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TAWNY FISH-OWL PREDATION AT FISH FARMS IN TAIWAN

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ABSTRACT.—We examined the conflict between cold-water fish farmers and endangered Tawny Fish-Owls (*Ketupa flavipes*) in Taiwan. From 1994–2000, we surveyed 144 fish farms to assess the level of fish predation by Tawny Fish-Owls and to document farmers' responses to owl predation. From July 1994–May 1996, studies were conducted at five farms on Nanshih Stream in northern Taiwan and Tachia Stream in central Taiwan to determine the size of fish taken by the owls and the factors affecting predation rates. Owl predation was reported at 25 (17.4%) of the fish farms. Most farmers claimed that owl predation was most frequent during winter, then spring, fall, and summer. At 16 of these farms, owls were trapped with steel leg-hold traps or mist nets, and 10 owls were found drowned or floating in the fish ponds of eight farms. At the five intensively-studied fish farms, the owls took 8–131 (0.04–0.66%) of ca. 20 000 fish available each year. As the water level in streams increased, owls visited fish farms more often than expected. Owls foraged more frequently on clear nights and caught 101–400 g of fish more often than expected.

KEY WORDS: *Tawny Fish-Owl*; Ketupa flavipes; *fish predation*; *mortality*; *fish farms*; *Taiwan.*

DEPREDACIÓN DE PECES EN GRANJAS POR PARTE DE *KETUPA FLAVIPES* EN TAIWAN

RESUMEN.—En este estudio examinamos el conflicto entre los cultivadores de peces de agua fría y la especie de búho amenazada *Ketupa flavipes* en Taiwan. Entre 1994 y 2000, estudiamos 144 granjas de peces para establecer el nivel de depredación de peces por parte de *K. flavipes* y para documentar la respuesta de los cultivadores ante la depredación por parte de estas aves. Entre julio de 1994 y mayo de 1996, se realizaron estudios en cinco granjas en el arroyo Nanshih en el norte de Taiwan y el arroyo Tachia en el centro del país para determinar el tamaño de los peces consumidos por *K. flavipes* y los factores determinantes de las tasas de depredación. Se reportó depredación por parte de esta especie en 25 (17.4%) cultivos de peces. La mayoría de los cultivadores dijeron que la frecuencia de depredación era máxima durante el invierno y seguidamente menor en la primavera, el otoño y el verano. En 16 de estas granjas se capturaron búhos con trampas de acero o redes de niebla y 10 individuos fueron encontrados ahogados o flotando en los lagos de ocho cultivos. En las cinco granjas estudiadas intensivamente, los búhos capturaron entre 8 y 131 (0.04–0.66%) de los aproximadamente 20 000 peces disponibles anualmente. A medida que el nivel del agua en los arroyos se incrementó, las aves visitaron los cultivos de peces más frecuentemente que lo esperado. Los búhos forrajearon más frecuentemente en noches claras y capturaron 101–400 g de peces con mayor frecuencia que lo esperado.

[Traducción del equipo editorial]

Fish-owls are often regarded as nocturnal counterparts of the diurnal Osprey (*Pandion haliaetus*), fish eagles (*Ichthyophaga* spp.), and sea eagles (*Haliaeetus* spp.). Fish-owls include four species of *Ketupa* in Asia and three species of *Scotopelia* in Africa (Fogden 1973). The Tawny Fish-Owl (*K. flavipes*), the only fish-owl found in Taiwan, occurs from the Himalayan foothills of Kashmir and Garhwal, east to the mountains of northern Laos, Vietnam, and south China, and north almost to the Yellow River (Voous 1988). In Taiwan, the Tawny Fish-Owl is rare, primarily due to the degradation of riparian habitat and illegal hunting (Severinghaus 1987). This species is listed as endangered under the 1989 "Wildlife Conservation Law" (Council of Agriculture 1989).

In Taiwan, cold-water fish farming in low-elevation mountain streams began in 1960–65 (Tzeng

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1988). Fish-owls prey upon farmed fish, including rainbow trout (*Oncorhynchus mykiss*) and ayu (*Plecoglossus altivelis*; Wang et al. 1994). Although protected, the owls have been illegally trapped or killed by farmers. While some farmers claim that owl predation causes major losses, to date no data have been presented to substantiate these claims.

Understanding the extent and cost of fish predation by owls is necessary to prioritize conservation activities and to implement effective management of this rare bird. In this study, we investigated Tawny Fish-Owl predation on farmed fish and the interactions between fish-owls and fish farmers.

STUDY AREA AND METHODS

We conducted this work in Taiwan. With an annual precipitation of 1000–6700 mm and an annual mean temperature of 22–24°C (Taiwan Forest Bureau 1995), about one half of the island is dominated by luxuriantly-forested mountains. Taiwan has ca. 129 streams, ranging from 10–200 km in length.

From the Taiwan Department of Fisheries database, we acquired information on 220 registered cold-water fish farms. We excluded farms in deforested suburban areas, where fish-owls do not reside (Sun 1996). The remaining 144 farms were located in the mountains in potential fish-owl habitat. From 1994–2000, the farmers of these farms were interviewed by questionnaire (with an owl picture) and by telephone. Questions included in the questionnaire simply asked whether farmers had seen this owl depredate fish or found fish scales and remains on walkways at their farms. Of the surveyed farms, 108 (75%) were located in central and northern Taiwan, where the climate is cooler and more suitable for cold-water fish farming, and 36 were located in southern Taiwan. We visited each farm that reported owl predation or found evidence of predation and asked farmers to rank the intensity of owl predation by season (spring: March–May, summer: June–August, fall: September–November, winter: December–February). Farmers provided a predation-intensity score from 1–4, which corresponded to owl predation that was very rare, rare, common, or very common, respectively. We also documented measures taken by farmers to protect fish from owl predation and the fate of owls trapped or taken by farmers.

From 1994–96, we closely examined Tawny Fish-Owl predation at four fish farms (two in each of two fish-owl territories) on Nanshih Stream (Sun et al. 2000) and at one fish farm in a fish-owl territory on Tachia Stream. Nanshih Stream ranges from 250–550 m above sea level, and is in northern Taiwan, 30 km south of Taipei. Three streams, Hawun, Chakung, and Talolan, join Nanshih Stream near Fusan, an aboriginal village. On the east and south banks of the stream, the vegetation consists mostly of subtropical rainforest dominated by *Ficus* and Lauraceae (Taiwan Forest Bureau 1995). Makino bamboo (*Phyllostachys makinoi*) and Cryptomeria (*Cryptomeria japonica*) plantations, farmland, and human habitations occupy much of the west and south banks. Tachia Stream is located in central Taiwan. It runs through warm-temperate, montane forests of Lauraceae trees (Taiwan Forest Bureau 1995), *Cyclobalanopsis* sp., alder (*Alnus formosana*), Taiwan red pine (*Pinus taiwanensis*) and Taiwan short-leaf pine (*P. morrisonicola*). We documented fish predation by Tawny Fish-Owls at the Malin Fish Farm, 1000 m in elevation.

Each fish farm hatched 30 000–100 000 trout and ayu each year, mainly during January–March. Fish were kept in circular or rectangular fish ponds; each circular pond has an outlet in the center, unlike the rectangular one with an outlet located at the other side of the inlet. Trout grow to marketable size (>500 g) in 12–14 mo and ayu (80–120 g) take 5–7 mo. After harvest, 100–900 trout remained at each fish farm where they continued to grow (to 1500–2000 g) through the following year. These fish were sold or consumed at a later date. Unlike trout, ayu perished after breeding. Hence, farmed fish usually were available to owls throughout the year. At these five farms, we documented fish stocks, prey remains, the size (g), and species of fish taken by owls and the dates that owls caught fish. The size of fish taken by owls from ponds with fish of only one age class was easily estimated. For fish taken from ponds with fish of more than one age class, we estimated prey mass from sizes of the gills and scales in the remains. We were able to record the time of some predation events by opportunistic observations and radio-tracking. Owls were seen grabbing fish out of the water by their talons, holding them in talons on the bank, and sometimes plucking the gills and bladders out before swallowing pieces of meat.

We captured two Tawny Fish-Owls in each two territories by trapping them at night on tree branches or on pond banks at fish farms with foot-snare traps. The owls were then radio-tagged prior to release. Radio transmitters (MD-205; Telonics Inc., Mesa, AZ U.S.A.) weighed 70–80 g (< 3.5% of the owl's body mass) and had a lifespan of ca. 2 yr. Transmitters were attached dorsally with a backpack harness of wire (1.5 mm in diameter) wrapped inside a tubular teflon ribbon. Owls were located by homing a directional hand-held H-antenna with a TR-2 receiver (Telonics Inc., Mesa, AZ U.S.A.) and by triangulation, taking at least two bearings for each location.

We also examined whether owls more frequently preyed on fish in different stream flow conditions or during periods of different rainfall levels than expected. For each season and owl territory, the expected values were determined based on the proportion of the number of nights in different rainfall or stream flow categories during our observation period. The observed values were based on proportion of nights that we observed owl predation on farm fish during the different rainfall and stream-flow categories. We obtained rainfall (mm) data from the Taiwan Central Weather Bureau and water flow (m^3s^{-1}) data from the local hydrographic station of the Taiwan Power Company, which was <1 km from fish farms. Rainfall was categorized into two levels: 0–10 and >10 mm/d. Stream flow was classified as: low (≤10 m^3s^{-1}), moderate (11–20 m^3s^{-1}) or high (>20 m^3s^{-1}).

Likewise, we examined whether owls preyed on fish in certain size classes more often than expected. For each owl territory, the availability of fish in each size class was estimated as the product of fish quantity ($\times 10^4$) and the

number of months the fish stayed in the pond. The proportion of fish in each size class taken by owls served as a measure of resource use.

Chi-square analysis (Conover 1980) was used to determine whether stream flow or rainfall was related to owl predation and to assess owl selection of fish by size. For significant relationships, analyses of selection (Bonferroni's Z test) described by Neu et al. (1974) were tested in terms of the use (observed) versus availability (expected) data. Differences in owl predation intensity among seasons were tested with the Friedman test (Conover 1980). Data were managed and analyzed with the Statistical Analysis System (SAS Institute 1989).

RESULTS

A total of 25 (17.4%) of the 144 fish farms reported owl predation. Two farms raised ayu, 18 had trout, and five farms raised both species. These farms were all from central and northern Taiwan, where most farms were located. Owl predation rates varied among seasons (Friedman, $\chi^2 = 17.0$, $P = 0.007$). Farmers claimed that owl predation was most frequent during winter ($\bar{x}$ predation intensity score = 3.5, $N = 25$), than spring ($\bar{x} = 2.4$, $N = 25$), fall ($\bar{x} = 2.2$, $N = 25$), and summer ($\bar{x} = 1.9$, $N = 25$). However, at the two ayu farms (Nanao and Tungao) owl predation was highest during the summer (predation reported as very common, rank = 4).

After discovering fish remains on banks, farmers would set steel leg-hold traps or mist nets to catch the predator. Usually, it was only after the owl was captured that the farmers became aware of this rare owl species. Of the 25 fish farms reporting predation, Tawny Fish-Owls were caught at 16 fish farms from 1970–present. One owl was caught at 10 farms, nine farms caught two owls, and three farms caught three or more owls. Alarmingly, two farmers who had been in business for over 10 yr had caught more than five owls each. Farmers removed 28–37 owls that were caught in steel leg-hold traps and three in mist nets.

In addition, we recorded 10 incidents in which fishing owls were unable to get out of a pond at eight farms. Five owls drowned and five were alive and floating when they were found by farmers in the morning. Most accidents ($N = 8$) involved owls preying on large trout (600–900 g); an equal number of such incidents occurred in circular and rectangular fish ponds.

At the three Tawny Fish-Owl territories monitored, the seasonal pattern of owl predation was somewhat mixed (Fig. 1). Predation intensity generally increased in October or November and was highest during the winter. At the Malin Farm, owl predation was highest in April, and it also appeared to increase during November 1995 and February 1996.

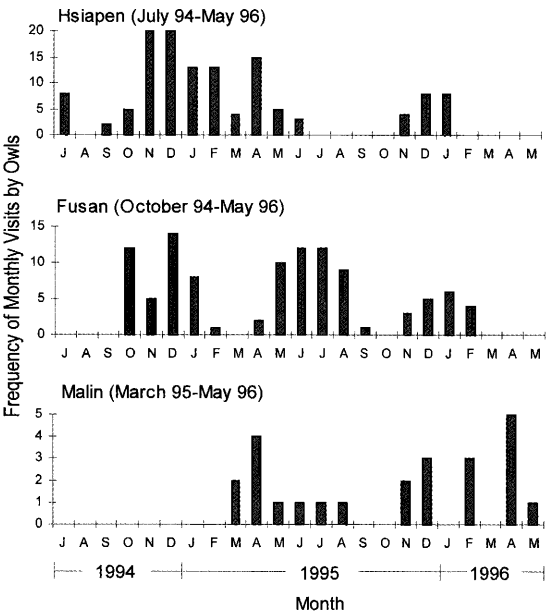

Figure 1. Tawny Fish-Owl foraging trip frequency (number of nights/mo) at cold water fish farms in three owl territories along Nanshih and Tachia streams, Taiwan, 1994–96. Data collected at the Hsiapen and Fusan farms were based on radiotelemetry, and date collected at Malin Farm based on fish remains found on the banks of fish ponds.

We recorded 206 hunting events, including sightings and fish remains, at the five farms. Except for one early morning hunt, hunting only occurred at night. Of the 53 hunts for which the time was known, 28 (52.8%) occurred before midnight. Individual owls visited 1–3 times each night, spending 6–22 min, with a mean of 12.1 min (SD = 7.0, $N = 7$ nights), hunting for trout near the water surface. Of 15 foraging attempts observed, five were successful (33.3%). Two trout were eaten immediately on the bank, and the other three were taken into a nearby forest. Sometimes, we found fish scales and remains at foraging perches near the farms. We observed a pair of owls fishing at the Fusan Fish Farm on nine nights. This farm was lit all night by lights. Usually, the owls perched on a nearby snag, immediately adjacent to the fish farm, where they watched for 1–53 min ($\bar{x} = 9.8 \pm 16.4$ min) before flying to the farm.

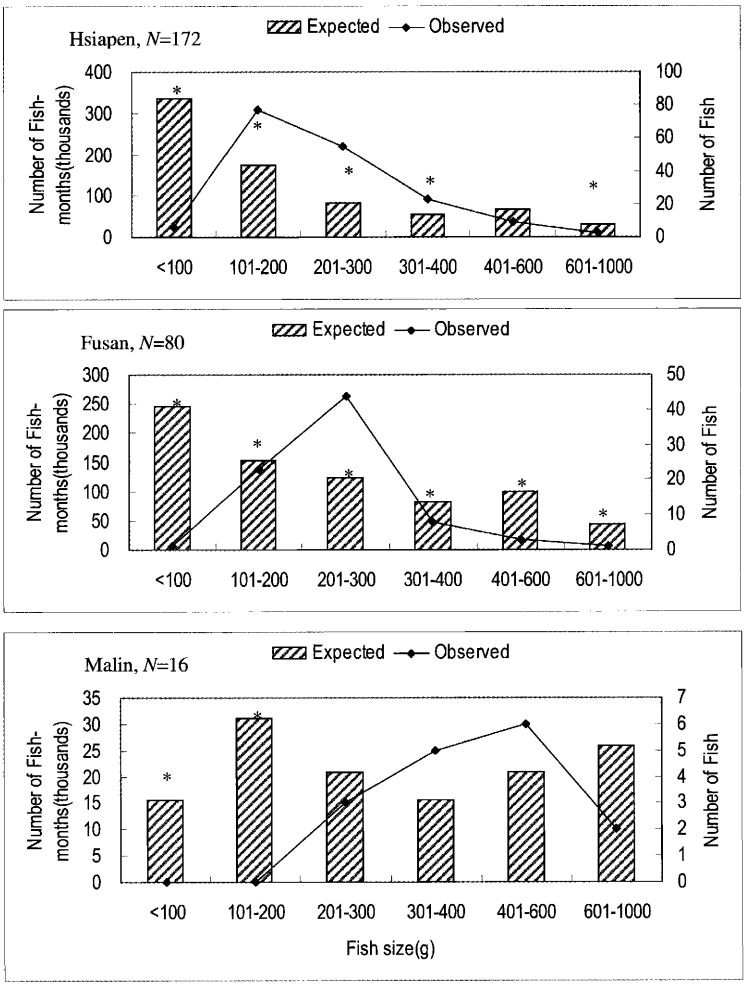

Figure 2. The observed number of fish taken by Tawny Fish-Owls and the availability of fish based estimated fish-months in mass classes (g) at fish farms in Taiwan, July 1994–May 1996. An asterisk (*) indicates $P < 0.05$, Bonferroni Z test.

We found the fresh remains of 60 trout on the banks of fish farms. All trout remains included bloodstains and scales, most also contained gills (77.7%), and some contained the stomach and/or jaws (16.7%). However, only bloodstains and scales were found at fresh ayu remains ($N = 37$). Tawny Fish-Owls took fish ranging from 80–1000 g. They chose fish of specific sizes at Hsiapen ($\chi^2 = 84.2$, df = 5, $P = 0.001$), Fusan ($\chi^2 = 46.5$, df = 5, $P = 0.001$) and Malin farms (Fisher exact test, $P = 0.004$; Fig. 2). Owls preyed on medium-sized fish (101–400 g) more frequently than expected, and on small fish (<100g) and large fish (>600 g) less often than expected (Bonferroni Z test, $P < 0.05$). At Malin Farm, owls foraged on slightly larger fish (300–600 g).

In summer, fall, and winter, Tawny Fish-Owls fished on nights with no or light rainfall (Table 1; Bonferroni Z test, $P > 0.05$). In spring, owls foraged slightly more frequently than expected during heavy rain at Fusan and Hsiapen, but this result was not significant ($P > 0.05$; Table 1).

Owls preyed at fish farms more frequently than expected when stream flow was medium and high (Bonferroni Z test, $P < 0.05$). However, the relationship between water flow and owl predation was not significant ($P > 0.05$; Table 2). Small sample size may have been a factor. In all seasons and ar-

Table 1. Tawny Fish-Owl nighttime foraging trips to cold water fish farms in three owl territories in Taiwan, in relation to rainfall and season, July 1994–May 1996.

TERRITORY	SEASON		RAINFALL (mm) 0–10	RAINFALL (mm) >10	NUMBER OF NIGHTS
Fusan	Summer	Expected	82	10	92
		Observed	21*	0*	21
	Fall	Expected	56	5	61
		Observed	16	1	17
	Spring	Expected	84	8	92
		Observed	13	2	15
Hsiapen	Summer	Expected	54	6	60
		Observed	16*	0*	16
	Fall	Expected	140	12	152
		Observed	45*	1*	46
	Spring	Expected	84	8	92
		Observed	27	5	32
	Winter	Expected	160	18	178
		Observed	53	5	58
Malin	7/95–6/96	Expected	311	23	334
		Observed	33*	0*	33

* Indicates observed value was significantly different than the expected value; $P < 0.05$, Bonferroni Z test.

eas, owls went to fish farms as often, or less often, than expected when water flow was low (Table 2).

From July 1994–June 1996, Tawny Fish-Owls took a total of 288 fish, including 260 trout (90.3%) and 28 ayu (9.7%) from five fish farms in three fish-owl territories (Table 3). At each of the five fish farms, the owls were known to take 8–131 (0.04–0.66%) of ca. 20 000 fish available during the year. The estimated annual cost of the fish taken from each farm ranged from $18–$316 US. In 1994–95, owls killed the greatest number of fish at Loshanchun and Hsinshen farms. In 1995–96, owl predation at these two farms decreased.

DISCUSSION

Tawny Fish-Owls took fish from less than 20% of the cold-water fish farms in Taiwan. We postulate those fish farms at which owls are not a problem do not lie within owl territories because original riparian forests have been eradicated (Sun 1996).

Our data suggested that Tawny Fish-Owls visited fish farms most frequently during the winter. This pattern may have occurred because owls required greater amounts of energy during the cold winter and because fish of suitable sizes were available. For instance, Sun and Wang (1997) reported that the daytime foraging activities of the predominately nocturnal owls were higher in the winter than in other seasons, based on radiotelemetry data. The stock of fish of the most-often-taken sizes (101–400 g in the Fusan and Hsiapen territories, and 301–600 g at Malin) was greatest in winter, when trout were 8–12 mo old. The availability of these medium-sized classes may have encouraged owl predation. Neither weather, stream flow, nor fish behavior seemed to explain the higher owl predation in the winter. In the study areas, rainfall was lowest during the winter, especially in central Taiwan (Central Weather Bureau 1995). Although rainbow trout that dwelled in deep (>20 m), cold water during the summer, resided in shallower water (<10 m in depth) in winter (Fast 1993), we suggest that seasonal changes in the depth at which fish live do not explain seasonal changes in the incidence of owl predation at fish farms. First, in cold water fish ponds, the water temperature changes very little over the year. Second, the water was less than 1.5 m deep in fish ponds. Finally, sick trout were more common during the hot summer, when water temperatures exceeded 24°C. Sick trout usually swam just beneath the surface, making them easy targets for owls.

Tawny Fish-Owl breeding activity may affect their use of Nanshih Stream fish farms during the spring. In spring 1995, a pair of owls nested in virgin riparian forest along Chakung Stream (Fusan territory), ca. 800 m from two fish farms. From

Table 2. Tawny Fish-Owl hunting trips to cold water fish farms in three owl territories in Taiwan, in relation to water flow and season, July 1994–May 1996.

Territory	Season		Water Flow			Number of Nights
			Low	Medium	High	
Fusan	Summer	Expected	52	37	3	92
		Observed	2	18*	1	21
	Fall	Expected	28	15	18	61
		Observed	0*	5	12*	17
	Winter	Expected	32	43	15	90
		Observed	2*	7	2	11
	Spring	Expected	45	42	5	92
		Observed	8	5	2	15
Hsiapen	Summer	Expected	22	26	16	60
		Observed	4	8	4	16
	Fall	Expected	53	56	43	152
		Observed	1*	41*	4*	46
	Spring	Expected	45	42	5	92
		Observed	12	16	4	32
	Winter	Expected	70	93	15	178
		Observed	13*	35*	10	58
Malin	July 95–June 96	Expected	183	119	32	334
		Observed	18	11	5	34

* Indicates observed value was significantly different than expected value; $P < 0.005$, Bonferroni Z test.

early February to mid-May, the owls stopped visiting the farms. We speculate that the distance between the nest and the farms may have been too great, especially for the male, who delivered food to the female during incubation and to the young during the brood-rearing period (Sun et al. 1997). At Sakatang Stream, pellets, droppings, and prey remains were mostly located within 500 m of the nest of a pair of breeding owls. In addition, for males, nest defense may be more crucial than access to a readily available food source. After mid-May, as more food was needed to feed the young, parent owls may be stimulated to take additional risks and forage at fish farms. In the remaining two

Table 3. Tawny Fish-Owl predation on farmed, cold-water fish and the estimated cost to fish farms in three owl territories in Taiwan, July 1994–96.

Date	Territory	Fish Farm	Number of Fish		Total	Cost (US)
			Trout	Ayu		
July 94–June 95	Fusan	Hsinshen	55	0	55	208.6
		Fusan	14	0	14	34.9
		Total	69	0	69	243.5
	Hsiapen	Loshanchun	122	9	131	316.3
		Hsiapen	13	8	21	58.3
		Total	135	17	152	364.6
July 95–June 96	Fusan	Hsinshen	21	0	21	79.6
		Fusan	3	5	8	18.0
		Total	24	5	29	97.6
	Hsiapen	Loshanchun	20	2	22	98.5
		Hsiapen	—[a]	—	—	—
July 95–June 96	Malin	Malin	16	0	16	60.4

[a] Data not recorded.

territories and other areas surveyed, variation in the predation rates during the spring and summer may have resulted from the distance between nesting sites and fish farms. In Taiwan, most fish farms were built near developed riparian zones in lowland areas. Tawny Fish-Owls are unlikely to nest near these farms or forage at them during the breeding season.

Mist netting was not as effective as steel leg-hold traps in capturing Tawny Fish-Owls that preyed on farm fish. This was because mist nets were erected to capture smaller predatory birds such as the Black-crowned Night Heron (*Nycticorax nycticorax*), a common nuisance in Taiwan. Therefore, the owls often can escape after initial entanglement. Tawny Fish-Owls can become trapped in pond water and drown. Poole (1989) proposed that drowned Ospreys were not pulled into the water by the large fish they seized. He argued that Ospreys, with the ability to catch prey weighing up to 1500 g, could readily remove their talons from prey if they were too heavy. No fish were found in the talons of injured or drowned Tawny Fish-Owls. However, the Tawny Fish-Owls we found in ponds containing large trout (>600 g). Photographs taken with an automatic camera placed at a fish pond revealed that fish-owls catch fish by plunging into the water, as do Osprey (Poole 1989). Blakiston's Fish-Owls (*K. blakistoni*) were also seen catching fish by plunging into the water (Yamamoto 1988). We assume that catching large fish takes more energy and increases the chance of a struggle in the water. Thus, the chance of injury and death may increase with fish mass, especially for slow-flying birds, such as most owls (Norberg 1987). Two owls preying on small fish also were trapped in the water. In these cases, we believe the strong current in the circular pond, which has an outlet in the center that generates a vortex, was probably responsible for these accidents. We also suggest that owls that fish near the outlet could be sucked into the vortex.

During this study, the fishing success of Tawny Fish-Owls at fish farms was 33.3%, somewhat lower than that of the Blakiston's Fish-Owl (45–50%) in a stream (Yamamoto 1988). Usually, Tawny Fish-Owls spent <1 hr fishing at a fish farm. The owls could quickly catch all the fish they needed because prey was abundant and they eat only 114–228 g of prey per day (Sun 1996).

Owls tended to avoid foraging at fish farms when it rained hard at night. Heavy rain also might reduce or stop owl foraging in streams by making it difficult for owls to detect prey. After moderate rains made the water in Nanshih Stream turbid, Tawny Fish-Owl hunting of farmed trout increased. This likely occurred because fish-pond water remained clear. Most of the small creeks that provide water for the fish ponds drain heavily-vegetated slopes. Water in these smaller streams remained clear during and after moderate rain. Consequently, owls foraged at the fish farms when ponds were clear. However, heavy rains made the water of small creeks and fish ponds turbid, probably decreasing owl predation.

Most farm fish caught by Tawny Fish-Owls weighed 101–400 g, or 4.1–16.5% of the owls' body mass (2200–2650 g). The prey/predator body mass ratio for Osprey, which catches 150–300 g fish, was also 8.3–16.7% (Poole 1989). We saw a number of large farm trout (600–1000 g) with scratches on both flanks, suggesting an owl had tried and failed to capture the fish.

After owls were captured and released at fish farms, they seemed to reduce their hunting at these facilities. In 1994–95, owls killed fewer fish at the Fusan and Hsiapen farms, compared to the Hsinshen and Loshanchun farms. This probably occurred because we first trapped, marked, and released two owls each at the Fusan and Hsiapen farms in the fall of 1993. In 1995–96, we captured, marked, and released the two owls that used the Hsinshen Farm within the Fusan territory, and one owl that used the Loshanchun Farm, of the Hsiapen territory, again causing a decrease in predation at the farms again. Specifically, the number of fish eaten by owls decreased by 83.2% and 61.8% at the Hsinshen and Loshanchun farms, respectively.

Lower owl depredation at Malin probably resulted from other factors, such as an increase in natural prey abundance and effective use of dogs as an aversion measure. The Fusan Farm owner even used the presence of Tawny Fish-Owls to attract birders and photographers, who paid boarding fees. Based on our data, fish farmers were relieved to find out losses to owls were relatively minimal.

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