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A Living Based on Breath-Hold Diving in the Bajau Laut

Sea nomads or ‘sea people,’ namely the ‘Bajau Laut’ in the Philippines, Malaysia and Indonesia are skilled divers, and many Bajau Laut make a living from freediving. Men do most of the spearfishing, but women also dive, predominantly for gathering sea food. They start to dive at an early age and spend most days of their lives on and in the sea.

Our objective was to study their diving and way of life, to reveal if modern humans have the physiological potential for making a living from breath-hold diving for fishing and gathering. Bajau Laut were visited for a total of nine months, during three periods from 2010-2013, in a combined physiological and social-anthropological study. The diving physiology studies focused on a total of 10 male divers, whose working day diving while spearfishing was logged with time-depth loggers. One group of 5 divers were engaged in shallow (5-7 m) spearfishing with an underwater working time of 60%, when diving for 2-9 h. The other group of 5 divers went to a mean depth of 10 m and had an underwater working time of 50%, when diving for 3-9 h per day. During that time, between one and eight *kilograms* of coral fish, blow fish, moray eels and octopuses were caught, per diver. Seafood collected by the women included clams, crustaceans, sea weed and sea cucumbers. Life among the Bajau Laut was much like it was 25 years ago, although in some areas the fish stock is diminishing, making it necessary for the Bajau Laut to spend more time in the water to obtain the same quantity of fish. It was concluded that modern humans do possess the physiological qualities necessary for making a living from hunting-gathering via breath-hold diving.

Introduction

In Southeast Asia, there are at least three groups of ‘Sea nomads’, ethnic groups who have traditionally lived in house-boats: Moken, Organg Laut and Bajau Laut, which are spread over a vast area (Figure 1). These groups are not considered to be related, but have a similar lifestyle, and all groups live from sea harvesting (Chou, 2009; Blust, 2007). Today, only fractions of sea nomads live all year around on houseboats. However, the majority still live a life closely interlinked with the ocean.



Figure 1. Sea nomads of Southeast Asia: Moken, Orang Laut and Bajau Laut. Places where sea nomad groups were visited by the authors:

1. Topa, Buton, Indonesia (1988, 2011, 2013)
2. Ambon, Indonesia (1988)
3. Matina Aplaya, Gulf of Davao, Mindanao, Philippines (2010-2013)
4. Tukangbesi Islands, Indonesia (2011)
5. La solo, Indonesia (2011, 2013)
6. Riau, Indonesia (1988)

In this study, we focused on the largest and most wide-spread group of sea nomads, the Bajau Laut. The Bajau Laut live in the Philippines, Indonesia, Malaysia and Brunei; they are known by neighboring people for their seafaring and diving skills. It is thought that they may *have lived on the sea for at least 1000 years* (Blust, 2007; Pallesen, 1985). Many Bajau Laut breath-hold dive to catch fish and collect food from the seabed, using no, or very little, equipment. The catch is consumed, or traded for cassava, rice, fruit and other staple foods (Nimmo, 2006).

We recently visited and studied the diving activities and lifestyles of two groups of Bajau Laut, located in Davao, Mindanao in the Philippines and in Buton, South East Sulawesi, in Indonesia. These groups of Bajau Laut have lived separately for more than 100 years, but their houses and fishing equipment are similar. They speak different dialects, yet nearly all words related to marine life are identical in both groups (Blust, 2007, Abrahamsson, personal observations).

Previous observations

In 1988, for a total period of 3 months, Schagatay studied the Orang Laut in Riau, and the Bajau Laut in Sulawesi and Ambon, Indonesia. All live either as nomads, on small houseboats, or in coastal settlements (Figure 2). The Orang Laut in Riau, who were studied extensively by Cynthia Chou, have a similar lifestyle to the Bajau Laut, but speak a different language (Chou, 2007; Blust, 2007). In these nomadic boat families, all family members dive for an important part of the day, sea harvesting and fishing. In large families, small boats are towed behind the houseboat (usually 4-6 m long), in which children can stay. It is common to have many children and one family had raised 23 children, all still alive, on one houseboat.



*Figure 2a. Nomadic Orang Laut in Riau.
Figure 2b. Bajau Laut settlement Topa, Buton.*

One Bajau Laut village visited was Topa, where about 350 people lived in stilt huts in a shallow bay, but the men, women and children spent most of their time in boats and in the sea (Figure 2b). For part of the year, the inhabitants left their settlement to make long boat trips, apparently much like the still nomadic groups of the Bajau Laut. Among the Bajau Laut, in the near shore villages, most fishing was carried out by the men. Physiological recordings have revealed that these people display a powerful and efficient diving response (Schagatay, 1991; Schagatay & Andersson, 1998; Schagatay, 1996). Some groups studied spent an average of 6 h per day in water, and the maximum time observed in water was 10 h (Schagatay, 1996). By timing diving and interval durations from the surface, the divers were estimated to spend about 50% of their working time under the surface. According to the divers, a sufficient catch to make a living was obtained by diving 2-3 h per day during the good season. Typical diving equipment consisted of small wooden goggles, and for fishing, a simple speargun. No fins or suits were used. Most individuals were engaged in diving for gathering seafood, although most of the underwater hunting was done by adult men. Children gathered seafood without goggles or any other equipment, and it was noted that they appeared to see well under water.

Aims of the present study

In subsistence diving, an important skill is not to remain under water for a long period of time during any given dive, but to maximize the underwater working time for extended fishing. Time spent on the seabed is crucial for the Bajau Lauts' success, both as harvesters and spearfishermen – enabling them to collect more sea produce, and find and catch more and larger fish. The first objective of the present study was to record the diving patterns of the Bajau Laut divers engaged in spearfishing, to reveal the underwater working time and depth. The second objective was to establish to what extent the Bajau Laut still lived on marine resources from diving, and therefore to assess whether modern humans have the physiological potential to make a living from breath-hold diving for fishing and gathering. Finally, we aimed to compare the life of the present day Bajau Laut in one community, Topa, in South East Sulawesi, Indonesia, with that observed 25 years ago in the same community.

Methods

This study was conducted during three periods of time, for a total duration of nine months, between February 2010 and January 2013. One author, Abrahamsson, lived for part of the time in a Bajau Laut community in Matina Aplaya, in the Davao Gulf of Mindanao, Philippines, where he observed fishing and gathering. In the Gulf of Davao, he specifically studied ten spearfishermen, aged between 14 and 65 years, in two sepa-

rate groups: Group A in 2010, and Group B in 2011. Group A were aged between 16 and 48 years (the mean age was 38 years); Group B were between 14 and 65 years (again, the mean age was 38 years). Both groups used essentially the same fishing equipment, except for one diver in Group A who used a wetsuit.

Dives were observed and timed from the surface, and also registered using dive data loggers (Sensus Ultra, ReefNet Inc, Ontario, Canada) which the divers were requested to wear on their swimming trunks. These loggers recorded time-depth profiles and temperatures during part of, or entire, dive shifts. Measurements were taken during regular fishing activities. A total of approximately 1000 dives by the ten divers were analyzed for dive duration, interval duration and depth, and total daily work time was noted.

In 2011 and 2013, Abrahamsson also visited the village of Topa, in southeast Sulawesi, Indonesia. Based on observations made by Schagatay in 1988, comparisons were made between former and present lifestyles, diving activities and diving methods. Direct observations were made of everyday life and fishing and diving expeditions. On both occasions, the chief Husimang and other key individuals were interviewed. For interviews conducted in 1988, Schagatay used an interpreter, whereas in 2011 and 2013 Abrahamsson conducted the interviews himself, having learned Indonesian Bajau during his previous stays in the region. Abrahamsson also visited the Tukangbesi Islands and Lasolo in Sulawesi, Indonesia to gain greater insight into Bajau Laut life.

Results

Seabed harvesting

The Bajau Laut harvest anything that is useful from the seabed, including molluscs, crustaceans (and other invertebrates), seaweed, algae, and fish. Fishing and gathering is carried out by men, women and children. However, men do most of the spearfishing and deep sea diving, while women and children dive to collect various species of clams, snails, sea cucumbers (echinoderms), crustaceans, and plants. During low tide, they also collect molluscs and other sea food. From direct observations, typical harvesting dives were between two and five meters deep, 10 m at most.

Further observations revealed that Bajau Laut children learn to swim and dive at an early age, and are introduced to water by older siblings or their parents. Some learn to swim before they can walk. Schagatay observed in 1998 that Bajau Laut children have good underwater vision, which allows the gathering of small clams without the use of goggles. It was later confirmed by Anna Gislén that Moken children from the coast of Thailand have superior under water vision – seeing twice as well underwater as European children (Gislén et al., 2003). These characteristics were further studied and she went on to explain why this was so: they have not only a very flexible lens allowing great accommodation, but in addition, they can constrict the pupil while diving to allow better focus (Gislén & Gislén, 2004). Moken children's vision on land is normal.

During the studies conducted in 2010-2012, it was established that children were still diving successfully, without any visual aids. Occasionally, women dived with goggles, but frequently also without. Most adult men, however, used small wooden goggles while spear fishing and sea harvesting, but some were accustomed to diving without goggles and did so frequently in shallow waters.

Spearfishing

Divers used wooden goggles, homemade rubber sling spear-guns, though typically no diving suit for thermal insulation. Most of the Bajau Laut in Indonesia dive with bare feet (Figure 3a), while some divers encountered in the Philippines used one or two self fabricated fins (Figure 3b).



Figure 3a. Bajau diver using goggles.

Figure 3b. Bajau diver using goggles, speargun and one fin.

Group A

In Group A studied in 2010, observations and recordings of diving profiles showed that dive durations were 23-58 s, with a mean (SD) of 28 (9) s. Surface intervals were 14-48 s; mean 19 (8) s, which was significantly shorter than the dive durations ($P < 0.001$). This group had a total underwater working time of 60 (SD 6) % (also reported in Schagatay et al., 2011). Depths were between 5 and 7 m (mean 6 m) and their daily working time in the water, at a mean temperature of 26 C, was 2-9 h.

Group B

In Group B studied in 2011, recordings revealed dive durations of 14-97 s, with a mean (SD) of 42 (3) s (Figure 4). The surface intervals were 5-201 s with a mean of 42 (5) s. This group's total underwater working time was 50 % of their fishing time. Dives were 3 to 25 m (mean 10 m) deep. Their daily working time in the water, at average temperatures of 26-29 C, was 3-9 h.

General observations

In both groups, most of the time underwater was spent searching for, shooting, or retrieving fish. Most dives did not result in a catch, and the time at the surface was used for reloading their rubber sling harpoons and resting. When fish were caught, more time was spent at the surface seeing to the fish. During dive shifts, considerable quantities of fish could be caught: between one and eight kilos of coral fish, blow fish, moray eels and octopuses, per diver. Typically, diving shifts lasted for five hours, with divers taking only short breaks for food, water and transportation to new fishing sites.

Two divers in Group B, aged 30 and 32 years, reached depths of up to 25 m, and repeatedly a depth of 20 m. The youngest divers, aged 14 and 16, had similar underwater working times as the older divers, but they did not dive as deep. Those with the greatest underwater working time and diving depths combined, were aged between 30 and 50. The oldest divers, aged between 55 and 65, were still successful fishermen, but with significantly reduced underwater working time, their fishing trips also tended to be shorter. However, it became evident that during daily repeated diving, the Bajau Laut do not dive to their maximum capacity.

Deep diving

In August 2013, a Bajau Laut deep diving competition was organized in Davao City in the 'no limits' category by the Freediving Philippine and Sinama Social Network for Sama and Bajau Laut. The competition had 18 contestants, 12 of whom were male Bajau Laut. They used weights to descend and then were pulled up by their colleagues onto the boat – this is a traditional form of deep diving among the Bajau Laut. All the men in the competition dived to 100 ft (33 m) or more. The deepest dive was 262 ft (79 m) and the longest time spent underwater was three minutes and one second. The person who finished second in the competition, a Bajau Laut from Matina Aplaya, dived 242 ft (73 m) using only a pair of small wooden goggles.

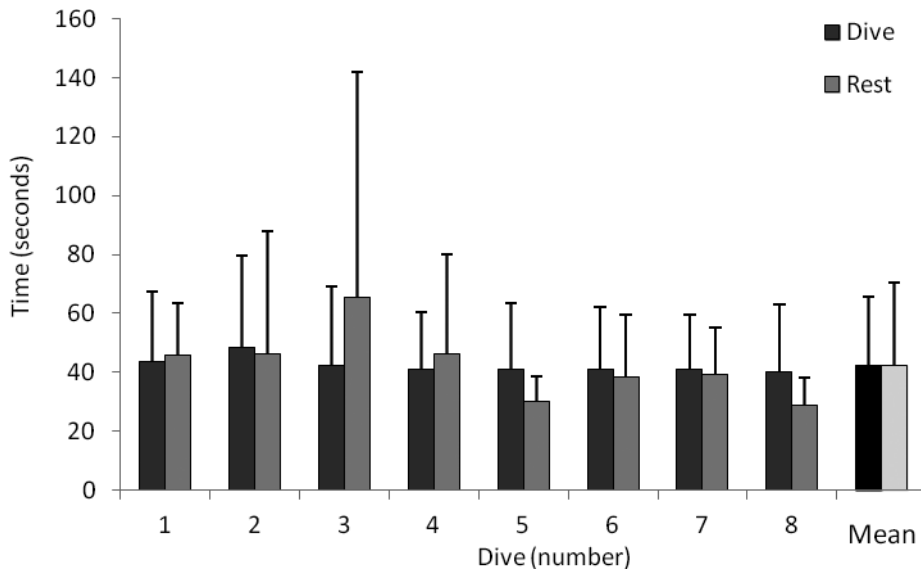


Figure 4. Mean (SD) durations of dives and surface resting intervals in 8 consecutive dives by 5 Bajau spearfishermen. Mean dive time and interval time were the same, 42 s.

Bajau life today

The Bajau Laut is by far the biggest group of sea nomads in Southeast Asia and is spread over large parts of the so called coral triangle – the most diverse marine environment in the world (Veron, 2000). While originally, they lived on houseboats in the Philippines, Malaysia and Indonesia, today only a small number of boat-dwelling Bajau Laut have remained. The majority of these people now live on the coast of Sabah (Malaysia), but there are also a few boat nomads left in the Gulf of Tomini, Indonesia (Langenheim 2010; Stacey, 2007). Today, most Bajau Laut, for at least part of the year, live in stilt houses along the shoreline.

Men still dive for fishing, although it would appear that women in settled Bajau Laut communities are less involved in the daily fishing than in boat-dwelling communities. Women in coastal settlements spend less time at sea and more time on household chores, e.g., washing, and selling fish to inland communities. Many, though not all, of the children in the settled Bajau Laut communities, also attend local elementary schools.

Life in Topa

When Abrahamsson first visited Topa in 2011, 23 years after Schagatay, the aging Husimang was still chief of the village. Upon his arrival, Husimang asked him directly if Schagatay had sent him. Only one other westerner, an Australian researcher, had visited since then. Abrahamsson gave them photographs taken in 1988. Now, two sons of Husi-

mang have taken over some of the responsibilities of the village, although most common decisions are made by the village elders (men and women), some older than 70 years. The population of Topa is still around 350.

The majority of the Topa population today make a living from the sea, even though some of the younger men work in Baubau, the major city on the island. Both men and women still breath-hold dive, with only wooden goggles. Children continue to learn to swim, dive and row dugout boats at an early age. Their houses, built mainly from palm trees with woven nipa roofs and walls, are positioned on the water in the same way as before (Figure 2b).

On the whole, the lifestyle of the Bajau Laut in southern Sulawesi has remained the same as it was in 1988, when Schagatay visited it. In this community, stilt huts are prevalent, and long excursions are made by boat. Many of the Bajau Laut in Topa and the Tukangbesi islands also go on fishing expeditions, undertaken by whole families to the island of Flores in southern Indonesia, across a 350 km wide strait (approximately 190 nautic miles), where they visit relatives before returning home. These journeys can last for many months. On these occasions, life resembles the self-sustained nomadic lifestyle of earlier times.

The main difference today is that the Bajau Laut face greater economic difficulties than they did 25 years ago – the result of diminishing fish populations. Their equipment is the same but ocean fish populations are considerably smaller, in part because of commercial fishing ships (Nimmo, 2005; Stacey, 2007). Consequently, the Bajau Laut fishermen have to spend more time on and in the sea in order to feed their families. Over-exploitation of the fish stocks was effectively prevented by spear fishermen, who only took the bigger fish, and historically, also by their migratory way of life – a self-sufficient, sustainable lifestyle now compromised by the introduction of modern fishing methods in the area. However, because of the relatively small populations in many of these areas, this type of lifestyle can continue despite the temporary exploitation of sea resources by other groups.

The lifestyle in Topa was observed to be very similar to that in the southern Philippines, even though these two groups have been separated for more than 100 years (Sather, 1997).

Discussion

Diving activities

It is evident from this study that the Bajau Laut may typically dive repeatedly to depths of 10 m and spend 50% of their working time under water, or dive to shallower depths and spend 60% of their time under water, with the ability to occasionally go much deeper. A considerable catch can be obtained in that time and particularly in rich environments, 2-3 h working time is sufficient to gain a living, even though as much as 9 h can

be spent immersed. Moreover, a considerable amount of seafood is gathered by shallow harvest diving. At these latitudes, neither the time spent in or under water seem to limit human sea foraging activities. This suggests that humans possess an atypical ability to forage in water for a terrestrial species.

Diving and gathering

Bajau Laut gathering would appear to be similar to that of some previously described marine gathering ethnic groups (Malm, 1999). Malm reported that 230 folk taxa of seaweed and marine invertebrates were collected and used in Tonga, and that women obtained most of the collection, while men were mainly engaged in fishing. Therefore, while fish are clearly central to their culture, they are not their only source of sustenance. Food sources obtained by gathering also included species in the intertidal zone, suggesting that humans have been able to use the whole littoral zone for obtaining a variety of food resources, also in ancient times by diving and wading. However, in modern Bajau Laut life freediving is necessary for a major part of these resources.

Spearfishing

Diving time: The observations in this study that Bajau Laut fishermen had an overall underwater working time of 50-60% on their fishing shift, lasting between three and nine hours, is similar to the observations made by Schagatay in 1988. For shallower dives, this means that the Bajau Laut fishermen can spend up to five hours a day under the surface, which resembles the diving activities of some semi-aquatic mammals and, to our knowledge, is something not known of any other terrestrial mammal. Therefore, the apneic duration, or the proportion of working time spent submerged, does not seem to be a limiting factor for obtaining enough food from diving. As previously observed in the Bajau Laut and other groups of subsistence divers, a number of physiological adaptations shared with typical mammalian divers are responsible for this ability (see Schagatay, this issue).

Temperature: Water temperatures of 26-29 C did not seem to limit human activity in water, given that the average immersion time was 5 h, with individuals spending up to 9 h per day in water. This demonstrates that the human body's subcutaneous fat insulation is sufficient for long periods in water at temperatures well below those normally considered thermoneutral. However, this is different to e.g., the Ama of Japan and Korea, who engage in full time freediving at colder latitudes; before the introduction of wetsuits, they had to take several breaks in their fishing activities to warm up using big bonfires (Rahn & Yokoyama, 1965; Schagatay, interviews with Ama divers 2013). However, before using wetsuits, the Ama were found to be better adapted to cold than average populations (Rahn & Yokoyama, 1965).

Depth: Bajau Laut divers dived at depths of 3-25 m for hunting fish, which is similar to the working depths reported for Ama divers (Rahn & Yokoyama, 1965). Dive durations were longer for deeper dives, because more time is needed to swim down and

up again, and adequate time must be spent on the seabed to catch fish. This explains why, for 5-7 m dives, mean durations were 28 s, and for 10 m average diving depths, durations were 42 s. Longer durations require greater recovery times since products accumulated from anaerobic work need to be removed before the next dive can begin. Therefore, for 5-7 m dives, interval durations were 19 s, and for 10 m dives, average intervals were 42 s.

Greater depths are usually only explored when there are insufficient resources in shallower water. This suggests that if catches diminish, because of overfishing or for other reasons, divers will probably have to go deeper. One may assume, from the depth records from the Bajau Laut competition, that much greater depths can be reached, at least when a ballast system is used. Ama divers in Japan also used a ballast system, with a helper in the boat, for extending diving depth, but this system has been abandoned in many places because of the associated risk of developing decompression sickness (Schagatay, 2011).

It is suggested in the divers studied, that mid aged divers may dive the deepest, but it cannot be determined if this is typical from the limited numbers of divers of different ages included in this study.

Sea nomad life today

Today, compared to 25 years ago, fewer young men are trained to become divers, but those who still make a living from the sea seem to push their limits even further. The average diving shifts of 5 h reported here are similar to the 6 h shifts reported of some groups earlier (Schagatay, 1991). However, in some groups, greater time needs to be spent fishing than before since there are less fish in coastal areas. According to the fishermen in the Davao Gulf, Philippines, at the beginning of the 21st century the speargun divers only needed to spend between 2-3 h at sea to obtain sufficient quantities of fish. This was also the case in 1988, as verified in the study by Schagatay. Yet today, a fishing tour generally lasts for 5 h. In other words, because of decreased fish stocks, fishermen make more demanding dives near their maximal capacity, leading to increased use of their diving potential.

As previously observed in the Ama divers of Japan, the Bajau Laut continue to dive into at least their 6th and 7th decade (Holm et al., 1998). This demonstrates that this type of work, although physically demanding, does not damage the body, which may not be the case with other types of physical labour at high ages.

When diving, they reach depths of 3-25 meters, which is the richest and most diverse area of a coral reef. It is also an area subject to sediments, nutrients from the land, and other pollutants. As long as there is no over exploitation or pollution, the sustainable life of the Bajau Laut could continue for many generations to come, if the younger generations choose to continue this way of life.

Further studies could be conducted to measure and compare diving profiles at different ages, and the diving skills and responses of men and women in the Bajau Laut and other breath-hold diving communities in different parts of the world.

Conclusions

Many of the Bajau Laut in the Philippines and Indonesia still make a living completely from breath-hold diving for spearfishing and gathering, with very little equipment. When shallow diving (mean 6 m), up to 60% of their working time is spent below the surface holding their breath, and while diving deeper (mean 10 m), 50% of their working time is spent under water. Therefore, the proportion of time spent submerged, does not limit human subsistence diving. Moreover, the long periods of time spent in water demonstrates that at these latitudes water temperature is not a limiting factor to human sea harvesting. Most members of these communities dive, and the quantity and variety of food procured from the sea shows that modern man can conduct a self-sustained living based on sea harvesting via natural breath-hold diving.

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