Biocultural Diversity of the Ryukyu Archipelago based on the Plant Diversity used as Fish Poison

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Abstract

Before the 1960s, in the islands of the Ryukyu Archipelago, there were natural landscapes that were formed in relationship between people's livelihoods and nature, which could be called "island's satoyama". Even though the islands belong to the same Ryukyu Archipelago, the "island's satoyama" varies greatly among islands. In this study, I attempted to understand the diversity of the "island's satoyama" from fish poison plants. As a result of my survey, in total, 41 species of fish poison plants belonging to 24 families were recorded from the islands of the Ryukyu Archipelago. The number of species used as fish poison plants differed greatly between the high islands and the low islands. In addition, the use of fish poison plants differed depending on the livelihood of the people and their connection to other islands.

Keywords

Ryukyu Archipelago, high island, low island, biocultural diversity, fish poison

Introduction

The nature around villages, which is familiar to people, has changed over time in accordance with changes in people's lifestyles. One of the major changes in the nature around the villages on the islands of the Ryukyu Archipelago has been caused by changes in people's lifestyles since the 1960s. One of the most evident examples is the decrease in the number of rice paddies on the islands.

The islands of the Ryukyu Archipelago are administratively divided into Okinawa Prefecture, South of Okinawa Island, and Kagoshima Prefecture, North of Yoron Island. Statistical data on rice cultivation in Okinawa show a sharp decline in rice paddy cultivation after 1963 (Moriguchi 2011). This was directly caused by the 1963 drought. However, droughts are recurring natural disasters on the islands of the Ryukyu Archipelago that occurred before 1963. However, the 1963 drought was different from previous droughts in which rice cultivation returned the year after the drought ended; in the

case of the 1963 drought, rice cultivation as well as cultivation of soybeans declined sharply. In the past, farmers in rural areas had a semi-subsistence lifestyle. In addition to the carbohydrates from grains and potatoes, miso and tofu made from soybeans were important sources of protein. In other words, the sharp decline in soybean production after 1963 indicates the integration of rural life into the commodity economy from that time onward (Moriguchi 2011). Even in areas where rice was grown at this time, sweet potatoes were the staple food, and rice harvested from rice paddies was largely positioned as a cash crop, although there were cases in which rice was consumed by farmers themselves.

The decline in rice production can be attributed to the shift in cash crops from rice to other crops. In contrast to the decline in rice and soybean planting, sugarcane planting increased in the pre-drought period. The sugarcane boom happened 1959 to 1965. The sugarcane boom was triggered by the Japanese government's greater protection of the sugar industry, a sharp rise in international sugar prices in 1963 (the Cuban Missile Crisis that occurred in October 1962), and sugarcane was changed high value cash crop due to larger sugar mills (Moriguchi 2011). Thus, the nature around the villages in the Ryukyu Archipelago until then had consisted mainly of fields where sweet potatoes were grown as a staple food and soybeans were the mainstay as a source of protein, and rice fields where rice was grown as a cash crop, as well as fertilizer and fuel to support other subsistence livelihoods. Following this period, nature around the village was drastically altered by the cultivation of cash crops, mainly sugarcane, and the purchase of fertilizer and fuel, as the grasslands and mountain forests around the village were cut off from people's livelihoods.

Island's Satoyama

On the Japanese mainland, the drastic reduction in Okinawa's rice paddies coincided with major lifestyle changes. A typical example is the change in the fuel needed for daily life: from around 1960/61, wood and charcoal, which had been the main sources of fuel, were switched to propane gas nationwide. With this change, the forested areas of the satoyama, which provided firewood and charcoal, underwent a major transformation. For example, a satoyama was an ecosystem in which people have maintained various relationships in their daily lives in a spatial area centered on a mountain near a human village, including adjacent wooded areas, bamboo forests, fields, reservoirs, and irrigation canals (Moriguchi 2019).

Whether nature around the Ryukyu Islands villages can be called satoyama may be judged differently by different people. For example, some islands in the Ryukyu Archipelago are flat, low islands with no mountains, forests, or rivers. However, some Ryukyu Islands are high islands with mountains, forests, and rivers. In this paper, I will use the definition of satoyama more loosely and refer to the area of nature that supports daily human life and has been strongly influenced by humans as "islands satoyama" whether on a low island or a high island.

An example of an" island satoyama" is Nakandakari, Nanjyo-shi, located in the southern part of Okinawa Island. The southern part of Okinawa Island has a low island environment and the northern part of Okinawa Island has a high island environment. Nakandakari village is located on a terraced cliff. The uppermost layer of the cliff is composed of red clay and limestone, and the lower part of the limestone is a deposit of mudstone called "kuchya." The boundary between the limestone with high permeability and the mudstone with low permeability is fed by a spring that flows down the terrace cliffs as a river, moistening the alluvial lands along the coast and flowing into the sea. The center of the settlement is a spring called Nakandakari-hījyā. This spring was used not only for agriculture but also for drinking and daily life. The spring was located below the village on a terrace. Therefore, it was difficult for the villagers to walk up the slope from the spring to the village to fetch water. There is also a "kumui" (pond) at the spring, where farmers bathed their horses.

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Until the 1960s, rice paddies were built on prime land around the village. These rice fields were located along a stream channel that flowed from the spring. As a result, the gently sloping terraced cliffs were formed in the shape of terraced rice fields. Topographically, the alluvial land below the terrace cliffs is flat and seems to be suitable for rice paddies. However, when the amount of spring water decreases, the water supply is quickly exhausted and the rice paddies are not well irrigated. Accordingly, the terraced rice paddies closer to the spring are valued more highly. Another reason for this land use is that limestone soils are inherently highly permeable and rice paddies have always been at risk of leaking water.

In the fields that were not suitable for rice paddies and were located off the flow paths around the springs, sweet potatoes, which are considered a staple food, and sugarcane, which is a cash crop, were grown. Sugar was produced in small sugar refineries located in villages before sugarcane was produced in sugar mills. In the past, sugar production required large quantities of firewood; therefore, the land that was reserved to obtain firewood for sugar production was called "sātā-damun-yama." The "sātā-damun-yama" was also used as "genya" (wilderness), an area of land not suitable for cultivation, which was also used for grazing called "mō." *Cycas revoluta*, which is used as a food source, also grows in "genya." Apart from "sātā-damun-yama," in areas such as limestone outcrops that are unsuitable for cultivation, *Pongamia pinnata* (Fabaceae), which grows in such areas (called "ukafa-yama") and whose leaves are used as green manure for rice paddies, is the dominant species.

Considering Nakandakari as an example, the "island's satoyama" is thus a mixture of settlements, farmland, springs, and waterways, as well as "sātā-damun-yama", "genya" and "ukafa-yama," (*P. pinnata* growing areas). One of the village inhabitants Z.K., who was interviewed in Nakandakari, mentioned that 4,290 m^2 of "genya" and 990 m^2 of "ukafa-yama" belonged to him and the paddy patches added up to an area of 2,310 m^2 (Moriguchi 2019).

Fuel consumption in satoyama

Let us consider the supply of fuel, which is an important part of satoyama. How much fuel was needed on a daily basis in the past?

For example, if a person eats potatoes in all three main meals, how many potatoes do they eat on a given day? There is a records from before World War Ⅱ that presents of the number of days potatoes were consumed in southern Okinawa, Miyako Islands, and Yaeyama Islands. According to the record, the consumption of sweet potatoes was 294, 239, and 270 days in southern Okinawa Island, Miyako Islands, and Yaeyama Islands, respectively. This estimate was derived from the number of sweet potatoes produced, the number of sweet potatoes harvested per hectare, and the population size, and the calculation is based on the assumption that each person consumes an average of 2.7 kg of potatoes per day (Fujima 1933).

Ikema Island is a typical low island in the Miyako Islands, with an area of 2.80 km^2 and a maximum elevation of 47.0 m, of which 63% is limestone plateau, the remaining 25% hills, and 12% lowlands (Mezaki 1985).

According to Noguchi, who conducted a survey of Ikema Island in 1961, the main industry at the time was fishing, including the production of dried bonito. A total of 313 households were engaged in fishing, whereas only 15 were engaged in farming. However, even households whose main occupation was fishing grew sweet potatoes in their fields, which served as their daily staple food (Noguchi 1972). The lower island of Ikema Island has no forests for firewood. Instead, there is an area along part of the island's coastline where a dense growth of *Pandanus odoratissimus*

(Pandanaceae), called "adan-nī," grows and provides fuel for cooking potatoes for the daily meal. The dead leaves of *P. odoratissimus* were primarily used as fuel to cook potatoes for daily meals.

At the time of Noguchi's survey, Ikema Island had a population of 2454, there were 368 families including rented houses (Noguchi 1972). Dividing the number of inhabitants, which excludes 238 islanders at that time (219 children under 6 years old and 19 elderly people over 80 years old who were probably not eating as much as adults), by the number of households, we find that the average number of inhabitants per household was 6.02. on Ikema Island. This means that on average 2.7 kg × 6 persons = 16.2 kg of potatoes were cooked per day.

How many leaves of *P. odoratissimus* would be needed to cook these potatoes?

In this regard, the data presented by Ikema Elementary and Junior High School Students at the 2017 Adan Summit in Ikema Island are instructive. When students conducted a replicated experiment of cooking potatoes with *P. odoratissimus* leaves, they found that 25 kg of dead *P. odoratissimus* leaves was used to cook 9.3 kg of potatoes (Miwa,Miwa Eds. 2018). This suggests that 43.5 kg of dead leaves would be required to cook potatoes for six people per day.

It should be noted that this value includes a number of assumptions. During the Adan Summit, women in their 80s who had used the dead leaves of *P. odoratissimus* as fuel came on stage and shared their stories with the moderator. They mentioned using about 30 bundles of *P. odoratissimus* leaves as fuel per day and cooking about 20 kg of potatoes per day (Miwa,Miwa Eds. 2018). Thus, the number of dead leaves required is not significantly different from the previous estimate.

For example, a record from Arakaki, Itoman-Shi on southern Okinawa Island before World WarII indicated that the amount of firewood used by a household to prepare daily meals was approximately 30 kg (Maeda, 1985). According to these records, a semi-subsistence lifestyle based on potatoes would require 30–40 kg of fuel per day, depending on the quality of firewood.

In response to the question of whether there would have been a shortage of dead leaves of *P. odoratissimus* within the island if the above amount of dead leaves of *P. odoratissimus* had been consumed at the time of the Adan Summit, it was explained that, in such cases, dead leaves of *P. odoratissimus* were harvested from Miyako Island on the opposite shore (Miwa,Miwa Eds. 2018). From this exchange, it is not clear how often the interviewee traveled to Miyako Island to obtain dead leaves of *P. odoratissimus*. It is also unclear how many dead leaves from outside the island were used. It should be noted, however, that in the case of "island's satoyama," when the island's own resources were insufficient, the island's connections with outside sources sometimes compensated for it. There have often been clear cases of fuel plant resources being brought from outside the island.

Sesoko Island, located on the coast of the Motobu Peninsula on Okinawa Island, has an area of 3.43 km^2 and a maximum elevation of 40.8 m, and is similar in size as Ikema Island. In 1955, the population of Sesoko Island was 400 families with 1953 inhabitants, which is also similar to that of Ikema Island. Main industry was agriculture in Sesoko Island but, although main industry was fishing in Ikema Island. Before 1960, the daily food in Sesoko Island was primarily sweet potatoes. In Sesoko Island, where there were no forests, the dead leaves of *C. revoluta* growing in various parts of the island and the dead leaves of *P. odoratissimus* found on the beach were used as fuel. Dew to dead leaves of *C. revoluta* as firewood for sugar production, people didn't use daily meals. So, people rode on a boat, harvested and carried dead leaf of *Dicranopteris linearis* from Motobu Peninsula in Okinawa Island (Editorial Committee of History of Sesoko

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1995). According to an interview, a man born in 1935, went to the Motobu Peninsula once a week to collect *D. linearis*, which was called “warabi” in Sesoko Island, from the time he was a junior high school student. According to memories of a man, life in Sesoko Island in the past, most people on the island probably had the same experience of going to the Motobu Peninsula to harvest *D. linearis,* and that the village youth went there on Sundays and during long vacations to harvest *D. linearis* together (Editorial Committee of History of Sesoko 1995).

Fish poison plants

In addition to arable land, the” island‘s satoyama” comprises a series of fields for fuel and fertilizer, as well as grazing land for livestock. Interviews conducted on the islands revealed great diversity in the types of plants used as resources and in the locations where plants for fuel and fodder grew (Moriguchi 2019). People have created and inherited a culture using natural resources to make a living in accordance with the island’s natural environment. In other words, biocultural diversity can be observed there. The Ryukyu Archipelago is famous as a region rich in biodiversity within the Japanese Archipelago; however, it is also extremely diverse in terms of biocultural diversity. During the interviews, the author began to believe that fish poisoning could be used as a measure of the biocultural diversity of these islands (Moriguchi 2022).

Fish poisoning refers to poison used in fishing methods in which fish are paralyzed by toxic compounds from plants, animals, or chemicals released into the water, to be caught subsequently. Fish poisoning has been reported worldwide, and a wide variety of fish poisoning methods have been used. Fish poison is sometimes made from animals, such as sea cucumbers, but in most cases, plants have been used.

For example, in Guam, the Chamoro people use the seeds of *Barringtonia asiatica* (Lecythidaceae) as fish poison to catch fish in coastal tidal pools. The following description is from *Useful Plants of Guam* (Safford 1905).

> *“The fruit is pounded into a paste, inclosed in a bag, and kept over night. The time of an especially low tide is selected, and bags of the pounded fruit are taken out on the reef the next morning and sunk in certain deep holes in the reef. The fish soon appear at the surface, some of them lifeless, others attempting to swim, or faintly struggling with their ventral side uppermost.”*

Herbal fish poisoning is a method of paralyzing fish by crushing seeds, leaves, roots, and other parts of the plant used, depending on the type of plant, and dropping them into the water to dissolve the poisonous components contained in the plant.

A variety of components are known to act as fish poisons, including rotenone, coumarin, quinone, lignan, terpenoid, alkaloid, saponin, and polyacetylene. The representative constituents are rotenone and saponin. Rotenone was extracted from *Lonchocarpus nicou* (Fabaceae) in Guiana, South America, by Geoffroy in 1895. Rotenone is a fish poison component commonly found in the Fabaceae family. Rotenone is an enzyme inhibitor of the mitochondrial electron transport chain that causes suffocation and paralysis, followed by death (Cannon et al. 2004). However, there is more uncertainty about the mode of action of saponins as a fish poison in Theaceae (Cannon et al. 2004).

Different plant species are used as fish poison in different parts of the world. In Guam, the seeds in the fruit of *B. asiatica* have been used as a fish poison, whereas in Samoa, also a Pacific island nation, *B. asiatica* has been used as a fish poison as well as *Tephrosia piscatoria* (Fabaceae) (Cox 1979). In contrast, the large fibrous fruits of *B. asiatica* float in

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seawater, are dispersed by ocean currents, and are often washed up on the shores of the islands of the Ryukyu Archipelago but are not used as fish poison in the Ryukyu Islands.

In his review of fish-poisoning plants worldwide, Heizer mentioned three species of fish-poisoning plants that have been used in Japan: *Buddleja curviflora*, *Dioscorea tokoro*, and *Zanthoxylum piperitum* (Heizer 1953).

Heizer identified Southeast Asia, Oceania, the Middle East, India, and South America as the centers of fishing using fish poison (Heizer 1953). However, Neuwinger subsequently listed 258 species of fish poisoning plants in 60 families from Africa, which Heizer had not included as a center of fish poisoning (Neuwinger 1994). Further, from mainland Japan, in addition to the three species listed by Heizer, *Juglans mandshurica*, *Styrax japonicus*, *Diospyros kaki*, *Albizia julibrissin*, *Persicaria longiseta*, *Pourthiaea villosa*, *Camellia japonica*, *Camellia sasanqua*, *Camellia sinensis*, *Clematis terniflora*, *Thuja standishii*, *Toxicodendron fernicifluum*, *Toxicodendron fernicifluum*, and other species have been reported to be used as fish poison (Moriguchi 2022). However, the total number of plant species used to treat fish poisoning worldwide remains unknown.

On the Ryukyu Islands, fishing using fish poison was practiced in many areas before the Fisheries Resources Protection Act of 1952 completely banned this practice. The author conducted interviews and a literature review throughout the Ryukyu Islands and found 41 species of fish poison plants from 22 families (Table 1), including some uncertain information. Based on these results, the Ryukyu Archipelago can be regarded as a region with a high diversity of fish poison plants in the world in terms of area. Fish poison fishing in the Ryukyu Islands differs from that in mainland Japan in many respects, both in the types of plants used and the form of fishing. The most common fish poison plants in mainland Japan are *Z. piperitum*, *J. mandshurica*, *S. japonica*, and *D. kaki,* which could serve as common indicators of regional environmental characteristics, on the other hand, fish-poisoning plants characteristic of the Ryukyu Islands include *Schima wallichii*, *Ternstroemia gymnanthera*, and *Anagallis foemina*. In addition to *Derris elliptica,* an introduced plant often called “derisu” after World War Ⅱ, is mainly used. In the Ryukyu Islands, fish poison fishing is often carried out in coastal tide pools or “inō” (moat, shallow lagoon) within in addition to rivers, while in mainland Japan it is carried out only in rivers.

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Table 1. List of fish poison plants at Ryukyu Archipelago

Family	Species	Common name
Hernandiaceae	*Hernandia nymphaeifolia*	hasunohagiri
Lauraceae	*Cassytha filiformis*	sunazuru
Polygonaceae	*Persicaria longiseta*	inutade
Euphorbiaceae	*Euphorbia helioscopia*	doudaigusa
	E. jolkinii	iwataigeki
	E. antiquorum	fukurogi
	Triadica sebifera	nankinhaze
Fabaceae (plant family)	*Derris elliptica*	derisu
	D. trifoliata	shiinokikazura
	Mucuna macrocarpa	irukanda
	Melilotus officinalis	shinagawahagi
	Pongamia pinnata	kuroyona
	Erythrina crista-galli	amerikadeigo
Sapindaceae	*Acer itoanum*	kusonohakaede
Anacardiaceae	*Toxicodendron succedaneum**	hazenoki
Meliaceae (plant family)	*Melia azedarach*	sendan
Rutaceae	*Zanthoxylum amamiense*	amamizansyou
	Z. beecheyanum	hirezansyou
	Murraya paniculata	gekkitsu
Theaceae	*Camellia japonica*	yabutsubaki
	C. sasanqua	sazanka
	C. lutchuensis	himesazanka
	Schima wallichii	ijyu
Pentaphylacaseae	*Ternstroemia gymnanthera*	mokkoku
Ebenaceae	*Diospyros anaritima*	ryukyugaki
Primalaceae	*Anagallis foemina*	rurihakobe
	Lysimachia mauritiana	hamabossu
	Ardisia sieboldii	mokutatibana
Styracaceae	*Styrax japonica*	egonoki
Rubiaceae (plant family)	*Galium spurium*	yaemugura
Solanaceae (plant family)	*Nicotiana tabacum*	tabako
Scrophulariaceae	*Buddleja lindleyana*	kofujiutsugi
Acanthaceae (plant family)	*Justicia procumbens* var. *riukiuensis*	kitsunenohimago
Laminaceae	*Callicarpa japonica* var. luxrians	oomurasakisikibu
	*Vitex rotundifolia**	hamagou
	V. trifolia	mitsubahamagou
Pittosporaceae	*Pittosporaceae boninense* var. *lutchuense*	okinawatobera
Adoxaceae	*Sambucus chinensis*	sokuzu
	Viburnum odoratissimum	sangojyu
	V. suspensum	gomojyu
Apiaceae	*Angelica hirsutiflora*	nangokuhamaudo

*Associated with uncertainties.

Example of fishing using fish poison in Oku, Okinawa Island

Even within the islands of the Ryukyu Archipelago, there were differences in the use of fish poison plants between the high and low island. While a wide variety of plants were available on the high island, only a limited number of plants were available on the low island, particularly woody plants. However, even on the high island, the use of fish poison plants varied from island to island.

In Oku, Kunigami-Son, near the northern tip of Okinawa Island, five plant species, *S. wallichii*, *A. foemina*, *Viburnum odoratissimum*, *Nicotiana tabacum*, and *D. elliptica* were used as fish poison. It was also clear that these fish poison plants were used differently depending on the location, user, and purpose of use (Moriguchi 2022).

Fish poison was used river and sea. The river is divided into the main stream of the Oku River, which flows beside the village and its upper reaches. The sea is divided into tide pools and “inō.” In terms of classification according to fish poison users, the areas can be divided into fishing by the community as a whole, fishing by adults (groups or individuals), and fishing by children. In terms of use of fish poison, it can be divided into fishing associated with events, fishing for public auction, fishing for specific fish species, and children’s games, as summarized in Table 2.

Table 2. Fish poison fishing at Oku, Kunigami-Son

	Name	Location	User	Fish poison plants
A	Burē-zasa	River (main stream)	Entire community	*S. wallichii*, *D. trifoliata*
B	Burē-zasa	Sea (“inō”)	Entire community	*S. wallichii*, *D. trifoliata*
C	"Hiku" fishing	Sea (“inō”)	Group	*S. wallichii*
D	Public auction of "inō"	Sea (tide pools)	Group	*S. wallichii*, *D. trifoliata*
E	Eel fishing	River (upstream)	Individual	*V. odoratissimum*
F	"Inuji" catting.	Sea (“inō”)	Child	*N. tabacum*
G	Children play	Sea (“inō”)	Child	*A. foemina*

Fishing using fish poison is undertaken as a fishery method by adults or as a play activity for children. In Oku, two types of fishing were used as children’s games (Table 2 F, G). One was for children in the third grade or younger to collect *A. foemina*, called “wanqwabīna,” which grows as a weed in fields, in a small tide pool on the beach, grind the whole weed, and put it in the pool to catch small fish. According to the interviewee, this was a safe way for children who could not swim or fish to play at sea without any skills or tools. Another use of fish poison by children was by those who had learned to swim and had outgrown the use of *A. foemina*. Once children were able to swim, they began to fish called “kusabi” (Labridae spp.) while standing and swimming with a homemade fishing pole in their hands. The “kusabi” prey on small octopuses called "inuji," that lurk in holes in the dried-out coral reefs. So, children rubbed with the leaves of *N. tabacum* and placed in the holes, “inuji” would be exited from the hole. Some adult-led fisheries target specific fish species by exploiting the properties of fish poison. One such fishery is the river fishery for *Anguilla marmorata* (Table 2 E), where fish poison is used to catch *A. marmorata* that hide in burrows during the day.

Fishing using fish poison is not effective if the amount of poison used is too less relative to the amount of water in the target system, or if the amount of water in the system is too high. However, excessive fish poison or excessively strong a poison can deplete the resources of the system. For this reason, when fishing using fish poison in the sea, fish poison is spread around tide pools that are left behind at low tide, or around parts of the water system that become shallow at low

tide. When fishing in rivers, it is difficult to apply fish poison in rivers with excessive water or during the high-water season. Therefore, fishing is conducted in the upper reaches and tributaries of rivers, whereas fishing in larger rivers is conducted only during dry period. Because of these characteristics of fish poison fishing, fishing by private individuals for *A. marmorata* in rivers has been conducted in small mountain streams, called "yamakawa" in Oku. At that time, the leaves of *V. odoratissimum* were used as a fish poison. According to the interviewee, sand was piled in the river, and *V. odoratissimum* leaves were placed on the sand and beaten with a stick to release the poisonous ingredients. *V. odoratissimum* is used for private fishing in rivers, but not in the sea. The toxic components of *V. odoratissimum* may be weaker than those of *S. wallichii*; therefore, *V. odoratissimum* was not used in large water systems. However, *V. odoratissimum* was easier to handle *than S. wallichii because the* active ingredient can be quickly washed out by tapping the leaves, making it suitable for private fish poison fishing.

Powder made from the bark of *S. wallichii* was used for "hiku" fishing, in which juvenile *Siganus fuscescens* , called "hiku" , which come to the "inō" in schools from offshore in early summer, are scooped with a net (Table 2 C). The "hiku" schools would come to the reef from offshore at high tide. In the past, a designated person would watch the reef to see if a school of "hiku" approached the reef during the season, and the community would be notified if this school was seen entering the reef. When a group of people had seen that this school approached the reef, the community was notified. At this point, fish poison was used to stop the movement of the "hiku" and make it easier to scoop them up with a net. This is another example of the use of fish poison to match the characteristics of the target fish. According to the interviews, if too much fish poison was used, the "hiku" would die and sink to the bottom of the" inō," making it difficult to pick them up. On many islands in the Ryukyu Archipelago, schools of *S. fuscescens* that appear in season are caught, preserved in salt, and used as food for daily meals; however, fish poison is not used as often as in Oku. The fact that fish are difficult to catch with nets, unless fish poison is used to weaken them, may have something to do with the microtopography of the "inō" where fishing takes place.

The public auction of "inō" (Table 2 D) was the sale by the community to individuals of the right to fish with fish poison in the tide pools that appeared on the "inō" in front of the community at low tide. According to records from 1965 in Oku, 21 tide pools were sold at public auctions at prices ranging from $2 to $21 (Moriguchi 2022). According to T. Kinjyo, who conducted a study on "inō," fish poison fishing in tide pools was conducted about once every six months, during a period selected before the New Year or before the Bon Festival, when food was needed more than usual. Kinjyo attributes this to the fact that "there was an awareness that there was no hope of recovering the resource if such a period was not allowed" (Kinjyo 2009).

Among the adult-led fish poison fishing, "burē-zasa" is a village-wide fish poison fishing (Table 2 A, B). The name "burē-zasa" also refers to group fish poison fishing, which can take place either in the river or in the "inō." During river fishing, the community was divided into two groups, one upstream and one downstream of the Oku River, and each group fished for fish poisoning. The main catch was *A. marmorata*, although *Mugi* spp. were reportedly caught downstream. The "burē-zasa" on the river was clearly conducted during the summer season according to the records kept, but it was not conducted annually at that time. The "burē-zasa" was conducted on the river only in 1951 and 1955 after Word War Ⅱ. While fish poison fishing can catch a large number of fish simultaneously, it also has a large environmental impact, and depending on the environment, fishing may not be the best way to catch fish. Once a fishery is conducted, it often takes time for the stock to recover depending on the environment. The public auction of the "inō" fish poison fishing in the tidal pools was also conducted only twice a year in the same tidal pool, as described above. Therefore, the fact that the "burē-zasa" of the river was not conducted every year may be related to the recovery of the stock.

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Fish poison fishing in the main stream of the Oku River requires a large amount of fish poison. Therefore, the entire village had to be involved in fish poisoning in the main stream. Before World War II, fish poison was made by peeling the bark of *S. wallichii* trees that grew naturally in the mountains behind the village and grinding it into a powder. After the war, a more potent powder made from commercially available *D. elliptica* was used to kill insects in the tea grown in village fields. The catch from the river "burē-zasa" was divided among the participating households.

The sea "burē-zasa" was held in a rented "inō" in front of Sosu, which is next to Oku. This was done because Oku's "inō" is too small to accommodate the entire community's fish poison fishing, while Sosu's population is smaller than Oku's and its "inō" is larger. To prevent fish from escaping, a part of the "inō" was surrounded by a rope with *Arenga engleri* leaves inserted, and fish poison was spread inside the rope. The "burē-zasa" of the sea is held the day before "abushi-barē," a community event held after rice planting to pray for a good harvest. The catch was served at the "abushi-barē" feast. The "burē-zasa" of the sea, however, was not held every year on the same day as the "abushi-barē," but rather once every few years.

Thus, Oku is characterized by the practice of fish poison fishing throughout the community. If it is too small, it is not suitable for village-wide fish poison fishing and an "inō" or tide pool of sufficient size is not available. Thus, community-wide fish poison fishing was conducted in Kedoku, Tokuno-shima, Tete, Tokuno-shima, Arime, Okinawa-jima, Ada, Okijawa-jima, Gesashi, Okijawa-jima and Shiraho, Ishigaki-jima. Fish poison fishing was conducted in tide pools in Kedoku and Tete, and in rivers in Arime, Ada, Gesashi, and Shiraho, but there were no examples of group fish poison fishing in either rivers or the sea, as in Oku.

Diversity of fish poison fishing in the high islands of the Ryukyu Archipelago

The type of plant used for fish poisoning varies among high islands (Moriguchi 2022).

Amami-ōshima Island is the largest island in the Ryukyu Archipelago, with a total area of 718.74 km^2, second only to Okinawa Island, with a total area of 1182.52 km^2; and its highest elevation of 694.4 m is higher than the highest elevation of Okinawa Island (498.0 m). According to interviews, people in Tean, use *S. wallichii* to catch *A. marmorata* in the river. The sea in front of Tean is a tidal flat; therefore, fish poison fishing in the sea was not practiced because of the lack of tide pools. In addition to *S. wallichii*, *Zanthoxylum amamiense* was used as a fish poison in Amami-oshima Island in many cases. In Ookasari, *Z. amamiense* was used in the river. In Ookasari, *A. foemina was* sometimes used for fish poisoning in tide pools in the sea. In addition, *S. japonica* has also been recorded as a fish poison, bringing the total number of fish poison plants recorded in Amami-ōshima Island to seven species.

Interviews revealed that Tokunoshima Island is smaller than Amami-ōshima Island, with a total area of 248.11 km^2 (highest elevation 644.8 m), but used a greater variety of fish poison plants. Fish poison was used in both tide pools and rivers in Kedoku. Fish poison used in the tide pools included *A. foemina*, *S. wallichii*, and *D. elliptica, as* well as *Pesicariar longeseta* and *S. japonica* berries. In addition, *C. japonica'*s seed meal, which is material for oil, was used as fish poison too. In Kedoku, fish poison was also used to catch juvenile *S. fuscescens* called "suku" as well as Oku. Because an excessively strong fish poison would kill the "suku" and cause them to sink to the bottom, *C. japonica*'s seed meal, which is the less potent, were used. In Inokawa, *A. foemina*, *S. wallichii*, *Vibrunum suspensum* and *Vitex rotundifolia* (with uncertainties) was used as fish poison. In addition, seed meal of *C. japonica*, and *C. sasanqua* were used as fish poison. *Z. amamiense* was used fish poison too, but there were few *Z. amamiense* around the village. Interestingly, in Kanami,

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where *S. wallichii* does not grow well, the crushed roots of *Ardisia sieboldii were* used as a fish poison in tide pools. In Tete *A. foemina* was used as a fish poison, as well as the fruit of *T. gymnanthera*. In total, 11 plant species have been used as fish poison in Tokunoshima Island.

The total number of fish poison plant species recorded from Okinawa Island, including interviews and literature review, was 11. Among these, *S. wallichii*, *A. foemina*, *D. elliptica*, and *V. odoratissimum* were the main species used, whereas *Toxicodebdron succedaneum*, *Callicarpa japonica* var. *luxurians*, *Vitex Toxicodebdron succedaneum, Callicarpa japonica* var. *luxurians, Vitex trifolia*, *Acer itoanum*, and *P. pinnata* were used only in a limited number of settlements. In Okinawa Island, the northern part is a high island environment and the southern part is a low island environment, and the fish poisoning plants used in each part are different. For example, *S. wallichii*, a typical fish poison in Oku in the north, does not grow in the south and is accordingly not used as a fish poison.

Kume Island is much smaller than Amami-ōshima Island, Tokuno-shima Island, and Okinawa Island, with a total area of 58.50 km^2 (the highest elevation is 326 m), but many species of fish poison plants have been recorded. According to an interview in Nakachi,*V. odoratissimum* was used for fish poison fishing in the river, whereas *S. wallichii* was not used. *A. foemina* and *D. elliptica* were also used as fish poison, whereas *D. elliptica was* used in tide pools. According to the interviewees, *Pittosporaceae boninense* var. *lutchuense* was also used. In Maja, *C. japonica* seed meal, *A. foemina*, and *Galium spurium* were used as fish poison. In addition to other studies have reported other plants (ex. *Tryadica sebifera, Derris trifoliata, Mucuna macrocarpa* et al.) , bringing the total number of plants used as fish poison on Kume Island to 15 species.

Ishigaki Island has a total area of 223.41 km^2 (highest elevation 525.8 m), and together with its neighbor Iriomote Island (total area 287.66 km^2, highest elevation 469.7 m), it is a representative high island of the Yeyama Islands. In Tonoshiro, Ishigaki-jima, *Zanthoxylum beecheyanum* was used as a fish poison in tide pools, and *Diospyros anaritima* was used as a fish poison in rivers. In Shiraho, as mentioned earlier, a group of people used fish poison, and fishing was performed during droughts by pouring fish poison into the Todoroki River in conjunction with rainfall events. The bark of *T. gymnanthera* was used in this practice, and it is documented that *Euphorbia antiquorum* was also used in the past (Moriguchi 2022). In addition to other studies have reported (ex. *Melia azedarach* et al.), in total nine species were used as fish poison in Ishigaki Island.

Fish Poison Fishing in the Low Islands of the Ryukyu Archipelago

Next, let us examine the fish poison plants used in the low island of the Ryukyu Archipelago.

Kikai Island, which belongs to the Amami Islands, is a low island with an area of 55.71 km^2 (the highest elevation (224.0 m), and 97% of the island consists of limestone plateaus. *A. foemina* and *Justicia procumbens* var. *riukiuensis* was used to catch small fish from tide pools.

Yoron Island, also part of the Amami Islands, is a low island with an area of 20.82 km^2 (the highest elevation is 97.1 m) and all the island are composed of limestone plateaus. *A. foemina* and *Euphorbia helioscopia*, which grows as a weed in fields, and *E. jolkinii* grows naturally on rocks along the coast are used as fish poison in this island.

It is interesting to note that fish poison was sometimes obtained from outside the islands of Kikai Island and Yoron Island. In Yoron Island, where it was reported that *S. wallichii* bark was brought from Okinawa Island for fish poisoning. In Kikai Island, *Z. amamiense* leaves and *S. wallichii* shavings were reported to have been brought from the neighboring

Amami-ōshima Island and used as fish poison (Moriguchi 2022). This was probably because *Z. amamiense* and *S. wallichii* were more effective as fish poison than *A. foemina* and other herbaceous fish poison plants.

In Okinoerabu Island, one of the low islands in the Amami Islands, with an area of 94.54 km^2 (the highest elevation is 246.0 m), 93% of the island consists of limestone plateaus, and the fish poison plants reported were *A. foemina*, *Melilotus officinalis*, and *E. antiquorum*. The area around the summit of Mt. Ōyama in Okinoerabu Island is a non-limestone area, where *S. wallichii* grows and was used as a fish poison. In this aspect, Okinoerabu Island can be viewed as an intermediate between the low and high islands. However, there is a record that Okinoerabu Island also used the bark of *S. wallichii* as a fish poison after it was transferred from Okinawa Island, suggesting that the amount *of S. wallichii* obtained from Mt. Ōyama was not sufficient.

Despite these differences between the high and low island, the background of the various fish poison fishing practices in the islands of the Ryukyu Archipelago seems to be related to the fact that the people of the islands of Okinawa Prefecture were strongly tied to the royal government-led agricultural policy, which focused mainly on tax collection, dating back to the Ryukyu Kingdom period; the people of the islands of Kagoshima Prefecture were similarly tied to agriculture dating back to the Edo period. For farmers who live on islands surrounded by the sea but lack specialized skills and tools, fish poison fishing may have been a valuable method of obtaining protein from the surrounding water systems. It has been suggested that the unique practice of public auction of “inō” in Oku may be due to the lack of full-time fishermen in Oku (Kinjyo 2009).

Discussion

What type of poison fishing was practiced in Sesoko Island and Ikema Island, where we mentioned the cases of fuel imported from outside the islands?

In Sesoko Island, *A. foemina* was used as a fish poison in tide pools. In addition, fish poison fishing is basically undertaken by adults. According to the literature (Editorial committee of History of Sesoko 1995), *S. wallichii* was also used as a fish poison, but this species was probably brought from Okinawa Island and used as a fish poison. In contrast, interviews in Ikema Island indicated that *A. foemina and M. officinalis* have been used as fish poison in tide pools, but this was limited to children’s games. Since Ikema Island is an island where fishing is the only occupation, fish poison fishing was considered only a children’s game.

Tarama Island, located between Miyakojima and Ishigaki-jima, is a low island with an area of 19.88 km^2, maximum elevation of 34.4 m, and 96% limestone. The fish poison used in Tarama-jima was *A. foemina* and *Cassytha filiformis*, and was used in a children's game. Why fish poison was used only children’s game in Tarama Island where the main industry was agriculture. Off the coast of Tarama Island, there is a small low island called Minna Island with an area of 2.51 km^2 and a maximum elevation of 8.0 m. Recently, most of the inhabitants have moved to other islands, but the island was originally a fishing island. The caught fish were brought to Tarama Island, where they were exchanged for potatoes and other products. *History of Tarama-son* (Vol. 4) states, “The exchange of fish caught by Minna Island residents for potatoes from Tarama islanders was also common”. The reason why fish poison fishing in Tarama Island was considered only a children’s game was because the catch was brought from Minna Island on a daily basis. This explains the role of poison fishing in Tarama island.

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Thus, even the seemingly unique case of fish poison reveals the diverse nature of the islands of the Ryukyu Archipelago, as well as the diverse cultures and interactions of people that have emerged in response to that nature.

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