events and widely discussed beforehand. During observations I recorded which of the canoes set sail, the names of the fishermen on each canoe, the time of departure and return for each canoe, the weight and species of each fish caught by canoe, and where each fish was distributed. Fish were distributed to either a village, compound, or individual. The data set on these fishing activities during the observation period is complete; no fishing events were missed, and no data were missed during any event. During the 75-day observation period, morning trolling occurred on 57 days, torch fishing on 12 days, and rope fishing on 2 days.[5]

Following the initial distribution of fish to villages or compounds, fish were often redistributed. Data on redistribution patterns were recorded for eight village-level and 24 compound-level redistribution events following morning trolling. Five compound-level redistribution events were monitored following torch fishing events. Fish were never redistributed following rope fishing events. The names of the distributors, weight and species of each share redistributed, and name of the compound that received the share were recorded during these observations.

FISH DISTRIBUTION PATTERNS

Morning Trolling Fish Distribution

Upon return from morning trolling, fishermen from each canoe throw their catch into a communal pile that is distributed after all the canoes return. On Falalop atoll, two men have the inherited responsibility of dividing the fish. The dividers determine the type of distribution and the amount of fish that is allocated to each recipient. During the 1994–1995 field session I observed five patterns of fish distribution following morning trolling on Falalop atoll. Multiple distribution types were often observed at the same distribution event. Here I will only provide a brief description of the five distribution types, which have been described in greater detail elsewhere (see Sosis et al. 1998; Sosis 2000a). The five types (Woleaian names in parentheses) are:

1. Canoe owner distribution *(shuliwa):* During a canoe owner distribution, compounds that own canoes receive the catch of their canoe. A canoe owning compound that receives fish subsequently redistributes the fish to other compounds, unless the catch is particularly small. Canoe owning compounds retained an average of 59.7% (s.d. = 25.0%; $n = 24$) of the fish they produced. Redistributed fish are generally directed towards compounds where kin and men who fished on the canoe reside (Sosis 2000a).

2. Village-level *ilet* distribution *(felang)*: Villages on Ifaluk are composed of plots of land that are owned by the matriline of particular compounds. Plots of land each have an *ilet* value, which affects the flow of food resources contributed and received by the owners of the land. All plots are valued at 1 *ilet*, with the exception of two plots that are valued at 2 *ilet*. On Falalop, compounds possess between 1 and 3 plots of land, and the total *ilet* maintained by compounds is also between 1 and 3. There are 19 *ilet* in Iyeur village and 11 *ilet* in Iyefang village. On Falalop, the number of *ilet* owned by a compound is positively correlated with the number of residents in the compound ($r = .72$, $p = .008$; Sosis et al. 1998).

During a village-level *ilet* distribution fish are divided into two piles, one for Iyeur village and one for Iyefang village. From these piles each compound receives an amount of fish proportional to the number of *ilet* it possesses. One or two women from each compound that owns *ilet* within the village convene at their respective piles to cook and redistribute the fish. The eldest women present are in charge of the redistribution. The number of *ilet* that a compound possesses determines the amount of fish that each compound receives. Compounds that have 1 *ilet* receive half as much fish from a redistribution as compounds that have 2 *ilet*, and one third as much fish as compounds that have 3 *ilet*.

3. Atoll-level *ilet* distribution *(metalilet):* Similar to a village-level *ilet* distribution, fish are distributed according to *ilet*. However, during an atoll-level *ilet* distribution there is no village-level distribution of fish. The dividers distribute the fish directly from the canoe house to the compounds.

4. Fishermen distribution *(gagolagol):* Fish are distributed directly to males who fished on the canoe that caught the fish. Fish are subsequently cooked and consumed by the residential compound of the fisherman.

5. Men's feast *(yafiileo/giubul):* Fish are cooked at the men's house and eaten by any male over 14 years old who desires to eat.

These distribution patterns can be classified as primary or secondary distribution types. The primary distribution types (canoe owner, village-level *ilet*, and atoll-level *ilet*) never co-occur, and nearly all distributions include one of these distribution types. The secondary distribution types (men's feast and fishermen distribution) generally occur in conjunction with one of the primary distribution types or with the other secondary distribution type. The most frequently observed distribution type was the canoe owner distribution, which occurred during 63.1% of all distribution events. The primary distribution types account for more than 90% of the total fish distributed. Canoe owner and village-level *ilet* distributions were clearly the most important distribution types observed. Together these distributions account for 80.9% of the total fish distributed and occur during 89.2% of all fish distributions.

Rope Fishing Fish Distribution

Following rope fishing events, the catch was separated into three piles according to size (large, medium, and small fish) and distributed via the atoll-level *ilet* and crew feast distribution systems described above. In addition, fish were also distributed via *sharug*, a distribution that rewards certain landowners. The land of each village is ranked hierarchically. The three highest-ranking plots of land in each village are referred to as *imtufai* or "high places" (see Table 2.4 in Sosis 1997 for names of high places). During both observed rope fishing events, the high places were given additional fish according to their rank. For example, in one event the compounds that owned the two highest-ranking plots of land each received four extra fish, the owners of the second-ranking plot of land received three extra fish, and the owners of the third-ranking plot of land received two extra fish. These benefits entail associated costs. The residents of high places are expected to contribute more rope when the long ropes or fishing nets used in rope fishing are made. For example, if compounds are instructed to contribute six fathoms of rope, the owners of the highest-ranking land must contribute ten fathoms, and the owners of the second- and third-ranking plots of land must contribute nine and eight fathoms of rope, respectively.

Torch Fishing Fish Distribution

Following torch fishing events, fish were distributed via a canoe owner distribution, crew feast, or both. During canoe owner distributions, fish were brought to the compound that owned the canoe on which the fish were caught. Fish were subsequently cooked and redistributed to other compounds. During crew feasts, fish were cooked and eaten at the canoe house. In contrast to crew feasts following morning trolling or rope fishing where any male over the age of 14 may participate, only men who fished on the entry day of that torch fishing period were welcome at torch fishing crew feasts. Table 3 shows the amount distributed via canoe owner distributions and crew feasts following the 12 torch fishing events that occurred during the observation period. Although fish were distributed more frequently via crew feasts, the majority of fish (87.2% by weight) were distributed via a canoe owner distribution. Fish were distributed via both sharing patterns following five torch fishing events.

There are several patterns that characterize how fish are redistributed from a canoe-owning compound. First, canoe-owning compounds retain a significant portion of the fish. During three observed redistribution events for canoe 1 in which fish were distributed widely, the canoe-owning compound retained on average 61% by weight (range 57–63%) of the fish they initially received. During one observed event for the same compound where fish were not distributed widely, the compound retained 94% of the fish. In the only observed redistribution event for canoe 2, the residents of the canoe-owning compound retained 43% of the fish they initially received. Similar to canoe owner distributions following morning trolling events, the less fish a redistributing compound initially receives, the higher the percentage of fish that is retained by the compound (Sosis 2000a).

The second pattern observed among canoe owner redistributions is that fish are generally redistributed to compounds where men who fished on the entry day of that fishing period reside. Logistic regression analysis was conducted using data on three observed redistributions from the owners of canoe 1 where fish were widely distributed. The dependent variable was whether or not a compound received fish during a canoe owner redistribution. There were 36 possible compounds that could receive fish. The results presented in Table 4 show that having a resident who fished on the *entry day* (see Subsistence: Dogtoothed Tuna Patch) is a significant predictor of whether or not a compound receives fish. Interestingly, whether

Table 3. Data on Production and Distribution for 12 Torch-Fishing Events

Event ID	*Date*	*Canoe ID*	*Amount Caught (kg)*	*Time (min)*	*Number of Fishermen*	*Mean per Capita Return Rate (kg/hr)*	*Amount Distributed to Canoe-Owning Compound (kg)*	*Amount Distributed to Crew Feast (kg)*	*Mean per Capita Consumption Rate (kg/hr)*
1	2/18	1	0.25	205	14	0.01	0.25	0.00	0.01
2	2/19	1	1.20	170	8	0.05	0.00	1.20	0.03
3	2/21	1	6.50	336	6	0.19	6.50	0.00	0.19
4	2/22	1	24.25	380	8	0.48	24.25	0.00	0.37
5	2/23	1	32.00	421	8	0.57	32.00	0.00	0.47
6	2/24	1	70.50	321	6	2.20	59.25	11.25	1.40
7	2/25	1	12.45	231	6	0.54	11.50	0.95	0.49
8	2/26	1	1.86	336	7	0.05	0.00	1.86	0.02
9	2/27	1	42.26	338	7	1.07	37.25	5.01	0.70
10	2/28	1	0.60	265	8	0.02	0.00	0.60	0.01
	2/28	2	0.00	129	9	0.00	0.00	0.00	0.00
11	3/1	1	30.00	355	6	0.85	20.50	9.50	0.45
	3/1	2	9.25	339	8	0.20	9.25	0.00	0.24
12	3/2	1	0.36	390	7	0.01	0.00	0.36	0.02
	3/2	2	18.82	395	9	0.32	17.50	1.32	0.25
Total			250.30	4611	117		218.25	32.05	
Average			16.69	307.4	7.8	0.44	14.55	2.14	0.31
Standard Deviation			20.24	87.64	2.01	0.59	17.57	3.60	0.37

Table 4. Logistic Regression Analysis of the Probability of Receiving Fish from a Canoe Owner Redistribution

Independent Variable	*Parameter Estimate*	*Standard Error*	*p*
Intercept	−2.211	0.3724	
Resident of compound torch fished	0.6242	1.2081	0.6504
Resident of compound fished on entry day	3.5328	0.6748	**>.0001**

Bold value is significant
−2 log likelihood for model covariates = 49.8, $p < .0001$, df = 2, $n = 108$

or not a man fished on the successful canoe is not a significant independent predictor of whether the compound where the man resides will receive fish. Additional analyses (not presented here) indicate that whether or not a crew feast co-occurs with a canoe owner distribution does not influence how fish are redistributed.

When fish are redistributed from a canoe-owning compound, the average observed package size of cooked fish received by compounds was 0.75 kg ($n = 36$; range 0.31–1.4), which is estimated to be about 1.2 kg ($n = 36$) of uncooked fish. The average amount of cooked fish retained by canoe-owning compounds in observed redistributions was 8.7 kg ($n = 5$), which is about 14.3 kg ($n = 5$) of uncooked fish.[6]

TORCH AND ROPE FISHING CONSUMPTION

Since men spend significantly more hours torch fishing than rope fishing, it is expected that consumption rates of torch fishers are higher than the consumption rates of rope fishers. Here I have not calculated individual consumption rates, but consumption at the compound level; in other words, the amount of fish an individual produced for his compound per hour of his labor. Fish caught by rope or torch fishing are never given directly to an individual; fish are distributed to a compound, or to a specific group of men in the case of a crew feast. Since food within a compound is generally shared from a communal pot it would have been nearly impossible to collect accurate data on individual consumption. Observations do indicate, however, that within-compound sharing (i.e., how much each individual consumes out of the communal pot) does not differ by fishing method. Although elsewhere I have estimated individual consumption using data on the age and sex of compound members (Sosis 2000a), here calculating consumption at the compound level is preferable because men undoubtedly fish not only for themselves, but also for their family and kin. Compound-level consumption rates capture this motivation better than individual consumption rates. Therefore, per capita consumption rates were calculated as the amount of fish produced by the fisher that is consumed by the residents of a fisherman's compound plus the estimated amount the fisher consumes at a crew feast,[7] divided by the amount of time he spent fishing.

The mean consumption rate of rope fishers (0.71 kg/hr) is higher than the mean consumption rate of torch fishers (0.27 kg/hr; see Figure 1). This difference is significant ($t = 7.71$; $p < .0001$) in the opposite direction than predicted. Figure 1 also shows that consumption rates are lower than production rates, as we would expect, since fish are occasionally distributed to compounds where kin, but no fishers, reside.

MORNING TROLLING AND TORCH FISHING CONSUMPTION

Previous analyses have shown that the consumption rates for morning trolling are much higher among canoe owners than non–canoe owners (Sosis 1997). Therefore, here I have considered canoe owners and non–canoe owners separately. During the observation period, men trolled and torch-fished on the same day 10 times. Figure 2 shows that for canoe owners the mean consumption rate for trolling (1.31 kg/hr, $n = 67$) is higher than the mean consumption rate for torch fishing (0.47 kg/hr, $n = 45$) on the 10 days that both activities were pursued. This difference is significant

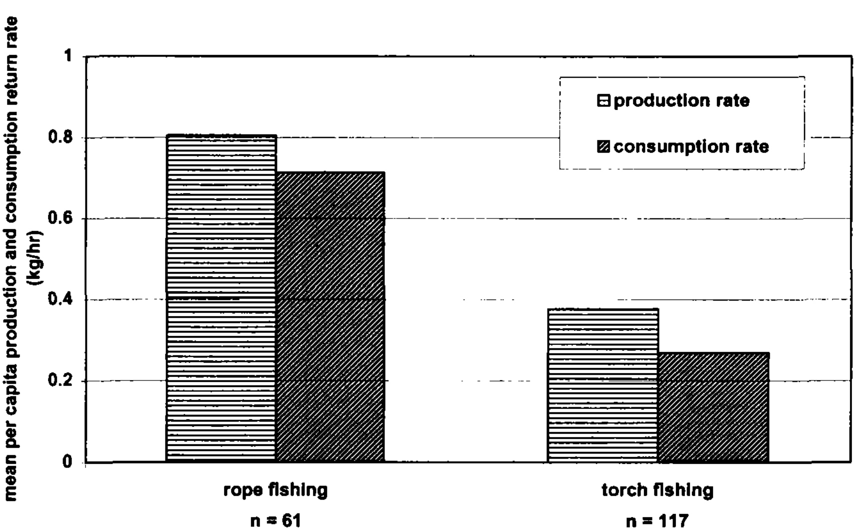

Figure 1. Mean per capita production and consumption return rates for rope- and torch-fishing.

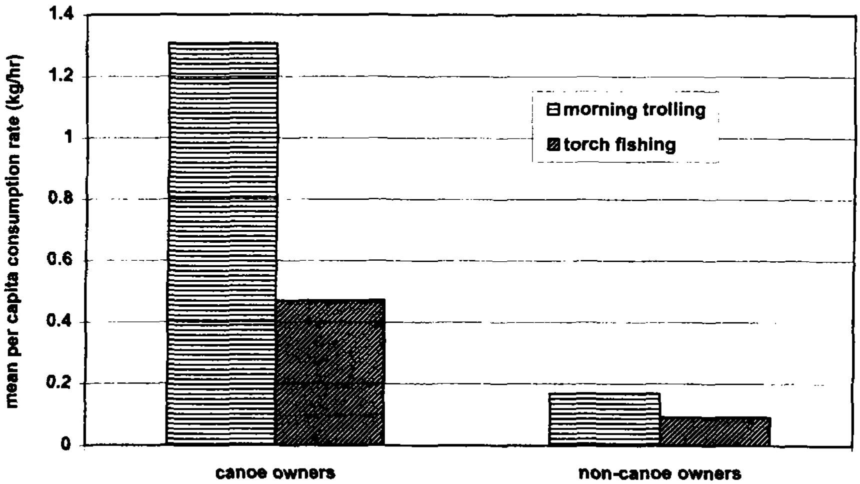

Figure 2. Mean per capita consumption rate by fishing method and canoe ownership on 10 days that men trolled and torch-fished.

in the opposite direction than predicted ($t = 3.33$, df = 80, $p < .001$). For non–canoe owners, the mean consumption rate for trolling (0.17 kg/hr, $n = 32$) is also higher than the mean consumption rate for torch fishing (0.09 kg/hr, $n = 58$). Again, this difference is significant in the opposite direction than predicted ($t = 1.63$, df = 39, $p = .055$).

Table 5 offers a closer look at the data; comparisons of consumption rates for torch fishers and morning trollers for each of the 10 days are presented. Table 5 shows that on four of the days the mean per capita consumption rates for canoe owners were significantly higher for torch fishing than morning trolling. On four of eight days (sample sizes prohibited statistical tests on two days) the mean per capita consumption rates for non–canoe owners were significantly higher for torch fishing than morning trolling.

DISCUSSION

The use of consumption rates as a currency to evaluate predictions generated from patch choice models has failed to explain why men torch fish for dogtoothed tuna. Similar to torch fishing production rates, the consumption rates of torch fishers are significantly lower than the consumption rates of rope fishers. In addition, when men go torch fishing and morning

Table 5. Mean Daily per Capita Consumption Rates of 10 Days That Men Morning-Trolled and Torch-Fished

		Canoe Owner			*Non–Canoe Owner*		
Event	*Date*	*Trolling Consumption Rate (kg/hr)*	*Torch Fishing Consumption Rate (kg/hr)*	*p*	*Trolling Consumption Rate (kg/hr)*	*Torch Fishing Consumption Rate (kg/hr)*	*p*
1	2/18	**1.67**	0.01	<.01	**0.24**	0.00	<.001
2	2/19	**1.43**	0.03	<.0001	0.02	**0.03**	NS
3	2/21	**1.45**	0.29	<.01	**0.18**	0.00	NS
4	2/22	0.00	**0.48**	<.0001	0.00	**0.18**	**
5	2/23	**6.26**	0.65	<.0001	**0.56**	0.24	<.01
6	2/24	0.00	**1.84**	<.0001	0.00	**0.52**	<.05
7	2/25	0.00	**0.72**	<.0001	0.00	**0.02**	<.0001
8	2/28	**0.01**	0.01	<.0001	**0.01**	0.00	**
9	3/1	0.03	**0.57**	<.001	0.03	**0.15**	<.001
10	3/2	0.00	**0.19**	NS	0.00	**0.13**	<.0001

Bold indicates the higher consumption rate.
** sample size too small to conduct statistical test

trolling on the same day, they only achieve higher consumption rates from torch fishing on roughly half those days.

It was expected that fish caught by morning trolling and rope fishing would be more widely distributed than fish caught by torch fishing. Indeed, during village-level and atoll-level *ilet* distributions that occur following morning trolling and rope fishing events, all compounds on Falalop receive fish, as well as several compounds on Falachig atoll (see Sosis 2000a). Fish caught by torch fishing are more narrowly distributed since canoe owners receive the majority of the fish. However, although fish caught by torch fishing are less widely distributed than fish caught by morning trolling or rope fishing, the empirical data on actual distributions suggest that torch fishers do not receive any more of the fish they produce than those who morning troll or rope fish. During the observation period, fishers and their compounds consumed on average 69.1% by weight (n = 793) of the fish they produced by morning trolling, 71.5% (n = 117) of the fish they produced by torch fishing, and 88.5% (n = 61) of the fish they produced by rope fishing.

Why are the consumption/production ratios for morning trolling and rope fishing not considerably lower than those for torch fishing? Although fish caught by morning trolling or rope fishing are more widely distributed than fish caught by torch fishing, more men are participating in these fishing events. On average, 8.6 men torch fish per event (s.d. = 3.5), 12.0 men morning troll per event (s.d. = 5.0), and 30.5 men rope fish per event (s.d. = 2.1). The fish distribution patterns on Ifaluk are a mix of investment-based distribution types (canoe owner distribution) and population-wide distribution types (*ilet* distributions, men's feasts), which ensure that all residents, or all male residents, receive fish regardless of their participation in production. However, even when fish are distributed widely, men still receive a significant proportion of what they produce because there are more producers. Although every compound on Falalop receives fish following rope fishing events, nearly every compound has at least one resident who participated in the harvest. Nevertheless, the number of fishers does not directly determine how fish are distributed on Ifaluk. For example, previous results have shown that the most important determinant of distribution type following trolling events is the size of the catch. When the catch is large, fish are distributed via an *ilet* distribution; when the catch is small, fish are distributed via a canoe owner distribution. It was also shown that although the number of fishers does not independently influence distribution type, catch size is positively correlated with the number of men who fish (Sosis 2000a). Thus, as more men fish, more fish are likely to be caught, and consequently, fish are more likely to be distributed widely via an *ilet* distribution.

Limitations of the Analyses

The analyses presented here introduce several issues of concern for patch choice studies of human foragers. Most notably, the analysis confronts a problem concerning individual decision making under the constraints of group foraging. Here it was assumed that individuals base their patch choice decisions on an assessment of patch profitabilities. However, when the mode of production is cooperative, patch choice decisions may not simply be the result of each individual's independent assessment of patch profitabilities. If a forager chooses not to participate in a collective pursuit, it may entail social costs. On Ifaluk, the social costs of not rope fishing appear to be much higher than for any other cooperative fishing method. Presumably, rope fishing requires the greatest number of fishers of any fishing activity on Ifaluk. This may result in an *expectation* that all men on the atoll will participate. Most men do indeed participate in rope fishing events; thus those who do not are conspicuously absent. Owing to the social costs of gaining a reputation as a free-rider, Ifaluk fishers may not be individually choosing which patches to exploit based on their assessment of patch profitabilites, but rather based on the social pressure of participating in a group fishing activity that others have decided will be profitable. Indeed, the determination of when to rope fish is made by a few influential men who attempt to mobilize others when they deem the conditions appropriate for rope fishing.

Cooperative foraging may also entail the additional costs of coordinating the labor effort of multiple individuals. The costs of coordinating the labor effort of many men may explain the infrequency of rope fishing on Ifaluk. Rope fishing, morning trolling, and torch fishing each pose collective action problems with different payoffs and different socially constructed solutions. The relative frequencies that men pursue each fishing method may be a reflection of the varying degrees of difficulty in solving each respective collective action problem. Rope fishing, with the largest labor force to coordinate, likely poses the most difficult collective action problem to solve (Olson 1965). It should be noted, however, that coordination and mobilization of large numbers of men are quite common in other areas of labor on Ifaluk, such as roof rethatching, canoe repairs, and house building. At least one of these activities occurs about every week on Ifaluk. For each of these activities there is an expectation that all men of the atoll will participate, and the compliance rates are very high (Sosis, unpublished data). In addition, during the summer atoll-wide cooperative fishing occurs about once every two weeks (see Betzig 1988 for description).

Another issue raised by the analyses presented here concerns how to evaluate whether foragers are pursuing a conservationist strategy when determining which patch to exploit (see Ruttan and Borgerhoff Mulder 1999; Smith and Wishnie 2000). It is possible that Ifaluk men rope fish infrequently in order to avoid overexploitation of the lagoon habitat. When asked, the high chief claimed that he would prevent men from rope fishing if he believed that the lagoon was being overexploited. Data that would allow us to determine how frequently rope fishing would have to occur to result in negative population growth of lagoon prey species are not currently available. Nevertheless, the chief apparently does not believe that one rope fishing event has much of an impact on prey density in the lagoon, since both rope fishing events occurred in a span of three days. In addition, conservationism is unlikely to explain why men rope-fished only twice during the entire trade wind season.

Lastly, the analyses presented were limited by assumptions about the costs of foraging activities. Here the costs of the three fishing activities were ignored; it was implicitly assumed that men face equal energetic costs when pursuing each fishing strategy. All patch choice studies on human foragers have either similarly ignored the costs of foraging activities or estimated the caloric expenditure of foraging activities using imprecise methods (e.g., Hill et al. 1987; O'Connell and Hawkes 1981, 1984; Smith 1991). Future work on human foraging decisions will need to focus on data collection methods that will produce accurate measurements of forager energy expenditure. This was one of the goals of the Ifaluk research project; however, owing to the video recording techniques used to collect energy expenditure data (see Sosis 1997), it was not possible to collect data on torch fishing (which occurred at night) and rope fishing (which occurred under water). It is possible that by ignoring the costs of fishing activities the relative net benefits of rope fishing have been overestimated. In other words, if rope fishing is energetically more expensive than torch fishing it may not be surprising that men pursue it less frequently. However, I suspect that the energetic costs of torch fishing are higher than the costs of rope fishing. Although swimming underwater is likely to be a very energetically expensive activity, rope fishers face none of the energetic costs of managing a large sailing canoe. Most important, torch fishers expend an enormous amount of energy on ritualistic behaviors (see Sosis 2000b), none of which occurs during rope fishing.

Why Do Men Torch Fish?

We are still left with our original question: why do Ifaluk men torch fish? Previously (Sosis in press, Sosis 2000b) I suggested that torch fishing might be a costly signal (Grafen 1990; Smith and Bliege Bird 2000; Zahavi 1977). In other words, the goal of torch fishing may not be long-term resource intake, but may be better understood as a display by certain males that advertises high quality and skills. A number of factors suggest that this hypothesis should be rigorously evaluated. The ritual activities and extraordinary preparations of torch fishing are energetically costly, suggesting that the net production rate of torch fishing may (comparatively) be even lower than the results presented here indicate. In addition, torch fishing events are the most public of all fishing events, suggesting that torch fishing may be some sort of display.

If the costly signaling hypothesis is correct it will also need to explain why canoe owners are torch fishing, since allocating their effort toward morning trolling has significantly greater gains than investing energy in torch fishing. One possibility is that canoe owners, who are either members of the same matriline or have children who are members of this matriline, are advertising the productivity of the matriline (Sosis 2000b). This and other hypotheses need to be further explored.

Do Ifaluk Men Have Control over the Fish They Produce?

Future research will also need to examine the causes of the fish distribution patterns on Ifaluk. Here I have not attempted to explain the distribution patterns but have considered them, as based on empirical observation, to be an assumed constraint. This assumption requires further discussion. In a commentary on Hawkes (1993a), Hill and Kaplan (1993) suggest caution when assuming that the sharing patterns are a constraint. They argue that Hawkes

> takes the redistribution patterns as unavoidable from the perspective of a provider and then models men's foraging decisions under this assumed constraint. We find it just as logical to take the male foraging decisions as a given (to be explained independently) and then model redistribution decisions after valuable resources have been acquired. In fact, the main issue that emerges from her paper is whether men have control over the redistribution of the resources they acquire or simply respond to redistribution outcomes beyond their control (p. 701).

Whether or not foragers have control over the resources that they produce is indeed an important issue. It should be noted that Hill and Kaplan's (1993) criticism was specific to the data Hawkes used in her analyses. They were particularly troubled by the lack of evidence to support the assertion that !Kung, Hadza, or Ache foragers have little control over the resources they produce (see Hawkes 1993b for a rebuttal and Hawkes 2000 for additional data and discussion).

Control over harvested resources is of course likely to vary across societies and resources. I have assumed here that Ifaluk fishers have little control over the resources they produce. Indeed, the formality of the sharing patterns on Ifaluk, not characteristic of !Kung, Hadza, or Ache sharing patterns, suggests that Ifaluk fishers have less control over their resources than these foragers. Ifaluk is a sedentary society that maintains a clan-based hierarchy; thus its social structure differs significantly from these hunter-gatherer societies. Given that chiefs have a significant amount of influence over all communal activities, it is not surprising that fishers have little control over the resources they collectively produce.

Following all collective fishing activities, fish are invariably tossed into a communal pile and are divided by one or two dividers. As with all status positions on Ifaluk, the position of the dividers is inherited and their authority rests on this inheritance. Fishers have little if any influence over how fish are distributed, and on occasion fishers are noticeably upset about the decisions of the dividers. However, I never observed anyone refusing to contribute to the communal pile (nor did any informant report such events). Why men voluntarily relinquish rights to the collectively acquired fish is worthy of further investigation. Here I can only suggest that if men refused to contribute their fish to the communal pile the chief would undoubtedly reprimand the offender. The most common punishment for malfeasance was the cutting down of all the trees owned by an offender.

Interestingly, informants claimed that the actual owners of collectively harvested fish are the women of the matriline that owns the canoe upon which the fish were caught. In practice, of course, women only have control of fish that they cook and redistribute. Indeed, not only do they have no influence at any initial distribution of fish (they are not even permitted to be present), they are entirely excluded from one of the distributions, the men's feasts.

Although Ifaluk fishers do not officially, or in practice, own the fish they collectively harvest, they are not producing a public good. It would also be a mistake to claim that the dividers own collectively harvested fish. The dividers' influence is limited by the expectations that others have about where fish should be distributed to, which is primarily influenced by the size of the catch (Sosis 2000a). Their greatest influence seems to be in determining whether or not a men's feast will occur. Preliminary work also suggests that dividers may punish men who do not regularly fish by altering the expected distribution patterns away from those men.

CONCLUSION

The consideration of consumption rates and the analyses presented here have failed to explain why men torch fish. However, a theoretically important set of hypotheses has been eliminated. Nevertheless, it would be imprudent to use these results to conclude that consumption rates are an irrelevant currency for understanding human foraging decisions. The analyses presented here were not a test of this general hypothesis. Even when sharing patterns are assumed, previous work has shown that consumption rates are a useful currency for understanding foragers' decisions concerning whether to join a foraging group (e.g., Smith 1991) or which patch to exploit (Minnegal 1997). Despite the negative results reported here, when foraging returns are distributed widely, consumption rates should indeed be used as a currency to model and evaluate human foraging decisions.

I wish to thank Rebecca Bliege Bird, Barry Glazier, Garnett McMillan, and Eric Smith for helpful discussions on the research presented here, and Rebecca Bliege Bird, Mike Gurven, David Waynforth, and two anonymous reviewers for reading this manuscript and providing very useful suggestions. The National Science Foundation (SBR9423070), L.S.B. Leakey Foundation, UNM Office of Graduate Studies, and UNM Department of Anthropology generously supported this project.

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NOTES

1. In one additional torch fishing event that occurred after the 75-day observation period considered in these analyses (see Methods), the mean per capita return rate from exploiting the dogtoothed tuna patch was less than the mean per capita return rate from the yellowfin tuna patch on that morning (0.04 kg/hr vs. 3.56 kg/hr).
2. Previous publications referred to this fishing method as "cooperative sail-fishing" (Sosis et al. 1998; Sosis 2000a). In this article I will refer to this fishing method as morning trolling or trolling for yellowfin tuna, and not as "cooperative sail-fishing," since two fishing methods that will be discussed here are cooperative and utilize sailing canoes.
3. See Burrows and Spiro (1957) for an excellent description of the role of the magician in Ifaluk society.
4. These five species were chosen among the 62 species of reef fish caught because of the availability of caloric information.
5. The complete database is available upon request from the author.
6. The uncooked estimates were calculated by determining what percentage each redistributed package was of the total fish redistributed and then multiplying that proportion by the total amount initially received by the compound.
7. This was estimated as the total amount of fish distributed via a crew feast divided by the number of men at risk of partaking in the crew feast.

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